PART 8

Rescue and Survival

CHAPTER 54

Wilderness Emergency Medical Services and Response Systems

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DEFINING *WILDERNESS* AND *WILDERNESS MEDICINE*

Wilderness is commonly defined as *an uncultivated, uninhabited, and inhospitable region*. In the context of medical care, we define wilderness as *those areas where fixed or transient geographic challenges reduce availability of or alter requirements for medical or patient movement resources*. According to this definition, wilderness settings are typically deserts, mountains, rivers, oceans, caves, and other remote areas, but the definition also includes urban areas during disasters or military operations and other environments not typically considered wilderness.

Wilderness medicine is the delivery of medical care in any of these environments. Practicing medicine in a wilderness presents unique challenges in locating, treating, and maintaining safe access to the patient.

Wilderness emergency medical services (WEMS) are entities in which formal health care providers (HCPs) offer the systematic and preplanned delivery of wilderness medicine. Box 54-1 lists teams and organizations that provide WEMS care.

Wilderness medicine in general does not presuppose injury or illness (excepting in environments that would inevitably cause injury without specific intervention, such as scuba diving or high-altitude mountaineering). The response to medical emergencies is, therefore, largely spontaneous and improvisational. Although an important part of wilderness medicine practice is preparation, the specific types of medical care delivered are usually unanticipated. Indeed, a hallmark of wilderness medicine is dealing with emergencies using improvisation and available equipment that is often intended for other purposes. Preparation for environmental factors and personal safety is an important part of WEMS planning, with the primary operational goal of delivering care to a patient in the wilderness. Providers within WEMS systems have an ethical obligation, if not a legal duty, to act, as their urban counterparts do; they are not the same as Good Samaritan providers, protected by statute in some areas, who might give basic assistance to an ill or injured person in the wilderness.

WEMS as a subdiscipline has important distinctions from its parent discipline of emergency medical services (EMS). EMS systems have been defined as providing a comprehensive approach to emergency medical services, including the following components: manpower, training, communications, transportation facilities, critical care units, public safety agencies, consumer participation, access to care, patient transfer, coordinated patient record keeping, public information and education, review and evaluation, and disaster planning. Modern WEMS leaders argue that all aspects of EMS should be present in a WEMS system.[129] However, many resources available to a traditional EMS provider, including rapid patient delivery, availability of physician consultation, and ambulance platforms for equipment carriage and delivery, may not be available in a wilderness environment. Because of this, WEMS providers should be authorized to follow protocols that allow them to adapt care to the environment in which they operate.[47] However, if WEMS providers are to follow operationally specific protocols, it is important to define the threshold at which a specific operation is no longer a traditional EMS* operation and has become a WEMS operation; both operational implications and regulatory and legal ramifications are affected by the distinction. As discussed in the first paragraph, the definition of *wilderness* may not be as obvious as one might think, and a more explicit and idiomatic definition may be needed for each EMS system.

Two examples further illustrate the differences between WEMS and wilderness medicine and WEMS and traditional EMS. **(1)** The principle of teaching and practicing first aid as "help until formal care arrives" demonstrates one difference between WEMS and wilderness medicine. Much wilderness medicine training presupposes that care is being delivered in a Good Samaritan or first-aid context; that is, the provider did not enter into the environment specifically planning to deliver definitive care according to a traditional level of training. Therefore, most wilderness medical training assumes that patients will be transitioned to a more formal level of care. The personnel providing that higher level of care are tasked with transporting the patient to a care facility and preparing themselves with all equipment that could be reasonably expected to be necessary for transport (Figure 54-1). WEMS addresses training, expectations, and operations of teams providing extraction and the early stages of definitive care, whereas traditional wilderness medicine addresses the ad hoc activities of an individual or group tasked with providing unexpected care. This is true even for a HCP who has formally agreed to serve as a medical resource for a group, such as

BOX 54-1 Examples of Wilderness EMS

- Search and rescue teams
- Ski patrol teams
- National, state, and local park rangers
- Expedition medical teams
- Specialized law enforcement or fire department teams
- Specialized military teams

FIGURE 54-1 Little Gasparilla fire-rescue response vehicles. *(Courtesy Seth C. Hawkins.)*

*Note that here, and in the remainder of the chapter, we refer to non-wilderness EMS as "traditional EMS." Other sources might refer to traditional EMS as "front country EMS," "urban EMS," or "street EMS," all of which are terms for the practice of EMS outside a wilderness environment.

expedition physician. Despite the fact that such a person is serving as a formal HCP in that environment (and thus is not operating under the precepts of Good Samaritan behavior), the HCP is not expected to provide 100% of standard prehospital care prior to arrival at a health care facility. Doing research on the availability and resources of local WEMS should be an important role of HCPs involved in medical care for any wilderness activity.

(2) Reducing a shoulder dislocation illustrates the difference between WEMS and traditional EMS. Reducing specific dislocations is essential training for many wilderness medicine providers. However, in most traditional EMS settings, EMS providers are not authorized to perform field reductions. With appropriate, operationally specific protocols, some WEMS systems allow these procedures, and so the vast majority of WEMS schools teach this skill. Consequently, many individuals with basic WEMS training have been trained to perform an intervention that may be illegal for most traditional EMS providers. Because of this, one must know if a provider is operating in the context of civilian first aid (in which case, ironically, a reduction might be permissible), traditional EMS (in which case a reduction would not be permissible), or WEMS (in which case a reduction might be permissible if the maneuver meets the predefined definition of being a WEMS procedure). As WEMS evolves, continued medical oversight and coordination will be required in order to resolve issues of scope of practice.

Hawkins and colleagues[47] offer a comprehensive explanation of WEMS via the National Association of EMS Physicians (NAEMSP) EMS textbook:

Although some authors will define WEMS as any situation that involves a minimum of a 1- or 2-hour transport time, this definition does not encompass every WEMS experience. There may be situations that require specialized medical care prior to extrication or transport even if the area is near a roadside, such as a patient injured on the hill at a ski resort or a hiker who has collapsed while walking in an urban nature preserve. Due to the specialized skills required to manage these patients, the inability to get supplies to the patient easily, or a complex extrication without the aid of an ambulance, these situations must also be considered wilderness. Therefore, it is the skills, expertise, and equipment needed to adequately manage the patient rather than the time of extrication or transport that define an EMS situation as wilderness.

WEMS is substantially more complex than application of traditional medical training in a wilderness environment. Indiscriminate application of traditional care and standards could be dangerous to patients or providers in a wilderness setting. WEMS represents organized efforts wherein providers are assigned to specific geographic areas or missions with a specific duty to act. The purpose of WEMS is to provide care to an ill or injured patient in a wilderness setting while still recognizing that the providers are functioning within the defined health care system. Therefore, it is the goal of WEMS to manage the patient in the field, extricate the patient, and transport to an acute care facility if needed. These goals are met with the concept that the patient should be receiving quality care with appropriate physician participation or oversight.

Based on this definition, it is our conviction that most EMS systems should prepare for some degree of WEMS operations. Conditions requiring WEMS care can arise from environmental factors such as severe weather, geographic factors such as absence of roads or presence of bodies of water, or potential for natural or manmade disasters resulting in a sudden need for austere medical care. A patchwork of protocols and levels of care exists across the United States because states and services grapple with how to anticipate and manage WEMS operations. There is not yet a national standard regarding scope of practice or what should be included in WEMS protocols. The intent is not to expand the scope of practice but rather to enable EMS personnel to be trained to use skills and medications that are appropriate for a given operational environment. A relevant comparison to this "appropriate care in the appropriate setting" ethos is seen in combat and tactical environments.

The Wilderness EMS Medical Director Course, a Delphi-driven curriculum endorsed by the Wilderness Medical Society (WMS) and NAEMSP,[78] emphasizes the fact that any EMS provider or system can expect to provide WEMS care.

RELATIONSHIP OF EMERGENCY MEDICAL SERVICES, WILDERNESS MEDICINE, DISASTER MEDICINE, AND TACTICAL MEDICINE

Wilderness medicine and EMS are both formal subspecialties of medicine. WEMS can be considered a subdiscipline of both wilderness medicine and EMS. WEMS shares features with other disciplines, including tactical EMS, military medicine, and disaster medicine. In terms of number of patients, disaster medicine is the largest setting in which WEMS principles are applied. Most WEMS operations, however, involve only a single patient or small number of patients. Occasionally, a traditional WEMS operation becomes a multiple casualty incident (MCI).[†] The current definition of an MCI, which could be extended without alteration to a WEMS MCI, is "a situation with numerous patients that does not overwhelm the routine capacity of the system."[61] In this case, the routine capacity could include mutual aid and other atypical resources, but local authorities can still manage the incident with resources identified by local emergency management planners.

In the United States, providers of disaster medicine must be better equipped to be safe in, and provide care similar to, what amounts to a WEMS system and operational environment, particularly in the first hours and days of the operation.[47] One exciting new hybrid of EMS, WEMS, and disaster medicine is the Community Relief Medic program developed by Landmark Learning, a WEMS school in Cullowhee, North Carolina. This program proposes activation of traditional EMS first responders to operate at a specifically defined, operationally specific scope of practice during declared disasters, after which traditional operational environments become WEMS environments.[63] This program is similar to the FEMA Pathfinders Task Force program,[37] but has an expanded scope of practice for EMS/WEMS activities of responders.

Many similarities exist between military medical care and civilian tactical EMS. There is extensive overlap between military experiences in recent conflict zones and WEMS operational experiences. In many cases the personnel are the same, in both leadership (administrative) and operational (field responder) roles. This continues a relationship between WEMS and military medicine that goes back to the earliest days of modern WEMS systems.

Examples of military innovations that have changed practice in WEMS operations include:

- Hemostatic agents
- Tourniquets
- Advances in blood products, including concepts of "forward blood" and field resuscitation of major trauma with significant blood loss
- Migration of tactical combat casualty care principles into civilian tactical operations

HISTORY OF WILDERNESS EMERGENCY MEDICAL SERVICES

Understanding the history of modern WEMS requires an understanding of the parallel growth of EMS and wilderness medicine, and their merger into WEMS systems.

Although WEMS is a recent development as a formal subfield of medicine, it has existed in a less formal configuration since the earliest days of human civilization. Quite obviously, humans have been organizing systems of care to deal with illness and injury since the beginning of recorded time. By the late 20th

[†]In contemporary nomenclature, MCI refers to multiple casualty incident, not mass casualty incident. Mass casualty incident is an obsolete EMS term for a disaster.[61]

century, wilderness regions had changed from areas in which basic sustenance and survival were difficult and human control was rare, to areas with definite geographic borders used mainly for recreation (at least in developed countries). Such changes led to the introduction of "modern" WEMS, with the goal of providing medical care to the greatest degree possible in wilderness areas.

Many authorities date the origin of "modern" civilian WEMS systems to the era immediately following World War II.[47,57] During the war, the American military recognized the need for a specialized ski-based mountain warfare unit. An important precedent for this was Finland's demonstration that ski-based troops could be used to defeat entire Russian tank divisions during the 1939 Soviet invasion of Finland. More importantly, the Americans needed specialized assets to fight Axis units in the snowy and vertical reaches of the Italian Alps. In 1943, the U.S. War Department, in cooperation with a predecessor of the National Ski Patrol and the American Alpine Club, created the 10th Mountain Division.[47] This unit's subsequent operations in the Italian Alps provided its members with extensive field medical experience in wilderness environments. When they returned home after the war, veterans of the 10th Mountain Division looked for ways to use their unique skills in the civilian environment. (In a later era, returning Army medics from Vietnam did the same, advocating for the creation of programs for physician assistants.) One niche obvious to them was the provision of medical care on civilian ski slopes, so many were pivotal in helping to develop the National Ski Patrol (NSP), which became one of the first teams to deliver systematic medical care exclusively in a wilderness environment.

Perhaps because the primary interest in medical training for wilderness environments was among wilderness enthusiasts themselves rather than HCPs, the first institutions to offer such training were commercial rather than academic. Wilderness Medical Outfitters may have offered the first formal course in wilderness medicine in 1967. Stonehearth Outdoor Learning Opportunities (SOLO), founded in 1976, was the first commercial school to build a campus solely devoted to training students in wilderness medicine. In developing a curriculum, SOLO administrators adopted the certification nomenclature and regulatory pathway of EMS, which were being developed at the same time, and the two disciplines were therefore linked from the start. Few disciplines other than wilderness medicine, if any, have evolved from independent educational and operational institutions, such as commercial schools and the NSP, rather than from hospital-based training programs or from academic institutions within the traditional "house" of medicine (even EMS began in the hospital setting).

As part of the development of EMS, in 1966, the National Academy of Sciences—National Research Council published *Accidental Death and Disability: The Neglected Disease of Modern Society*. It lamented the paucity of formal or systematic care for emergency medical conditions prior to hospital arrival and laid out 24 recommendations for addressing the situation. The recommendations formed the blueprint for EMS care in the United States and spurred development of international EMS programs. The Emergency Medical Services System Act of 1973 formalized a federally standardized model of EMS. Although it established a federal mandate for EMS care, this Act delegated decisions on defining and funding EMS to smaller communities, regions, and states. By 1982, all federal funding under this Act and its reauthorizations had been discontinued. This set the precedent still seen today for debates and challenges in funding and operating EMS systems, both traditional and wilderness systems.

COMMERCIAL WEMS SCHOOLS IN THE UNITED STATES

The 1970s saw continued maturation of WEMS schools for teaching proprietary curricula using EMS nomenclature and certifications; wilderness first responder (WFR) and wilderness emergency medical technician (WEMT) were two of the designations used. Although both certifications had been established by the U.S. Department of Transportation and were regulated by the state in which a program was based, use of the term *wilderness* was unregulated. Each program was only as good as the school backing it. The scope of practice (maximum practice threshold) and required skills (minimum practice threshold) of wilderness modules were also unregulated, and were defined by each school.

Numerous programs followed the path pioneered by Wilderness Medical Outfitters and SOLO. Peter Goth taught many WEMT courses for Outward Bound in the 1970s on the American East Coast. His work eventually led to the foundation of Wilderness Medical Associates (now Wilderness Medical Associates International [WMAI]) in Maine. Stan G. Bush pioneered the idea of a wilderness medical technician for the Emergency Medicine Committee of the National Association for Search and Rescue (NASAR) in the mid-1970s.[24] In 1981, a formal proposal was made for this certification; unfortunately, the committee disbanded shortly after that because of restructuring of NASAR, and the initiative was abandoned. It reemerged later with a more commercial format, similar to that of other wilderness medicine schools at the time.[24] Had it continued in its planned trajectory, it might have developed an early course of certification for wilderness medicine that was completely different from the course for EMS, including in nomenclature and regulatory oversight. (The Outdoor Emergency Care [OEC] program was able to do this.) In any case, it has been cited as contributory to Dr. Keith Conover's work in developing the Wilderness Emergency Medical Services Institute (WEMSI) in 1985 and development of the WEMSI public-access curriculum.[24] In 1990, Buck Tilton and Melissa Gray, two SOLO instructors, established the Wilderness Medicine Institute in Colorado. The school was originally conceived as a SOLO-affiliated school with exclusive rights to teach SOLO curricula in the American West.[60] However, in 1999 the school was purchased by the National Outdoor Leadership School and moved to Wyoming, and it is now known as the Wilderness Medicine Institute of the National Outdoor Leadership School (WMI-NOLS).

SOLO, WMAI, and WMI-NOLS currently generate the most classroom days among commercial WEMS schools. Numerous other schools in the United States and other countries have emerged to fill various commercial niches, including Aerie Backcountry Medicine, Wilderness Medicine Training Center, and Longleaf Wilderness Medicine. Landmark Learning is a useful example of how these schools have continued to evolve the model of a commercial wilderness medicine or WEMS school. Landmark Learning is a WMI-NOLS affiliate and uses the WMI-NOLS curriculum; however, it has truly embraced its simultaneous EMS, wilderness medicine, and higher education roles by taking the unusual step of becoming certified as a state-endorsed EMS training school and the unprecedented step of becoming accredited by the Accrediting Council for Continuing Education and Training as an institution of higher learning.[6]

In-House Training in the United States

Numerous institutions recognized the need for their staff to be trained in wilderness medical skills and developed their own internal curricula and training programs. Because they served designated areas and were primarily configured to provide medical care, these programs fit the definition of WEMS systems. Prototypical examples are the NSP OEC program and the National Park Service (NPS) ParkMedic program.

The NSP was perhaps the first formal WEMS system in the country. Its first certification course was in winter emergency care, which subsequently evolved into OEC. NSP's OEC textbook is now in its fifth edition.[76] The OEC program now teaches WEMS skill sets and knowledge at a level exceeding the emergency medical responder (EMR) curriculum but below the level of an EMT program.[26] The current curriculum addresses all environments, rather than just snowy or alpine environments, as in previous editions, so that it is a viable commercial option for persons seeking the equivalent of WFR certification in addition to its original purpose of training ski patrollers.

The NPS provides medical care and other services to millions of visitors each year, and certainly qualifies as a prototypical WEMS system. NPS has run the ParkMedic training program since the 1970s. In this program, as in all EMS programs, formal medical training and oversight are provided by physician-level providers (not only physicians but other advanced care providers, such as nurse practitioners and physician assistants)[2] at the University of California San Francisco–Fresno Emergency Medicine Residency Program in Fresno, California. The ParkMedic program was originally designed for specific rangers in Sequoia and King's Canyon National Parks, but the certification has been expanded to parks throughout the United States. Some believe that the NPS system is one of the most sophisticated, comprehensive WEMS systems in the world.[47] The NPS taught its first formal EMS class in 1972 in North Carolina, and the formal ParkMedic program was established in 1978 in California.[116] The scope of practice of ParkMedic practitioners is more extensive than that of an advanced EMT but less extensive than that of a paramedic.[26] In most of the larger national parks, the ParkMedic practitioner is able to provide both traditional care and WEMS care. The UCSF-Fresno staff continue to offer ParkMedic training every 2 years and serve as medical advisors to the NPS EMS system as a whole, with one author of this chapter (WS) serving as system medical director.

Because the NPS has been in operation for nearly a half-century and has generated data for much of that time (longer than many WEMS systems have been in existence), it has provided much of the best epidemiologic information on WEMS operations. NPS data suggest that U.S. national park visitors experience an equal number of medical and traumatic EMS events (with more deaths resulting from the traumatic events) and that the incidence of EMS events in the national parks is 46 per 1 million visitors.[30] Other data show that WEMS are different from EMS; for example, for WEMS, 77% of patients do not require transport, 28% of patients require contact with a base hospital, and only 16% of patients requiring advanced life support (ALS) also required transport.[58] The data demonstrate that WEMS providers in this system have been working for decades in a different operational environment than most traditional EMS authorities would recognize. This same series showed that ALS care was needed in 10% of cases. Although this would be seen as a very low number for traditional EMS services, it might surprise some wilderness medicine providers that, when available, ALS care is used in as many as 1 in every 10 WEMS encounters. It is even more interesting to note that, of those requiring ALS services, fewer than one in five required transportation, so that four out of five received definitive care in the field.[58] In 2003 alone, 3251 visitors required rescue operations, many of which involved emergency medical aid. Although 124 of these visitors died, authorities estimate an additional 427 patients who would have been expected to die were able to survive because of NPS intervention.

Growth of Wilderness Medicine

After its beginnings in commercial and nongovernmental (NGO) programs, the field of wilderness medicine matured (in the 1960s) into a recognizable medical subspecialty. As this took place, textbooks were written, a professional society was organized, a scientific journal was developed, and training opportunities were formed at all levels within the traditional medical infrastructure.

Wilderness medicine has become a field embraced by the academic medical world. Multiple universities and medical schools have developed wilderness medicine programs. In 1983, three physicians from California, Dr. Paul Auerbach, Dr. Edward Geehr, and Dr. Kenneth Kizer, founded the Wilderness Medical Society (WMS). The formation of a professional society was crucial to the development and professionalization of wilderness medicine as a discrete medical subspecialty. The WMS subsequently founded the Academy of Wilderness Medicine and began to recognize fellowship in the academy, another important step in establishing legitimacy for practitioners in wilderness medicine. In 2007, the first Fellows were recognized, and the first Master Fellow was recognized in 2011. Unlike most honorific fellowship designations, the title of Fellow is not restricted to physicians or particular HCPs. This gives EMS personnel an opportunity to become Fellows in a health care specialty via WEMS, an opportunity not available to them in any other subspecialty of medicine. It is notable that the first physician to achieve Master Fellow status earned this designation for specialization in the realm of WEMS.[52] WEMS has been an intrinsic part of the growth of wilderness medicine, from the first proprietary schools up to the breaking wilderness medicine news and events of today.

WILDERNESS EMERGENCY MEDICAL SERVICES AGENCIES

Numerous WEMS teams exist throughout the world.* In the United States, WEMS teams are usually either governmental agencies or NGO agencies. Governmental teams include search and rescue, technical rescue, dive rescue, and EMS-based wilderness teams. NGO teams include mountain rescue teams, volunteer ski patrols, cave rescue teams, search and rescue teams, and others. Oversight and advocacy organizations have been developed for various WEMS specialties. These include the National Cave Rescue Commission, NASAR, Mountain Rescue Association, NSP, American Canoe Association (providing swiftwater rescue standards), and others. The National Fire Protection Association (NFPA) is a U.S. trade association that creates and maintains consensus (i.e., optional) standards. NFPA 1670 addresses technical rescue and is often used as a national, and sometimes international, standard for the technical rescue (nonmedical) portions of care delivery. Portions of NFPA 1670 relevant to the WEMS community include rope rescue, confined space rescue, water rescue (including ice, swiftwater, surf, and dive rescue), wilderness search and rescue, and trench rescue. NFPA standards are often held in high regard by local governmental teams, especially those with a historic or current basis in governmental emergency management or fire services.

Other teams fall into a contested region where they meet many or all characteristics of a WEMS system but may not always be considered WEMS programs. Examples of programs in this category include some lifeguard and ski patrol systems. One area of growth within WEMS organizations would be to more clearly define systems that definitively meet the WEMS definition. It is the conviction of these authors that all ski patrols and most lifeguard programs meet that definition.

WILDERNESS EMERGENCY MEDICAL SERVICES PROVIDER TYPES, STANDARDIZATION, AND SCOPE OF PRACTICE

As attested in the position statement *Medical Direction for Operational EMS Programs,* which was jointly published in 2010 by NAEMSP and the National Association of EMS Officials, "Operational EMS programs, which include ski patrols and wilderness search and rescue teams, should function within and not outside the mainstream health care system, and their providers should function within their defined scopes of practice."[88]

The importance of the operational EMS program position statement cannot be overlooked or minimized in the development of WEMS programs. In 1996, the National Highway Traffic Safety Administration and the Health Resources and Services Administration published the *EMS Agenda for the Future* (often referred to as the *EMS Agenda*), which argued that EMS should be community based and fully integrated with the overall health care system.[91] Now, 20 years later, physicians with experience and expertise in both wilderness medicine and EMS are making it clear that patients who are injured or sick in the wilderness are part of the community and deserve out-of-hospital health care that meets the standards of the *EMS Agenda.*

*In discussing teams that provide technical rescue, it is important to recognize that a team is only a WEMS team if it provides some type of medical training for its members and promises some type of medical care to those it serves. For example, some SAR teams only provide search services, and any medical care rendered is done by interface with a WEMS team, or EMS team, equipped with certified medical providers. Such teams would not be considered a WEMS team.

The *EMS Agenda* of 1996 pointed out that in developing EMS programs there should be, "…significant flexibility to adapt to local needs."[92] Despite the fact that the resources available for managing patients in the wilderness are different than those in the urban environment, the expectations of the patient population do not change significantly. A basic assumption of the concept of delivering high-quality care in a wilderness environment is that the health care delivered will be standardized and provided by a health care system.

The integration of WEMS into the overall emergency response system may seem onerous to some because it is based on the assumption that it is possible to create a systematic approach to health care delivery in an environment without urban resources; however, this integration is not only possible but is necessary for delivering high-quality emergency care to the wilderness patient population.

Development of a systematic approach to providing emergency care in a wilderness environment begins with physician medical oversight and delivery of care by providers with a defined scope of practice. The scope of practice and level of care that should be provided to a patient are defined by the *National EMS Scope of Practice Model,* a by-product of the *EMS Agenda;* the scope of practice defines the health care that is legally permitted to be provided.[93] The *National EMS Scope of Practice Model* identifies different levels of emergency care providers for the out-of-hospital environment and outlines the minimum knowledge and skills for each level.

In an effort to standardize delivery of emergency care throughout the United States, the model identifies four levels of EMS providers: emergency medical responder (EMR), emergency medical technician (EMT), advanced emergency medical technician, and paramedic. The scopes of practice for these providers, according to the national model, are defined by education, certification, licensure, and credentialing.[93]

Although there are a number of training programs that educate, and in some cases certify, skills taught to WEMS providers, the legal permission to perform these skills requires licensure and credentialing. The rules vary widely from state to state, with some states licensing EMS providers independently, others licensing only advanced EMS providers, and still others requiring no license at all. Furthermore, the licensure of EMS providers, regardless of environment, requires recognition by a state regulatory authority. Finally, even in states that independently license EMS providers, a defined scope of practice still requires a final seal of approval, that is, credentialing, which necessitates that the EMS have oversight from a qualified physician medical director.

The concepts of scope of practice, physician oversight, and standardization of delivery of care remain important to the development of WEMS systems, but there still remain two significant gaps.

First, the idea that WEMS programs should have physician oversight with concomitant continuous quality improvement programs in place is seen by many as an impossible feat and a radical shift in the culture of the search and rescue community. Nevertheless, there are physicians with interest in WEMS system development, and a training program exists to teach physicians how to be a medical director for a WEMS program.[78]

Second, despite the fact that the *Scope of Practice Model* recognizes that there are EMS professionals that function in "nontraditional roles," as noted earlier there currently exists neither standardization in the training of WEMS providers at various levels nor universal recognition by state regulators that WEMS providers need additional skills beyond what is taught in urban EMS courses. Although there are projects in development designed to promote recognizing a need for wilderness-specific scopes of practice, universal acceptance is still lacking.

One such completed effort was initiated by the WEMSI, based in Pittsburgh, Pennsylvania. The WEMSI established public domain curricula for various levels of WEMS training. This was in part intended to provide a de facto standard by being freely available.[25,47] The idea of public domain curricula is regarded as an innovative contribution to the industry. Similarly, in 1995, the American Society of Testing and Materials International developed standards for WFRs, both in terms of training[7] and of scope of practice.[8] Although the guidelines succeeded in the critical step of addressing both minimum training standards and maximum scope of practice standards, they failed to reach a necessary threshold of acceptance and currency in the WEMS and wilderness medicine communities. Neither approach has been widely adopted.

A more often cited and used standard, written by industry leaders, established the "Minimum Guidelines and Scope of Practice for Wilderness First Aid."[59] Unfortunately, this proposed standard did not discuss the maximum scope of practice for a wilderness first aid (WFA) practitioner, which is the more pressing topic. A similar published standard, with similar limitations, also exists for the WFR certification.[70]

Regardless of the challenges in recognizing scopes of practice of wilderness EMS providers, there are a number of programs that are teaching wilderness-specific skills for defined levels of providers. In addition, a number of WEMS programs operationally field EMS providers despite the absence of national standards. This is often based on state or local standards or culture. Examples of current levels of WEMS providers include WFA, WFR, and OEC providers; wilderness paramedics; wilderness advanced practice Clinicians (APCs); and wilderness physicians.

LEVELS OF WILDERNESS EMERGENCY MEDICAL SERVICES PROVIDERS

Wilderness First Aid Provider

The wilderness first aid (WFA) certification translates basic first-aid skills into a wilderness environment. The typical WFA course includes approximately 16 to 24 hours of content. Individuals holding WFA certification are generally not intended to be the medical component of a formal wilderness rescue, in the same way that traditional first-aid certification is not usually considered sufficient for serving on a formal EMS response team (first responder or EMR being the more typical threshold certification). The intent behind WFA certification is to train individuals to provide interventions at a non-health care professional (HCP) level in Good Samaritan circumstances. As noted earlier, in 2013 a consensus panel primarily composed of wilderness medicine schools published a statement establishing minimum standards and a minimum scope of practice for WFA providers.[59] A more pressing question may be the maximum scope of practice for a WFA provider. The demarcation between "first aid" and "formal medical care" is controversial, but it is critically important; a formal distinction must be drawn in defining the training and practice of non-HCPs delivering unsupervised and unexpected care (i.e., not requiring a medical license) versus the training and practice of HCPs delivering anticipated care in a supervised setting (a traditional definition of EMS, requiring a medical license, either directly or via delegated or supervised practice). The class of WFA provider became even more confused with the availability of certifications such as advanced wilderness first aid offered by some wilderness medicine schools. Some of these advanced classes significantly exceed the hours and scope of a standard WFA class, can recertify a WFR, and can be used as the minimum standard for various guide licenses, with presumably an equally expanded scope of practice.[131]

Wilderness First Responder

The wilderness first responder (WFR) is the most basic provider skill set serving as part of an organized WEMS system. There is also a growing standard for guided wilderness trips (e.g., rafting, climbing) to have a guide certified to this level. The use of EMS terminology in terms of first responder begs the question as to whether a WFR requires medical oversight of their practice at that level; currently, medical oversight in the traditional EMS sense is rare outside of formal WEMS teams, and that itself begs the question of where the "credentialing" described earlier occurs in WFR practice. WFR courses are approximately 80 hours in length. The WFR is trained to recognize potential life-threatening injuries and stabilize the patient for transport out of the wilderness environment. At times the WFR may be trained to administer life-saving medications, such as epinephrine, oxygen, and glucose. The WFR may also be trained in other protocols that include dislocation reductions, selective spinal immobilization, and termination of resuscitation. Whether or not these activities require medical oversight is jurisdictionally variable and controversial, and some skills (such as dislocation reduction) are disallowed even for paramedics in most regions of the United States. In 1999, the WEMS Curriculum Committee published minimum course content guidelines for a WFR curriculum.[70] It should be noted that under the new EMS nomenclature, the term first responder will be discontinued in favor of emergency medical responder (EMR). This will provide an opportunity to see if the wilderness medicine community continues certifying WFR providers or transitions to the WEMR terminology. So far, despite the fact that all NREMT and many state certifications in the United States will have transitioned to EMR terminology by 2016, the wilderness medicine training community has not yet embraced the term WEMR. Nearly universally, this level of responder is still identified as a WFR. How this terminology evolves may be an important marker of whether these certification levels will move more into a regulated form of medical care existing within the EMS infrastructure (as WEMR) or remain a practice level more akin to first aid, an unregulated instance of medical care existing outside the traditional medical infrastructure (as WFR).

Wilderness Emergency Medical Technician

The wilderness emergency medical technician (WEMT) course is approximately 150 hours long. WEMT training includes advanced techniques, such as manipulation of dislocations and administration of certain medications, only sporadically offered in WFR courses. Because the EMT designation is historically the most generic form of EMS certification, nearly all of these courses will also offer a pathway to become a state-certified (and sometimes National Registry–certified) EMT-basic (now simply EMT in the new EMS nomenclature). Most programs therefore offer a curriculum that meets their state's requirements for EMT-basic training, with additional unique modules for wilderness circumstances and practice. Despite absence of a standardized curriculum for this wilderness component, the curricula between at least three of the major wilderness medicine schools (WMI-NOLS, WMAI, and SOLO) are similar enough that they will recertify each other's students.[130,132] In general, the wilderness modules appended to these WEMT curricula involve an additional 48 to 80 hours of training beyond standard EMT curricula.[130,132]

Outdoor Emergency Care Provider

As noted earlier, the NSP developed the outdoor emergency care (OEC) course as its own proprietary certification course, which certifies its graduates as OEC-technicians. In its current fifth edition, OEC trains students in all environments, not just ski environments, and positions itself as a comprehensive wilderness medicine and WEMS certification.[76] The OEC curriculum and scope of practice exceed that for EMR certification, but they do not have all the elements of EMT certification.[26] Many ski areas use OEC-technician as a responder certification, but others prefer EMT certification,[104] and some patrols accept patrollers' own traditional medical certification or licensure and exempt them from field certification altogether.[22] Although ski patrols meet all the characteristics of a WEMS system[46] and most medical authorities agree that ski patrols should be part of the overall EMS system[15,22,44,89,127,129] (including the OEC curriculum itself),[96] they vary in the degree to which they operate within, versus outside, EMS and the mainstream health care system. Some American states have pursued specific actions to integrate ski patrols into the health care infrastructure. One such action is to specifically recognize the OEC program from the NSP as one way of fulfilling the requirement of WEMS training in order to use specially designed state WEMS protocols and be recognized within the state's EMS system (Maryland).[72] Another is creation of a category of operational EMS providers intended to include ski patrollers (Washington, Pennsylvania).[23,46,104] In 2011, Idaho passed legislation that amended the Idaho Code regarding the unlicensed practice of medicine to stipulate that "those individuals trained in and holding the outdoor emergency care (OEC) credential, as issued by the National Ski Patrol, Inc., while rendering aid in accordance with the standards of training of such credential, where no fee for the service is contemplated, charged or received" would be exempt from any allegation of the unlicensed practice of medicine.[64] An amendment was added limiting this exception to ski areas.[65]

This Idaho legislation has significance not only for the ski patrol and OEC community but for WEMS and even EMS in general. Without the amendment, in theory, any volunteer rescue agency working in any environment could bypass state EMS oversight by using OEC certification rather than EMS certification. Even with the amendment, this is a landmark piece of legislation for WEMS. It grants governmental privileges to practice volunteer medical care without traditional licensure or credentialing to a specific corporation, that is permitted to self-regulate and self-define what the scope of that medical care will be through a private, proprietary, and evolving curriculum (OEC).[46]

Wilderness Paramedic

Commercial training companies, who usually train and certify at the WEMT level, do not generally recognize the wilderness paramedic as a certification level. However, numerous systems have paramedics who operate as wilderness paramedics. In general, a wilderness paramedic is able to administer medications with a similar scope of practice as the traditional paramedic, and in many instances has an expanded scope of practice for certain medications, such as antibiotics, not available to their traditional counterparts. In addition, some WEMS systems train providers at this level in prolonged care procedures (i.e., insertion of Foley catheters for urine drainage and nasogastric tubes for gastric decompression). However, the scope of practice in the sense used in EMS does not necessarily follow a linear path from WFR to wilderness paramedic.

Wilderness Physician and Advanced Practice Clinician

Wilderness physician-level providers have the broadest scope of practice within the WEMS certification/licensure rubric. In general, physicians have broad authority under state medical boards to practice medicine in any environment, including wilderness environments, to the level of their specialty training. Although there is no specific "wilderness physician" board certification track at this time, physicians may receive special wilderness training through fellowship programs and/or special courses. Such courses include WMS conference courses and proprietary professional school courses such as the wilderness upgrade for the medical professional, wilderness advanced life support, wilderness medicine for the professional practitioner, and remote medicine for the advanced provider. Advanced wilderness life support certification is available from AdventureMed, which licenses numerous institutions around the world to teach this course. The WEMSI has historically offered a wilderness command physician course; although this course is not now routinely available, the curriculum could still be used by anyone following WEMSI's unique public-access policy.

Most germane to this chapter in terms of EMS is the task of providing medical oversight for other WEMS providers, an important role for wilderness physicians. However, many physicians have neither the EMS nor the wilderness experience to perform this task, despite interest in doing so. In light of this, NAEMSP and WMS jointly endorsed the Wilderness EMS Medical Director Course, which provides training for physicians involved as medical directors or medical advisors for WEMS systems. The curriculum of this course was developed using a Delphi process for scientific integrity; it specifically provides supplemental wilderness training for EMS physicians and EMS training for physicians who are more familiar with the wilderness, so that more physicians will be available and equipped to serve as WEMS medical directors.[78]

A controversial question within the EMS community is the role of advanced practice clinicians (APCs, previously often referred to as midlevel providers, and including provider categories such as physician assistants and nurse practitioners). In general, APCs perform in the field much the same as they do in their traditional practice environments, both in scope of practice and requisite physician oversight, if any. The role APCs can play in EMS medical oversight (including WEMS oversight) is more variable.

Emergency Medical Dispatchers and Telemedicine Providers

Emergency medical dispatchers (EMDs) are sometimes forgotten as an integral part of the EMS system and are not typically included in a discussion of wilderness medicine. However, as telecommunications capabilities expand further into wilderness and remote regions, the capability grows for remote medical care and EMS activation via telephone and other communications devices, such as sophisticated emergency beacons and text-capable mapping/rescue tools.[47] A public-safety answering point and the EMD who works within it often make up the first point of contact for wilderness rescues that would have until recently been too remote. For example, in 2015, reliable third-generation mobile phone coverage was established on the summit of Mt Everest.[47] Clearly, EMDs must be considered as a viable source of remote medical care during WEMS operations, and the opportunity to train them in novel wilderness protocols should be considered. EMDs and other telecommunications point-of-contact services can provide lifesaving wilderness medical instructions. EMDs can be crucial in obtaining initial information for search and rescue and other types of WEMS calls, including victim location and resources needed, and in giving prearrival instructions. For example, the most important intervention in the case of cardiac arrest from drowning or lightning strikes is immediate cardiopulmonary resuscitation (CPR); EMDs are uniquely prepared to give instructions by telephone to persons at the scene in how to give CPR, perhaps hours before a medical responder arrives at the scene.[47]

MEDICAL OVERSIGHT

MEDICAL ADVISORS VERSUS MEDICAL DIRECTORS

The difference between a medical advisor and a medical director is a contested topic. There is no specific national standard defining these roles. Traditionally, a medical advisor is a provider who offers consultation services for an organization regarding their medical operations and risk management preparedness. The title implies no specific authority, but rather a consultative function. A medical director is someone who offers medical oversight or direction; this title carries a degree of authority not seen in an advisor role. Some states permit basic life support providers (generally considered to be EMT-basic and below) to operate without formal medical oversight, although this action is not supported by the National Association of EMS Officials.[89] Many organizations currently use the terms medical advisor and medical director interchangeably, or have local definitions of these terms. One could expect in coming years that this distinction might become more important as WEMS and wilderness medicine continue to grow.

DIRECT MEDICAL OVERSIGHT

Direct medical oversight (DMO), sometimes known as online medical direction, is physician or APC supervision in the immediate care of a patient or patients. Supervising providers can perform direct medical oversight by their physical presence on the scene or by remote direction via telephone, radio, or other telemetry tool. DMO may involve actual patient care from the supervising provider. The key element of DMO is immediate involvement in a specific patient case in real time.

The process of DMO for WEMS operations can at times be quite difficult. Although it may be ideal to have the medical director on scene with EMS providers, this is typically not feasible. In addition, because WEMS operations are often remote, it may be impossible to contact a physician by either radio or cell phone.

Despite the challenges of DMO for EMS providers in a wilderness setting, there is still a need for close physician involvement with WEMS operations. Therefore, EMS agencies involved with WEMS operations should work with a physician who is familiar with their type of work. The challenges of WEMS are unique, and a physician with experience only in a more traditional urban EMS setting may not be able to provide adequate input into management of a patient in the wilderness environment. Physicians involved with DMO of WEMS operations should have appropriate experience and participate in field training exercises with EMS providers. They are encouraged to participate in actual rescue operations.

INDIRECT MEDICAL OVERSIGHT

In contrast to DMO, indirect medical oversight involves protocols, procedures, “standing orders,” and other directives from a physician or APC that guide the medical behavior of a WEMS provider, with the assumption that the physician/APC will not be involved in immediate patient care. Quality improvement is also a component of indirect medical oversight, and is particularly important in WEMS, because there are typically a small number of calls for unique or unusual circumstances.

Indirect medical oversight is the cornerstone of medical direction for WEMS systems. Because it is often difficult for WEMS providers to communicate DMO in real time, it is important to have regular educational sessions to review field assessments and protocols.

Although written protocols may seem too rigid for the wilderness environment, well-designed written protocols can largely eliminate the need for DMO. Wilderness protocol development must allow for a certain amount of flexibility in the application of the protocols by EMS providers. Because the case volume for WEMS operations is lower than for urban EMS settings, it is important to develop a program for regular case review. Case review can be the foundation for continuing educational activities and a rigorous quality improvement program.

OPERATIONS

INCIDENT COMMAND SYSTEM

Organized wilderness rescue can be quite complex. The most efficient method for managing complexity is to apply a systems approach; hence the need for development of specific WEMS systems. An organized rescue may involve multiple agencies and personnel, each with its own area of expertise. Although multiple agencies may be cumbersome, differing skill sets and areas of expertise often facilitate a successful rescue. A large-scale search may need individuals with expertise in high-angle or avalanche rescue, or experience working with horses or snowmobiles. Large-scale searches often require complex communications and logistic support for supplies and food. The best way to manage different agencies and individuals that may be needed for a successful search is to use the incident command system (ICS). An example of the structure of a WEMS incident command is shown in Figure 54-2. See Chapter 55 (Search and Rescue) for further discussion of ICS integration into wilderness operations.

In addition to operational concerns of maintaining command and control of multiple agencies that may be involved in a WEMS event, there are legal, financial, and ethical concerns that should be considered. Many large-scale WEMS events will involve both paid and volunteer EMS personnel. Regardless of personnel costs, a search may require significant financial resources. Although the financially responsible party for a search will vary by jurisdiction, it is advisable that each jurisdiction anticipate this prior to an event.

The primary consideration of any WEMS event is finding the balance between rescuing the injured person and not placing rescue personnel in harm’s way. Medical oversight and representation in the ICS structure can be critical in making appropriate decisions when balancing all of the issues for WEMS and patient care.

Although there may be a role for a safety officer for this reason, it is important that the incident commander be the ultimate authority to decide if parties will be deployed, or if there are environmental considerations for which risks to rescuers outweigh potential benefits of finding and rescuing the injured party.

One area in development is the role of the medical director within the traditional ICS structure. Traditionally, medical

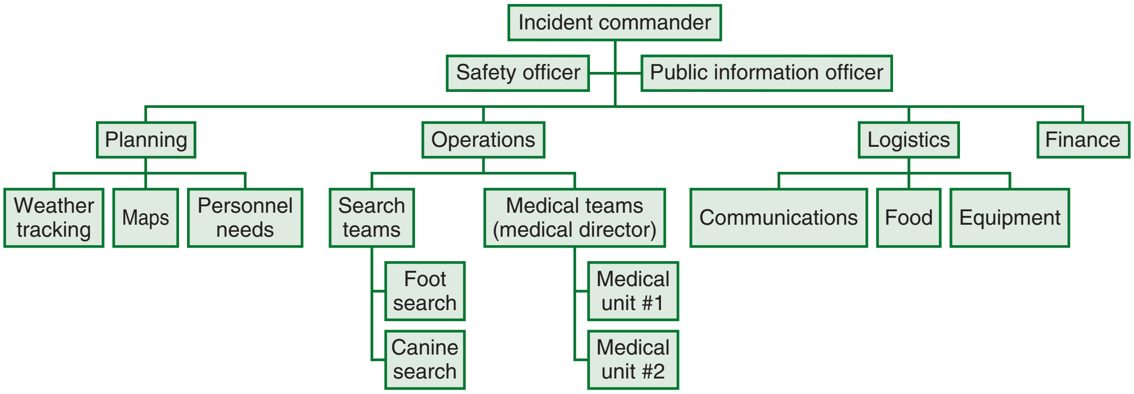

FIGURE 54-2 Incident command system. *(Redrawn from Hawkins SC, Millin MG, Smith WS: Care in the wilderness. In Cone DC, Brice JH, Delbridge T, Myers JB, editors:* Emergency medical services: clinical practice and systems oversight, *2nd ed., Chichester, United Kingdom, 2015, John Wiley & Sons, pp 377-391.)*

directors are viewed as expert advisors on content within the incident commander's staff. Although this is indeed an important role for a WEMS medical director, she or he also has an important role in the direct oversight of patient care within operations, as well as assisting the planning section in deciding when an operation changes from a rescue effort to a body recovery effort.

PROTOCOLS

In EMS, an EMS physician delegates the delivery of clinical care to EMS providers with a defined scope of practice. Consequently, EMS supervising physicians demarcate clinical care, typically in the form of written protocols. Protocols should rely on the best available scientific evidence for a given clinical situation, balanced with the realistic constraints of the operational environment.

For scientific support for a particular protocol, studying peer-reviewed literature specific to the WEMS environment is a good starting point. Because WEMS is a relatively new field, however, there is a paucity of literature regarding many clinical conditions encountered in the EMS environment, and research data for WEMS protocols is often incomplete or nonexistent. Gaps in scientific support for protocol development should be filled by extrapolated information from other clinical environments (e.g., emergency medicine, critical care medicine, and trauma medicine), professional society publications (e.g., WMS Practice Guidelines Series),[28] and consensus statements (e.g., NAEMSP Position Statements).[83] It is also valuable to review protocols written for other EMS systems with similar operational environments because this can establish a unified standard of care for the practice of WEMS medicine.

The WEMS program's medical director should lead protocol development with active involvement of WEMS providers and other relevant stakeholders. These might include traditional medical partners, such as trauma surgeons, intensive care specialists, nurses, and pharmacists or toxicologists; but for WEMS protocols, they might include a more diverse collection of allies, such as recreationalists and wilderness area administrators. In fact, it is stated in the original 1973 EMS Act that a robust EMS system includes consumer participation, and therefore WEMS protocol development should include input from relevant outdoor enthusiast groups.[125] Although there is benefit in involving many stakeholders in protocol development, the final decision regarding implementation of protocols is left to the system medical director, with ultimate approval by the relevant regulatory authority.

Individual protocols typically are packaged in a succinct published unit. Protocols should be comprehensive but focused enough so that providers can use them in real time in the field during patient care. The balance between comprehensiveness and ease of use often leads systems to develop a pocket protocol manual using clinical algorithms and a comprehensive protocol book or training manual that provides a more in-depth explanation of protocols that providers can study before going into the field. It is important to note, however, that a textbook is not a protocol book; a textbook teaches providers how to provide care, whereas protocols outline care that is permissible in a delegated practice. Protocols often provide the majority of off-line medical oversight for a WEMS program.

Regardless of the format used, protocols should be written in a manner that is easy to understand, even for the least experienced provider. Thus, protocols should be written in a step-wise manner, identifying the correct order and process for managing a patient in a given clinical situation, and should be easy to follow even for an individual with minimal patient experience.

Although written protocols may be grounded in straightforward assumptions, the clinical practice of medicine is dynamic and complex. Traditional EMS protocols often allow consultation with a base station physician by radio or phone for real-time direction when written protocols fail to address a unique clinical situation. Consultation may also occur when a patient is critically ill and needs care beyond the scope of practice of the EMS provider. Although direction to contact a physician in real time in an urban environment may be reasonable, WEMS differs in that direct communication is limited due to the environmental and technological constraints and cannot be assumed.

The inability for WEMS providers to contact physicians in real time mandates that WEMS protocols provide greater flexibility and independence for practitioners to provide appropriate care based on their training and scope of practice. The need for flexibility does not negate the importance of physician oversight and rapid physician involvement, but emphasizes the importance of active physician medical oversight and a trusting relationship between WEMS providers and the system medical director. Integrating physicians into the team as qualified field team members that regularly train in the field with the providers helps build trust and adds the potential for a more advanced level of care when the physician is available to accompany the team.[127] Further, because real-time physician involvement is often not available, a quality improvement program that reviews all cases is critically important to identify weaknesses in the protocols and areas for further education of WEMS providers.

WEMS protocols differ from traditional protocols by prioritizing patient extraction from the environment. For example, traditional EMS protocols have little need to include reduction of dislocated joints, but in the wilderness, joint reduction may be critical for safe patient extraction. Furthermore, in comparison with traditional EMS protocols, wilderness protocols should account for prolonged patient contact, occasionally lasting more than 24 hours, such that there may be a need for advanced wound care management, and addressing the nutritional needs and bodily functions of the patient. Finally, WEMS protocols should account for unique environmental conditions of specific wilderness environments.

SPECIFIC PROTOCOLS

Anaphylaxis

According to the American Academy of Allergy and Immunology, anaphylaxis is a systemic inflammatory reaction resulting from exposure to a known or suspected allergen.[3] True anaphylaxis can be life threatening, resulting in airway compromise, respiratory insult, and cardiovascular collapse. Although anaphylaxis may be accompanied by a histamine skin reaction resulting in hives and itching, a patient can die of anaphylaxis without skin manifestations, and the current clinical diagnosis of anaphylaxis does not require either hives or respiratory distress.[111] Thus, clinicians and protocols guiding WEMS providers should direct care for anaphylaxis based on clinical identification of anaphylaxis using modern criteria and not exclude it based on the absence of hives or dyspnea if other clinical indicators are present.

The only definitive treatment for anaphylaxis is epinephrine.[85,56] Although many treatment protocols instruct providers to give diphenhydramine, unless epinephrine is given as a higher priority, diphenhydramine will prevent itching as the anaphylactic attack progresses, sometimes to a fatal outcome. Other protocols also allow for steroid administration, usually dexamethasone or prednisone, to help stabilize the allergic response.

Although autoinjectors, such as the EpiPen, provide an easy method of administering epinephrine for inexperienced providers, they are costly and have a short shelf life, especially in hot environmental conditions.[82] Due to operational and cost constraints of autoinjectors there may be value in developing protocols for all levels of EMS providers to use vials of epinephrine with a syringe and needle. Administration is intramuscular (IM), ideally in the thigh, because this facilitates the quickest onset of action. Many WEMS teams were previously taught deltoid administration for epinephrine delivered via needle and syringe. However, unless environmental conditions contraindicate exposure of the thigh, the vastus lateralis (thigh) injection site is now preferred for both needle and syringe and autoinjector injections due to the known decrease in time to drug absorption (although actual outcome data comparing administration routes is lacking).[40,67,68,74,114,115] In wilderness care, environmental considerations may eliminate thigh administration as an option, in which case the deltoid would be a suboptimal but available route. A new prefilled syringe epinephrine product is currently undergoing Food and Drug Administration testing and may be commercially available soon; this could offer a lower-cost alternative for equipping WEMS teams with epinephrine.[1]

The recommended dose of 1:1000 epinephrine is 0.3 mg intramuscularly for adults and 0.15 mg intramuscularly for pediatric patients. Severe asthma is often included in this treatment protocol because the same symptoms and treatment algorithm can be used for this condition.

An emergency technique has been described for extracting additional doses from autoinjectors traditionally intended to have only a single dose.[48] Although this technique could be beneficial for wilderness medicine providers delivering unexpected care, WEMS teams should ensure they carry sufficient epinephrine to treat protracted anaphylaxis cases or multiple-patient scenarios. However, planning and protocols cannot anticipate all situations, and there have been published cases where extraordinary amounts of epinephrine have been needed in field situations, suggesting that this technique may be useful for WEMS teams as well in unusual circumstances.[120] Suggestions have also been made for ways WEMS providers could use this technique for weight-based dosing from an autoinjector, which would not normally be suggested or available for non-EMS personnel due to absence of additional training and equipment.[48]

Termination of Resuscitation

Despite the fact that several professional societies have published evidence-based guidelines for termination of resuscitation (TOR) during cardiopulmonary arrest, it can be difficult for emergency care providers to decide that resuscitation is futile and to cease their efforts. Nevertheless, especially in a wilderness environment, application of a TOR guideline is critically important for maintaining the safety of rescuers. Resuscitation of cardiopulmonary arrest is highly resource intensive and even in the most stable environments places rescuers at risk of harm.

Unless adequate postresuscitation care can be provided, which is difficult in a wilderness environment, the likelihood of a successful resuscitation with full recovery of neurologic status is quite small. Successful resuscitation requires a high CPR fraction (the percentage of time that chest compressions are performed within any given minute). Therefore, the intent of CPR should be to resuscitate on scene and not move the patient toward definitive care until a return of spontaneous circulation can be achieved. The focus is resuscitation on scene, and WEMS providers should be empowered to terminate resuscitation on scene so they are not obligated to move the patient.[84,86]

In the setting of a nontraumatic cardiopulmonary arrest, an evidence-based TOR protocol includes an unwitnessed arrest, a nonshockable rhythm, and failure to achieve a return of spontaneous circulation prior to transport.[79]

In a wilderness setting where a defibrillator may not be available, it is scientifically, logistically, and ethically reasonable to discontinue CPR and other resuscitation efforts after 20 to 30 minutes without a return of spontaneous circulation.[4,38] In the setting of a traumatic cardiopulmonary arrest, it is reasonable to terminate resuscitation after 10 minutes of CPR unless advanced resuscitative procedures (i.e., blood administration) can be brought to the patient's side by air medical resources within 10 minutes of arrest.[77]

WEMS providers should also be empowered to withhold resuscitation efforts entirely in situations that will put them in danger, or in cases with obvious death such as decapitation or hemicorpectomy.[102]

Wound Care

Traditional EMS protocols for wound care begin with hemorrhage control and quickly proceed to bandaging without other interventions. This may be adequate in operational environments with short out-of-hospital times, but in the wilderness more extensive treatment protocols are needed.

WEMS wound care protocols should include washing wounds to remove gross debris; may include closure with sutures, staples, tissue adhesive, duct tape, or a combination of the above; and should include consideration for administration of antibiotics to prevent soft tissue infections. Once the wound is cleaned and advanced care is initiated, it is appropriate to bandage for comfort, facilitation of extrication, and prevention of further tissue injury. Tourniquet application should, be taught for use when traditional bleeding control is not immediately adequate. Conversion techniques should be taught in prolonged care settings to allow removal of a tourniquet if bleeding can be reassessed and controlled by other means (i.e., direct pressure, wound packing, pressure bandage). In some technical settings, or MCIs, just as in some tactical or combat settings, a tourniquet first concept may be used to ensure no bleeding before a full assessment can be performed. Legitimate criticisms of improvised wilderness tourniquets have appeared in the EMS literature. For example, in 2008 Doyle and Taillac[33] wrote "the tourniquet should ideally be manufactured for its purpose. Improvised tourniquets will tend to apply pressure unevenly and often have sharp edges, increasing risk of underlying tissue damage. Examples of suboptimal improvised tourniquets include belts and similar straps, which can entrap skin and directly cause injury. Cravats or elastic dressings can bunch when twisted with a windlass." In acknowledgement of this, WEMS teams should carry commercially available and proven tourniquets, and should routinely train in their use.

Pain Management

Adequate pain management relieves suffering and facilitates safe extrication from the wilderness environment. Patients with extreme pain will be reluctant to move independently. Providing even moderate pain relief helps with self-extrication, which is always safer than a rescuer carry in a wilderness environment.

Pain management may be easily achieved with oral medications (e.g., acetaminophen, ibuprofen, or oxycodone). When oral opioids are not available or appropriate, intranasal (IN) fentanyl is an excellent choice for pain management. Ketamine is also being used for analgesia, after considerable experience with this drug in tactical and combat medicine. In general, oral or IM medication routes are preferred to IV routes in the wilderness; if an IV line has already been established for other purposes, IV medication administration is reasonable. The WMS has published a Practice Guideline with recommendations for acute pain management in the wilderness.[110] This is an excellent resource for WEMS teams considering their pain management strategies.

Joint Reduction

Unlike traditional EMS protocols, WEMS joint reduction protocols are crucial for facilitating safe patient extrication from a wilderness environment, restoring compromised neurovascular function, and preventing locked joints that would require operating room management with prolonged dislocation time. Most WEMS dislocation protocols allow for reduction of the patella, finger joints, and shoulder joint. With appropriate training and technique, it is possible to reduce a dislocated joint without medication administration, especially when the reduction is performed as quickly as possible after the initial injury. When medication administration is needed and if available, IN fentanyl or ketamine can facilitate field joint reductions. Advanced providers, such as physicians with appropriate training, may consider the risk-to-benefit ratio of other reductions, such as elbows and hips (especially if neurovascular compromise exists), and may choose to perform field reductions if benefits outweigh the risks of failure to reduce the dislocation.

Spinal Cord Protection

Immobilizing a patient on a long rigid spine board with a cervical collar has long been suggested management for a patient with suspected spinal cord injury. However, a recent literature review suggests long board use has demonstrated harms as well as theoretical benefit.[128] The historical literature has proposed that spinal column movement can cause delayed onset of neurologic symptoms from spinal cord injury. This theory also proposed that a long board would help prevent this movement and, thus, delayed neurologic symptoms. No research has demonstrated that delayed neurologic symptoms are due to patient movement. There been no demonstrated benefit to long board use in preventing delayed onset of neurologic symptoms.[62] In addition, recent literature demonstrates significant harm from backboard use in the form of impaired respiratory function and airway maintenance,[11,126] severe pain,[10,66] onset of skin breakdown with decubitus ulcers,[16,27,69,113] increased and unnecessary radiologic testing,[17,39,43,71] and prolonged out-of-hospital time. In the wilderness environment, placing a patient on a backboard condemns rescuers to carrying the patient, increasing exposure time, and increasing risk of injury to providers and patient.

Given a lack of evidence demonstrating benefit from backboards, a developing body of evidence demonstrating harm from backboards, and increased risk associated with backboard use to rescuers, it is reasonable to develop a protocol that only uses rigid to semirigid immobilization devices (e.g., vacuum mattresses) to extricate a patient that is not able to ambulate, has profound paralysis preventing ambulation, or is unconscious. An evidence-based protocol that eliminates unnecessary spine immobilization can allow patients to ambulate by themselves out of the wilderness. NAEMSP, the American College of Surgeons Committee on Trauma, and the WMS have all developed published statements addressing spinal immobilization; these statements promote algorithms to select patients who may not require immobilization in the first place, and reduction of backboard use in the out-of-hospital/wilderness environment.[87,106] One study showed that trauma patients in a predominantly rural country where backboards are not used had statistically significant less disability than those cared for in an urban American EMS system where backboards were used.[44] In summary, there is no clear evidence-based medical benefit to using backboards in a wilderness setting aside from initial technical extrication.

A growing body of literature questions the use of cervical collars in EMS, and thus WEMS, operations.[13,14,18,122] The evidence of harm from cervical collars is not as great as the evidence of harm from backboards, and given their theoretical benefits (although still unproven), some WEMS systems continue to use cervical collars. Other systems have omitted their use because of concerns for tissue necrosis, airway obstruction, and specific exacerbation of C1-C2 fracture pathophysiology,[13] and instead rely on basic physiologic splinting to limit cervical motion without use of commercial cervical collars to achieve the same result. Studies exist that support this approach, showing that an individual who got out of a vehicle under his or her own power had less cervical spine motion than one who had traditional cervical spine immobilization with a collar.[32,112]

The WMS Practice Guidelines on Spinal Immobilization recommend changes to other traditional WEMS practices regarding spine immobilization.[106] For example, they contend that a trapezius muscle squeeze provides superior manual cervical spine immobilization than a traditional head squeeze[19]; that a traditional log roll used to reduce spinal motion is actually less effective than the lift-and-slide, or BEAM (body elevation and movement), technique taught in many wilderness medicine programs[19,31,51]; and that, when properly applied, an improvised cervical collar using a SAM splint can be as effective as a Philadelphia collar.[75]

Acute Coronary Syndrome

Although a patient with a true acute coronary syndrome needs definitive treatment at a center with percutaneous cardiac intervention, research and consensus guidelines have documented a benefit to prehospital or out-of-hospital administration of aspirin in its management.[54] Therefore, it is wise to have a protocol to treat chest pain, shortness of breath, or other coronary angina equivalents with aspirin followed by rapid extrication to definitive care. Arguments can be made for including automated external defibrillators (AEDs) in field deployment, because early defibrillation dramatically improves survival rates. Some newer, smaller AEDs could be deployed with a search and rescue team rescuing a known patient with chest pain or other acute coronary syndrome, and at least one case report exists of deploying full-scale EMS defibrillators for suspected cardiac patients in the wilderness.[5] Internationally, AED familiarity and deployment have become common in mountain rescues. The International Commission of Mountain Emergency Medicine states that AED use should be taught in all mountain rescue curricula,[34] and that "a defibrillator should be considered to be in every physician's backpack," noting that 50% of physicians on mountain rescue teams already carry an AED.[35] In addition, they suggest that AEDs be installed in ski areas and mountain huts near cable cars or popular hiking trails.[36] Certainly for WEMS teams whose gear is carried by pack animals or mechanized or floating vehicles, AEDs and full EMS defibrillators become less onerous. In general, an AED is useful only if it is applied within a few minutes of collapse; this speed of response is atypical for most WEMS operations. Some authors suggest that unmanned aerial systems could carry AEDs and thereby resolve the issues of weight and speed for their use in the wilderness.[12]

Ectopic Pregnancy

Because the definitive treatment for ectopic pregnancy is surgical and the decision to mobilize resources for emergent extrication of a female patient with pelvic pain can be quite costly, there is value to having a protocol to perform a urine pregnancy test when clinically indicated. Especially in a remote environment or where evacuation can be extremely risky, the ability to rule out an ectopic pregnancy can be critically important in field decision making.

Hypoglycemia

Typically written as part of an altered mental status protocol, management of suspected hypoglycemia (or proven with a fingerstick glucose check) can be life-saving. WEMS providers should have protocols allowing for administration of oral glucose and IN or IM glucagon. WEMS medical directors may consider developing protocols for advanced-level providers to administer IV dextrose (either D50 or D10); protocols for IV fluid administration should account for environmental conditions and the weight of carrying IV fluids. Gel sports packets can be used as a substitute for oral glucose formulations typically used in traditional basic life support EMS systems.

Common Ailments

Although treatment protocols should focus on life and limb threats, there is also utility to symptomatic care so the patient feels better. Perhaps the most common medical ailments in the wilderness are viral respiratory illness and gastrointestinal upset. Thus, treatment protocols for symptomatic care of respiratory illness, gastroesophageal reflux, nausea, and diarrhea should be considered. The oral dissolving tablets of ondansetron (Zofran) have given field providers a reasonably good treatment for some causes of nausea and vomiting and can lead to on-scene hydration and prevent some evacuations.

Medication Administration

Typical urban EMS system protocols use IV medication and fluid management. Although this does typically allow for a quicker onset of action of medications, maintenance of an IV line and the weight of IV fluids and medications make IV administration less than practical for the wilderness setting. Therefore, whenever possible, WEMS protocols should dictate oral and IN administration of fluids and medications.

EQUIPMENT SPECIFICALLY NEEDED IN WILDERNESS EMERGENCY MEDICAL SERVICES

WEMS providers must frequently carry equipment needed for personal survival in addition to meeting the survival and medical needs of the patient. Further, equipment used to manage a WEMS event is typically carried in the WEMS provider's backpack. Because the speed of patient extrication from the wilderness environment can be inversely related to the weight of equipment carried by the WEMS provider, equipment should be compact and lightweight.

For personal and patient survival, WEMS providers may need to carry equipment for establishing shelter and protection from environmental elements; adequately hydrating themselves and the patient; and providing nutritional support for themselves and the patient, generally for a 24-hour period.

Medical equipment brought into a WEMS environment should support preestablished patient care protocols and be standardized for all WEMS providers in a given unit. Some principles to consider are that oral medications weigh less and last longer than IV medications; IN opiates provide adequate pain relief and provide a route for parenteral opiate administration without a need for IVs or needles; and it is always safer, whenever possible, for a patient to self-hydrate and self-extricate. Perhaps the only medication that must be administered with a needle system in a WEMS environment is epinephrine for management of anaphylaxis.

WEMS providers may need to decide whether to carry oxygen, a cardiac monitor, and other advanced technologic devices such as a portable ultrasound machine. Although monitors and ultrasound units may be useful in advanced diagnostics and should be considered for base station operations, their weight makes them impractical for many WEMS units. Carrying a portable oxygen delivery device may be helpful in some instances, but it is important to recognize that a portable "D" cylinder running at 10 L/min will only last about 30 minutes.

Patients who are critically ill in the WEMS environment, requiring establishment of an advanced airway, are at high risk for death, and rescuers should consider air medical transport whenever possible to extricate such patients. Rescuers should plan for proper sedation and liberal use of paralytics because patient movement and airway dislodgement may have significant complications. Rescuers should consider the use of a King supraglottic airway because it is lightweight, easily placed, and does not require laryngoscope blades. The laryngeal mask airway is not adequate in the WEMS environment, because it does not adequately protect against aspiration. A patient with an advanced airway in place should have the neck immobilized as much as possible in a neutral midline position to help prevent dislocation of the airway. This can be done with proper positioning of a vacuum mattress or a cervical collar.

Because the primary cause of death following trauma is hypovolemic shock secondary to hemorrhage, WEMS units need to be able to adequately manage external hemorrhage with simple bandages and tourniquets, and have diagnostic and management protocols to extricate as quickly as possible patients with a high risk for internal hemorrhage. WEMS units also need to be able to manage orthopedic injuries because they have a risk for complications and, if not adequately managed, result in prolonged extrication times.

A final consideration is equipment for protecting the rescuer from exposure to bodily fluids. Before going into the wilderness environment, all WEMS providers should have current tetanus prophylaxis and immunization against hepatitis B. WEMS providers should carry nitrile (latex-free) medical examination gloves and an alcohol-based hand-cleansing solution. Rescuers should carry an identified biohazard bag to carry soiled bandages and other articles soaked with bodily fluids. WEMS systems should have training in blood-borne pathogens and should have protocols to follow in the event of inadvertent exposure.

THE FUTURE OF WILDERNESS EMERGENCY MEDICAL SERVICES

CHALLENGES TO WILDERNESS SYSTEMS

Provider Shortages

A critical paramedic shortage in traditional EMS operations has been described both in the media and by formal organizations, such as the Committee on the Future of Emergency Care in the United States Health System.[53] This shortage is expected to extend to WEMS operations and cause similar stressors on availability of qualified WEMS responders, especially as the field grows more sophisticated and more advanced levels of responders (such as paramedics) are increasingly sought.[45,47]

Even if most WEMS responders require less training than a paramedic, another challenge exists: in the United States, most WEMS providers are volunteers.[47] This is particularly true of technical rescue WEMS teams, such as mountain rescue teams, ski patrols (especially in the eastern United States) and cave rescue teams, which have historically been regionally based and consist of volunteers rather than government employees. Using volunteers might have been sustainable in the past, but increasingly is not a viable prospect. Time and financial constraints, two of the most frequently cited reasons why personnel leave rural EMS systems, are also detrimental for volunteer WEMS teams. The 9/11 terrorist actions in the United States generated a spike in volunteerism, but since that time there has been a steady decline;[20,73] declines are especially dramatic in numbers of rural volunteer fire rescuers, who often become WEMS providers.[90] Of the nation's fire departments, 73% are made up of volunteers only; 70% of rural EMS services struggle to recruit and retain volunteers, and one fifth of these services expect the problem to worsen.[41] The growing complexity of the industry, the extent of its regulatory requirements, and the substantial increases in training requirements, although marking an increase in professionalism and standards, also mark an increased burden in terms of time and finances for the average volunteer.[107] Cultural changes, such as differences in generations X and Y from prior generations and changes in parental roles, may drive decreasing volunteerism in rural EMS and WEMS.[41]

In the United States, the NPS, which is probably the single largest WEMS system, suffers from a critical ranger shortage,[45,99,117,124] a problem also seen by rangers in other systems.[101] Hiring of new rangers is increasingly difficult. Combined with decreased recruitment, about 50% of rangers specializing in law enforcement (which includes search and rescue and EMS providers) must retire from 2010 to 2015 under federally mandated age guidelines.[80] The rangers who remain have often been reassigned away from wilderness settings, or their funds have been reallocated for monument protection and other nonwilderness priorities, following the terrorist attacks of 2001. By 2004, millions of dollars in fees had been diverted to increased security requirements, resulting in a shortfall of $600 million annually.[94]

Ranger work capacity is also stretched by the fact that as resources are being reduced, the number of visitors to parks is increasing. In 2014 in North Carolina (also a formal WEMS system), a record number of people visited its parks, a 10% increase in volume over 2013.[97] A recent analysis showed that visitors to NPS parks increased by more than 60 million people but the number of permanently commissioned rangers dropped by 16% and the number of seasonal rangers dropped by 24% over the same period.[94] It has been estimated that one in five persons who requested search and rescue assistance in the national parks would have died without the response of medically trained NPS personnel.[50] Obviously, the growing mismatch in numbers of park visitors and EMS personnel could have dire consequences for visitors and their medical outcomes if it is not corrected.

In addition to paramedic and ranger shortages, a physician shortage exists. In particular, as with EMS in North America, physicians are often not part of a field response. This is not the case in Europe and parts of Asia, where physicians are often heavily involved in mountain rescue and other wilderness rescue operations. An increased emphasis on physician field response is an important element in modern EMS in the United States, and particularly in WEMS, where autonomous decision making is a critical skill and protocols can rarely anticipate all situations.

Even without a field response, adequate physician oversight is a *sine qua non* of EMS operations. This should be equally true for all WEMS systems as well. In some systems this has already been accomplished, such as WEMS teams that have been built within an existing infrastructure. Other WEMS programs, such as ski patrols, ocean rescue programs, and some mountain rescue teams, do not meet this standard. WEMS organizations should be encouraged to meet these standards insofar as they consider themselves an EMS service, or as their authority to practice medical care does not stem from a source other than EMS medical practice.[46]

Authorities have also recognized shortages of lifeguards in WEMS systems.[2,109,118,123] In some state parks, open water sites have had to be left unguarded; at least one documented death has occurred in a lake that would otherwise have been staffed with a lifeguard.[123] Reasons cited for this shortage are similar to those for other WEMS systems, including increased training costs, minimal compensation, and, more specific to lifeguarding, employment that is often only seasonal, and, in most sites, absence of career opportunity.[2,109,118] More urbanized swimming areas can limit hours to address the shortage, but this is more difficult for beaches and public access/wilderness open water.[2]

Insufficient Funding

Insufficient funding has always been a challenge for WEMS teams; as noted earlier, this is a theme of EMS in general. Grant funding, fundraisers, product sales, and direct community appeals are all frequently used tools. Interestingly, most teams prefer not to charge for their services. Some teams obtain governmental endorsement and subsequent governmental funding.

Not all elements of WEMS are underfunded. One common misunderstanding about helicopter-based WEMS/rescue is the perception that it is a particularly expensive and unfunded service, or a service funded by additional taxpayer levies. In fact, most helicopter-based rescues involve state or federal assets and these operations are usually rolled into preexisting training budgets at no additional cost.[47] However, there exist examples of nonprofit helicopter-based WEMS and rescue services. Funding may be as difficult, or even more difficult, for these services, given the expense of helicopter operations. For example, the Snohomish County (Washington) Search and Rescue Helicopter Team has been a long-standing nonprofit, independent team for which the federal government provides funding for fuel and maintenance. When such funding was discontinued in April 2013, the team was required to seek other sources for this expensive nonprofit WEMS/rescue operation.[42]

Validity of and Reimbursement for Services

One future challenge to WEMS is a philosophical and political question regarding the fundamental appropriateness of WEMS. Opponents of WEMS argue that the absence of formal medical care and rescue availability is intrinsic to the concept of "wilderness" and is also part of its appeal. This philosophy posits that individuals venturing into these areas should be self-sufficient and not require or request rescue or medical care.[47]

A less extreme but similar position is that services rendered by WEMS should not be free. Unlike most EMS operations in the United States, rescues and WEMS medical care are usually provided by uncompensated volunteers or by the government and are implicitly paid for by taxpayers.[45] (This is in contrast to Europe, where the standard is to charge for services rendered, so that most individuals and groups there purchase rescue insurance.)[30] Advocates of billing for rescue suggest that some culpability for the need for rescue falls on the individual(s) in jeopardy, which means they should absorb some of the cost. The more often rescue is needed for those pursuing activities that the general public considers extreme or risky, the more likely there are to be demands that the rescuees pay. Opponents of billing for rescue argue that individuals injured or ill and in jeopardy in a wilderness environment will delay calls for help because of fear of the cost. For example, the Mountain Rescue Association has a policy that no charge be levied by affiliated organizations. Also, despite the fact that state and national parks have no specifically mandated "duty to rescue," such authorities do have an obligation to protect the safety of participants in their regions, which is often extended to rescue and thus uncompensated medical care.[47] In some areas that are considered particularly high risk, a prospective rescue fee may be levied on visitors. For example, a $150 fee was required of climbers attempting Denali in 1995 to defray rescue costs. Some argue that this unfairly targets activities like mountaineering that *appear* to be riskier but may not actually be so based on data. For example, when studied, only 5% of rescues in Alaska involved climbing; the remaining 95% of rescues did not include a fee to defray the rescue costs for their nonclimbing recreational activity, despite the fact that, for example, Coast Guard rescues in Alaska are substantially more expensive in aggregate than climbing rescues.[103] It is worth noting that the NPS, U.S. Coast Guard, Mountain Rescue Association, American Alpine Club, and most search and rescue authorities do not support levying individual bills for mountain search and rescue or coastal rescues.[9,95,108] Some exceptions do exist, such as Telluride County, Colorado, where rescues may be billed to individuals who are pursuing "high-risk recreational pursuits."[29] In a very interesting legal precedent, in 2013 a volunteer who fell off a 110-foot cliff while involved in a search in California sued an individual who was eventually rescued, charging that the rescuee was responsible for the rescuer's injury. The plaintiff (the search team volunteer) argued that the defendant (the rescuee) "headed out unprepared and unqualified to a remote and dangerous mountain area with the intent to take hallucinogenic drugs, knowing the likelihood of becoming disoriented, lost and requiring… rescue." The case was settled out of court.[105] In legal terms, this concept of "foreseeability" invokes *Palsgraf v. Long Island Railroad Co.*,[98] a seminal case that established foreseeability as the test for proximate cause. Should this establish a trend of tort exposure to rescues (that certain actions by an individual in a wilderness setting might foreseeably lead to need for rescue, and allow for individual rescuers to sue either for injuries incurred during that rescue or for the rescue itself), the landscape of rescue finances and medicolegal parameters of wilderness rescue could change dramatically. Although this legal maneuver is novel, it does not appear to be changing the basic philosophical conviction of most American WEMS and search and rescue organizations that rescue should not incur a fee.

Defining No-Rescue Areas

In the extreme, even if rescue is desired and regardless of financial concerns, some regions have been designated as no-rescue areas. Upon entering these areas, in the opinion of some wilderness medicine ethicists and other members of society, people automatically place themselves at such a high level of risk that assistance need not be given. Examples include Neil Armstrong and Buzz Aldrin venturing to the moon (surely the epitome of a wilderness environment in which no medical care aside from WEMS would be available) or early mountaineers venturing above 8000 m (26,247 feet). As planning for rescue operations and, in some cases, completion of operations have occurred even in such environments, one wonders whether no-rescue areas still exist today.[47,55] Whether or not certain places should be designated as no-rescue areas, remote areas continue to be cited in the literature where no organized rescue services exist, such as the Brazilian Amazon east of Manaus.[121] There is an obvious tension here for wilderness advocates. Each time WEMS protection of human life is extended to an area that had been a no-rescue area, it represents a success for the continued growth and reach of WEMS. On the other hand, adventurers (who have existed since the dawn of human history) hope that some areas in our universe will remain true wilderness, in which there is no hope of rescue by others and to which they can venture with full knowledge that they are completely self-sufficient.

FUTURE AREAS OF GROWTH IN WILDERNESS EMERGENCY MEDICAL SERVICES

Intersection of Rural Emergency Medical Services and Wilderness Emergency Medical Services

An important area of growth for WEMS in its capacity as a medical subspecialty involving resource-deficient or austere medical care is its intersection with rural EMS systems. In many areas, EMS systems use resources found in their areas and essentially operate as WEMS agencies in the course of their “traditional” operations (e.g., in Hyde County, North Carolina; on Little Gasparilla Island, Florida; and at the Burning Man Festival medical operation in Nevada).[21] In some countries with little urban development or established medical care, all EMS systems could be viewed as wilderness or austere services.

Technology

A significant difference between WEMS and wilderness medicine is the technology available to the WEMS provider. In some instances, a WEMS provider may have more resources than a hospital-based provider. This is why defining WEMS exclusively as a medical operation in a resource-deficient environment is problematic. For example, Denali National Park rangers, clearly operating in a WEMS system, have access to a high-altitude A-Star B3 helicopter owned by the NPS. This resource is unavailable to any non-WEMS hospital-based provider in the United States. Similarly, in North Carolina, an innovative NC HeloAquatic Rescue Team merges civilian EMS personnel with military UH-60 Black Hawk helicopters and flight crews.[100] The team has completed many WEMS operations, including the first nighttime climbing rescue pickoff in North Carolina history, in environments (and in weather conditions) that no civilian hospital-based emergency physician would be able to reach.

Many technologic innovations and concepts, including portable ultrasound units, ultra-small defibrillators, innovative water treatment systems, and next-generation patient packaging concepts, are introduced elsewhere in this textbook. One new tool

BOX 54-2 Suggested Internet Resources for WEMS

Adirondack Wilderness Medicine: adkwildmed.com
AdventureMed: awls.org
Aerie School of Backcountry Medicine: aeriemedicine.com
Allegheny Mountain Rescue Group: amrg.info
American Alpine Club: americanalpineclub.org
American Medical Response Reach and Treat Team: summitpost.org/article/172226/amr-reach-and-treat-who-we-are-and-what-we-do.html
American Mountain Guides Association: amga.com
American Safety and Health Institute: hsi.com/ashi
Appalachian Center for Wilderness Medicine: appwildmed.org
Appalachian Mountain Rescue Team: appalachianmountainrescue.org
Appalachian Search and Rescue Conference: asrc.net
APT Antincendio: aptgroup.it
Carolina Wilderness EMS Externship: hawkventures.com/externship
Carolina Wilderness EMS Seminar: hawkventures.com/seminar
Carolina Wilderness EMS Summit: hawkventures.com/summit
CDS Outdoor School: cdsoutdoor.com
Crag Rats: cragrats.org
Diploma in Mountain Medicine: theuiaa.org/mountain_medicine.html
Divers Alert Network: diversalertnetwork.org
Federal Emergency Management Agency: fema.gov
Front Range Institute of Safety: frisfirstaid.com
Global Rescue: globalrescue.com
Harvard University Wilderness Medicine Fellowship: massgeneral.org/education/fellowship.aspx?id=94
Hawk Ventures: hawkventures.com
International Commission for Alpine Rescue: ikar-cisa.org
International Institute for Sustainability in Emergency Services: greenems.org
International Society for Mountain Medicine: ismmed.org
International Surf Lifesaving Association: islasurf.org
Landmark Learning: landmarklearning.org
Lifeguards Without Borders: lifeguardswithoutborders.org
Longleaf Wilderness Medicine: longleafmedical.com
Médecins Sans Frontières/Doctors Without Borders: doctorswithoutborders.org
Medic Response Safety: medicresponse.com
Medical Commission of the International Mountaineering and Climbing Federation (Union Internationale des Associations D’Alpinisme): theuiaa.org
Medical Officer, Ltd.: medofficer.net
Mountain Rescue Association: mra.org
Nantahala Outdoor Center: noc.com
National Association for Search and Rescue: nasar.org
National Cave Rescue Commission: ncrc.info
National Disaster Life Support Foundation: bdls.com
National Disaster Medical System: phe.gov/Preparedness/responders/ndms/Pages/default.aspx
National Ski Patrol: nsp.org
National Speleological Society: caves.org
Professional Outdoor Medical Educators: wildernessmedicine.com/pome-evaluation
Remote Medical International: remotemedical.com
Rescue 3 International: rescue3.com
Rigging for Rescue: riggingforrescue.com
Royal National Lifeboat Institution: rnli.org
Stanford University Wilderness Medicine Fellowship: emed.stanford.edu/specialized-programs/wilderness-medicine/fellowship.html Stonehearth Outdoor Learning Opportunities: soloschool.com
United States Coast Guard: uscg.mil
United States Department of Defense: defense.gov/
United States National Park Service: nps.gov
University of California San Francisco–Fresno ParkMedic Program: fresno.ucsf.edu/em/parkmedic/
University of New Mexico EMS Fellowship and Wilderness and Austere Medicine Fellowship: emed.unm.edu/education/current-fellowships/index.html
University of Utah Wilderness Medicine Fellowship: medicine.utah.edu/surgery/emergency_medicine/fellowships/ems_wilderness_fellowship.php
Vertical Medicine Resources: vertical-medicine.com
Wilderness Emergency Care: wildernessemergencycare.com
Wilderness and Emergency Medicine Consulting: wildernessdoc.com
Wilderness EMS Institute: wemsi-international.org
Wilderness EMS Medical Director Course: wemsmdcourse.com
Wilderness First Aid: wfa.net
Wilderness Medical Associates: wildmed.com
Wilderness Medical Society: wms.org
Wilderness Medicine Institute of the National Outdoor Leadership School: nols.edu/wmi
Wilderness Medicine Outfitters: wildernessmedicine.com
Wilderness Medicine Training Center: wildmedcenter.com

is the Compensatory Reserve Index, developed by the U.S. Army Institute of Surgical Research in San Antonio, Texas, in conjunction with Flashback Technologies.[49,81,119] This device uses a pulse oximeter waveform and, by means of an analytic program, can predict the hemodynamic reserve of a patient. If this tool is found to be accurate, it will predict when a patient will go into a state of shock or hemodynamic collapse and what will be the appropriate level of response (e.g., high-risk helicopter evacuation or low-risk ground transport). It could also be used to guide ongoing treatment.

WEMS systems must keep abreast of these innovations and implement them when appropriate for a given patient population and environment and when financially viable. In the future, WEMS will likely include high-technology services for patients while they are in the wilderness rather than when they arrive at the hospital.

EMS as a Physician Subspecialty

The importance of the formal recognition of EMS by the American Board of Medical Specialties in 2011 as a discrete medical subspecialty cannot be overemphasized in the context of the future of WEMS. The associated initiation of accredited EMS fellowships and the potential for full-time field EMS physician providers has several implications for WEMS. We anticipate more physician involvement in field medical care, with extension into WEMS field operations. Also, current Accreditation Council for Graduate Medical Education requirements include WEMS components that must be covered for an EMS fellowship to receive accreditation. Many urban EMS fellowships have not provided this training before now, so accreditation will mean that EMS providers will receive at least a minimal amount of WEMS exposure.

SUMMARY

WEMS is a hybrid subspecialty, merging elements from wilderness medicine and EMS. The critical difference between wilderness medicine and WEMS is that the primary mission of WEMS is to provide EMS in an environment with few resources and to act within that environment. WEMS providers and teams therefore require specialized training and protocols to meet the challenge of serving as formal EMS providers in austere and wilderness environments. Specialized medical oversight, robust field protocols, encouragement of appropriate field medical decision making, and reality-based training are all critical to the success of a WEMS program.

SUGGESTED INTERNET RESOURCES FOR WILDERNESS SERVICES

Box 54-2 lists a number of Internet resources for WEMS.

REFERENCES

Complete references used in this text are available online at expertconsult.inkling.com.

CHAPTER 55
Search and Rescue

DONALD C. COOPER AND WILL SMITH

As ever-increasing numbers of outdoor users turn to the wilderness for recreation, the medical community and search and rescue (SAR) organizations are contending with a growing number of lost, sick, and injured persons. Wilderness SAR and associated medical interventions required in isolated outdoor environments are unique in several ways. All aspects of SAR are generally more time consuming than similar front country traditional emergency medical services (EMS) and SAR responses. Simply raising the alarm for someone lost or injured in an isolated area may take hours, days, or even weeks. Organizing a response, including obtaining equipment and transportation for responders, requires a variable amount of time, depending on the level of preparedness and resources of the response organization(s). Locating, gaining access to, stabilizing, and transporting/transferring a victim to definitive care can be a lengthy process.

Because it takes many people to perform a wilderness rescue (six or eight people are required to carry a litter 1 mile; Figure 55-1), logistic considerations such as food, shelter, and transportation for responders quickly create their own problems. SAR personnel are also subjected to the same risks and environmental stresses that compromise victims. To avoid further tragedy, SAR personnel must have a heightened awareness of potential danger, adverse conditions, and personal limitations. In addition to (at least) basic prehospital medical training, rescuers must have extensive wilderness experience (or experience in the particular environment in which they will be operating) that combines practicality with creativity and resourcefulness. SAR personnel must have training in survival, improvisation, communications, leadership, navigation (e.g., map, compass, and Global Positioning System [GPS] techniques), first aid, and specific SAR techniques. Many medical interventions common in the hospital or emergency department environment are difficult, if not impossible, in the wilderness setting. As compared with tactical EMS guidelines (tactical emergency casualty care [TECC] or tactical combat casualty care [TCCC][8,9,33]), the right procedure or intervention must be carried out in the right continuum of care so the patient and rescuers are not compromised (e.g., extraction should be a much higher priority than attempting to start an IV on the side of a cliff where obvious dangers still exist). Patient assessment may be hampered by bulky clothing, environmental conditions, the patient's location, and/or numerous other challenging situations encountered while providing care in the SAR environment. Medications and equipment are subject to rough handling and extremes of environmental factors (e.g., temperature, altitude, humidity), which may render them ineffective, unsterile, or inoperative (see Appendix: Drug Stability in the Wilderness).

Finally, decision making that optimizes patient care while not unduly risking the well-being of SAR personnel requires experienced leadership grounded in operational decision making, common sense, and technical skill. The situation, usually urgent, dictates where, when, and how rescuers practice their art. The same situation that has already compromised at least one person's health and safety may subsequently, and often more significantly, endanger those attempting the rescue.

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FIGURE 55-1 Carrying a litter across rough terrain is resource intensive, fatiguing, and fraught with opportunity for injury. *(Photo courtesy of Eve Vigil, San Luis Obispo, CA, SAR.)*

SEARCH AND RESCUE: AN OVERVIEW

SAR systems provide the response for overdue, lost, injured, or stranded persons, usually in connection with outdoor activities and environments. In the context of SAR, *wilderness* can take on several meanings. For instance, most consider wilderness to be a region uninhabited and uncultivated. Response personnel may be called out to search a natural area such as a large park or desert, but it is also likely that a search will be urban, in an area devastated by a natural disaster such as an earthquake or hurricane. Because most people in the United States reside in urban areas, emergency responders and SAR personnel are often more likely to encounter an urban wilderness than a natural one. This chapter focuses on the nonurban setting. However, many of the same principles can be applied in any location.

Types of SAR emergencies vary nationally and internationally, as do the responders. Programs, equipment, and personnel differ geographically in accordance with local needs and available resources. SAR can generally be defined as "finding and aiding people in distress—relieving pain and suffering."[12] However, contemporary references find it most useful to define *search* and *rescue* separately (Box 55-1).[30]

SAR often involves a great many volunteers and entails a multitude of skills. Consider the following examples of significant, yet vastly different, threats, hazards, and environments requiring widely diverse sets of SAR skills[7,45,59]:

BOX 55-1 Search and Rescue Defined

Search: An operation using available personnel and facilities to locate persons in distress

Rescue: An operation to retrieve persons in distress, provide for their initial medical or other needs, and deliver them to a place of safety

From the International Maritime Organization and International Civil Aviation Organization (IMO/ICAO): *International aeronautical and maritime search and rescue manual:* vol I, *Organization and management;* vol II, *Mission co-ordination;* and vol III, *Mobile facilities,* London/Montreal, 2013, International Maritime Organization and International Civil Aviation Organization.

- The eruption of Mt St Helens in Washington State in 1980
- The terrorist attacks on the World Trade Centers and Pentagon in 2001
- Multiple Atlantic hurricanes that struck the southeastern United States in 2004 and 2005, including Katrina and Rita
- The Sumatra-Andaman earthquake and subsequent tsunamis of 2004 (300,000 dead)
- Cyclone Nargis in 2008 (84,500 dead and 53,800 missing)
- The 2010 Haiti earthquake (250,000 dead and 2,000,000 homeless)
- The 2011 Tohoku earthquake and tsunami (15,894 dead and 2562 missing)

Management of these SAR operations can range from directing the actions of a few responders in a small community to managing an effort involving thousands of responders in a large urban disaster. Often, large situations involve several geopolitical subdivisions (e.g., cities, counties, states, countries) and coordination of air, ground, and/or marine resources. Local governments and other agencies that participate in SAR must coordinate diverse, all-hazard responders. In addition, many agencies that collectively support multiorganizational SAR responses operate under their own specific statutory authority.[64,65]

Time is almost always a factor in SAR operations, which tend to focus efforts on a quick conclusion. The general idea is to find or rescue the missing, lost, or injured subject before he or she succumbs to the effects of the environment, injuries, or a specific hazard.

INTERNATIONAL AGREEMENTS

International conventions are often what countries use to establish rules between them. The Convention on International Aviation, the International Convention on Maritime Search and Rescue, and the International Convention for the Safety of Life at Sea include rules requiring countries that are parties to these agreements to provide aeronautic and maritime SAR coordination and services for their territories and territorial seas. Coverage of the high seas is apportioned among the member countries by these instruments as well. To carry out its SAR responsibilities, a country usually establishes a national SAR organization or joins one or more other countries to form a regional SAR organization. In the United States, the national SAR organization is called the National Search and Rescue Committee (NSARC).

While airborne, virtually all commercial aircraft on international routes are under positive control (e.g., followed by radar and in direct communication with air traffic controllers) by air traffic services units. The International Civil Aviation Organization (ICAO) has linked air traffic services units into a worldwide system. Consequently, SAR agencies are usually notified very quickly when an international commercial flight has an emergency. Commercial aircraft on domestic routes and general aviation aircraft may not be under positive control, which can result in delayed reporting of their emergencies. The international aeronautic distress frequency is 121.5 MHz, and is monitored by the air traffic services units, some commercial airliners, and other aeronautic facilities where needed to ensure immediate reception of distress calls. Emergency locator transmitters (ELTs) are carried in most aircraft and required in most aircraft flown in the United States (see section on COSPAS-SARSAT), but none of these technologies or systems guarantee a quick rescue, especially when vast oceans and wilderness areas are involved. For example, in March 2014, Malaysia Airlines flight 370, carrying 12 crew and 227 passengers from 15 countries, disappeared while flying from Kuala Lumpur to Beijing. The last voice contact occurred while the aircraft was over the South China Sea. The plane was last plotted by military radar over the Andaman Sea. After a multinational search effort, one believed to be the largest and most expensive in history, there has been no confirmation of any flight debris or crash site.[3,43]

Additional information on international SAR may be found at the International Maritime Organization (IMO) website (imo.org) and ICAO website (icao.int).

BOX 55-2 Five Stages of SAR

Awareness
Initial action
Planning
Operations
Conclusion

From the International Maritime Organization and International Civil Aviation Organization (IMO/ICAO): *International aeronautical and maritime search and rescue manual:* vol I, *Organization and management;* vol II, *Mission co-ordination;* and vol III, *Mobile facilities,* London/Montreal, 2013, International Maritime Organization and International Civil Aviation Organization.

INTERNATIONAL STAGES OF SAR OPERATIONS

The international SAR community has developed an approach to organizing operations that evolved over the past several decades. This system is documented in the *International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual,*[30] which was developed jointly by the ICAO and the IMO. Each of the three *IAMSAR Manual* volumes is written with specific SAR system duties in mind and can be used as a stand-alone document or in conjunction with the other two volumes as a means to attain a full view of the SAR system. Volume I, *Organization and Management,* discusses the global SAR system concept, establishment and improvement of national and regional SAR systems, and cooperation with neighboring countries to provide effective and economical SAR services. Volume II, *Mission Co-ordination,* assists personnel who plan and coordinate SAR operations and exercises. Volume III, *Mobile Facilities,* is intended to be carried aboard rescue units, aircraft, and vessels to help with performance of search, rescue, or on-scene coordinator functions and with aspects of SAR that pertain to their own emergencies.

The *IAMSAR Manual* describes a series of five stages through which most SAR events pass: awareness, initial action, planning, operations, and conclusion (Box 55-2). The manual suggests that "These stages should be interpreted with flexibility, as many of the actions described may be performed simultaneously or in a different order to suit specific circumstances."[30] The reason the *IAMSAR Manual* does not have a "preplanning" stage is twofold. First, the five stages of a SAR are about what happens in a specific incident. Preplanning can address types of incidents but not specific incidents. Second, the preplanning function is addressed in what are called plans of operations or operations plans. These are standing plans for how to deal with various kinds of situations.

Awareness Stage

A SAR organization cannot respond to an incident until it becomes aware that someone is in need of assistance. At this stage, information is received that someone (or an aircraft or a vessel) is, or will be, in distress. There may not be enough information to initiate action, or action may not yet be necessary. When traveling in remote locations, even raising the alarm when help is needed may be an issue. Help may not be available, easily accessible, or able to respond fast enough to be of any assistance. Thus, persons traveling in remote locations must be capable of, and prepared for, self-rescue as necessary.

Initial Action Stage

When enough information is available, immediate action may be necessary. The first action is always to evaluate the information available, attempt to gain more, and determine the degree of the emergency. The "phase" of the emergency is used by the SAR authority to describe the level of confidence in the available information and concern it raises about the safety of an aircraft or a vessel and the persons on board. The *IAMSAR Manual* describes three emergency phases: uncertainty, alert, and distress.

- Uncertainty phase: A situation wherein doubt exists as to the safety of an aircraft or vessel and the persons on board
- Alert phase: A situation wherein apprehension exists as to the safety of an aircraft or vessel and the persons on board
- Distress phase: A situation wherein there is reasonable certainty that a vessel or other craft, including an aircraft or person, is threatened by grave and imminent danger and requires immediate assistance

An overdue aircraft, as an example, may be late for a wide range of reasons. The phases of the emergency allow personnel in charge to establish and communicate a summary of the available information that matches its validity, urgency of action, and extent of the response required. The *IAMSAR Manual* requires specific initial actions based on the established emergency phase.

Planning Stage

Planning operations is essential, especially when the location of the distress situation is unknown. "Proper and accurate planning is critical to SAR mission success; if the wrong area is searched, there is no hope that search personnel will find the survivors, regardless of the quality of their search techniques or the amount of their search effort."[30] The *IAMSAR Manual* suggests the use of computers for operational planning but also includes basic information on manual methods of planning searches.

Operations Stage

The operations stage encompasses all the physical activities involved in finding, providing assistance to, and rescuing people in distress. In short, this phase is where the plans are carried out.

Conclusion Stage

The conclusion stage is entered when it is determined that no one is in distress, when the search or rescue is concluded, or when nothing was found and the search is called off. This phase is when all SAR resources are notified that the mission is concluded.

COSPAS-SARSAT

The SARSAT system (search and rescue satellite-aided tracking) was developed in a joint effort by the United States, Canada, and France. In the United States, the National Oceanic and Atmospheric Administration (NOAA) is the lead agency and coordinates national participation in SARSAT and associated international programs. The COSPAS system (*cosmicheskaya sistyema poiska avariynich sudov* [in English, "space system for the search of vessels in distress"]) (Box 55-3) was developed by the Soviet Union. The United States, Canada, France, and Russia banded together in 1979 to form COSPAS-SARSAT. In 1982, the first satellite was launched and the first life saved using the system. The system was declared fully operational in 1984. The COSPAS-SARSAT system ceased satellite processing of the original 121.5/243-MHz beacons on February 1, 2009. Second-generation 406-MHz beacons were introduced in 1997 that allow transmission in the 406-MHz message of encoded position data acquired by beacons from global satellite navigation systems such as GPS, using internal or external navigation receivers. As of this writing, the four original member nations have been joined by many other nations and two regional organizations that operate ground stations and mission control centers that convey alert data to six data distribution regions worldwide (United States, France, Russia, Australia, Japan, and Spain). As of October 2014, the

BOX 55-3 COSPAS-SARSAT Abbreviations

COSPAS: *cosmicheskaya sistyema poiska avariynich sudov* (Russian [in English, "space system for the search of vessels in distress"])
ELT: emergency locator transmitter
EPIRB: emergency position–indicating radio beacon
PLB: personal locator beacon
SARSAT: search and rescue satellite-aided tracking

From the National Oceanic and Atmospheric Administration: National Environmental Satellite, Data and Information Service, Search and Rescue Satellite-Aided Tracking (SARSAT) (sarsat.noaa.gov).

COPAS-SARSAT system had provided assistance in rescuing more than 35,000 persons in over 8000 incidents.[47] Visit cospas-sarsat.org or sarsat.noaa.gov for more details.

The system uses satellites to detect and locate emergency beacons carried by ships, aircraft, and individuals transmitting on 406 MHz. The system consists of a network of satellites, ground stations, mission control centers, and rescue coordination centers. When an emergency beacon is activated, the signal is received by a satellite and relayed to the nearest available ground station. The ground station, called a local user terminal, processes the signal and calculates the position from which it originated. This position is transmitted to a mission control center, where it is joined with identification data and other information on that beacon, if the beacon has been registered with NOAA, which is required by law in the United States (see below). The mission control center transmits an alert message to the appropriate rescue coordination center (RCC), based primarily on the geographic location of the beacon. If the location of the beacon is in another country's search and rescue region (SRR), the alert is transmitted to the appropriate mission control center.[47]

COSPAS-SARSAT is in the process of upgrading its system by placing SAR repeaters on Global Navigation Satellites (GPS from the United States, GLONASS from Russia, and Galileo from Europe) orbiting the earth. These new COSPAS-SARSAT assets will be part of a system known as MEOSAR, for Medium-altitude Earth Orbit Search and Rescue system, which is scheduled to be operational in 2016. MEOSAR will offer the advantages of both the current satellite systems used by COSPAS-SARSAT, without many of their current limitations, by relaying beacon distress messages and simultaneously calculating the beacon location anywhere on Earth almost instantly as the alert signal is received. The MEOSAR system also will allow an optional "return link" transmission back to beacons, which could provide confirmation to the person in distress that the alert message has been received.[47]

Distress Radio Beacons

The most recognizable component of the SARSAT system is the distress radio beacon, also known as a "beacon." There are generally three types of beacons used to transmit distress: emergency position–indicating radio beacons (EPIRBs) designed for maritime use, emergency locator transmitters (ELTs) designed for aviation use, and personal locator beacons (PLBs) designed for use by individuals and land-based applications. Although the three types of devices are physically different due to the differing environments in which they must operate, they all work on the same principle and in the same way. When turned on (automatically or manually), each transmits alert signals on specific frequencies intended to be received by COSPAS-SARSAT satellites.

Only a few frequencies are used by these beacons:

- 121.5 and 243 MHz are used by many existing analog beacons, but the COSPAS-SARSAT system ceased satellite processing of these signals in 2009. Other devices (such as man-overboard systems and homing transmitters) that operate at 121.5 MHz and do not rely on satellite detection are not affected by the cessation of satellite processing of 121.5 MHz. The 121.5 frequency is still used in aviation for voice communication of an emergency.
- 406 MHz is used in digital beacons and is the only type of beacon currently detected by the COSPAS-SARSAT satellite system.

Emergency Position–Indicating Radio Beacons. There are several types of EPIRBs in use for maritime applications. The U.S. Coast Guard (USCG) maintains a website with more information on EPIRBs: navcen.uscg.gov/?pageName=mtEpirb. Chapter 70, Safety at Sea, also addresses the use of EPIRBs.

Emergency Locator Transmitters. ELTs were the first emergency beacons developed, and most aircraft are required to carry them. ELTs were originally intended for use on the 121.5-MHz frequency to alert aircraft flying overhead. Obviously, a major limitation to these is that another aircraft must be within range and listening to 121.5 MHz to receive the signal. One of the reasons the COSPAS-SARSAT system was developed was to provide a better receiving source for these signals. Another reason was to provide location data for each activation (something that overflying aircraft were unable to do).

Different types of ELTs are currently in use. There are thousands of the older-generation 121.5-MHz ELTs in service in the United States. Unfortunately, these have proved to be highly ineffective. They have a 99% false-alert rate, activate properly in only 12% of crashes, and provide no identification data. To fix this problem, 406-MHz ELTs were developed to work specifically with the COSPAS-SARSAT system. These ELTs have unique identifiers and dramatically reduce the false-alert impact on SAR resources, have a higher accident survivability success rate, and decrease the time required to reach accident victims by an average of 6 hours.

Most aircraft operators are now mandated to carry an ELT. Although 121.5/243-MHz ELTs used by some aircraft may still be used, the COSPAS-SARSAT system ceased satellite processing of these beacons in 2009, and alerts from these devices (and from 121.5/243-MHz EPIRBs) are no longer acted on unless detected by an overflying aircraft or ground-based receivers. This is why all beacon owners and users must replace their 121.5/243-MHz beacons with 406-MHz beacons as soon as possible and register their beacons with NOAA at beaconregistration.noaa.gov.

Personal Locator Beacons. PLBs are portable units that operate much the same as EPIRBs or ELTs (Figure 55-2). These beacons are designed to be carried by an individual person instead of on a boat or an aircraft. Unlike ELTs and some EPIRBs, they can only be activated manually and operate exclusively on 406 MHz in the United States. Similar to EPIRBs and ELTs, all PLBs also have a built-in, low-power homing beacon that transmits on 121.5 MHz. This allows rescue forces to home in on a beacon once the 406-MHz satellite system has put them within 3.2 to 4.8 km (2 to 3 miles). Some newer PLBs also allow GPS units to be integrated into the distress signal. This GPS-encoded position dramatically improves the location accuracy down to within 100 m.

In the United States, PLBs were in limited use until July 1, 2003, after which they were fully authorized for nationwide use. In 2013, the Air Force Rescue Coordination Center (AFRCC) investigated 266 nonmilitary PLB activations that led to 31 missions (SAR operation that requires the activation of federal assets) and resulted in five lives saved.[1]

NOAA encourages all PLB users to be acutely aware of the responsibility that comes with owning one of these devices. A PLB is a distress-alerting tool and works exceptionally well, but only if registered. PLB users should register their devices (beaconregistration.noaa.gov), familiarize themselves with proper testing and operating procedures to prevent false activation, and

FIGURE 55-2 An example of a personal locator beacon (PLB). Shown is an ACR ResQLink+ (3.3 × 4.8 × 9.9 cm, 130 g). *(Courtesy of ACR/ARTEX [acrartex.com].)*

FIGURE 55-3 The DeLorme inReach Explorer satellite communicator allows remote tracking of its location, sends and receives 160-character text messages with GPS coordinates to cell numbers and email addresses worldwide, confirms delivery of messages, and has powerful navigation features, including an on-screen map view (14.8 × 6.2 × 2.6 cm, 190 g). *(Courtesy of DeLorme, a Garmin Brand.)*

be careful to avoid their use in nonemergency situations.[47] One misunderstanding of the use of a PLB caused some consternation when the owner thought he was supposed to turn it on when he went out, like an avalanche beacon, and turn it back off when he arrived home. Familiarity with the technology is essential if it is to be helpful when needed.

Technology now includes satellite communicators that can provide even more accurate geographic location information, texting capabilities, and voice communications through low earth–orbit satellite networks that have extensive global coverage. These communicators and associated services are more expensive than those of a PLB, but their cost has decreased in the past few years. The devices allow tracking by remote parties and much more precise geographic location services, which could preclude or replace the need for activation of an emergency beacon such as a PLB. DeLorme offers the inReach series of satellite communicators (Figure 55-3), SPOT offers the SPOT Gen3 satellite communicator (Figure 55-4), and Iridium offers a number of satellite-based options, including the Iridium GO!, which is a satellite-based "hot spot" that can allow Internet access and smart phone use almost anywhere on Earth.[32] This is not an exhaustive list of options. The power of these devices to improve safety for individuals operating in isolated locations is increasingly recognized. Their impact on the use of less expensive emergency beacons will only be fully understood when their market penetration increases.

OTHER INTERNATIONAL SEARCH AND RESCUE ORGANIZATIONS

The International Commission for Alpine Rescue (ICAR; also known as Internationale Kommission für Alpines Rettungswesen and Commission Internationale du Sauvetage Alpin) is a working group of national mountain rescue organizations whose mission is to "provide a platform for mountain rescue and related organizations to disseminate knowledge with the prime goal of improving mountain rescue services and their safety."[28] Located in Switzerland, the ICAR is divided into four commissions: terrestrial rescue, air rescue, avalanche rescue, and mountain emergency medicine (also known as MEDCOM). ICAR is an independent global organization that promotes international cooperation for mountain rescue services. Learn more at ikar-cisa.org/.

The International Climbing and Mountaineering Federation (UIAA; also known as the Union Internationale des Associations d'Alpinisme), located in Switzerland, promotes the growth and protection of mountaineering and climbing around the world, mostly through the work of its eight commissions: access, antidoping, ice climbing, medical, mountain protection, mountaineering (including the Training Standards Panel), safety, and youth. Although all of the commissions do important work, the UIAA Safety Commission may be the most recognizable to climbers because it develops technical safety standards for equipment which are used by many of the biggest manufacturers of mountaineering equipment around the world. Equipment that has been tested to UIAA standards is permitted to bear the UIAA Safety Label Symbol. The Safety Commission also accredits laboratories that test equipment and offers advice on how to treat their equipment and avoid accidents.[27] For more information on the UIAA, visit their website at theuiaa.org.

The International Search and Rescue Advisory Group (INSARAG) is a global network of more than 80 countries and organizations under the United Nations umbrella that deals with urban SAR and issues related to structural collapse. One goal of the group is to establish minimum international standards for urban SAR teams and a methodology for international coordination in earthquake response based on the INSARAG guidelines endorsed by the 2002 United Nations General Assembly Resolution 57/150.[31] You can learn more about the organization and their guidelines at insarag.org.

SEARCH AND RESCUE IN THE UNITED STATES

SAR involves many agencies and volunteers. The federal government assumes some responsibility for overall coordination, especially of federal or military resources requested by local or state agencies.

U.S. National Search and Rescue Plan

The U.S. National Search and Rescue Plan (NSP) was first published in 1956. It provides guidance to signatory federal agencies (the Departments of Transportation, Homeland Security, Interior, Defense, and Commerce, as well as the Federal Communications Commission, and the National Aeronautics and Space Administration) for coordinating civil SAR services to meet domestic needs

FIGURE 55-4 The SPOT Gen3 Global Satellite GPS Messenger is best hung on equipment (backpack) in view of the sky; it allows remote tracking of its location, sending custom messages and alerting selected contacts of the need for assistance, of an emergency, or that the wearer is okay (8.5 × 6.5 × 2.5 cm). *(Courtesy of SPOT [findmespot.com].)*

and international commitments. The federal government assists with coordination of certain SAR services, including any federal or military resources that are requested by local or state agencies.

NSARC[50] is responsible for coordinating and improving federal involvement in civil SAR for aeronautic, maritime, and land communities within the United States. It is also the federal-level committee formed to oversee the NSP and coordinate civil SAR matters of interagency interest within the United States. Member agencies of NSARC are the signatories of the NSP. More information about NSARC may be obtained at uscg.mil/NSARC.

The NSP defines *search and rescue region* (SRR) as "an area of defined dimensions, recognized by IMO or ICAO, associated with a rescue coordination center (RCC), within which SAR services are provided."[50] An RCC is a unit responsible for promoting efficient organization of SAR services and for coordinating the conduct of SAR operations within an SRR. For every SRR, there is one RCC, and the goal is to have no overlaps or gaps between SRRs around the world. The ultimate goal is to ensure that SAR services are available to those in need of them. To this end, SRRs are not considered to be either jurisdictional or territorial in nature. They do not supersede territorial sovereignty, not even for SAR missions. However, clearances for entry into territorial waters or air space are usually expedited and/or relaxed for SAR activities. In addition, the SAR mission coordinator for an incident may not be located with the RCC responsible for the SRR; he or she may be located anywhere. For example, when the *Achille Lauro* caught fire and sank in international waters off Somalia in 1994, the SAR mission coordinator was located at RCC Stavanger, Norway, which had received the vessel's radio distress calls and was able to establish communications with her and other vessels in the area to coordinate the rescue of passengers.

In the United States, there are two types of SRRs: maritime and aeronautic. Although only the ocean areas surrounding the United States and its territories fall within the maritime SRRs (marine vessels cannot sail on land), both the ocean and land areas of the United States fall within aeronautic SRRs (aircraft can fly over both water and land). The maritime SRRs surrounding the United States include, in the Pacific, Juneau, Honolulu, Seattle, and Alameda, and in the Atlantic, Boston, Norfolk, Miami, New Orleans, and San Juan. The oceans surrounding the United States and its territories also fall within aeronautic SRRs whose names and limits coincide with their maritime counterparts. However, with the exception of U.S. islands (e.g., Hawaiian Islands, Puerto Rico) that are contained entirely within maritime SRRs and the Great Lakes (Cleveland Maritime SRR), all U.S. land falls within either the Elmendorf Air Force Base (Anchorage, Alaska) Aeronautical SRR (Alaska) or the Tyndall Air Force Base (Panama City, Florida) Aeronautical SRR (continental United States).

According to the NSP, a SAR coordinator is "a federal person or agency with overall responsibility for establishing and providing SAR services for a search and rescue region(s) for which the U.S. has primary responsibility."[50] The SAR coordinators for the United States are as follows:

- *U.S. Air Force:* Recognized SAR coordinator for the U.S. aeronautic SRR corresponding to the continental United States other than Alaska
- *U.S. Pacific Command:* Recognized SAR coordinator for the U.S. aeronautic SRR corresponding to Alaska
- *U.S. Coast Guard:* Recognized SAR coordinator for all other U.S. aeronautic and maritime SRRs. This includes the State of Hawaii, as well as waters over which the United States has jurisdiction, such as navigable waters of the United States.

Outside these federal SAR coordinators, state and local authorities are responsible for land-based SAR and may designate a person to be "SAR coordinator" within their respective jurisdictions. In addition, the U.S. Department of the Interior National Park Service is responsible for providing emergency services on land and water administered by their agency, and the Federal Emergency Management Agency (FEMA) is responsible for overseeing the national urban search and rescue (US&R) system. All U.S. states have an agreement with the AFRCC that delegates authority for land SAR to the local law enforcement agency, most often the county sheriff, and aeronautical SAR to an appropriate statewide aeronautics or aviation agency.

The NSP covers most types of SAR operations, such as land, maritime, aeronautic, urban, mass rescue, and those associated with what the document defines as "Incidents of National Significance." However, it does not cover air ambulance service that does not result from a SAR or recovery operation; rescue from space operations, military operations, salvage operations, civil disturbances; or "operations and coordination in addition to those…that might be carried out concurrently with civil SAR operations on scene, such as could occur during a disaster or terrorism response situation, or an Incident of National Significance."[50] Because of the unique scale and SAR challenges in Alaska, the USCG is often the lead federal agency for inland SAR incidents in certain areas of the state, including the Alaska Peninsula (south of 58 degrees N), Aleutian Islands, and other coastal islands. The reason for this is simple: In these areas, USCG assets can often respond much more quickly than can those available through the U.S. Alaska Rescue Coordination Center at Ft Richardson, Alaska, north of Anchorage. For Alaskan inland areas, SAR is carried out by Air National Guard units, the Alaska State Troopers, and local borough SAR organizations. Because of the unforgiving environment, all federal, state, and local agencies work together closely in response to SAR missions in Alaska.

Many U.S. states have chosen to retain established SAR responsibilities within their boundaries for incidents primarily local or intrastate in character. In such cases, agreements have been made between federal SAR coordinators and relevant state organizations.[50] These local and state SAR coordinators, if established, become important contacts for federal SAR coordinators.

National Response Framework

The National Response Framework (NRF),[65] updated in 2013, is a guide that details how the United States responds to all types of disasters and emergencies, from the smallest local incident to the largest national catastrophe. It establishes a comprehensive, national, all-hazards approach to domestic incident response and identifies guiding response principles, as well as the roles and structures that organize a national response. The document describes how communities, states, the federal government, and private-sector and nongovernmental partners apply these principles for a coordinated, effective national response (Box 55-4). In addition, it describes special circumstances in which the federal government exercises a larger role, including incidents in which federal interests are involved and catastrophic incidents for which a state would require significant support.

The NRF is organized into four parts: the NRF base document, emergency support function (ESF) annexes, support annexes, and incident annexes. The base document includes sections that describe the scope, roles and responsibilities, core capabilities, coordinating structures and integration, relationships to other mission areas, operational planning, and supporting resources. The ESF annexes describe the federal coordinating structures that group resources and capabilities into functional areas that are most frequently needed in a national response. ESF No. 9 is specifically for SAR and addresses the three federal SAR response operational environments (structural collapse urban SAR [US&R], maritime/coastal/waterborne SAR, and land SAR) and the core capabilities and actions of each agency in each operational environment. The support annexes describe the essential supporting

BOX 55-4 Guiding Principles of the National Response Framework

Engaged partnerships
Tiered response
Scalable, flexible, and adaptable operational capabilities
Unity of effort through unified command
Readiness to act

From the U.S. Department of Homeland Security: *The national response framework*, 2nd ed, Washington, DC, 2013 (fema.gov/emergency/nrf, p 5).

processes and considerations that are most common to the majority of incidents (e.g., financial management, public affairs, volunteer and donations management, worker health and safety). The incident annexes describe the unique response aspects of incident categories (e.g., biologic, catastrophic, cyber, mass evacuation).[65]

The NRF lays the groundwork for a unified national response and is intended to be used by the entire community, not just leaders and emergency responders. The idea is to enable a full range of stakeholders (individuals, families, communities, the private and nonprofit sectors, faith-based organizations, and local, state, tribal, territorial, insular area, and federal governments) to participate in national preparedness activities and to be full partners in incident response. This concept is based on the idea that government resources alone cannot meet all the needs of those affected by major disasters. All elements of the community must be activated, engaged, and integrated to respond to a major or catastrophic incident.

The NRF is built on the same scalable, flexible, and adaptable concepts identified in the National Incident Management System (NIMS, see below), and describes specific authorities and best practices for managing incidents that range from small to large and from local to national. The NRF Resource Center (fema.gov/NRF) is an online reference center that provides access to the NRF and supporting documents.

The National SAR Supplement

NSARC also directs preparation of the National SAR Supplement (NSS) to the *IAMSAR Manual,* which provides guidance to federal agencies concerning implementation of the NSP. The NSS provides specific additional national standards and guidance that build on the baseline established by the *IAMSAR Manual*. It provides guidance to all federal forces, military and civilian, that support civil SAR operations.[52]

Specifically, the NSS is designed to serve as both a training tool and an operational tool for civil SAR operations. SAR planning is both an art and a science, relying greatly on the creativity and experience of the involved personnel. Because of the many variables encountered during SAR operations and the individuality of each SAR case, the guidance provided in the NSS must be tempered with sound judgment, having due regard for the individual situation. Very little in the NSS is mandatory because it is not intended to relieve SAR personnel of the need for initiative and sound judgment.[52]

Each of the signatory agencies of the NSARC (and NSP) is encouraged to develop an addendum to the NSS for its agency. Such documents could include policies, information, procedures, and so forth on civil SAR matters applicable to the agency concerned and consistent with the *IAMSAR Manual* and NSS.

Catastrophic Incident SAR Addendum to the National SAR Supplement. The tragedies of September 11, 2001, Hurricane Katrina in 2005, Hurricane Sandy in 2012, and other calamitous events continue to challenge federal, state, tribal, territorial, and local SAR responders in the planning and execution of large-scale SAR operations. NSARC realized that the federal government's response to large-scale catastrophic incident SAR (CISAR) needed to improve. As a result, the CISAR Addendum to the NSS[48] was developed to provide guidance for SAR (Box 55-5) operations during catastrophic incidents to complement the overarching strategy for a national response to a catastrophic incident provided in the Catastrophic Incident Annex of the NRF.

BOX 55-5 Catastrophic Incident as Defined in the U.S. National Response Framework

Any natural or manmade incident, including terrorism, which results in extraordinary levels of mass casualties, damage, or disruption severely affecting the population, infrastructure, environment, economy, national morale, and/or government functions.

From The U.S. Department of Homeland Security: *The national response framework*, 2nd ed, Washington, DC, 2013 (fema.gov/emergency/nrf, p 1).

CISAR consists of civil SAR operations carried out as all or part of the response to an emergency or disaster declared by the president, under provisions of the NRF and its ESF No. 9, Search and Rescue. This CISAR Addendum does not supersede other federal, state, tribal, or territorial SAR plans.

There are many different federal, state, tribal, territorial, and local SAR response cultures. Each possesses unique capabilities and responsibilities and has its own language. During a catastrophic incident, NSARC member departments and agencies are required to conduct multiagency SAR operations within a unified command (e.g., a command in which responding agencies and/or jurisdictions with responsibility for the incident share incident management). The CISAR Addendum is intended to (1) provide a concise description of the federal government's civil SAR response to catastrophic incidents; (2) guide federal authorities involved in the response; and (3) inform states, tribes, and territories about what to expect from federal SAR responders.[48]

The primary federal agency responsible for CISAR operations depends on the nature of the SAR operation to be conducted. ESF No. 9 of the NRF lists FEMA and its Urban Search and Rescue Response System as being responsible for urban SAR; the USCG as being responsible for maritime, coastal, and waterborne SAR; and the U.S. Departments of the Interior and Defense as being responsible for land SAR during a CISAR event. Regardless of which federal agency takes the lead, the primary agency works closely with the respective federal SAR coordinator in the affected area.

Land SAR Addendum to the National SAR Supplement. In 2011, NSARC created the Land SAR Addendum to the NSS,[49] which expands on the implementation of the NSP. NSARC defines "land SAR" as "the provisioning of civil SAR services for persons in distress or missing within the land areas of the U.S., including persons in distress in aircraft."[49] The Land SAR Addendum is intended to provide guidance to federal land SAR authorities and offer technical information and best practices for nonfederal SAR training, planning, and operations. The purpose of the document is "…to provide standardized guidance and information concerning land-based SAR operations."[49]

The Land SAR Addendum emphasizes the importance of standardized search planning theory and describes two general categories of land SAR:

- Aeronautical SAR involving persons in distress in aircraft on or over land areas, particularly in wilderness areas; and
- SAR of persons missing or in distress.

The document describes the U.S. SAR system, land SAR resources and capabilities, communications, various types of searches, navigation systems, and search planning, and becomes very detailed in its description of the various elements of search theory and their application to land search. In terms of search methodology, it provides a standard, easy-to-follow approach that has evolved from SAR mission experience and advances in search theory. In short, for SAR missions on land in the United States, this document provides the best guidance currently available.

U.S. Rescue Coordination Centers

The USCG and Air Force both operate RCCs in the United States, but each service takes a slightly different approach. The Air Force RCC (AFRCC) coordinates inland SAR activities in the continental United States but does not directly conduct SAR operations. In most situations, the Civil Air Patrol (CAP), state police, or local rescue services conduct the actual SAR operations. In contrast, the USCG not only coordinates but also conducts SAR missions.

U.S. Air Force Rescue Coordination Center. Established in 1947 to meet the growing demand for SAR and its legislated responsibility, the original three AFRCCs have evolved into a single RCC located under the 1st Air Force at Tyndall Air Force Base in Florida. As the U.S. inland SAR coordinator, the AFRCC serves as the single agency responsible for coordinating on-land federal SAR activities in the 48 contiguous United States, Mexico, and Canada. Since the center opened in 1974, the AFRCC recorded more than 60,000 SAR missions, resulting in more than 15,300 lives saved.[60]

The AFRCC functions around the clock and is staffed by people trained and experienced in coordination of SAR operations. The center is equipped with extensive audio and digital communications equipment and maintains a comprehensive resource file listing federal, state, local, and volunteer organizations that conduct or assist in SAR.

There are four types of authorized AFRCC missions: search, rescue, MEDEVAC, and mercy.

Search Missions. Once a distress situation is determined to exist but a location is unknown, federal SAR forces may be activated to search for, locate, and relieve the distress situation. The object of these searches may be overdue aircraft, ELTs, hunters, hikers, or children.

Rescue Missions. A rescue mission entails the use of federal SAR forces to recover persons in distress whose location in a remote area is known but who need assistance. This may be in the form of transportation to safety or to an adequate medical facility. These requests are normally received by the AFRCC from National Park Service personnel or the local law enforcement authority.

MEDEVAC Missions. Transportation by federal assets of persons from one medical facility to another is defined as medical evacuation, or MEDEVAC. Requests are normally received from a local hospital when no commercial transportation is available, the person's life is in jeopardy, and time is critical. Each request is evaluated, and the decision to use federal resources is weighted heavily by the attending physician's medical opinions.

Mercy Missions. A mission to transport blood, organs, serum, medical equipment, or personnel to relieve a specific time-critical, life-threatening situation is referred to as a mercy mission. Requests are normally referred from a local hospital authority or, in some cases, the American Red Cross when commercial transportation is not available.

Although the AFRCC will accept and act on initial notification from any person or agency, it will attempt to determine the urgency and the facts pertaining to the situation before obliging assets. Several aspects of the situation are considered before a mission is opened, including the following:

1. Medical evaluation and urgency
2. State agreement requirements
3. Posse Comitatus Act
4. Conflict of interest with commercial resources
5. Resource availability

The medical condition of the victim or victims is the most important aspect of mission consideration. The AFRCC will consider a request valid only when there is an immediate threat to life, limb, or sight. A mission will be started only to prevent death or aggravation of a serious injury or illness. The observations and opinions of a physician at the incident site weigh heavily on the decision to open a mission, and a flight surgeon is on call at the AFRCC when a local physician is unavailable.

Each state has an agreement on file in the AFRCC describing the responsible agency and coordinating requirements for the various types of SAR missions. Each request for federal assistance is evaluated to ensure the requirements stipulated in the relevant agreement are met. Title 18 USC 1385 (the Posse Comitatus Act; Box 55-6) prohibits military participation in civil law enforcement activities. Although there are some exceptions to the prohibition, as a general rule, Department of Defense forces, including the CAP, will be restricted from participating in searches in which the person being sought is evading searchers or is a fugitive, or when foul play is considered.

On MEDEVAC or mercy missions in which the patient is not eligible for Department of Defense medical benefits, federal assets cannot be used when commercial resources are available. Even when a patient is unable to pay or is destitute, commercial resources will be checked for availability and provided the opportunity to accept the mission before federal resources are allocated.

Although any SAR-capable asset belonging to the federal government may be requested, each resource is evaluated for distance from the distress location, special equipment requirements, urgency of the situation, and which resource can best accomplish the mission. Military forces may be called on to assist in civilian SAR missions. However, their participation in these activities must not interfere with their primary military mission. With ongoing military conflict, the military resources once relied upon for civilian missions are available far less frequently. Once the decision has been made to use federal resources, a mission number is assigned and SAR forces are selected based on the geographic location and mission requirements. The Air Force coordinator then works closely with the responsible agency in an attempt to provide the resources best suited to accomplish the mission.[60]

Additional information on the AFRCC can be found at 1af.acc.af.mil/units/afrcc.

U.S. Coast Guard Rescue Coordination Centers. The USCG, now a division of the U.S. Department of Homeland Security (DHS), is designated as the federal SAR coordinator for the maritime SRRs surrounding the United States and large portions of the high seas. The USCG is responsible for providing and coordinating SAR services over 28 million square miles of the world's oceans, mostly in the northern hemisphere. This responsibility is divided into several districts, which are further divided into sectors (several per district) and stations. A 24-hour alert status is maintained year-round at all levels; Coast Guard resources can be under way or airborne within minutes of notification of a SAR incident. At its headquarters, each district maintains a fully staffed operations/command center responsible for coordinating operations within the area or district on a 24-hour basis. When coordinating SAR missions, these operations centers are called RCCs. Although minor SAR incidents are often resolved at the station or sector level, the district assumes the duties of the SAR mission coordinator in more complex or large-scale missions.[61]

The USCG arguably undertakes more SAR missions than does any other organization or agency in the world. In 2012, the USCG and its more than 43,000 active duty members, 8000 reservists, 8800 civilian employees, and 30,000 volunteer auxiliarists responded to 19,700 SAR cases and saved 3560 lives and more than $77 million in property.[61] It is also notable that the USCG, although considered an important part of the U.S. military forces, is a separate federal agency now under the DHS, not under the Department of Defense, as is the Air Force.

An important global SAR-related service of the USCG that has its roots in the *RMS Titanic* disaster in 1912 is the automated mutual-assistance vessel rescue (AMVER) system. AMVER is a global system that involves ships, regardless of flag, voluntarily providing information about their capabilities (e.g., medical personnel on board, rescue equipment), sail plans for voyages, and regular reports of their locations to a computer system that tracks their whereabouts. When a situation arises that requires SAR capabilities, a surface picture is produced that graphically shows the locations of all AMVER participants in the vicinity. The RCC can use this information to select the best ship or several ships to respond to the emergency and allow all others to continue their voyages. Today, more than 22,000 ships from hundreds of countries participate in AMVER. On any given day, there are more than 7000 vessels available to divert and assist in a distress situation, with more than 100,000 voyages tracked annually. The AMVER system has saved more than 2800 lives since 2000, and 450 in 2007 alone.[62]

BOX 55-6 Posse Comitatus, Defined

The Posse Comitatus Act (18 U.S.C. 1385) prohibits the use of any part of the Army or the Air Force to execute or enforce the laws, except as authorized by the Constitution or Act of Congress; includes prohibition of direct participation in a search, seizure, arrest, or other similar activity. This restriction is in addition to the constitutional limitations of the power of the Federal Government at the local level.

National Search and Rescue Committee: *Land SAR addendum to the national SAR supplement to the IAMSAR Manual (CISAR)*, version 1.0, Washington, DC, November 2011 (https://www.uscg.mil/hq/cg5/cg534/nsarc/Land_SAR_Addendum/Published_Land%20SAR%20Addendum%20(1118111)%20-%20Bookmark.pdf p xx).

Another "preventive SAR" service provided by the USCG as a direct result of the *RMS Titanic* disaster is the International Ice Patrol, with operations funded by signatories of the International Convention for the Safety of Life at Sea.[29] Since 1913, the Ice Patrol has amassed an enviable safety record, with not a single reported loss of life or property caused by collision with an iceberg outside the advertised limits of all known ice in the vicinity of the Grand Banks. However, the potential for a catastrophe still exists, and the Ice Patrol continues its mission using high-tech sensors and computer models.[61]

The USCG also performs or coordinates medical evacuation of seriously ill or injured persons from vessels at sea if the patient's condition warrants and USCG assets are within range. For less serious situations, USCG flight surgeons offer medical advice by radio. On rare occasion, the RCC may coordinate with a U.S. Navy ship to allow a USCG MEDEVAC helicopter to refuel to extend its range. On rare occasion, the RCC may coordinate with the Air Force to dispatch pararescue personnel to parachute to the vessel and stabilize the patient. In either case, these actions are taken only in the most serious situations, when one or more lives depend on such drastic actions.

If a vessel is reported overdue or unreported (i.e., failed to check in when expected), USCG assets may or may not launch immediately, depending on whether the overdue craft is thought to be in immediate danger. Regardless, an extensive investigative effort is initiated immediately. During this investigation, a preliminary communications check and extended communications check will likely take place. These actually include more than just contacting intended destinations. They also include interviewing persons who may be knowledgeable about the craft, as well as dispatching USCG vehicles or small boats to physically check harbors, marinas, launching ramps, and the like. In addition, an urgent all-ships broadcast is initiated, requesting information on any recent or future sightings that might be the missing vessel, and extended communications checks are repeated on a regular basis.[21]

If none of these communications and investigation efforts produces positive results (i.e., locating the vessel or indications that the persons on board are not in immediate danger), a search is undertaken. Search planning is conducted by the RCC staff, but additional assets can be requested from other agencies (e.g., U.S. Air Force and Navy) or foreign governments in a position to assist. With assistance from the USCG's Search and Rescue Optimal Planning System (SAROPS), the RCC develops scenarios based on available information. These scenarios are then weighted according to a subjective estimate of how likely each one is to represent the true situation. Further analysis of available information leads to development of probability maps (using SAROPS), from which SAROPS computes an optimal (maximum probability of success) search plan. Orders are then issued to all participating units. The search continues until either the survivors are found and rescued or it is deemed that further searching would be fruitless.[21]

Because SAR regions are not construed as boundaries to effective SAR action, and because the aeronautic SRRs are surrounded by the maritime SRRs, coordination between the AFRCC and the Coast Guard RCCs is a daily occurrence. Missions that involve portions of both regions will be coordinated through the AFRCC or the appropriate Coast Guard RCC. It is not unusual for the Coast Guard to call on the AFRCC for a particular resource needed to pursue a mission in the maritime region or, conversely, for the AFRCC to use a Coast Guard resource in the aeronautic region.

Additional information about the USCG can be found at uscg.mil.

Federal Aviation Administration. The Federal Aviation Administration (FAA), through its air route traffic control centers and flight service stations, monitors and flight-follows aircraft filing flight plans in the aeronautic SAR regions. In some cases, individual citizens contact an FAA facility when they have knowledge of a probable SAR situation involving aircraft. Therefore, the FAA is usually the first agency to alert the AFRCC of a distressed or overdue aircraft. The AFRCC is tied directly into the FAA's computer network, and FAA facilities use this system to alert the AFRCC.

Once the AFRCC is alerted, the FAA and AFRCC work together to determine the urgency of the situation and locate the aircraft. Initially, radio communications are reviewed to determine the last known location of the distressed aircraft. Concurrently, other FAA facilities begin a check of all possible airports where the aircraft might have landed. In the meantime, the AFRCC contacts relatives, friends, and business associates of the pilot or passengers aboard the missing aircraft, with the hope of establishing the whereabouts of the aircraft or to gather information about the personnel aboard. Through these contacts, the AFRCC determines the pilot's intentions, flying capabilities, emergency equipment aboard, and other pertinent information that would assist if a search were to become necessary. Through experience, the FAA and AFRCC have learned that most alerts for missing aircraft are due to the pilot failing to either close the flight plan or inform some person or agency of his or her intentions. For this reason, only a small percentage of alerts issued by the FAA result in an actual airborne search for a missing aircraft.

All air route traffic control centers have the capability of recalling recorded radar data. The National Track Analysis Program can identify and track targets that are at a sufficient altitude to be tracked by radar regardless of whether they are being controlled by the ARTCC. Tracking information of the National Track Analysis Program requested by the AFRCC has proved to be a key ingredient in aircraft searches, providing the route of flight and last radar position.

With the congressional mandate requiring most aircraft to be equipped with an ELT, the FAA works very closely with the U.S. Mission Control Center and the AFRCC to readily locate the source of ELT signals. All ELT signals reported to FAA facilities are immediately forwarded to the AFRCC and jointly investigated as probable distress signals.[67]

Unmanned Aircraft Systems. A new area of focus involving SAR and the FAA is unmanned aircraft systems (UASs), or drones. Some local jurisdictions have been using UASs on a limited basis in SAR activities for many years, but their increasing use and scrutiny by the FAA and other agencies has brought new attention to and concern about them. A UAS can be a very effective SAR tool because it can provide less costly (than a helicopter) aerial assets for a search. Advancement and miniaturization of visual optics, thermal imaging, and forward-looking infrared technology can be placed on UAS platforms for effective searching. There is growing concern, however, that as the use of UASs becomes more prevalent in SAR situations, by law enforcement, and in wildlife management, as well as by individuals for many reasons, UASs may violate personal liberties or interfere with general aviation and commercial aircraft.

Current armed conflicts have provided the military with extensive experience in the use of UASs in air space controlled by the military. Small, personal UAS platforms in general use have limitations that larger, more durable UAS platforms have overcome. These larger platforms are currently required to operate under an FAA Certificate of Waiver or Authorization when flying alongside other air space users.[18] UASs are evolving from traditional, personal remote-controlled vehicles to effective search tools, but they require appropriate regulation and control. SAR techniques are being tested that use crowd sourcing to help put "more eyes" on the ground through remote viewing of UAS video feeds. In some cases, using a UAS may be a lower-risk option than using a crewed aircraft, but separation between all aircraft must be maintained at all times.

Civil Air Patrol. In 1948, the Civil Air Patrol (CAP) was permanently chartered by the U.S. Congress as the official auxiliary of the U.S. Air Force (Figure 55-5). This nonprofit organization of volunteers was charged with three primary missions: development of aviation through aerospace education, a cadet youth program, and emergency services. The CAP boasts more than 60,000 members, including thousands of cadets between the ages of 12 and 21 years; the world's largest fleet of single-engine, piston aircraft; and access to 1000 emergency service vehicles. It is proud of the fact that nearly 100 lives are saved each year by CAP members.[11]

Under their emergency services mission, the CAP provides SAR mission coordinators, search aircraft, ground teams, personnel on

FIGURE 55-5 The Civil Air Patrol (CAP) owns the largest fleet of single-engine piston aircraft in the nation, primarily Cessna 172s and 182s. CAP pilots fly these planes to perform missions in service to their local communities. *(Courtesy Will Smith.)*

alert status, and an extensive communications network to support emergency response efforts. CAP members provide services to national relief organizations during disasters; transportation of time-sensitive medical materials; and aerial reconnaissance, airborne communications support, and airlift of law enforcement personnel in the national counterdrug effort. When CAP resources are engaged in a SAR mission, they are reimbursed by the U.S. Air Force for communications expenses, fuel and oil, and a share of aircraft maintenance expenses. In addition, CAP members are covered by the Federal Worker's Compensation Act in the event of injury while participating in a SAR mission.

The CAP is the AFRCC's prime air resource for the inland area. The AFRCC maintains an alert roster provided by CAP wings in each of the 48 contiguous states and is the central point of contact for CAP participation in SAR missions. The AFRCC also works closely with CAP national headquarters and directly provides input for CAP training in emergency services. Visit gocivilairpatrol.com for more information.

U.S. Coast Guard Auxiliary. The USCG Auxiliary is to the USCG what the CAP is to the U.S. Air Force. The auxiliary is made up of citizens who volunteer time and boats or aircraft to enhance and maintain the safety of boaters. When the Coast Guard "Reserve" was authorized by an act of Congress in 1939, the Coast Guard was given a legislative mandate to use civilian volunteers to promote safety on and over the high seas and the nation's navigable waters. The Coast Guard Reserve was then a nonmilitary service composed of unpaid, volunteer U.S. citizens who owned motorboats or yachts. Two years later, passage of the Auxiliary and Reserve Act of 1941 designated the Reserve as a military branch of the active service, whereas the civilian volunteers, formerly referred to as the Coast Guard Reserve, became the auxiliary.

When America entered World War II, some 50,000 auxiliary members joined the war effort. After the war, their attention returned to recreational boating safety duties in compliance with the auxiliary's four cornerstones: vessel examination, education, operations, and fellowship. Following passage of the Coast Guard Authorization Act of 1996, the auxiliary assists the Coast Guard, as authorized by the commandant, in performance of any Coast Guard function, duty, role, mission, or operation authorized by law. Today, as in 1941, auxiliarists are civilian volunteers whose activities are directed by policies established by the commandant of the USCG. Although under the authority of the commandant, the auxiliary is internally autonomous, operating on four organizational levels (smallest to largest): flotilla, division, district regions, and national.

When auxiliary resources are engaged under USCG "orders," they are reimbursed by the USCG for communications expenses, fuel and oil, and a share of vessel and aircraft maintenance expenses. In addition, auxiliary members are covered by the Federal Worker's Compensation Act in the event of an injury while participating in an authorized mission.

Many members of the auxiliary spend their weekends providing free boating safety courses to the public and free courtesy safety inspections to boaters. However, members also respond to minor SAR incidents, and the local USCG station, group, or district RCC coordinates their activities. Some auxiliarists have become qualified to work in the RCCs or assist regular USCG facilities with regulating and patrolling regattas and other maritime events.[63]

With 30,000 members, the auxiliary saves hundreds of lives each year, in addition to assisting thousands of boaters, performing courtesy marine examinations, teaching public and youth classes, and assisting the USCG in both administrative and operational missions.[63]

Other Federal SAR Resources

The United States has many resources that could be brought to bear on a SAR mission, and several have been specifically developed to support disaster and other SAR operations.

FEMA serves as the coordinating agency for the National Response Framework's ESF No. 9, Search and Rescue Annex. As such, FEMA coordinates the efforts of the four primary agencies with the responsibility, "to provide lifesaving assistance to local, state, tribal, territorial, and insular area authorities, including local SAR Coordinators and Mission Coordinators, when there is an actual or anticipated request for Federal SAR assistance."[65] The four federal primary agencies responsible for providing SAR support are the USCG, FEMA Urban Search and Rescue (US&R), Department of Interior National Park Service (NPS), and Department of Defense North American Command (DOD/NORTHCOM). During times of natural or manmade disasters, the USCG is the lead agency for ESF No. 9 when maritime/coastal/waterborne areas are the primary search area. When the disaster is urban and land based, FEMA US&R takes the lead and the NPS and Department of Defense share joint responsibility for inland SAR support.

A detailed description of the response capabilities of each of the four ESF No. 9 primary agencies is beyond the scope of this discussion. Generally, the USCG and NPS ESF No. 9 response elements are assembled from units that perform SAR missions on a day-to-day basis within their assigned areas of operation. The military's response elements are assembled from across the United States and function under doctrine identified in the military's Defense Support of Civil Authorities mission.[68]

The FEMA US&R Response System, including its 28 type I 80-member task forces, is designed to provide a coordinated response to disasters in the urban environment. Special emphasis is placed on the capability of locating and extricating victims trapped in collapsed structures, primarily of reinforced concrete and steel construction. However, the most common deployment of FEMA US&R task forces is to conduct SAR operations following disasters that affect a large geographic area, such as high-impact tornados, hurricanes, and major flooding incidents. See FEMA's US&R website for further information (fema.gov/urban-search-rescue).

The U.S. Department of the Interior National Park Service (NPS) provides extensive SAR and other emergency services on lands and waters administered by the NPS. These services often include SAR and emergency medical operations in a wide variety of environments, such as remote and rural areas, lakes, rivers, oceans, deserts, mountains, and caves. They also often require extended response times and use of specialized equipment. The NPS attends approximately 5000 SAR incidents and 16,000 EMS requests across the country. Because of the limited SAR resources in some areas of the United States, numerous mutual aid agreements exist between NPS units and surrounding jurisdictions to provide a coordinated approach to SAR services in and around the national parks and lands.

The U.S. Department of Health and Human Services oversees the U.S. National Disaster Medical System (NDMS). This system operates 80 teams across the United States, which are made up of local groups of health care providers and support personnel. Of these teams, 55 are Disaster Medical Assistance Teams (DMATs) designed to provide medical care during a disaster or other event in the United States. DMATs are composed of physicians, nurse practitioners, physician assistants, nurses, pharmacists and pharmacy technicians, respiratory therapists, emergency medical technicians, and a variety of other health and logistical personnel. DMATs typically have 120 to 150 members, from which the team leader chooses up to 50 members to deploy on missions requiring a full team. Smaller strike teams or other modular units can also be activated and deployed when less-than-full-scale deployments are needed.

DMATs are designed to be a rapid-response element to supplement local medical care until other federal or contract resources can be mobilized, or the situation is resolved. DMATs deploy to disaster sites with sufficient supplies and equipment to sustain themselves for a period of 72 hours while providing medical care at a fixed or temporary medical care site. The personnel are activated for a period of 2 weeks.

In addition to DMATs, the NDMS oversees response teams that specialize in specific types of medical emergencies, such as hazardous material handling or decontamination situations, and Logistics Response Assistance Teams (LRATs), which primarily support any of the response teams under the NDMS umbrella. Additional NDMS response teams include Disaster Mortuary Operations Response Teams, National Veterinary Medical Response Teams, International Medical/Surgical Response Teams, and Incident Response Coordination Teams. Visit the Department of Health and Human Services NDMS website for more information (phe.gov/preparedness/responders/ndms).

The State's Role in SAR: Coordination and Support

All states carry legislation that provides for direct support to local government entities during emergencies or life-threatening situations, and most states have a specific agency responsible for overall coordination and support for local SAR problems. This support can take many forms, but most often is in the area of coordination and "one-stop shopping" for resources. Each state must establish an agency or central location that is familiar with all aspects of emergency management and the resources available to aid in life-threatening situations. Many of these resources belong to the state and can be used to aid local jurisdictions.

A number of states, especially in the Northwest, have designated a state agency to be responsible for directing and coordinating air SAR activities. These state agencies develop and maintain aviation SAR response programs with cooperation and support from local and federal agencies. Experience shows that this system usually works better than those in other areas of the country that rely on the federal government to initiate and carry out aircraft SAR activities.

If a local emergency manager, sheriff, or fire chief requests outside assistance in the form of specialized teams, search dogs, air support, or enhanced communications, the state agency for emergency services or emergency management can in most cases locate the nearest resources available and coordinate the response. If federal resources, such as air support or military personnel, are needed, the state agency provides a direct link to that resource. For instance, the AFRCC at Tyndall Air Force Base in Florida[60] has working agreements with all states. Technically, the resources of local and state governments must have been exhausted or be unable to perform a task before federal support can be rendered. However, policy provides for immediate aid when time is critical and in life-or-death situations. Much discretion is given to military installation commanders regarding aid to civilian authorities, as long as the primary (military) mission of the resource is not impaired. In fact, most commanders appreciate the opportunity to fly actual missions. Access to these resources must be gained through the state and the AFRCC.

Every state's emergency management agency is responsible for providing support, guidance, training, and coordination to local political subdivisions within that state. As such, it produces a vital behind-the-scenes effort to help local jurisdictions prepare for emergencies, including SAR. The state also promulgates laws and regulations necessary to enhance effective actions for SAR response. Such legislation often indemnifies volunteer SAR teams, provides their medical coverage and insurance, and in some cases replaces personal property lost during SAR work. Although most volunteers work willingly until the job is done, this recognition and coverage by the state often provide additional incentives for volunteer participation.

Local SAR Response

The official response to the call for a wilderness SAR situation is usually delegated to a political subdivision within the state (i.e., county). The legal responsibility for SAR is generally vested with the county sheriff or chief law enforcement officer at the local level, but this varies by region and state. In some cases, it is the responsibility of state police agencies, and in others, it belongs to land management agencies. The SAR response for one jurisdiction may differ greatly from that of another. For instance, many national parks in some areas of the country handle all of their own SAR incidents. Others jointly manage the function, whereas some rely entirely on outside resources. National forest land is managed solely by forest service personnel, but when it comes to SAR, the forest service usually relies on, and provides support to, local SAR resources.

In urban and suburban areas, police officers, firefighters, emergency medical personnel, and emergency management organizations maintain some degree of disaster and emergency readiness through daily missions that often involve SAR work. Fire departments have historically been responsible for front country rescue and response to emergencies within certain geographic or political areas, and volunteers augment many departments. Law enforcement agencies also maintain full-time, efficient response systems designed for their particular SAR requirements. Ambulance and rescue vehicles operated by a variety of private enterprises and volunteer organizations augment existing local government services. Through local emergency response planning and coordination, these services respond to a spectrum of everyday emergencies, including fires, collapsed buildings, hazardous material spills, vehicle extrications, and medical emergencies.

County sheriffs, reserve law enforcement, volunteer fire departments, and a variety of volunteer SAR units have been established to address local SAR problems. Delivery of SAR aid to rural and wilderness areas often presents many special logistic problems, which may be compounded by distance, terrain, and weather. The demand for wilderness SAR is often seasonal and unpredictable. Volunteer mountain rescue units, Explorer SAR groups, SAR dog teams, CAP squadrons, motorized units, and many types of volunteer composite teams (e.g., teams that have a variety of capabilities) are usually formed locally in response to the type and nature of recurring SAR problems. Regardless of what type of SAR emergencies occur, local resources and effort must be developed because they are closest to the problem. State and federal resources are subject to problems with authority, time lag, distance, weather, logistics, and bureaucracy. The same storm or disaster that incapacitates a local area may also prohibit outside (and sometimes inside) emergency response and resupply.

Although official agency responses differ greatly around the country, the major factor that remains constant is the dedicated and unfailing willingness of volunteers to respond and work until the job is done. The volunteer effort in SAR nationwide is the backbone of aid to people in distress, as is stated in the rescue service motto: "These Things We Do That Others May Live." The volunteer response has proved crucial to wilderness-type situations. Volunteer organizations, communications, and special skills cannot be replaced by any "official agency" resources.

Because wilderness SAR missions are often in response to a lost person who requires some level of medical evaluation and treatment, SAR teams usually have some organic medical training and medical oversight (see Chapter 54, Wilderness Emergency Medical Services and Response Systems). Adapted protocols that provide optimal patient care in remote settings may deviate from traditional front country protocols. Some SAR teams may use outside EMS providers, and others have personnel on the team who have both technical SAR skills and additional medical skills.

Standards and Regulations

Standards and regulations relevant to various SAR disciplines have evolved significantly over the past few years. They generally fall into three categories: training (individual and organizational), operations (individual and organizational), and manufacturers (equipment and clothing).

Standards and regulations are important because they are always intended to improve safety, have usually evolved from tragic events, and may involve penalties if not followed (some may have the force of law).

Regulations (e.g., rules or codes) are compulsory and usually written by government agencies with specific responsibilities for the subject matter. Failure to comply with or adhere to regulations could result in fines or other penalties. A regulation sometimes references a standard, which has the effect of incorporating the standard into the regulation. However, a standard is generally not compulsory unless it is referenced in a regulation or otherwise required by law. The Occupational Safety and Health Administration is an example of an organization that develops regulations.

Standards are typically written by committees, often made up of volunteers, working under the auspices of a standards-writing organization. "Consensus standards" are distributed to, and then agreed upon, by groups of interested parties prior to publication. The specific process varies among standards-writing organizations, but is usually well described in their educational literature and on their websites. Each of the standards-writing organizations has procedures for initiating standards, fairly developing and revising standards, allowing for public comments, addressing public comments, and publishing the standards. The National Fire Protection Association, ASTM International, and American Society of Safety Engineers are examples of standards-writing organizations.

The American National Standards Institute is a nonprofit organization with a mission to enhance the global competitiveness of U.S. businesses by "…promoting and facilitating voluntary consensus standards and conformity assessment systems…."[2] The institute oversees creation, promulgation, and use of standards, and accredits other organizations that develop consensus standards.

The European Committee for Standardization (Comité Européen de Normalisation [CEN]) is a nonprofit standards organization that provides, "…a platform for the development of European Standards and other technical documents in relation to various kinds of products, materials, services, and processes."[17]CEN writes standards for a wide variety of fields, including health and safety and personal protective equipment, which can affect the SAR field. These standards may also be relevant to SAR personnel because European recreational climbing equipment may bear the familiar CE mark. The CEN collaborates with the UIAA to harmonize each organization's standards, but the two standards may still be slightly different.

ORGANIZATION OF A SEARCH AND RESCUE EVENT

SAR requires people who take action and meet objectives to achieve a common goal, often with one or more lives in the balance. For any combination of actions to be effective in a particular situation, the enterprise must be systematically coordinated and organized. All participants must know their responsibilities, what is expected of them, who is in charge, and to whom they answer. If this knowledge is lacking at any level, the effort can quickly become chaotic, ineffective, and dangerous. Nowhere are these issues more important than in an emergency, when time is a crucial factor.

NATIONAL INCIDENT MANAGEMENT SYSTEM

In Homeland Security Presidential Directive-5 (HSPD-5), the president of the United States called on the DHS to develop a national incident management system to provide a consistent nationwide approach for federal, state, tribal, and local governments to work together to prepare for, prevent, respond to, and recover from domestic incidents, regardless of cause, size, or complexity. On March 1, 2004, after collaboration with state and local government officials and representatives from a wide range of public safety organizations, DHS issued the National Incident Management System (NIMS). It incorporated many existing best practices into a comprehensive national approach to domestic incident management, applicable at all jurisdictional levels and across all functional disciplines. Among these best practices, and a key component of the NIMS, is the incident command system (ICS), which has been established by the NIMS as the standard organizational structure for the management of all incidents.

HSPD-5 also required DHS to establish a mechanism for ongoing coordination to provide strategic direction for and oversight of NIMS. The National Integration Center's Incident Management Systems Integration Division, formerly the NIMS Integration Center, was established to support routine maintenance and continuous refinement of NIMS.

In 2008, the NIMS document was revised to incorporate a wide range of feedback, best practices, and lessons learned from recent incidents; it clarified concepts and principles and refined processes and terminology throughout the document.[64]

The NIMS represents a core set of doctrines, principles, terms, and organizational processes to enable effective, efficient, and collaborative incident management at all levels. To provide the framework for interoperability and compatibility, the NIMS is based on a balance between flexibility and standardization.

INCIDENT COMMAND SYSTEM

The system designed to address the challenges of managing emergency incidents in the United States, including SAR, is called the Incident Command System (ICS). It has been used for many years.[19] This function-based system was designed to be adaptable to various types and sizes of incidents in a proactive, rather than a reactive, manner. The system groups similar tasks into five functional areas: command, operations, planning, logistics, and finance/administration. Each of these functions is performed at every incident to one degree or another, and all can easily be expanded as the size and complexity of the situation dictate. This expansion, however, is based on the premise that the span of control (the ratio of the subordinates to each supervisor) should never exceed seven to one and should more commonly be five to one. When this is exceeded, another level is added to the hierarchy to maintain an acceptable span of control (Figure 55-6).

The command section is led by the incident commander and provides overall management of the organization. Within ICS, the command section is responsible for dealing with other agencies (liaison officer), the news media, and other external influences (public information officer) and is responsible for the overall safety of the operation and its participants (safety officer). If the incident is too small for these functions to be performed by separate individuals, the incident commander performs them.

The operations section is led by the operations section chief, who is responsible for coordinating and performing all tactical operations. This role is commonly performed by the incident commander until the incident becomes so large and complex that the function must be performed by another individual. When multiple casualties are involved in an incident, their triage, treatment, and transport fall under the purview of the operations section. In such an incident, the operations section is divided into functional groups, often including, at least, triage, treatment, and transport groups. The person in charge of managing and coordinating the efforts of each group is the group supervisor. If the operations section is better divided using geography, a division rather than a group is formed. For instance, injured persons at an auto accident might be found on two sides of a road. An east division and a west division might be established to deal with the geographic separation of the resources. The person in charge of managing and coordinating the efforts of each division is the division supervisor. In a small organization, the supervisor of each division would answer directly to the operations chief.

To respond to specific challenges within an incident, a task force or strike team might be formed. A task force is any combination of single resources assembled for a particular tactical need, with common communications and a leader. For instance, FEMA combines search, rescue, medical, and technical resources to form an urban search and rescue (US&R) task force. A strike team, on the other hand, is a combination of a designated

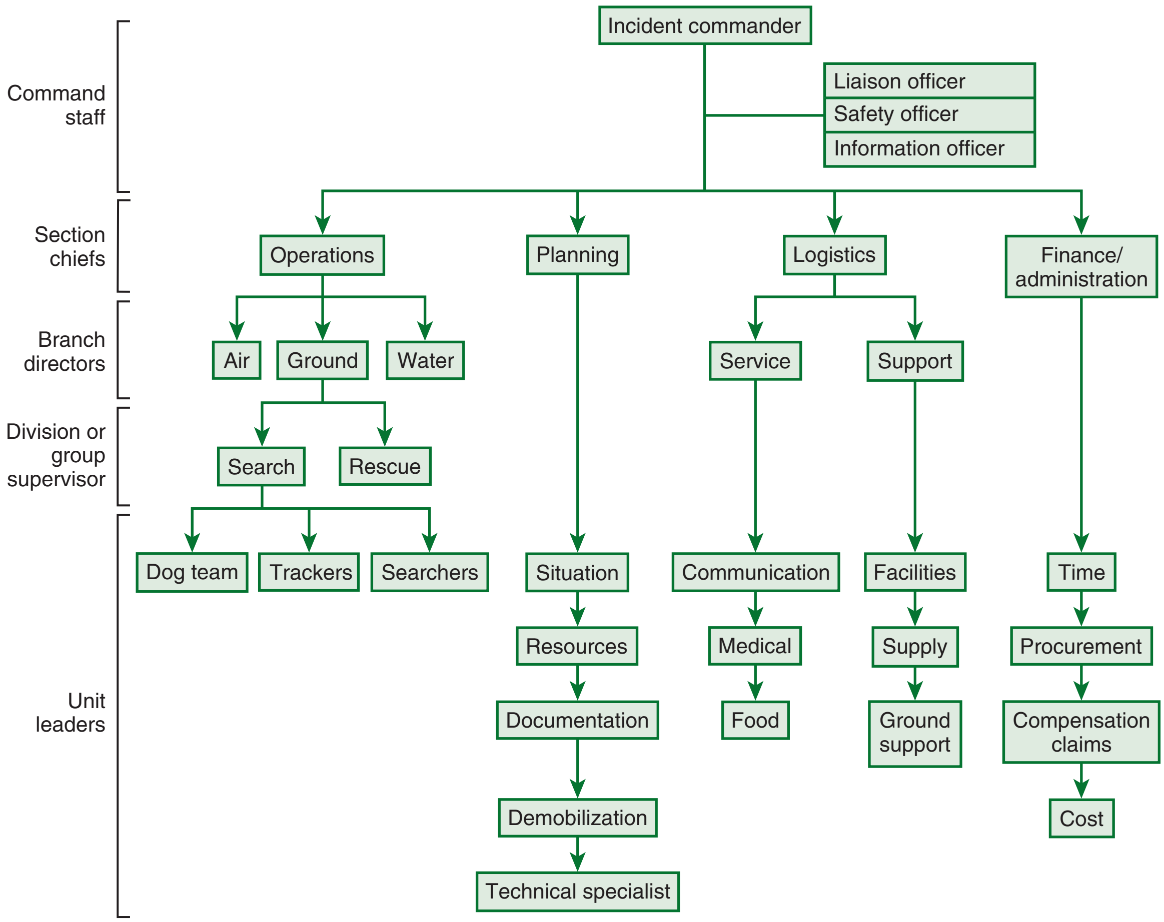

FIGURE 55-6 Functional hierarchy of the Incident Command System commonly used in search and rescue in the United States. *(From Cooper DC, editor:* FUNSAR: Fundamentals of search and rescue, *Chantilly, VA, 2005, Jones & Bartlett.)*

number of the same kind and type of resources with common communications and a leader. The number of resources used in the team is based on what is needed to perform the function. For instance, four three-person hasty search teams may be combined to form a strike team. These two combinations of resources permit the necessary flexibility when allocating resources.

The planning section is led by the planning section chief, who is responsible for collecting, evaluating, and distributing all incident information. As with the other sections, the incident commander performs this function unless the size and complexity of the incident dictate otherwise. In SAR, the planning section is particularly important because it evaluates search evidence and determines, based on what has been learned, what future actions should be taken or how current actions should be modified. Because such interpretation and evaluation often require great technical knowledge, personnel such as hazardous materials specialists, physicians, structural engineers, and other technical specialists may be required to help the planning section develop and revise the incident action plan.

The logistics section is led by the logistics section chief, who is responsible for providing personnel, equipment, and supplies for the entire incident. This awesome task involves ensuring that personnel are available, rested, and fed; that all equipment, including communications equipment, is available and operable; that vehicles are fueled and repaired; and that medical care is provided for all incident personnel. Basically, logistics is charged with seeing that the physical tools required to meet the overall objectives are available, operable, and maintained.

If the size and complexity of the incident prevent the incident commander from monitoring finance and administrative issues, the finance/administration section is led by the finance/administration section chief. This section is responsible for tracking all financial data for the incident, such as personnel hours, resource costs, costs for damage survey, and injury claims and compensation. Because most agencies involved in SAR can usually handle financial issues on their own, and most incidents are small and of short duration, the incident commander usually performs the functions of this section. Only in the largest or most complex incidents is it necessary for the incident commander to assign an individual or staff to perform finance section duties.

For access to free online ICS training and a more comprehensive treatment of ICS, the understanding of which is necessary for effective SAR operations in the United States, visit FEMA's ICS Resource Center at training.fema.gov/emiweb/is/icsresource/.

Incident Management Teams

An incident management team (IMT) is a scalable group of trained individuals who work together to augment/assist ongoing operations through provision of infrastructure support, or, in a large and/or complex incident or event, provide for command, control, coordination, support, and management of the organization and resources necessary to address the needs of the incident or event. The comprehensive resource that is an IMT may either augment ongoing operations through provision of infrastructure support or, when requested, transition to an incident management function to include all components/functions of a command and general staff.[66]

The organizational structure an IMT generally would use follows NIMS ICS doctrine and most often looks something like the flow chart illustrated in Figure 55-7.

An IMT has the following characteristics:

- Includes command and general staff members, unit leaders, and support personnel

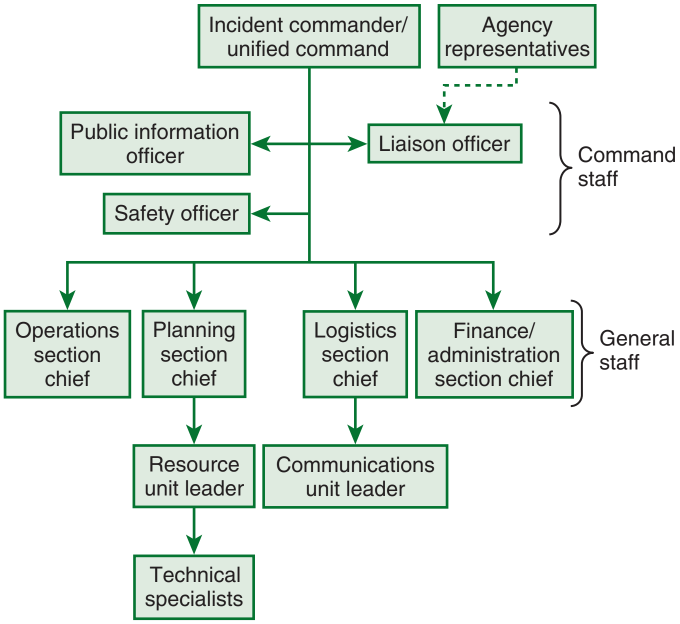

FIGURE 55-7 Organizational chart showing primary elements of an incident management team.

- May have statutory authority and/or formal response requirements and responsibilities
- Has predesignated roles and responsibilities for members (rostered and on-call: identified and able to be contacted for deployment)
- Is available 24 hours a day, 7 days a week, 365 days a year
- Is scalable, depending on incident/event size and complexity

IMTs are designated by "type," based on capability, level of training and experience, and reasonably anticipated incident response requirements, with type 1 being the most capable. There are four types of IMTs:

- *Type 1:* National or state team for the largest and most complex incidents of national significance
- *Type 2:* National or state team for incidents of national significance
- *Type 3:* State or regional multiagency/multijurisdictional team for complex or extended incidents
- *Type 4:* Single or multiagency team for expanded incidents

Much like search, rescue, and hazardous materials capabilities, incident management capabilities should be based on response requirements that might be reasonably anticipated. If a local incident expands beyond the capability or experience available, a response agency should have the capability to establish a type 4 IMT on site or can request a type 3 IMT regionally or through the state. A state type 3 IMT may take 2 to 4 hours to deploy and arrive. If the incident so warrants and the state does not have a type 2 or type 1 IMT, the state can request, through FEMA or other agreements, a national IMT. However, national teams are expensive (approximately $1 million per day, on average) and require some type of mobilization order and payment agreement. Depending on the national situation (e.g., during fire season, none may be available), incident type/complexity, and location, the National Interagency Fire Center (nifc.gov) may deploy either a type 1 or type 2 IMT if one is requested. However, a state type 3 IMT is definitely more economical and more likely to be available than a national team, and its benefits (because of local knowledge, local accountability, and improved responsiveness) may be more extensive than those of a national team.

Upon arrival, the IMT's incident commander will meet with the local incident commander and agency administrator (e.g., state agency director, county executive, city manager or mayor) to determine what they desire or expect from the IMT and to obtain any necessary delegation of authority. The incoming incident commander will brief the rest of the incoming IMT about roles and expectations. The IMT integrates as requested into the current ICS structure.

SEARCH AND RESCUE OPERATIONS

The five International Stages of SAR (awareness, initial action, planning, operations, and conclusion) through which most specific SAR events pass were described earlier in the section on the *IAMSAR Manual*. Historically, many have found it helpful to think of the operations stage as having four sequential phases: locate, access, stabilize, and transport.[12] These four phases will be used here as a framework for describing the components of a SAR operation.

LOCATE PHASE

The first step in addressing any emergency situation is locating the subject or subjects in need of assistance. This may be as simple as asking for an address or as complex as conducting an extended search for a lost person or persons. If the subject is easily found, rescuers can quickly move into the access phase. However, if locating the subject is difficult, this phase may turn into the crux of the SAR problem.

First Notice

The first notice of a SAR incident is often conveyed by relatives who report an injury or missing person, by a witness to an incident, by a government agency reporting distress signals (such as an ELT), by bystanders who perceive a problem, or by a caller to an emergency access number such as 911. Once the initial notice is received, the individual taking the information must know what to do and whom next to call.

Planning Data and Their Uses

The information gathered at the onset of an incident begins an ongoing investigation. It is used to determine the appropriate response and to help predict how the subject or subjects might react to the situation. This information, or *planning data,* includes any information that might affect what should be done to resolve the situation. Examples of planning data include the name of the subject, situation that caused the problem, last known location of the subject, subject's physical and mental conditions, subject's plans (where was he or she going?), available resources, weather information (present and predicted), geographic information, and history of similar incidents in the area. The purpose of collecting all this information is to help decide what to do next while predicting what the subject might do to help or hinder the situation.

The investigation and gathering of information continue throughout the incident and are used to modify initial plans. As new information is acquired, an action plan is developed and revised until the end of the incident cycle, when planning for the next incident commences.

Once information is gathered, the urgency of the situation is assessed. This assessment ultimately determines the speed, level, and nature of any response and may indicate whether a nonurgent or an emergency response is needed. The specific information used in urgency determination includes the age and condition of the subject, current and predicted weather, and relevant hazards. Figure 55-8 shows an example of an urgency determination form, which can be used by SAR personnel to determine how urgent the response should be.[12] Urgency also contributes to allowable risks and thus influences searcher safety, which is a primary consideration for search managers.

Search Tactics

During the initial (locate) phase of the incident, the emphasis is on searching for the subject. Accomplishing this is a priority, especially if it is expected to be difficult. SAR managers first use techniques, or tactics, by which the subject can be found in the shortest possible time. Tactics may be indirect (e.g., not requiring actual field searching) or direct (e.g., requiring deployment of

Search Urgency

Remember: the lower the number, the more urgent the response!!!

Date Completed: ______________
Time Completed: ______________
Initials: ______________

A. SUBJECT PROFILE .... ________

Age

Very Young	1
Very Old	1
Other	2-3

Medical Condition

Known or suspected injury or illness	1-2
Healthy	3
Known fatality	3

Number of Subjects

One alone	1
More than one (unless separation suspected)	2-3

B. WEATHER PROFILE .... ________

Existing hazardous weather	1
Predicted hazardous weather (8 hours or less)	1-2
Predicted hazardous weather (more than 8 hours)	2
No hazardous weather predicted	3

C. EQUIPMENT PROFILE .... ________

Inadequate for environment	1
Questionable for environment	1-2
Adequate for environment	3

D. SUBJECT EXPERIENCE PROFILE .... ________

Not experienced, not familiar with the area	1
Not experienced, knows the area	1-2
Experienced, not familiar with the area	2
Experienced, knows the area	3

E. TERRAIN AND HAZARDS PROFILE .... ________

Known hazardous terrain or other hazards	1
Few or no hazards	2-3

TOTAL .... ________

If any of the seven categories above are rated as a one (1), regardless of the total, the search could require an emergency response.

•••THE TOTAL SHOULD RANGE FROM 7 TO 21, WITH 7 BEING THE MOST URGENT.•••

8-11 Emergency Respone *12-16 Measured Response* *17-21 Evaluate and Investigate*

FIGURE 55-8 Urgency determination form. *(From Cooper DC, editor:* FUNSAR: Fundamentals of search and rescue, *Chantilly, VA, 2005, Jones & Bartlett.)*

searchers to the field). Examples of indirect tactics include confining the search area to limit movement of the subject and others into and out of the area, identifying and protecting the point last seen or the last known position, and attracting the attention of the subject if he or she is expected to be responsive.

Indirect techniques are usually quicker and easier to apply, so they are started first. As the incident progresses, direct tactics are initiated. In managing an incident, quick-response resources are usually begun in areas where early success is most likely, that is, the best, most effective search resources are deployed as early as possible to areas where the subject is most likely to be. In addition, identifying and protecting the point last seen or last known position are crucial indirect techniques that can mean the difference between success and failure of the entire effort.[12]

Direct techniques include sending teams of searchers into an area to search for clues and the subject. They are categorized by level of coverage, which is defined in search theory as the ratio of the search effort to the area searched.[13] A fast, relatively low coverage search of high-probability, unbounded areas is called a *hasty search*. This type of search would be conducted at campsites, buildings, and other locations where the subject would likely be found. Alternately, high-coverage techniques, or slow, highly systematic area searches, are used only when the highest probability of detection is required. Unfortunately, this is almost always at the expense of time and resources. In short, the more extensive the coverage, the more resource-intensive and time-consuming is the technique, assuming the search speed does not increase. Said another way, more coverage requires more search resources and/or more time spent searching.

Clues and Their Value

Clues are discovered during the investigative and tactical phases of a search. Their importance cannot be overemphasized. They may take the form of physical evidence, such as a footprint or discarded item, an account by a witness, or information gleaned from the investigation. Clues serve as the rudder that steers the overall search operation. Relevant clues are the basis for all search strategies and can determine or modify nearly all operational actions. Their powerful influence should be obvious; this is why searchers are taught to be "clue conscious" and to seek clues, not just subjects. There are many more clues than there are subjects.

People generate clues. A person exudes scent in the form of dead skin cells, crushes or disturbs vegetation, and, when traveling, leaves marks on the ground or other physical evidence of passing. This evidence is often discoverable if the appropriate resource is applied in a coordinated, organized search effort. Searchers must be sophisticated enough to discover this evidence and interpret its meaning before it is destroyed or decays. Because evidence important to a search effort is often easily destroyed once it is discovered, it is important to protect it from damage until it is completely analyzed.

Search Resources

Resources are defined as all personnel and equipment available, or potentially available, for assignment to support the search effort. Specific types of active tactics are categorized by the resource that performs them, such as dog teams, human trackers, ground search teams, and aircraft. Other common resources include management teams (e.g., overhead teams, public information officers), water-trained responders (e.g., river rescue, divers), cold weather responders (e.g., ice climbers, avalanche experts, ski patrollers), specialized vehicle responders (e.g., snowmobiles, four-wheel-drive trucks, all-terrain vehicles, mountain bikes, horses), and technical experts (e.g., communications experts, interviewers, chemists, rock climbers, physicians, cavers). In addition to these, other less common resources might also be available. These could include attraction devices (such as horns, flags, lights, sirens), mine detectors (military), noise-sensitive equipment (supermicrophones), infrared devices (forward-looking infrared technology on aircraft, night-vision equipment, thermal imagers), thermistors, and even witches, seers, prophets, and diviners, who sometimes show up during a well-publicized search.

FIGURE 55-9 Search dogs can work in areas where other searchers have been, with other search resources such as trackers, and using scent articles can discriminate for the missing person in heavily populated areas. They are able to work day and night, in most kinds of weather, and are especially effective where visual searchers are most limited (e.g., in the dark, in dense woods or heavy brush, or in debris [as found in earthquakes, floods, and tornadoes], and even underwater [the scent rises to the surface]). *(Photo courtesy of Eve Vigil, San Luis Obispo, CA, SAR.)*

Just about any person or thing imaginable may be available for use in a SAR incident. Their use is limited only by the creativity of those in charge. Here we discuss a few of the most common and useful.

Dogs. Dog teams are a common type of active search resource in the wilderness and are composed of a dog (occasionally more than one) and a human handler (Figure 55-9). The dog uses scent to search for and follow a subject while the handler interprets signals from the dog and searches visually for evidence. Three common categories into which dogs fit are tracking, trailing, and air-scenting dogs.

Tracking dogs follow scent on the ground from a person's footsteps and usually very closely follow the trail where a person traveled, regardless of the wind. Trailing dogs follow scent that has fallen onto the ground from the subject along the route of travel. Unlike the tracking dog, the trailing dog may follow the scent at some distance from the actual tracks of the subject, and may therefore be more affected by wind. Tracking and trailing dogs are most effective when used in areas that have not been contaminated by humans other than the subject. Also, weather and time tend to destroy scent available to these types of dogs, so the earlier they are used in a search, the better their chances of finding something.

Air-scenting dogs work off-lead to follow a subject's scent to its source. Specifically bred and trained air-scenting dogs can even discriminate between individual humans. They may detect scent from articles of clothing and can often follow it to discover a person buried in rubble or snow or even submerged under water. Wind is very important to this type of dog, as are other environmental forces, such as sun and rain. As long as the source exists, an air-scenting dog can usually detect the scent carried in air currents and follow it to the source.

Human Trackers. Human trackers use their visual senses to search for evidence left by a person's passing (Figure 55-10).

FIGURE 55-10 Tracks like these are easy to detect and follow. However, trained "mantrackers" can detect and interpret impacts with an environment that are far less obvious, put them together to determine direction of travel, and ultimately find a lost or missing subject quickly. *(Photo courtesy of Donald Cooper.)*

Human trackers "cut" or look for "sign" or discoverable evidence by examining the area where the subject probably would have passed. This process of looking for the first piece of evidence from which to track is called "sign cutting." Following the subsequent chain or chronology of sign is called "tracking."[16]

In SAR, most trackers use a stride-based approach called the step-by-step method.[16] This simple, methodical approach emphasizes finding every piece of possible evidence left by a subject. However, its most important role is undoubtedly the ability to quickly determine the direction of travel of the subject and thus limit the search area.[16]

Ground Search Teams

Hasty Teams. A hasty team is an initial response team of well-trained, self-sufficient, highly mobile searchers whose primary responsibility is to check out the areas (e.g., trails, roads, road heads, campsites, lakes, clearings) most likely to first produce the subject or clues. Their effectiveness is often based on how quickly they can respond and the accuracy of initial information.[12]

Ideally, hasty teams should include two or three individuals who are knowledgeable about tracking. They should be clue oriented, familiar with the local terrain and dangers in the area, and completely self-sufficient. Also necessary are the ability to skillfully interview witnesses and to use navigational skills with pinpoint accuracy. Team members should at least be trained in advanced first aid, emergency medical responses, or wilderness first responses; many teams have adopted these requirements as a minimum. Hasty teams usually operate under standard operating procedures, so they do not have to wait for specific instructions. They carry all the equipment they might need to help themselves and the lost subject for at least 24 hours.[12]

Grid Teams. Grid searchers use a more systematic approach to searching. They usually examine a well-defined, often small, segment to discover evidence. The classic approach to grid searching involves several individuals standing in a line, shoulder to shoulder, walking through an area in search of evidence or subjects (Figure 55-11). However, such resource-intensive approaches to searching are generally less preferred than those that use fewer personnel in a more efficient manner, such as tracking dogs or aircraft. In addition, high-coverage grid searching tends to damage the search environment and damage or destroy evidence and is generally difficult to coordinate.

Although grid searching may be an acceptable approach in certain limited circumstances, experience has shown that when the subject of a search is a live person, searching in this thorough manner should be used only as a last resort. Experiments involving grid searching have suggested that other, more efficient, uses of resources are often better.

Aircraft. Aircraft serve the same purpose as grid searchers, only from a greater distance, at a greater speed, over a larger area, and usually with a lower level of thoroughness. Within a search effort, aircraft can serve both as a tactical tool to look for clues and as transportation for personnel and equipment. They also provide an excellent attraction device for the missing subject as well as witnesses who may have information about the incident. Both fixed-wing (airplanes) and rotor-wing (helicopters) aircraft have their place in SAR and, like other resources, have their advantages and limitations. Among the most obvious limitations are expense and complex use requirements. Aircraft not only require specialized personnel and cost a great deal to operate, they also have very strict weather and environmental restrictions. For instance, it would be difficult to search from an aircraft in a snowstorm, and terrain may prevent searching certain areas from the air. However, most of these difficulties can be adequately addressed and minimized in a well-developed preplan.

Search Planning Considerations

State-of-the-art searching for lost persons has come a long way from the familiar lining up of volunteers shoulder to shoulder and walking in a straight line to search an area (Figure 55-12). Many new lifesaving concepts have been developed by the national SAR community. By borrowing from the fields of psychology, mathematics, and business and by analyzing past incidents, search planning and management have evolved into sophisticated sciences. Search effectiveness has also been improved through the study of human behavior, statistics, probabilities, and leadership and the use of good planning and management principles (Figure 55-13).

Search planning is guided by two general considerations: where am I going to look for the lost or missing person (strategy), and how am I going to find this missing or lost person (tactics)? To be effective, modern searchers follow basic principles and techniques that include:

1. Respond urgently—a search is an emergency.
2. Confine the search area.
3. Search for clues and the subject.
4. Search at night if the risk of darkness can be mitigated.
5. Search with a plan and in an organized manner.
6. Use grid searching (high coverage) as a last resort.

FIGURE 55-11 Although grid searching may be an acceptable approach in certain limited circumstances, experience has shown that when the subject of a search is a live person, searching in this type of highly thorough manner should be used only as a last resort. *(Photo courtesy of Eve Vigil, San Luis Obispo, CA, SAR.)*

FIGURE 55-12 State-of-the-art searching for lost or missing persons has come a long way from the familiar lining up of volunteers shoulder to shoulder and walking in a straight line to search an area. Many high-tech tools exist today to help in the search management process. These include task-specific computer software, smart phone apps, and navigation devices such as GPS receivers. *(Photo courtesy of Eve Vigil, San Luis Obispo, CA, SAR.)*

Every day, emergency responders receive calls to perform their duties, and they never know what to expect once they arrive. Life-threatening or time-critical situations have engendered what is known today as the "firehouse response." This means that emergency responders have to assume the worst until proved otherwise. Unfortunately, people who report incidents are often wrong in their initial assessments, and because of this, every call must receive the same urgent response. Any search situation for a lost or missing person should be considered an emergency that justifies an urgent response, a high priority, a thorough assessment, and immediate action.

Search Theory. The mathematical basis for searching and study of search theory had its beginnings during World War II in the work of the U.S. Navy's Anti-Submarine Warfare Operations Research Group and was originally based on searching for the wakes of warships as seen by aircraft flying over the ocean.[20] The results of this work were collected in a seminal report by B.O. Koopman in 1946,[41] but the report was not declassified and generally available until 1958.[5] In 1980, Koopman developed a somewhat expanded version of this work.[42] Although Koopman's work is clearly aimed at naval interests, the general theory of search he established is applicable to virtually any type of search problem. Since this early work, search theory has undergone continuous research and development by agencies such as the USCG and U.S. Navy in both the maritime and aeronautic environments, by mining and oil businesses in search of mineral and petroleum deposits,[23] and even by archeologists in search of lost cities, such as Troy.[56] The fundamental usefulness of search theory lies in its ability to help determine where and how to search. It accomplishes this by (1) quantifying the likelihood of a missing subject being in a particular area, and the likelihood of searchers finding the subject; and (2) offering tools with which one can estimate the chances of success of a particular search.

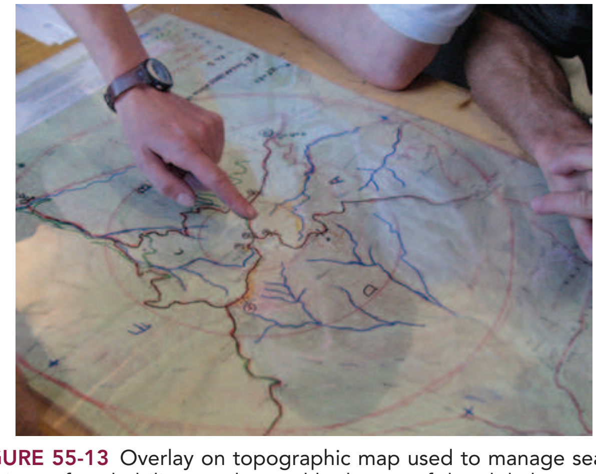

FIGURE 55-13 Overlay on topographic map used to manage search. Regions of probability are denoted by letters of the alphabet.

The application of search theory requires appropriate use of probability theory, a branch of mathematics used for estimating the likelihood of uncertain events, in planning a search. The chance that the missing person is in the search area is called *probability of containment* (POC) or, in the land search community, *probability of area* (POA). The conditional probability that a search resource will find the missing person, if he or she is indeed in the area being searched, is called *probability of detection* (POD). The product of these two important variables produces *probability of success* (POS = POA × POD).[56] The foremost objective and major challenge for search planners is to deploy the most capable search resources (POD) into segments most likely to contain the subject (POA) to produce the most POS in the least amount of time. On the surface this seems to be a straightforward proposition. However, myriad critical factors, such as resource detection capability, environmental influences, search object characteristics, probability density, probability distribution, coverage, and sweep width, conspire to make the most correct search action a complex, nonintuitive series of difficult choices.

Several initiatives have been undertaken to simplify the process of applying search theory to land search, including standardizing terms[13] and developing simplified, yet mathematically correct, approaches to quantifying the variables in less subjective ways.[14] Advanced methods have also been developed to optimize the increase in POS over time[10,57] and integrate motion and other models into land search problems.[69] User-friendly computer software will be required for such advances to enjoy widespread use by land search planners.

During the past several years, much has been done to improve how scientific search theory is applied to land search. Before 2001, much more research on the topic of search and detection had been conducted in the maritime environment than on land. In 2001, the NSARC Research and Development Working Group convened a meeting of land search experts.[51] After this meeting, several research projects sponsored by NSARC, and supported by several national and international organizations, were developed and funded. The first project produced a model for conducting detection experiments on land.[54]

In 2004, using the model developed, five detection experiments were conducted across the United States in five different ecoregions.[4,39] The results provide tremendous insight into methods of quantifying visual detection on land. That same year, NSARC, with funding from the Departments of Defense and Homeland Security, published a report that compared published land search procedures with the science of search theory. The full report identified several significant opportunities for improvement in multiple, long-practiced land search procedures and concepts.[15] Analysis of data from additional detection experiments in 2014 revealed a reasonably reliable field estimator for sweep width, which is an essential part of computing the probability of detection.[38]

Although software is available to assist in the mathematical computations, less-than-optimum but historically acceptable results have been achieved when a search planner applies the principles of search theory as an intuitive combination of hard science and experience. In the final analysis, search success is based on more than just science. At its finest, it involves the artistic application of science and a high degree of organizational and management skill, sprinkled with intuition and punctuated with a bit of luck.

Lost Subject Behavior. Modern search management is based on the use of what is called a complete subject profile. Such a profile identifies as much as is known about the missing subject, including general state of health, past experiences, and state of mind, through use of a form called the Missing Person Questionnaire. This information is collected and used by search planners to predict how an individual would react in various situations. Analysis of this information from past incidents and understanding how the involved individuals behaved in given circumstances have offered great insight for search managers.

It is important to note that most data on abductions of children and adults have been purposefully excluded from SAR research. Although some important work has been done in this area, the study of abductions and related criminal activity is often more about the perpetrator than the subject of the crime.[6,22] This is in stark contrast to the study of lost subject behavior, for which the actions of the subject are the research focus.

One classic land SAR reference suggests that the first rescue-related statistics were recorded by monks in the early 18th century who, through a system of hostels, guided travelers through the mountains of Europe. This system is best known for the St Bernard dogs that helped monks locate and rescue victims of severe snowstorms in the dangerous St Bernard Pass, a route through the Alps between Italy and Switzerland.[55] In the many years since, retrospective analysis of historical data from previous incidents has been widely recognized as a key contributor to our understanding of preventing, preparing for, and responding to modern-day searches and rescues.

In 1973, Kelley[34] published an analysis of 380 incidents from the Montrose (California) SAR team. Although it included only a limited set of data, it is thought to be the first modern-day research into the behavior of lost persons.

Although it is not difficult to appreciate the importance of predicting how a subject might react when lost, the scientific approach to the topic truly began with Syrotuck's seminal paper[58] in 1977. This paper was based on the premise that individuals have similar travel habits when compared with others in the same "category." The six categories initially identified by Syrotuck included small children (1 to 6 years), children (6 to 12 years), hunters, hikers, older adults (>65 years), and "miscellaneous adults," such as nature photographers, fruit gatherers, bird watchers, and other outdoor enthusiasts. The author also described two "special categories" (persons with intellectual disabilities and despondent persons) for which there were very little data. In his study, Syrotuck described the behavioral characteristics of a representative member of each category and computed "probability zones" for each, based on distances traveled. This distance was measured "as the crow flies," or as a straight-line distance, between the point where the subject was last seen and the location where the subject was eventually found. Realizing that there was likely a substantial difference between how far a lost subject actually traveled and the crow's-flight distance, the author argued that "it is more important to realize that a known percentage of all lost persons are found within a one- or two-mile radius than it is to know how they got there." Syrotuck studied 229 cases, most from wooded areas of Washington and New York States, and all involved subjects traveling on foot.[58]

Beyond identifying categories, Syrotuck[58] also documented and described six other factors that were thought to affect the search plan. He suggested that search personnel in possession of the following information could more accurately predict the subject's location:

1. Circumstances under which the person became lost
2. Terrain
3. Personality
4. Weather
5. Physical condition at time of loss
6. Medical problems

He went on to describe how one's general state of health, past experiences, and physical situation (e.g., hot, cold, altitude) contribute to predicting behavior patterns. How one reacts to being lost, he also suggested, can affect the type and quantity of clues (e.g., disrobing, discarding equipment), survivability (e.g., failure to build a fire), detectability (e.g., bright clothing, bad weather), and tendency to follow travel aids such as rivers, roads, and trails. What Syrotuck produced was the first relatively scientific description of how people might react to being lost and how searchers could use this information to improve operations.[58]

In 1980, with endorsement from the National Association for Search and Rescue, Mitchell[44] began collecting SAR case data from various regions across the United States using a standardized incident report form. The author collected and reported on 3511 cases and described a relationship between the behavior of lost subjects and the region of the country in which the incident occurred. In addition to much of what Kelley and Syrotuck reported, Mitchell also reported on how long a subject was mobile after being lost and a number of "survival factors."[44]

Following the theme of lost person behavior and using the crow's-flight distance, Koester and Stooksbury[40] performed a retrospective study of persons who suffered from what they termed at the time *dementia of Alzheimer's type* and who became the subjects of organized SAR efforts in Virginia. They initially studied 25 cases from the Virginia Department of Emergency Services' lost-subject database and compared the dementia patients' behavior with that of lost older adults who possessed normal cognitive abilities. Their findings were of great interest to search managers and planners in that this was the first time research of this type had been conducted for the inland SAR community. The authors also described a "subject profile summary" and suggested specific search techniques for lost dementia of Alzheimer's type patients. Notable in their findings were the facts that none of the subjects in the cases they studied yelled for help, and they were usually found within 0.8 km (0.5 miles) from the point last seen. Since this initial research, Koester[36,37] has extended his analysis of the Virginia Department of Emergency Services data.

Also using the crow's-flight distance, Hill[25,26] described distances traveled and probability zones for lost persons in Nova Scotia. Hill found it useful to modify and add to Syrotuck's categories of lost persons. Hill divided young people into four categories: children 1 to 3 years, children 4 to 6 years, children 7 to 12 years, and youths 13 to 15 years of age. He described characteristics for fishermen, skiers, and walkaways (e.g., people who walk away from a constant-care situation) and was the first to report characteristics for those who are despondent.

A similar and ongoing study was undertaken in Great Britain in 2001 by Mountain Rescue—England and Wales (formerly Mountain Rescue Council of England and Wales) using data collected from mountain rescue incidents in England, Wales, Northern Ireland, and Éire. The latest version of these data was published in 2011 and includes analyses of 1271 cases.[53]

Taking a slightly different approach, Heth and Cornell[24] published a study of 162 incidents involving persons lost in wilderness areas in southwestern Alberta, Canada. They tabulated crow's-flight distance traveled and angular dispersion of travel (the angle from a line that connects the point last seen with the intended destination) by different categories of wilderness users. They formed 10 categories of outdoor user (Table 55-1) and included only subjects propelled by muscle (no vehicles or machinery). The authors found a behavioral distinction between "front country" users (i.e., "front" referring to parking lots, groomed trails, frequent signage, along with good, available maps; these areas attracted users with a large range of outdoor experience and skill) and backcountry users (i.e., remote, undeveloped areas; these areas attracted prepared and experienced users). Not unlike Syrotuck and Hill, Heth and Cornell discovered that, with the exception of despondent persons, there is a similar distribution of distance traveled by persons lost outdoors. However, they went further and suggested that there might be a linear relationship between certain data sets. For instance, their analysis indicated that hikers travel about 2.3 times farther than do campers, and cross-country skiers breaking trail travel about

TABLE 55-1 Formal Estimates of Crow's-Flight Distance (kilometers) between the Point Last Seen and the Point Found for Persons Lost during Different Wilderness Activities*

	Percentile			
Activity Group (N)	**25**	**50**	**75**	**90**
Campers (18)	0.722	1.559	3.001	4.931
Cross-country skiers: break trail (5)	4.537	9.795	18.860	30.988
Cross-country skiers: groomed trail (18)	0.842	1.819	3.501	5.753
Despondents (6)	0.229	0.656	1.793	4.664
Hikers (38)	1.691	3.650	7.028	11.548
Hunters (5)	1.222	2.638	5.079	8.345
Mountain bikers (18)	3.759	8.116	15.626	25.675
Scramblers (7)	1.165	2.515	4.843	7.958
Walkaways (14)	0.701	2.007	5.486	14.274
Other (13)	1.765	3.812	7.339	12.058

From Heth DC, Cornell EH: Characteristics of travel by persons lost in Albertan wilderness areas, *J Environ Psychol* 18:223, 1998.
*Estimates for despondents and walkaways were based on a different Wakeby distribution than that used to estimate the percentiles of the other user categories.

5.4 times farther than do cross-country skiers using groomed trails. The implication is that if archival data are possessed for a category in one region and are compared with categories of lost subjects similar to those described by Heth and Cornell, a scalar parameter could be applied to extrapolate crow's-flight distances for other subject categories. Such a possibility is exciting to search managers, who only rarely have access to relevant and reliable archival data.[24]

The largest and latest attempt to collect data on the behavior of lost subjects began as part of a U.S. Department of Agriculture small business grant in 2001. After years of collecting data for what he termed the International Search and Rescue Database, Koester[35] published a book in 2008 that described lost person behavior data from seven countries (91% from the United States), 40 separate sources (including reports from 9 previously published papers), and 16,863 searches. The book describes 34 categories of lost subjects and their interaction with the environment in terms of ecoregions, or geographic areas that characterize the effects of local influences such as climate, terrain, and vegetation.[4] The specific data reported for each category include distance from the initial planning point, elevation change from the initial planning point, mobility hours, dispersion angle (angle established between the direction of travel and the bearing defined by the initial planning point and where the subject was found), find location (e.g., road, brush, woods, field), scenario causing the subject to be missing, track offset (shortest perpendicular distance from an intended track or where the subject was found), and survivability. With each category description, the author also suggests initial reflex tasking and investigative questions for search managers.[35] Tables 55-2 through 55-10 show examples of tabular data from the book for the category of "hiker." For inland searches, the data summarized and reported by the author have been of significant value in planning searches.

Search planners have used these behavioral studies and summary reports in a number of valuable ways. By direct analysis and limited extrapolation, search planners have been able to find answers to important planning questions that are helpful in determining where and how to search. Such efforts have also taught search managers the importance of collecting behavioral data on lost persons and the predictive value of such data.

ACCESS PHASE

After the subject is located, the search is over. Rescuers must now gain access to the subject to assess and treat injuries, evaluate the situation, and mitigate the problem. Accomplishing these objectives may be as simple as walking up a trail to reach the subject or as complex as reaching a climber on the face of El Capitan in Yosemite National Park. Regardless, planning for this eventuality should be complete and ready to be carried out at the conclusion of the locate phase.

TABLE 55-2 Hiker: Distance (Horizontal) from the Initial Planning Point (kilometers)

	Temperate		Dry		
	Mountain	**Flat**	**Mountain**	**Flat**	**Urban**
N	568	274	221	58	8
25%	1.1	0.6	1.6	1.3	
50%	3.1	1.8	3.2	2.1	2.6
75%	5.8	3.2	6.5	6.6	
95%	18.3	9.9	19.3	13.1	

Data from Koester RJ: *Lost person behavior: a search and rescue guide on where to look—for land, air and water,* Charlottesville, VA, 2008, dbS Productions, p 184.

TABLE 55-3 Hiker: Elevation (Vertical) Change from the Initial Planning Point (feet)

	Temperate			Dry		
	Uphill	**Down**	**Same**	**Uphill**	**Down**	**Same**
%	32%	52%	16%	48%	52%	
25%	182	160		317	500	
50%	480	400		956	975	
75%	1175	1166		1500	2109	
95%	2634	2175		3623	5094	

Data from Koester RJ: *Lost person behavior: a search and rescue guide on where to look—for land, air and water,* Charlottesville, VA, 2008, dbS Productions, p 184.

TABLE 55-4 Hiker: Horizontal Change from Initial Planning Point (Miles) for Mountainous Terrain

	Temperate			Dry		
	Uphill	**Down**	**Same**	**Uphill**	**Down**	**Same**
N	58	131	34	47	57	0
25%	0.5	0.7	0.0	1.8	1.0	
50%	1.4	1.7	0.0	2.2	2.0	
75%	2.6	4.0	1.5	4.0	5.0	
95%	7.2	17.4	12.8	10.7	12.3	

Data from Koester RJ: *Lost person behavior: a search and rescue guide on where to look—for land, air and water,* Charlottesville, VA, 2008, dbS Productions, p 184.

TABLE 55-5 Hiker: Mobility (hours)

	Temperate	**Dry**
N	232	112
25%	0	4
50%	3	8
75%	6	12
95%	14	26

Data from Koester RJ: *Lost person behavior: a search and rescue guide on where to look—for land, air and water,* Charlottesville, VA, 2008, dbS Productions, p 185.

TABLE 55-6 Hiker: Dispersion Angle (degrees)

	Temperate	Dry
N	134	28
25%	2	20
50%	23	47
75%	64	124
95%	132	175

Data from Koester RJ: *Lost person behavior: a search and rescue guide on where to look—for land, air and water,* Charlottesville, VA, 2008, dbS Productions, p 185.

TABLE 55-7 Hiker: Find Location (%)

	Temp	Dry	Urban
N	312	196	17
Structure	13	10	24
Road	13	17	35
Linear	25	31	18
Drainage	12	18	6
Water	8	9	12
Brush	2	2	
Scrub	3	3	
Woods	7	6	
Field	14	1	6
Rock	4	2	

Data from Koester RJ: *Lost person behavior: a search and rescue guide on where to look—for land, air and water,* Charlottesville, VA, 2008, dbS Productions, p 185.

TABLE 55-8 Hiker: Scenario (%)

N	2242
Avalanche	
Criminal	
Despondent	
Evading	1
Investigative	1
Lost	68
Medical	2
Drowning	
Overdue	16
Stranded	4
Trauma	7

Data from Koester RJ: *Lost person behavior: a search and rescue guide on where to look—for land, air and water,* Charlottesville, VA, 2008, dbS Productions, p 185.

TABLE 55-9 Hiker: Survivability

	Wilderness	Urban
Uninjured	78%	59%
Injured	16%	24%
Fatality	6%	12%
No trace		6%
Survivability	Alive	n
<24 hr	97%	2460
>24 hr	76%	361
>48 hr	60%	118
>72 hr	52%	51
>96 hr	49%	23

Data from Koester RJ: *Lost person behavior: a search and rescue guide on where to look—for land, air and water,* Charlottesville, VA, 2008, dbS Productions, p 185.

TABLE 55-10 Hiker: Track Offset (meters)

n	40
25%	50
50%	100
75%	238
95%	424

Data from Koester RJ: *Lost person behavior: a search and rescue guide on where to look—for land, air and water,* Charlottesville, VA, 2008, dbS Productions, p 185.

Once rescuers reach a subject, the situation and scene must be assessed. In emergency services terminology, this is called the *size-up*. The size-up consists of identifying hazards to the subject and rescuers and then developing a strategy to deal with the problems. For instance, a subject might be trapped by a winter storm in a high alpine environment. Safety considerations for rescuers entering such a hostile and dangerous environment would certainly influence further actions and may well take precedence over the entire rescue effort.

Specialized skills may be required for rescuers to safely gain access to the scene. For instance, rescuers may need to rappel to a patient who has fallen onto a ledge in the Grand Canyon, or they may need to climb sheer rock faces to reach an injured mountaineer on Half Dome in Yosemite National Park. These are examples of how complex the access phase of a rescue may be and point to the importance of thorough and proper planning.

If the size-up indicates that the situation or environment is so hazardous that remaining on the scene poses an immediate threat to the subject, accelerated rescue techniques may be required. Accelerated rescue techniques are immediate actions required to remove a subject from a dangerous environment without stabilization. They often entail deviations from local standard operating procedures and protocols. Examples of such situations include poisonous gas environments (e.g., in caves), fires, unstable terrain (such as avalanches and rock slides), adverse weather (hurricanes, thunderstorms, severe snowstorms), or any hostile environment that threatens the subject or rescuers, or both.

STABILIZATION PHASE

The stabilization phase has three primary components: physical, medical, and emotional. Once rescuers have access to the subject, the scene must be quickly evaluated, or sized up, for immediate physical hazards and threats from the environment. Scene safety is an initial priority in the size-up, and risks to everyone must be weighed against the benefits to be gained. An example of physical stabilization would include an occupied automobile teetering on the edge of a cliff. Before the occupant can be medically assessed, the situation must be stabilized to best protect the rescuers and the patient. Other examples of physical stabilization might include protecting the patient from further injury or removing the hazard.

Once the physical environment is stabilized and free from immediate hazards, medical management and stabilization can begin. This process usually follows accepted procedures, starting with primary and secondary physical examinations and progressing through treatment with basic to advanced life support. The process should treat the identified illness and/or injuries as appropriate and, without exception, with some type of protection from the environment. The goal of medical stabilization is usually to prepare the subject for transportation to a definitive care facility. If medical care is not required, confirming this fact may be all that is necessary at this stage before moving into the transport phase.

Emotional stabilization is necessary because an anxious victim is a hazard to rescuers and himself or herself. The goal is to best protect both the rescuers and the victim. Simple, calm communication with the patient, slowly describing what happened and what rescuers are doing, is often enough to calm a nervous subject.

FIGURE 55-14 Prior to being moved, patients being transported by helicopter should be informed of the noise, rotor wash, and other consequences of this mode of transportation. *(Photo courtesy of Eve Vigil, San Luis Obispo, CA, SAR.)*

FIGURE 55-15 Even though the personal equipment necessary is dictated by both the rescue environment and the needs of the specific situation, it usually includes head, hand, foot, and eye protection, at a minimum. *(Courtesy DC Copper.)*

Stabilization, like assessment, should continue throughout the transport phase. The overall objective is to prepare the victim for transport to definitive care while maintaining his or her comfort and safety.

TRANSPORT PHASE

In the fourth phase of SAR, the subject is moved to definitive care. For this to occur, the stabilized subject must be "packaged" so that he or she can be moved safely and efficiently while stabilization and assessment continue. Transportation will range from foot travel, with the subject walking on his or her own, to evacuation by aircraft. If helicopter extraction is going to be used, the injured person must be briefed thoroughly on what to expect (Figure 55-14). This should include everything from the effects of "rotor wash" to movement and noise. The appropriate mode of transportation can be determined by weather, type and severity of injuries, overall urgency, terrain, and available resources, to name a few.

Chapter 57, Litter and Carries, addresses the numerous considerations that exist when a patient will be packaged and transported from an isolated wilderness area to definitive care.

Rescue Equipment

Today's rescues often occur in remote and unusual environments and may therefore require extremely technical rescue equipment and skills. Responders trained in the appropriate techniques and technologies should be the only personnel to apply them. Much of the gear and many of the techniques have been derived from those first developed by mountaineers, climbers, cavers, and white-water enthusiasts.

Rescue equipment is generally broken down into three broad categories: personal gear, rescue software, and rescue hardware. Personal equipment includes such items as footwear, gloves, helmets, articles of clothing, eye protection, and other protective apparel. Software is equipment such as rope, webbing, slings, and harnesses that are made of soft, strong synthetic materials specifically designed and manufactured for rescue. Hardware includes equipment such as carabiners, cams, friction devices, pulleys, and litters made of steel and alloys specifically designed and manufactured to endure the rigors of rescue.

Personal Protective Equipment. Rescuers must often wear special equipment to protect them from accidents and the hazards of SAR. Head, eye, and hand protection are considered mandatory in virtually all rescue environments. Additional personal protective equipment (PPE) requirements are dictated by the rescue environment and the specific needs of the situation (Figure 55-15). Medical PPE may also need to complement SAR PPE and is described in Chapter 21, Wound Management.

Special Gear. In addition to the usual challenges of the rescue environment, certain hazards require specialized equipment. Examples of such equipment include fire-resistant clothing worn by structural and wildland firefighters, personal flotation devices used by rescuers in and around water (Figure 55-16), netting used in outdoor settings when insects become a problem, bulletproof garments used by law-enforcement and military rescue personnel, and chemical protective suits worn when exposure to hazardous materials is possible.

No clothing or protective gear meets all of the requirements for involvement in or around a rescue scene. Rescuers study situations so that they understand all hazards before anyone becomes involved. Their conclusions help them identify protective equipment requirements. Gear that may be necessary for one environment can be dangerous in another. A firefighter's turnout gear may be required in a structure fire but can be deadly in a river rescue situation. Every rescuer is responsible for understanding the rescue environment and how best to prepare for it.

Software

Rope. Rope is by far the most versatile piece of rescue equipment and serves as the universal link in most rescue environments. The material from which the rope is made (e.g., nylon, polyester, polyolefin) and the design (laid, kernmantle, flat) are important in consideration of the use for which a rope is intended.

In most rescue environments, nylon is preferred because of its overall strength, resistance to abrasion, and ability to stretch and absorb energy. Natural-fiber ropes such as hemp are no longer considered for use in rescue; synthetic materials are far better. Although the design and amount of materials used influence strength, the new nylon rescue rope that is 13 mm (0.5 inch) in diameter usually has a tensile strength in excess of 40 kN (9000 lb) (Figure 55-17).

The most common design of rescue rope is kernmantle, a term derived from German, meaning "core in sheath." With this

FIGURE 55-16 Rescuer wearing a personal flotation device and helmet often used for rescue in and around moving water. *(Courtesy DC Copper.)*

FIGURE 55-17 Example of 13-mm (0.5-inch), nylon, static, kernmantle rope of the type commonly used in rescue. Rescue rope should be checked over its entire length for damage before use. *(Courtesy DC Copper.)*

design, a core of material (often parallel fibers) is surrounded by a braided sheath. The sheath protects the inner core, which supplies much of the strength of the overall rope. Other designs, such as laid (twisted) and braided, are also used in rescue rope.

Kernmantle rope is either dynamic or static. Dynamic kernmantle stretches more than 4% of its length to absorb the impact of a fall and is used primarily in lead climbing. Static kernmantle stretches less (no more than 4% of its length); it is used in rescues in which a great deal of stretch would be a nuisance or even dangerous.

Because of the importance of rope in the rescue chain, frequent inspection, care, and maintenance are important. Rope used in rescue is kept clean, inspected often, and protected from sharp edges, high temperatures, sunlight, chemicals, and abrasion. In addition, a detailed history of rescue ropes is kept so that an educated decision can eventually be made regarding each rope's removal from rescue service.

FIGURE 55-19 An example of a full-body harness. Shown is a CMC ProSeries Harness Combo. Note that this harness encompasses both the pelvis and the thorax. *(Copyright CMC Rescue.)*

Webbing. Flat rope or webbing is another common link in rescue systems. The two common configurations are flat and tubular. Tubular webbing is manufactured as a tube in such a way as to seem flat when in use. In cross section, however, it is obviously tubular and a bit less stiff than true flat webbing. Tubular webbing that is 2.5 cm (1 inch) in diameter can be used in rescues to tie anchor slings and harnesses. It has a tensile strength of about 17.8 kN (4000 lb) when new.

Flat webbing is flat in cross section. Its strength is directly proportional to the amount of material used in its manufacture. Automobile seat belts are an example of the material used in rescue harnesses and anchor slings, where strong, flat software is beneficial (Figure 55-18).

Harnesses. Harnesses come in many sizes and shapes; they are used to attach something (usually a rope) to a person's body. They may be "full body," encompassing the thorax and the pelvis (Figure 55-19); "seat," encompassing only the pelvis; or "chest," encompassing only the thorax. Each type of harness has its use and associated advantages and disadvantages. Classically, the

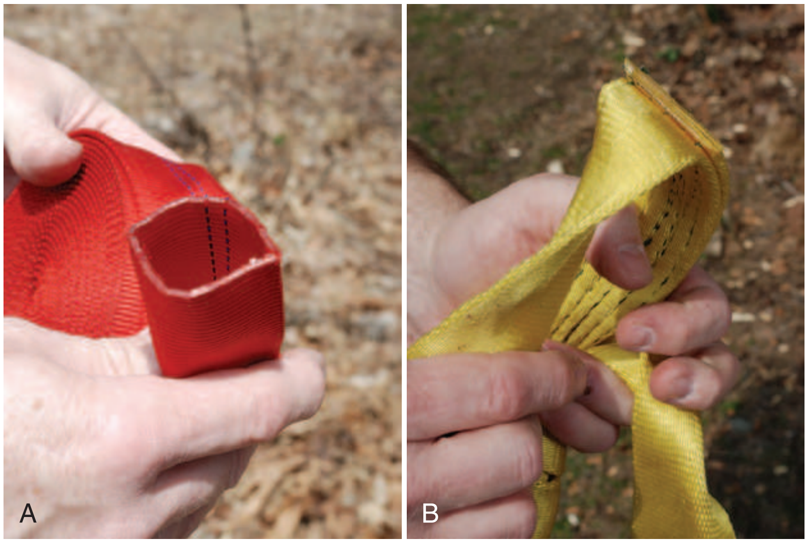

FIGURE 55-18 **A,** Tubular webbing with cross section visible. **B,** Flat webbing used in anchor sling. *(Courtesy DC Copper.)*

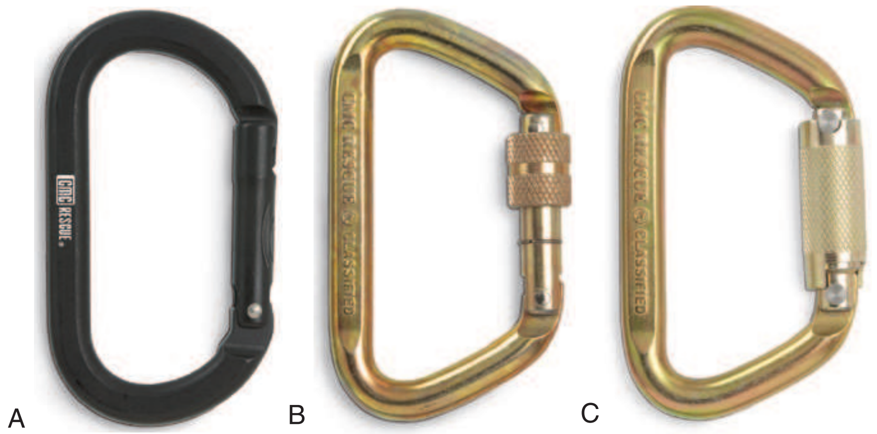

FIGURE 55-20 Carabiners are most often made of aluminum or steel and their shape and color can be varied to suit a specific need. There are several options for gate locking mechanisms, the most common being screw-lock and auto-lock, the latter of which uses a spring-loaded mechanism and quarter-twist lock to secure the gate. Examples shown are **(A)** aluminum, oval, nonlocking carabiner; **(B)** steel "D" screw-lock carabiner; and **(C)** steel autolock carabiner (UL Classified to NFPA 1983, General Use). Note that locking carabiners should always be locked when in use. *(Copyright CMC Rescue.)*

most common harness for climbing has been the seat harness. However, rescue practitioners have been trying to standardize the full-body harness for rescuer use, with the separate seat and chest harnesses having only limited special use by trained individuals.

Webbing can be tied into a large loop (runner) and applied to a person in such a way as to serve as an improvised harness. Although this is not a preferred method of attachment to a rope, it can work if other harnesses are not available.

Hardware

Carabiners. Carabiners are metal, gated links used to connect various elements of a rescue system, such as a rope and anchor. They are occasionally called biners, snap links, or crabs and consist of a spring-loaded gate that pivots open, a spine that supports most of the load and lies opposite the gate, a latch, and, depending on the specific style, a locking mechanism.

Carabiners are most commonly made from steel or aluminum. Size for size, steel is stronger and heavier, but aluminum is lighter and stronger pound for pound. In rescue, steel is almost always preferred unless weight is a factor, as it is in remote alpine situations.

Common shapes of carabiners include oval, D, offset D, pear, and large offset D. The design best suited for any situation is dictated by the specific use. No matter what the shape, carabiners used in rescue usually have a mechanism for locking the gate closed so that opening it takes a specific effort, usually twisting or unscrewing. This design feature not only improves the strength of the device when locked but also reduces the possibility that a carabiner will open accidentally at an unexpected time (Figures 55-20 and 55-21).

Aluminum, nonlocking, oval-shaped carabiners (see Figure 55-21B) are common in sport climbing and mountaineering but are generally not recommended for use in rescue situations, because of their lack of a locking mechanism and relative weakness when the gate is opened. When available in rescue situations, locking carabiners are usually preferred. When a locking carabiner is not available, two reversed and opposed oval, nonlocking carabiners are sometimes used in its place. One can confirm that the two nonlocking carabiners are configured safely (reversed and opposed) when the open gates form an X (see Figure 55-21C).

Descent and Belay (Friction) Devices. Many different descent and belay devices all primarily apply friction to the rope to allow controlled lowering of a load. Although some useful and specialized options have come onto the market in the past few years (e.g., Conterra Scarab, Petzl I'D, Traverse 540°, CMC Rescue MPD [MultiPurpose Device], Petzl Tuba, Petzl GriGri, heightec Quadra, Petzl Stop, CMC Rescue Escape Artist), the most common and robust descent devices in rescue remain the figure-eight plate and the brake bar rack.

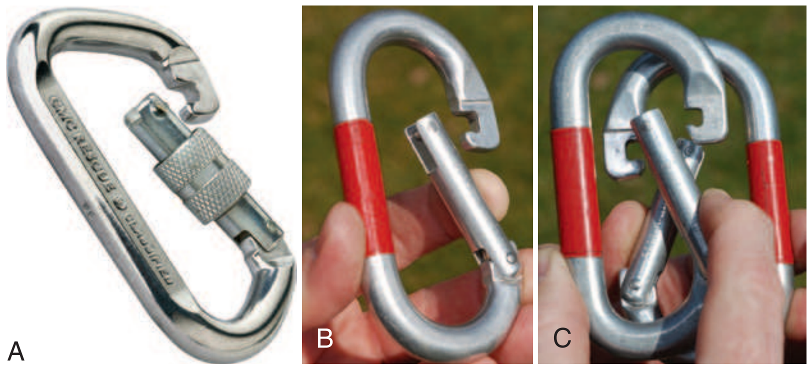

FIGURE 55-21 **A,** Close-up view of CMC Rescue aluminum carabiner. Note the locking gate and offset D shape. **B,** Close-up view of an oval, nonlocking, aluminum carabiner often used in climbing. This type of carabiner is usually not recommended for rescue applications but is common in climbing due to its light weight and ease of use. **C,** Although not generally recommended for rescue applications, two nonlocking carabiners with their gates reversed and opposed (visually confirmed when opening the gates makes an X) are sometimes used when locking carabiners are not available. *(**A,** Copyright CMC Rescue.)*

FIGURE 55-22 Example of figure-eight plate descending device (with "ears") commonly used in rescue. Shown is a CMC Rescue 8 with ears; aluminum *(left)* and steel *(right)*. *(Copyright CMC Rescue.)*

FIGURE 55-24 SMC National Fire Protection Association brake bar rack. Straight frame shown; frame also available with eye twisted 90 degrees. The top bar has been modified to allow a secure tie-off. *(Copyright CMC Rescue.)*

The figure-eight plate gets its name from the general shape. It has two rings of different sizes. The larger ring produces friction on the rope; the smaller ring is used primarily as an attachment for the load (e.g., the rescuer during rappel). Friction is produced by passing a bight of rope through the large ring and around the small ring and then attaching the small ring to either an anchor (for a lowering system) or a rescuer's harness (for a rappel or abseil) with a locking carabiner (Figure 55-22).

The brake bar rack, or simply "the rack," uses either steel or aluminum bars on a steel rack to produce friction on a rope. When the rope is threaded alternately around the bars, and the load or rescuer is attached to the "eye" in the rack, friction is applied. The number of bars applied to the rope and the distance between them can be varied to change the friction. This variable friction allows versatility not available with the figure-eight plate; however, the rack takes more training to use safely (Figures 55-23 and 55-24).

Ascenders. Ascenders are devices that grip or hold the rope. They have been adapted from climbing and caving equipment, with which they can be used in a system to ascend or climb a fixed rope. In rescue, they can used to climb fixed lines when necessary, but can also be used in hauling systems to grip the rope. In this way, they hold fast when the rope is pulled in one direction and allow the rope to slide easily when it is pulled in the other direction (Figures 55-25 and 55-26).

When multiple ascenders are used in a fixed rope climbing system, one or two ascenders are fixed to the rope and support

FIGURE 55-23 **A,** RSI Rigging Rescue Rack brake bar rack in use. **B,** SMC National Fire Protection Association brake bar rack with welded eye twisted 90 degrees; configured for use. The top bar has been modified to allow for a secure tie-off. **C,** Brake bar rack tied off. When the bars are pulled tightly together, excessive friction prevents movement on the rope. *(Courtesy DC Copper.)*

FIGURE 55-25 **A,** Gibbs ascender applied to rope. When the device has been assembled and attached to the rope and the eye of the cam is pulled, the cam squeezes the rope and holds fast. When the cam is released, the device can be moved along the rope. **B,** Gibbs ascender dismantled with shell around rope. Note cam *(lower left)* and pin *(upper right)*. **C,** Clog-handled ascender. Although used where climbing a fixed rope is required, handled ascenders are rarely used in rescue. **D,** A three-wrap Prusik hitch can sometimes be used in lieu of a mechanical ascender. *(Courtesy DC Copper.)*

the load while one is moved into position ahead. When this action is repeated in an alternating manner, a skilled climber can move up a rope with relative speed and ease. Certain rope hitches (e.g., a Prusik hitch) can be used in lieu of an ascender (see Figure 55-25D) and when used in a system such as a Purcell Prusik system (three Prusiks of different lengths; two foot Prusiks and one harness Prusik), can be quite effective in ascending a fixed rope.

FIGURE 55-26 Alternate type of cam ascender specifically designed for rescue. Shown is a Petzl Rescucender for use with 11- or 13-mm (0.45- or 0.5-inch) rope. *(Copyright CMC Rescue.)*

Pulleys. Pulleys are simple machines that apply a turning wheel to reduce friction on a rope as it rounds a turn. In rescue, these metal devices serve primarily to change the direction of a rope, such as within a mechanical advantage system. The sheave is the wheel or pulley, and there may be more than one. The side plate or cheek is the side of the device that makes contact with the anchor at the hook, which is usually the weakest part. The axle or sheave pin is what the wheel turns on; it is supported by the side plates. In rescue pulleys, the side plates are movable so that the pulley can be attached to a rope anywhere along its length (Figure 55-27).

FIGURE 55-27 One example of a high-quality pulley commonly used for rescue. The latest technology in high-efficiency rescue pulleys uses large anodized aluminum sheaves (5.7-cm [2.25-inch] sheave shown), sealed ball bearings, a large carabiner hole to accommodate more than one carabiner, rounded edges on high-strength side plates, and a bottom shape designed to work well with Prusik hitches. CMC Rescue ProSeries Pulley shown. *(Copyright CMC Rescue.)*

The larger the diameter of the pulley, the more efficient the device. That is, the bigger the pulley, the more the friction (theoretically) is reduced. A rule of thumb often used by rescuers is that a pulley with the largest diameter possible should be used, but never less than four times the diameter of the rope. Therefore, because 13-mm (0.5-inch) rope is commonly used in rescue, a pulley diameter of at least 52 mm (2 inches) should be used.

A variation of the pulley is the edge roller. This device uses 10.2- to 15.2-cm (4- to 6-inch) open-face pulleys to reduce both the friction of a rope passing over an edge and any damage to the rope by protecting it from excess abrasion. Single units can protect the rope from 90-degree angles, and multiple units tied together can provide protection for complex projections.

Litters. Litters or stretchers are the conveyances in which victims are transported when they cannot travel under their own power. New high-technology materials and designs have greatly improved the choices available. In past years, rescuers were forced to choose between wooden backboards, old military stretchers, the wire Navy Stokes basket, or the "scoop" stretcher. Today, strong, lightweight synthetic materials and inventive designs have improved the strength, weight, durability, and comfort of litters.

The goals have not changed during evolution of the perfect wilderness transportation device. Rescuers still want a device that is comfortable for a person in pain, serves well as a platform for assessment and medical care during transport, allows for full-body immobilization, and provides complete security and protection of the occupant from the rescue environment. See Chapters 56 (Technical Rescue, Self-Rescue, and Evacuation) and 57 (Litters and Carries) for additional information regarding specific litters, packaging, handling, and evacuation techniques.

ANATOMY OF A SEARCH AND RESCUE INCIDENT

To summarize how all of the previously discussed information fits together, it is convenient to dissect a SAR incident into its component parts and then analyze how all of the parts fit together (Figure 55-28).

From the SAR operative's perspective, an actual callout is merely an interruption of planning for an incident. That is, people involved in SAR are constantly in a state of readiness and are prepared to respond. When a situation occurs, this constant planning stage is suddenly interrupted by the report of an incident. The individual taking the information is charged with conveying it to the appropriate authority. The authority determines the urgency, continues the investigation process, begins to develop an operational strategy, and generates an incident action plan. At the same time, those in charge begin to muster appropriate resources to carry out the action plan. In SAR, this is termed *resource callout,* or just callout.

Once notified of an incident, individual resources are gathered at a collection point and signed in. The sign-in process enhances safety and allows tracking of the types and quantity of resources that are available on scene. Once signed in, resources are given assignments designed to meet the goals of the action plan within a specific operational time frame. This physical implementation of the incident action plan is referred to as *tactics.*

Deployment of resources to the field continues until there is reason to suspend this phase of the operation. If the subject is found, the search is suspended, and the access phase can commence. Once rescuers have access to the subject, the focus turns to stabilization and transportation. If at any point the operation cannot be continued (e.g., the subject was never found, access cannot be gained, transportation is impossible), suspension and demobilization may occur without completion of the entire cycle. The decision to discontinue active search efforts is difficult and involves complex management issues, almost always of the "no-win" variety.

When a situation is resolved, mission suspension and demobilization begin. In larger incidents, this may involve structured deactivation of multiple resources, pulling teams out of the field, dismantling facilities, completing documentation, and returning resources to service. Basically everyone finishes what he or she was doing at this incident and gets ready to do it again. All of this takes planning and preparation and should be addressed in the overall preplan long before it is required.

After every incident, participants realize that if they had to do it all over again, they would do some things differently. If these thoughts and ideas are not documented, they can be lost, and future responses may be fated to repeat past mistakes. This is one reason why every incident should contain some type of evaluation of the entire mission, known as the *postincident critique*. The critique can be formal, involving every participant at a sit-down meeting, or informal, involving just a brief discussion of recent events. The critique documents lessons learned and should provide a basis for revising the preplan. Thus the cycle continues, and lessons learned from one mission influence the next.

SEARCH AND RESCUE ENVIRONMENTS WITHIN THE WILDERNESS SETTING

SAR teams throughout the world are frequently called on to solve complex problems in a wide spectrum of environments. Even within the environments addressed in this text, widely diversified subenvironments exist that present unique sets of problems and

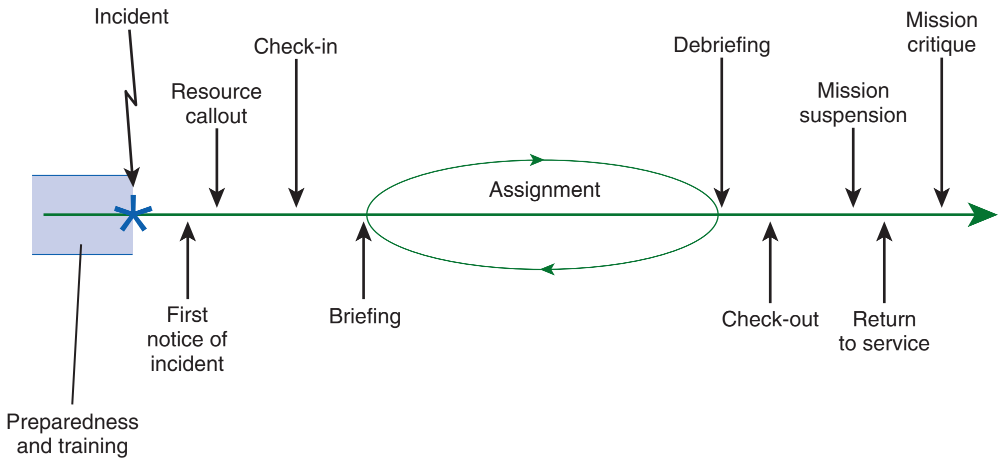

FIGURE 55-28 Time progression or the "anatomy" of a search from a searcher's (operational) perspective. The process is actually a continuous cycle that pauses in the planning and preparation phase until an incident occurs.

hazards to SAR personnel. When confronted with the numerous and dangerous environmental conditions found in the wilderness setting, SAR personnel must be prepared to work where others have been unable to cope. An old military motto becomes the SAR credo: "Adapt, improvise, overcome."

It is beyond the scope of this text to discuss in detail how SAR personnel adapt to each of these environments, but it is important to note that adaptation and improvisation are required in nearly all wilderness situations. The particular improvisation depends on the situation, as well as the skill and experience of the individuals involved.

Regardless of the type of rescue environment encountered by rescuers, the following general rules should be followed:

1. Use technical personnel for technical rescue.
2. If a missing person is found dead, the rescue becomes a recovery, so evacuate the victim only when there is no risk to team members or at least when the hazard has been assessed and the risk justified.
3. Stabilize any injured person before evacuating, and continue stabilization during transport.
4. Find and use the easiest route for evacuation.
5. If a carry-out is required, appoint someone to serve as route finder who has a radio and markers to report potential hazards and problems.
6. Litter teams of six to eight persons per team should be used, with three teams minimum. Normally, there should be no more than 20 minutes per shift. Additional personnel may also be required to carry equipment.
7. Use accepted procedures to care for and protect the victim.
8. A radio carrier brings up the rear.
9. If using a helicopter for evacuation, ensure the following:
   a. The patient is thoroughly briefed.
   b. The patient is protected.
   c. Someone goes with the patient who knows what has been done medically. In some cases, because of agency or military service protocols, assisting medical personnel will not be allowed to go with the patient. In these cases, it is imperative that a written log specifying assessment and treatment up to that point accompany the patient.

SPECIAL ENVIRONMENTS IN SEARCH AND RESCUE

Specialized SAR environments produce diverse problems and potential complications. Each environment presents its own obstacles to increase the complexity and difficulty of particular rescues.

Technical Rock

Mountaineering, rock climbing, and casual scrambling have created a need for specialized SAR expertise. Individuals and groups involved in rock rescue have refined and developed techniques for most situations. The hallmark of a technical rock rescuer is the ability to improvise and modify tools or techniques to meet any crisis. He or she must be comfortable using climbing gear and being exposed to heights.

Once an individual is located in a rock environment and the situation is surveyed, access to the site is the next step. Sometimes, local groups familiar with well-known areas will have already solved this problem. The solution will involve either climbing up or dropping down to the victim. Because any accident during a rescue is almost always catastrophic, safety for all persons involved is of paramount importance. Ascent up rock always requires knowledge of rock-climbing techniques, proper equipment, and familiarity with its designed use and limitations. Local outing clubs or mountaineering stores can be contacted for more detailed assistance. Specialized technical rock rescue teams, such as those sanctioned by the Mountain Rescue Association, routinely practice climbing techniques and solving vertical rescue problems.

Caves and Mines

Standard obstacles in caves or mines include poor communications, extreme darkness, difficulty with lighting, small and wet spaces, and a questionable atmosphere. The various environments included here are collectively termed *confined spaces* (see also Chapter 63, Caving and Cave Rescue).

The levels of moisture in water-containing, or "live," caves can vary over a considerable range. Some are merely muddy; others have flowing rivers. Caves in the western United States are generally drier than eastern caves; however, humidity, wetness, and cold temperatures create potential for hypothermia in both areas. This is a fact that is greatly underestimated. Flooding can be a lethal problem, and many cavers have died because of inattention to the weather on the outside. During heavy rains, the caves become natural drains for streams. Wind and temperature are other underestimated problems associated with cave and mine emergencies. It is not unusual for strong winds to develop along subterranean passages, which intensifies convective air chilling.

Confined passages, low crawls, and squeezes pose unique problems for the rescue of injured cavers. The use of standard items, such as litters, backboards, and splints, may be impossible in such places. Confined passages with varying, or even toxic, constituent gases can lead to difficulties for victims and rescuers alike. A self-contained breathing apparatus or surface-supplied air may be required. The potential for toxic gases justifies extensive atmospheric monitoring while operating in the underground environment.

An essential part of any cave or mine rescue operation is thorough orientation to the hazards associated with a particular underground area. This involves pinpointing the locations of pits, waterfalls, siphons, canyons, and other difficult formations that may pose problems in extrication, search, or safety. Many caves have been mapped by the National Speleological Society and the National Park Service.

The real difficulties may begin only after a victim is located. The goal is to move the person rapidly, safely, and comfortably to the surface. Without practice underground, that task will be virtually impossible. Neoprene exposure bags similar to body bags have been used for this purpose and can keep an injured person dry and protected during what may be a very long and slow evacuation.

Medical care procedures must be performed under dark, cold, and muddy conditions. Experienced cave rescuers agree that repackaging supplies and equipment for underground use is essential. Streamlining kits, packs, and containers is imperative for unobstructed passage through tight spaces in cold, damp conditions.

Team members must carry very specialized equipment, often including a minimum of 24 hours of light in a helmet-mounted lamp; two additional sources of light, with spare bulbs and batteries; and waterproof matches and candles. Depending on the situation, other equipment is also required. Essential caving skills include all of the capabilities for rock climbing, including vertical rope technique, ascending, rappeling, belaying, and being comfortable working at the end of a rope. All these skills must be practiced until they can be done in the cold and wet without the benefit of light. Team practices are conducted both on the surface and underground, with participants being forced to work in mud, suffocatingly tight squeezes, soaking waterfalls, and complete darkness. This may be a difficult evolution for even the most experienced rescuer to endure, but just another "hang in the hole" for a seasoned caver.

Whitewater (Swiftwater) River

There are dozens of potentially dangerous situations that can arise in the river SAR environment (i.e., white water or swift water; see Chapter 62, Whitewater Medicine and Rescue). Log and debris piles at various bends in the river can function as "strainers" for the recreational victim, but they may be death traps for the would-be rescuer. The banks of the stream may be deeply undercut, with treacherous overhanging debris and snags that can catch on clothing, equipment, and skin. Combined with muddy and rapidly rising water, these factors render river rescue difficult and very unpredictable.

Swiftwater is defined in one SAR standard as "water moving at a rate greater than one knot (1.85 km/hr [1.15 mph])."[46] In

FIGURE 55-29 Common personal river rescue equipment. In the CMC Water Rescue Kit shown *(clockwise from upper left)* is a gear bag, type III/IV personal flotation device, emergency strobe light, glow-in-the-dark Fox 40 whistle, McNett Saturna knife, NRS neoprene paddler's gloves, Cascade Swiftwater helmet, and CMC SRT Rescue EZ-Stuff Throwline bag. *(Copyright CMC Rescue.)*

fast-moving water, the single greatest problem is that responders underestimate the power and threat of moving water. Foolhardy heroics and excessive enthusiasm frequently lead to further tragedy. Cold-water immersion, coupled with wind and cold temperatures, predisposes everyone to hypothermia. Wet clothing, darkness, and injury add to the insult. The noise of moving water may obviate clear communications and result in poor contact between the victim and rescuers. These same factors could also affect communications between rescuers and lead to additional confusion and danger.

All potential responders in this environment must be properly equipped (Figure 55-29) and know how to read the water for capsize points, submerged rocks, reversals, and other dangerous phenomena. The hydraulics of low-head dams, collapsed bridges, and other submerged structures can produce a virtual "drowning machine" for unsuspecting individuals. Rescue team members must know how to protect themselves in fast-moving water at all times. Mandatory in this environment are good judgment, strong swimming ability, knowledge of all types of technical systems, equipment used in climbing, and a thorough understanding of river dynamics and hydraulic influences.

Ocean Surf

Like river white water, ocean surf can present some very different problems in rescue because there is no "average" beach. There are recurring rescue situations that pose unique problems in the ocean surf environment.

Along with the potential for immersion hypothermia, lacerations and contusions can result from being dashed against barnacle-encrusted rocks in the wild and unpredictable ocean

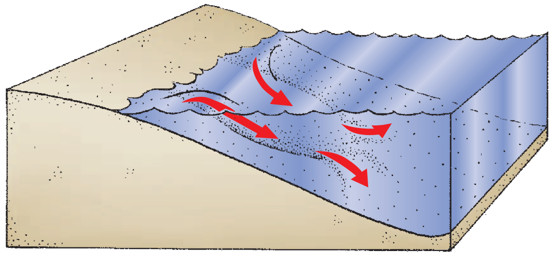

FIGURE 55-31 Rip. A depression in the beach floor concentrates returning water into a strong current. To escape, a person should ride with the current or swim to the side and out of the pull.

surf. Contact with venomous sea life is always a possibility. However, the greatest threat to ocean beach users is the action of the water itself and the possibility of drowning through inattention or unfamiliarity with ocean surf hazards in the forms of runouts, undertows, and rips.

Runout. A runout occurs when an offshore sandbar or ledge is built up over a long period. Millions of tons of water flow over the bar during daily tidal changes. Eventually the water may equal or exceed the level outside the bar. Any weak spot in the bar usually gives way, causing a funnel effect (Figure 55-30). Water rushes toward the bar at a terrific rate, sweeping everything with it. This common phenomenon can be easily spotted from the beach. Usually 14 to 46 m (15 to 50 yards) wide, it is characterized by choppy, jumbled-up, little waves. The water often has a dirty, foamy, or debris-laden surface moving seaward. If a bar is visible offshore, definite breaks can be seen where the water pours through. Surfers often seek runout currents for fast transportation out beyond shoreline waves.

Swimmers caught in a runout have two options. They may swim parallel to the shoreline out of the strip of current, or if the bar is visible (usually characterized by breaking waves), they may relax and let the current complete its runout. About 23 m (25 yards) beyond the bar, the current dissipates. This is an offshore phenomenon; current force increases near the bar, but is often negligible near shore.

Rip. A far worse problem close to the beach is a rip, which can knock children and even adults off their feet and carry them to deep water in seconds. Rips are caused by a slight depression on the beach where wave water rushes after breaking on shore. Water rushing to the depression soon becomes an irresistible seaward flow (Figure 55-31). It may be as narrow as 14 m (15 yards) at its source and usually does not travel as far as a runout. Rips generally dissipate a few yards beyond the breakers. A rip looks like a runout, with a streak of turbulent discolored water or a line of foam leading directly out from shore. A swimmer has the same options as in a runout, either to swim parallel to the beach or to relax and ride the current until it ebbs. A person who swims straight toward the beach will never make it. A beach with several rips moving up and down in unpredictable patterns is very dangerous. An unwary swimmer could panic and drown.

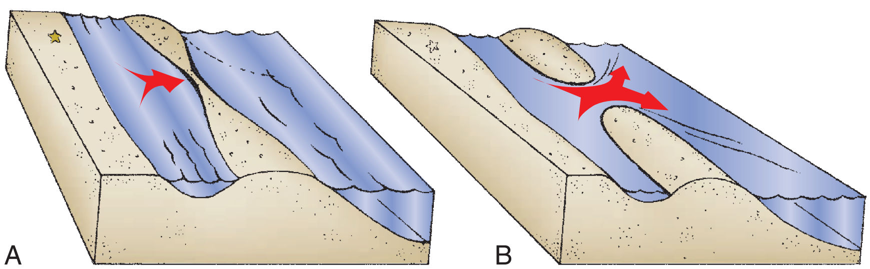

FIGURE 55-30 Runout. **A,** This phenomenon begins with an offshore sandbar. As waves roll in, the water level builds up behind the bar until a section gives way. **B,** As the sandbar "dam" gives way, the water develops a very rapid current running seaward. The recommended action is to swim across the current until out of the pull.

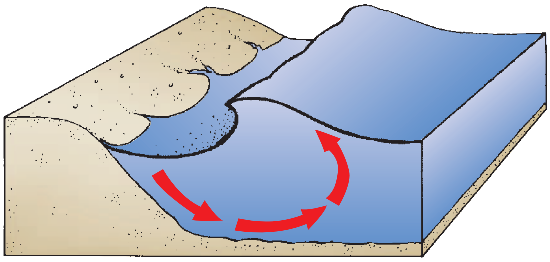

FIGURE 55-32 Undertow. This hazard develops on a steep beach where the water returns rapidly seaward after being tossed up by the wave action. A person should never fight this action but should relax and rise to the surface and then ride to shore on the next wave.

Undertow. On narrow, steep beaches, a type of current known as undertow can be found. It is caused by gravity acting on water thrown up on the beach by wave action. Water retreating back down the steep shore continues under oncoming waves (Figure 55-32). Undertow is usually of very short duration and is ended by the next breaking wave. Wading near shore on a steep beach, an individual could be pulled under in this current and find himself or herself quickly in deep water. If the person resists the current, the next wave may break directly on the person's back. In some circumstances, this could cause traumatic injury, especially to the neck and back. A person caught in an undertow should let the current pull until it ceases, then swim to the surface and ride the next wave into shore.

Cold, Snow, and Ice

Perhaps no other type of SAR environment requires a more broadly based foundation of personal and team skills than do winter snow and ice. These skills include downhill and cross-country skiing, snowshoeing, technical climbing, winter survival, and a good understanding of snow and ice physics. Unlike rock, snow and ice conditions change on a daily and even minute-to-minute basis. The effects of gravity, wind, temperature, slope, heat exchange, load factors, and avalanche continually impose problems for missions under these conditions. Technical and nontechnical SAR problems in snow and ice environments take longer to address and are more taxing, technical, and complex. Combined with shorter days, extremes of weather, and the ever-present threat of hypothermia and localized cold injuries, technical missions of this type are unacceptable for all but the most experienced SAR personnel. Several chapters in this book address very important issues related to this type of environment: avalanches (Chapter 4), thermoregulation (Chapter 6), accidental hypothermia (Chapter 7), immersion in cold water (Chapter 8), frostbite (Chapter 9), nonfreezing cold-induced injuries (Chapter 10), and polar medicine (Chapter 11).

Versatility and improvisation are essential components of the overall strategy that must be used in snow and ice. Transportation of the victim is often one of the most difficult problems, but it can usually be resolved through detailed preplanning. Innovations, such as covering a litter with a canvas cover or improvising an attachment to cross-country skis, are clever solutions to common winter problems. Commercial products, such as the Sked litter, have streamlined the laborious task of transporting injured people across snow and ice.

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CHAPTER 56

Technical Rescue, Self-Rescue, and Evacuation

KEN ZAFREN, LOUI H. MCCURLEY, CHARLES S. SHIMANSKI, WILL SMITH, AND GIACOMO STRAPAZZON

ACCIDENT ON MT KENYA—,1970

On September 5, 1970, two young but experienced Austrian climbers, Gert Judmaier and Oswald Oelz, both medical doctors, climbed Mt Kenya (5199 m [17,057 feet]), the second highest mountain in Africa. After 6 hours of pleasant climbing on firm granite, they were enveloped in fog. With some difficulty, they managed to find Shipton's Notch, the key to the last part of the summit ridge. It was snowing when they reached the summit, and snow squalls increased as they descended back to Shipton's Notch.

Gert held onto a boulder while looking at the descent route as his partner, Oswald, prepared a rappel anchor. All of a sudden, the boulder and Gert both fell down the rock face. Oswald was able to catch the uncoiling rope in his hands, although he lost skin from his fingers and palms; Gert's fall was broken momentarily by a rock rib, and Oswald was then able to wrap the rope around his left arm and elbow to stop the fall.

When Oswald climbed down, he found Gert was bleeding profusely from an open tibial fracture. Oswald made a binding to control the bleeding. There was little hope of evacuating the injured climber down the long and complex descent route. It seemed certain that Gert would die from hemorrhagic shock, hypothermia, or fat embolism, but as long as Gert was alive, Oswald was determined to do what he could. He packed Gert in extra clothes and put him in a bivouac sack, which he anchored to the wall by two pitons. He then left Gert with all of their provisions: a deciliter of whiskey and a box of stewed plums.

After a harrowing descent in a snowstorm, Oswald reached the Kalmi Hut, where eight British and American climbers were waiting for favorable weather to attempt the climb. Some of the group descended to a lower hut that night where they found a radio and medicines.

The next day, Oswald and one of the other climbers tried to ascend to his injured partner. The snowfall became heavier.

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The other climber had increasing symptoms of acute mountain sickness. They had to turn around, and they reached the hut again after dark. Oswald felt terrible that his friend would now die alone if he wasn't already dead. Four climbers from the Kenya Mountain Club had arrived with medicines and rescue equipment, but they were also suffering from acute mountain sickness. They had previously discussed the possibility of rescuing someone with a serious injury from Mt Kenya. They had concluded that it would be impossible; however, they still wanted to try.

The following day, Oswald and one of the rescuers reached Gert, 48 hours after Oswald had left him. At first there was no answer when they called, but then Gert pushed the bivouac sack to one side and said, "My God, you're still alive." Oswald called into the radio that Gert was alive, but received no answer. However, more rescuers had arrived and heard the message. Oswald gave Gert an injection of morphine. Gert drank a little water and immediately threw up. All three men spent a cold and uncomfortable night on the rock ledge.

The next day, September 8, they made a splint for Gert's leg. The other climber tried to carry Gert on his back, but Gert immediately cried out in pain and fainted. Gert seemed to be dying and he could not swallow fluids, but Oswald did not yet have intravenous (IV) fluids. That night, Gert asked Oswald several times to unclip him from the anchor so that he could roll over the rock ridge and fall to his death.

In the morning, the group heard several airplanes and then a helicopter. Their hopes rose, but then there was a loud bang followed by silence, and the helicopter sound stopped. Their assumption that the helicopter had crashed later proved to be correct; the pilot had been killed trying to save them. That afternoon, four more rescuers arrived and brought IV fluids. After at least 20 attempts, Oswald got the needle into Gert's vein, but it slipped out again. Finally, Oswald was able to establish an IV line and to give Gert a liter of fluid. During the night, however, the IV fluids froze. In the morning, Oswald thawed out the bottle with a gas stove.

The morning of September 10 was very cold. Five rescuers built a highline for the difficult traverse to the ascent route. Attempting to transport Gert on the highline caused him unbearable pain, so they had to wait for a litter to arrive. Meanwhile, Oswald used up the IV fluids and morphine. Everyone's morale reached a low point during a heavy afternoon snowstorm.

On September 11, Gert had been lying on the small rock projection for 6 days and 6 nights. He was still alive, but he was delirious and had a high fever. At midday, the litter arrived. The rescuers used the highline to carry the litter on a traverse through technical terrain. By dark, they reached the top of the vertical pitch through which they would have to lower Gert down.

After a restless night, the group began descent by rappel, using two ropes at all times to secure the litter and accompanying rescuers. During a violent snowstorm, they reached the beginning of a traverse over a sharp ridge. There was no way to build a 60-m (197-foot) highline to the next rock tower with the little remaining rope. It was an impossible problem.

At that moment, Werner Heim, a well-known Austrian mountaineer and rescuer, emerged from fog and snow squalls. He and six other rescuers from Tyrol, Austria, had heard about the accident 24 hours after it had happened. They had flown to Nairobi on one day's notice. Two days later, they arrived at the foot of the mountain. Five of them had just returned from the Himalayas and were still acclimatized to high altitude, so they were able to ascend quickly. They had already prepared the entire further rappel route. The remaining lowering was very rapid as a result of the help of these well-trained rescuers, who functioned as a coordinated team. It was midnight when they arrived at the foot of the mountain. Meanwhile, Dr. Raimund Margraiter, a member of the rescue team, had given Gert additional IV infusions.

At 4 AM, Dr. Margraiter and Oswald undid the bandages on Gert's leg. The smell and sight of the protruding tibia chased away all other onlookers. That morning, police porters helped litter-carry Gert several hours to the nearest road. They reached the hospital in Nairobi that evening. The surgeon cleaned the wound and, contrary to expectations, did not perform an amputation.

Oswald was proclaimed a hero in Kenya. Gert underwent a series of operations over a period of more than 1 year. Both Gert Judmaier and Oswald Oelz went on to distinguished medical careers. Twenty years later, they climbed Mt Kenya again, along with some of the rescuers. At the spot of the fall, they thought about the young helicopter pilot, and fastened a bronze plaque to the rock with the following inscription: "In memoriam, Captain Jim Hastings who lost his life in saving mine. Gert Judmaier 1970-1990."

Adapted with permission from Mit Eispickel and Stethoskop (With Ice Axe and Stethoscope) by Oswald Oelz (Oelz O: Mit Eispickel und Stethoskop, Zürich, 1999, AS Verlag).

WARNING

Technical rescue can be extremely hazardous. The descriptions of technical rescue techniques in this chapter are intended as background information only, not as a substitute for a formal rescue course in which all training is supervised by qualified instructors.

Activities in wild and remote areas can bring great rewards but also carry risks of illness, injury, and death. Resources for treating illnesses and injuries are limited in the wilderness. The best plan is to decrease the likelihood of medical problems by taking steps to decrease risks. For example, it is best to ascend slowly to decrease the risk of altitude illness. It is also wise to know how to recognize altitude illness and to know when and how to descend to a lower altitude.

In practice, the terms *rescue* and *evacuation* have considerable overlap. The processes of rescue or evacuation may include additional provision of medical care. This chapter is primarily about mountain rescue, but the principles are applicable to general rescue. The best plan for a rescue in the mountains is not to need one. If someone is stranded, ill, or injured in the mountains, the next best option is self-rescue or rescue by one's own party. If these plans fail, help from outside resources and agencies will be necessary.

The most basic forms of rescue are self-rescue, performed by the subject, and companion rescue, performed by the subject's companions. Organized rescue by outside agencies originally evolved from companion rescue. Organized rescue can often offer use of specialized resources and equipment to accomplish a rescue. This chapter focuses primarily on companion rescue and on problems of rescue and evacuation in specific situations, especially technical climbing, mountaineering, and canyoneering.

Medical care in technical settings is neither just emergency medical services provided on a mountain,[76,102] nor is it the same as combat casualty care. However, there are similarities to both. Care is usually delayed as compared with most prehospital settings. There is more blunt and less penetrating trauma than in combat casualty care.[44] Subjects with serious airway problems or severe bleeding are likely to be deceased by the time medical care arrives, although immediately life-threatening bleeding is less likely from blunt than penetrating trauma.

It is challenging to provide medical care in technical environments. In addition to the limitations of wilderness medicine, "the art of the possible," there are dangers for both rescuer and patient. Medical providers who plan to work in technical terrain should have adequate skills to ensure they can function safely in conditions that they expect to encounter. These skills should be learned through proper instruction and training before providing medical care in wilderness and remote areas.

TERMS USED IN TECHNICAL RESCUE

Technical terrain is terrain in which travel is difficult or dangerous or requires use of special equipment (e.g., ropes) for safety. Examples include mountainous terrain with cliffs or very steep slopes (i.e., rock, snow, or ice) and glaciers. Operations in technical terrain include mountaineering and climbing, glacier travel, canyoneering (usually called *canyoning* outside of North America), and caving.

Rescue refers to removal of an ill, injured, or stranded person from a dangerous or unstable situation. *Technical rescue* refers to rescue in technical terrain. *Self-rescue* involves a climber who rescues himself or herself (e.g., an injured climber might self-lower to the ground or self-extricate from a crevasse). *Companion rescue* is rescue of a member of a party by other members of the same party (e.g., lowering of an injured climber *[climber pick-off]* by a climbing partner or extrication of a person from a crevasse). Organized rescue involves use of external resources to rescue an injured party. This chapter covers self-rescue, companion rescue, and organized rescue in technical terrain.

Evacuation is removal of an ill or injured person from an area in which medical care and other resources (e.g., food, water) are limited to an area in which resources are available or in which a higher level of medical care can be provided.

Transport refers to the method by which a person is evacuated.

EPIDEMIOLOGY

Wilderness travel is generally safe, with the exception of high-risk activities such as extreme high-altitude mountaineering,[48] backcountry skiing in avalanche terrain, and paragliding. There are limited data about the types of illness or injury and causes of death of wilderness travelers and even less about injuries to and deaths of rescuers. Rescuers should be well prepared for the most common causes of injury and illness in rescue subjects.

RISKS OF WILDERNESS TRAVEL

No American wilderness that I know of is so dangerous as a city home 'with all the modern improvements.' One should go to the wilderness for safety, if for nothing else.
—JOHN MUIR[81]

In a study of helicopter rescues and deaths among trekkers in Nepal from 1984 to 1987, there were 23 deaths and 111 helicopter rescues with a total of 148,000 trekking permits.[111] The incidence of helicopter rescue was 75 per 100,000 and the incidence of death was 15 per 100,000. The most common causes of death were trauma (11 persons), illness (8 persons), and altitude illness (3 persons). In a follow-up study of deaths among trekkers in Nepal from 1987 to 1991, there were 40 deaths among 275,950 trekkers, a death rate of 14 per 100,000.[110] Trauma was the cause of 12 deaths, and altitude illness caused 10 deaths. Four deaths were attributed to heart attacks and three deaths to apparent diabetic ketoacidosis above 4000 m (13,100 feet). A small cohort study of three trekking groups in Nepal from 1993 to 1995 showed that rates of illness were similar between trekkers and porters.[6]

At Everest Base Camp Medical Clinic in Nepal from 2003 to 2012, there were 3545 patients, most of whom (85%) had medical complaints.[82] Respiratory diagnoses, primarily high-altitude cough and upper respiratory infections, accounted for 38% of medical complaints. Trauma accounted for 14% of diagnoses. The most common site of trauma was the skin (56% of traumatic complaints), usually caused by frostbite or lacerations. High-altitude pulmonary edema and frostbite resulted in the most evacuations.

In the Alps, an Austrian study estimated the death rate for mountain hiking at 4 per 100,000 hikers annually during an unspecified 9-year period. About 50% of these were sudden cardiac deaths.[19]

In North America, there have been several studies in national parks. Many of these are difficult to interpret, because they include both wilderness and nonwilderness activities, so the risk of wilderness activities cannot be determined. From 1997 to 2001, a study of two national parks in Washington State reported the overall injury rate as 22 per million visits.[115] Two-thirds of the injuries occurred during hiking (55%) and mountaineering (12%), but the number of visits related to these activities was not reported. A study of eight California national parks from 1993 to 1995 that examined wilderness activities estimated a mortality rate of 0.26 deaths per 100,000 visits, mostly as a result of heart disease, drowning, and falls.[77] The rate of nonfatal events was 9.2 per 100,000 visits. Injuries accounted for more than 70% of all nonfatal events, and these most frequently affected the lower extremities (38%).

A Japanese study of summer climbing incidents on the most popular trail on Mt Fuji from 1989 to 2008 found 155 incident reports, including 28 deaths, among an estimated three million climbers (0.9 per 100,000).[54] The majority of nonfatal incidents, most of which "involved tripping," occurred during descent. Over half the incidents were reported at the "8th Step" at about 3000 m (9843 feet). There were 28 incidents reported as acute mountain sickness or "fatigue."

The risks of climbing in wilderness areas are harder to quantify because the number of participants is not known. In data from mountaineering accidents in North America that included climbing accidents in nonwilderness areas from 1951 to 1995, 80% of accidents involved falling, slipping, or being hit by a falling object.[61] In more recent figures (from 1951 to 2007 in the United States and 1951 to 2005 in Canada), 71% involved falling, slipping, or being hit by a falling object, 4% involved "exceeding abilities," and 3% involved illness.[132]

Several studies have attempted to quantify the mortality rate of various activities, including mountaineering. One review claimed that in the United States, the mortality rate per 100 participants was 0.6 (60 per 100,000) for mountaineering and 0.2 (20 per 100,000) for hang gliding.[134] The number for mountaineering is not substantiated by any data or reference, is not credible, and is likely too high. A New Zealand study estimated a fatality rate of 1.9 per 1000 climber-days in Mt Cook National Park, with a large variation between high-risk areas (6.5 per 1000 climber days) and low-risk areas (0.3 per 1000 climber-days).[70] A study of climbing fatalities on Denali estimated three climber deaths per 1000 summit attempts.[72] Fatality rates on the world's highest mountains generally increase with increasing altitude.[48] Fatality rates on the 14 highest mountains in the world, the 8000-m (26,247-foot) peaks, are increasing for expedition members but not for porters.[104,127]

For more information about avalanche risks, please see Chapter 4.

INJURIES AND ILLNESSES IN MOUNTAIN RESCUE SUBJECTS

There are many published studies of mountain rescue victims, or *subjects*. The main limitation of most studies is that the number of people at risk cannot be determined, making it impossible to quantify the risk of illness, injury, or death.

A Scottish study of 622 callouts in 1998 and 1999 reviewed 333 subjects[44] with 57 fatalities. Of surviving subjects, 78% had traumatic injuries, 8% had major trauma, 4% had spinal injuries, 8% had nontraumatic medical problems, and 14% were cold or exhausted. The author concluded that mountain rescuers provide "an advanced level of care" for many subjects. Another study, which included the entire United Kingdom from 2002 to 2006, showed a preponderance (75%) of rescue casualties due to "hillwalking," with more than one-half of the injuries affecting lower extremities.[79]

A North American study of mountain search and rescue subjects from three national parks in the Canadian Rockies found 317 emergency operations that involved 406 persons from 2003 to 2006.[131] Of these incidents, 44% involved hikers and 50% were the result of "slips and falls." About 60% of subjects were injured. Extremity injuries accounted for 68% of injuries. There were 40 fatalities, 45% caused by avalanches and 28% caused by slips and falls.

A study of wilderness search and rescue in New England from 1999 to 2001 examined 321 incidents involving 457 subjects, 57% of whom were hiking at the time of the incident.[36] Injuries occurred in 39% of rescues; 40% involved lost and missing persons. The author noted that a rescuer was injured during 2.5% of rescues.

There were 1912 search and rescue missions with 112 fatal cases from 1990 to 1999 in Yosemite National Park, California, for a case fatality rate of 4.8%.[50] Hiking and snowshoeing accounted for the majority of fatalities. Deaths were predominantly due to falls.

A study of climbers on difficult routes in the Sierra Nevada Mountains of California found 215 mountaineering accidents during the 5-year period from 1975 to 1980.[75] Acute mountain sickness or hypothermia was noted in 104 patients. There were 17 deaths, most commonly as a result of head injury. There were 94 injuries involving the ankle and distal tibia.

In Boulder County, Colorado, a study from 1998 to 2011 found 428 rock-climbing rescue subjects, about one-fifth of all mountain and wilderness rescue subjects. There were 23 fatalities, 9 from unroped falls, 5 from lead falls, and 9 from other causes. Lower-extremity injuries were most common, accounting for about 30% of injured subjects. Most subjects were uninjured; 43% were stranded or lost.

In Denali National Park, Alaska, a study of search and rescue activities from 1990 to 2008 showed that 1.2% of climbers on Denali required a search and rescue response. Of medical cases, 69% involved high-altitude illness or cold injuries. The majority of traumatic injuries (76%) were due to falls.[72] A related study from Denali National Park from 1992 to 2011 found that 831 of 24,079 climbers on Denali required medical assistance from the National Park Service.[74] Of 819 diagnoses, 502 were medical and 317 traumatic. Frostbite was the most common single diagnosis (18%), and high-altitude illness accounted for 29% of encounters. All fatalities but one were excluded by the study criteria. A separate study of fatalities on Denali from 1993 to 2006 found 96 deaths, of which 45% were due to falls.[73] The fatality rate decreased during the study period to 3.1/1000 summit attempts.

A study of "glacial sports" examined admissions to an adult level 1 trauma center in Bern, Switzerland, with diagnoses of injuries caused by "glacial crevasse or ice field fall" from 1997 to 2003.[105] There were 12 injuries, 6 from each mechanism. Five patients had head injuries; eight patients had a Glasgow Coma Scale score of 8 or less; and eight patients had "severe hypothermia."

A Swiss study of glacier crevasse accidents from 2000 to 2010 found 415 victims of crevasse falls.[88] The on-scene mortality rate was 11%. About one-fourth of victims had a National Advisory Committee for Aeronautics (NACA) score higher than 4, signifying severe injury. About one-fourth of victims were uninjured.

Rescue operations using helicopter winching (see the section on helicopter rescue later in this chapter) are usually performed in difficult terrain where it is not practical to land a helicopter. This is a form of technical rescue, although not necessarily in wilderness locations. Two studies looked at incidents involving the winching of physicians near Lausanne, Switzerland. The first, from 1998 to 2002, included 133 patients, of whom 102 had traumatic injuries.[25] Only one rescue site was "accessible by car." Half were accessible by foot and the other half were "not accessible at all." The most common injuries were to the extremities and pelvis. There were 14 patients with minor injuries not airlifted to a hospital and 9 patients who were severely injured. The second study, covering 2003 to 2008, found 921 missions in which the emergency physician was winched.[85] There were 840 trauma victims, of whom 210 were severely injured (NACA score of 4 to 6) and 46 who were deceased at the scene. Most victims were injured during "winter sports" or "mountain-related" activities in summer. Falls caused 700 injuries (76% of patients), and illness caused 81 (9%) of the missions. There were 28 avalanche rescues and 13 glacier crevasse rescues.

PREVENTIVE DECISION MAKING

RISK REDUCTION

Technical rescue, especially technical self-rescue or technical companion rescue, is often difficult and sometimes dangerous. The challenges may be so difficult that an ill or injured person may not survive. The best strategy is to prevent the need for rescue.

Proposed wilderness trips, companion rescue attempts, and organized rescue missions should be examined carefully to ensure that risks are within tolerable limits. In aviation, this is formalized through use of rules and, especially, checklists that cover multiple aspects of a proposed flight. Tolerable limits in commercial aviation are very strictly defined, and risk tolerance is extremely low. In mountaineering, there may be a high level of unavoidable risk. The acceptable risk varies with the purpose of a trip or mission. A recreational rock climb has a very low acceptable risk, whereas an expedition to a remote unclimbed peak or a military mission in technical terrain may have a much higher level of acceptable risk.

Factors to be considered before approving a proposed trip, companion rescue attempt, or organized rescue mission include whether the abilities, training, and experience of the participants are adequate to meet the demands. Participants should have an appropriate level of fitness and technical skills to complete the operation safely. Unless there is only one participant (i.e., a solo climb), it is important that participants be able to function as part of a team. This may require special training, ideally with the individuals who will be their teammates. Interpersonal skills, especially the abilities to communicate and to get along well with others, may be crucial to both prevent and solve problems.

The acceptable level of risk should be decided before a trip or operation begins. All participants should agree regarding the acceptable level. As problems arise, proposed solutions should be examined in terms of acceptable risk. Only in extreme circumstances should the level of acceptable risk be adjusted during an operation.

One key to reducing the risk of injury or illness is to establish and adhere to a culture of safety. Aviation operations provide lessons regarding how to establish and maintain a culture of safety. Aviation takes place in a highly technical environment in which one small mistake can be fatal. The high degree of safety in modern aviation, especially commercial aviation, is due in large part to enforcement of a culture of safety. Every procedure that occurs during activities in technical terrain should be scrutinized to avoid introducing unnecessary risks. For example, climbers should check the security of each other's climbing harnesses and tie-ins before climbing or descending, no matter how experienced the climbers. It is best if the team also agrees to standard procedures, such as always tying in to a rope the same way. This makes deviations from safe procedures less likely to occur and easier to identify.

The aviation industry depends heavily on the use of checklists. This innovation has allowed commercial aviation, an inherently hazardous activity, to achieve low levels of risk to the traveling public. Because flying is a well-characterized activity, the decision process can be successfully characterized. Variables (e.g., weather, aircraft maintenance, flight crew training) and flight crew fitness factors (e.g., rest, prohibition of the use of alcohol and other drugs) can be quantified and acceptable limits established. The decision of whether to launch a flight or not is tightly regulated.

Parameters of wilderness operations are not as well defined or regulated as those of aviation, but many aspects can be characterized. Checklists that address equipment and its operation are underused. For example, climbers can use checklists to guide their use of climbing harnesses, rope systems, and other technical aspects of operations. Checklists are used by organized rescue groups to inspect individual systems such as anchors, knots, rigging of litters, and communications.

Another example from the aviation industry is use of redundancy and backup systems. No commercial aircraft takes off with only a single working altimeter. Although weight restrictions in wilderness operations often make redundancy problematic, it is worth considering what would happen if each piece of equipment were to fail. Trusting one's life to a single rope or carabiner is often necessary in climbing. However, during an organized rescue, backup systems are standard.

There are many wilderness areas from which successful evacuation would be extremely difficult or even impossible in case of injury or if crucial equipment were lost or damaged. Expeditions in these areas require an extra degree of care to avoid the need for evacuation, but members should also be aware of and accept the risks. Soldiers on military operations routinely accept risks that would be unacceptable in civilian life. Many expeditions in the Himalayas are now done “alpine style,” with climbers planning rapid ascents with minimal equipment, rather than in traditional “expedition style,” with a series of camps and a chain of supplies placing climbers close enough to the summit for a 1-day push to the top. The alpine style is riskier, even with a high level of training and skill, but it can achieve goals that are impossible with expedition-style climbs.

Increased risk has always been the price for pushing the envelope in wilderness travel. Ernest Shackleton allegedly advertised his famous Antarctic expedition with this unlikely description: “Men wanted for hazardous journey. Small wages, bitter cold, long months of complete darkness, constant danger, safe return doubtful. Honour and recognition in case of success.”

PLANNING

Any climbing trip, expedition, or rescue mission should have a plan of operation that is determined well in advance; this is sometimes called a *preplan*. The preplan should be differentiated clearly from the ongoing planning that continues during an operation. A preplan includes such aspects as a timeline for preparation, travel, and achievement of objectives, as well as the roles of each participant, including leadership and working groups. A preplan should also evaluate potential difficulties of travel to remote areas, anticipate risks, and formulate strategies for dealing with problems and contingency plans. Safety culture and standard operating procedures are part of the plan.

Medical planning assesses group members to address preexisting medical conditions and to prepare for known medical risks, including infectious diseases, environmental exposures, preventable conditions, and injuries. There should also be a plan for evacuation, including methods of evacuation, choice of medical facilities, and provision of evacuation and medical insurance.

Planning considers the skill sets of participants and determines if these match the particular technical environments that will be encountered and if they are commensurate with the acceptable level of risk. If some group members lack specific technical or medical skills, they can plan additional training and practice before departure. Alternatively, at the start of the trip, members can be added who possess the necessary skills, or a decision can be made to accept a higher level of risk. It is possible to add members in support roles who do not participate fully in an expedition. Examples of supporting members include medical providers who will stay at base camp on a mountaineering expedition, and contact persons who are not participants on an expedition but who can activate an organized rescue if necessary.

No expedition or group can include rescue experts and medical providers with the necessary skills and equipment to deal with all possible problems. The plan should include responses to problems that are beyond the capabilities or expertise of the group. Organizers will establish a balance among expertise (both technical and medical), available equipment, and level of risk. It is better to do this explicitly rather than after problems arise during the expedition. Equipment that fails or is lost cannot be replaced during a wilderness trip. Equipment for rescue or medical care must be carried if it is to be available when needed. Planning for a wilderness trip must include decisions about taking backup equipment, rescue equipment, and medical supplies.

It is important to recognize that physicians or other medical providers who are participants may not have the level of training and experience necessary to function effectively, especially in austere environments. Potential limitations include problems outside of the provider’s specialty area that require special training the provider does not possess, or special equipment that is unavailable. Even highly trained and well-equipped wilderness medicine experts will not be able to provide the same level of care in the wilderness that they can provide in an ambulance or hospital.

Trip organizers and participants should plan their response to illness, injury, or death. How will rescue or recovery be organized? Will the group stay together or be split? A good preplan can organize a group and increase overall safety of the activity. Beyond self-rescue, the group should consider a plan for coordinating outside rescue if needed. With cell phones and satellite phones, no part of the world is completely isolated. Although individual travelers and groups may prefer the risk of being completely on their own, most groups now have the ability to communicate with outside help. The group can also delegate a support person who is not on the trip to arrange outside help if the group fails to communicate according to a prearranged plan.

LEADERSHIP

Leadership is part of the planning process and should be decided beforehand. Although small climbing groups do not necessarily need a leader, most expeditions should have one and possibly a deputy leader. Larger expeditions may have an overall leader as well as specialized leaders, such as technical climbing leaders and those in charge of transportation, food, medical care, and other aspects. Organized rescue groups usually have a well-defined leadership structure. In the United States, this generally follows a system known as the *incident command system*.[76] Rescue groups also have general plans of operation that can be applied to individual missions.

COMMUNICATIONS

To operate effectively, climbing and rescue teams should have a standard vocabulary that is used and understood by all members. For example, a rock climber will not start climbing until the person using the rope to safeguard progress (i.e., the belayer) has indicated readiness to hold a fall. The technique of “read-back” is used to minimize errors. The climber asks, “On belay?” The belayer answers, “Belay on.” The climber then says, “Climbing.” The belayer answers, “Climb” or “Climb on.”

Many standard vocabularies have evolved over time to be concise and limit the potential for confusion. In aviation, each letter has a corresponding word. For example, the letters *f* and *s* can be easily confused when spoken, but corresponding words from the NATO phonetic alphabet, *Foxtrot* and *Sierra,* are quite distinct. Ground-to-air signals (signs and arm signals) and radio language are other examples of standard vocabularies that can be useful for climbers, expeditions, and rescue teams.

Climbers sometimes find themselves in situations in which communication has been disrupted. It can often be surprisingly difficult to communicate by voice with a climber at the other end of a rope. Difficulties can be caused by wind or running water. Communicating with a climber who has fallen into a crevasse will also be difficult. Radios are generally the best method of communication in such circumstances, but small climbing parties may not have radios and radios may fail. A redundant form of communication involves using tugs on the rope to communicate. Climbers must know the system of rope signals to be used and practice with each other in advance to avoid potentially fatal misunderstandings.

Many expeditions and most rescue operations will require use of radio communication among members and often with outside parties. All participants should be able to use standard radio etiquette. Although there are some international variations in vocabulary, the form is relatively standard worldwide. Organized rescue units may use special codes during radio communications, but this is seldom the case with spontaneous or companion rescue efforts. Unless coded communications are clearly arranged and agreed upon in advance, it is best to use plain language.

Spare batteries should be available, and preplans should be in place should radio communications fail. In some areas, use of cell phones for communication is practical. Expeditions should consider carrying satellite phones in areas that do not have other reliable means of communication with external rescue resources.

In case of an emergency, if the usual means of communication are not available or have been disrupted, participants may need to give a distress signal. Special equipment (e.g., headlamps, whistles, flares) may be useful to call for help. A recognized distress signal is any signal in groups of three. The recipient of a distress call should answer with using the same means, if possible, so the subject's party knows that the distress call has been received. Communications are covered in further detail in Chapter 105.

HAZARDS IN WILDERNESS TRAVEL AND RESCUE

> ***Daring is fine! Reckless impetuosity is stupid! It is therefore wise to discover and learn from the experience of others and to match boldness to mature consideration, ability to good sense. True courage is shown only by one who is fully aware of all the consequences of his actions.***
> —WILHELM PAULCKE[90]

Wilderness travelers, whether in technical or nontechnical terrain, sometimes need to be rescued. The need for rescue may arise from injury, illness, or simply being lost. The problem may be caused by bad decisions or bad luck, or a combination of both. The rescue effort may be a self-rescue, it may be performed by other members of the party, or it may involve external rescue. Rescues often introduce additional risks, especially in technical terrain. Wilderness travelers who understand the possible hazards can minimize the risk of having to be rescued.

Experience can be helpful but is not a guarantee against future problems. A climber can use the same flawed technique or make the same wrong decision repeatedly without consequences and come to believe that the technique or decision is correct. Rescuers must also be aware of their potential to lose attention to detail after they have been involved in many search and rescue operations.

As compared with many other endeavors, there are real risks for rescuers. The first priority is the rescuer's own safety. An injured rescuer is a liability to the team and to the accomplishment of a rescue mission. The rescuer's second priority is the rescue team's safety. The third priority is subject safety and successful completion of the mission. Rescuers should be aware that they are not invincible and that one can never eliminate all risk.

Although it is critical that rescue groups work to fine-tune their rescue skills, it is equally essential that rescuers, especially rescue leaders, have a clear understanding of hazard evaluation and risk assessment. These skills should be an integral part of rescue training. Rescue operations are often time critical. This urgency can lead to "go fever." No rescue operation should take place until a determination has been made that the operation can be accomplished with a reasonable margin of safety (Figure 56-1). Sometimes one must decide that an operation is a *"no go"* or that it must be delayed until conditions allow for a greater degree of safety.

The remainder of this section will emphasize hazards that are important to consider during wilderness travel, especially in mountainous, glaciated, or other technical terrain. Although these hazards are discussed separately, many "accidents" in the mountains are caused by a combination of hazards. Wilderness travelers and rescuers should be aware that small hazards can be compounded until they become larger ones. As conditions change, it is important to reassess the overall effects on safety.

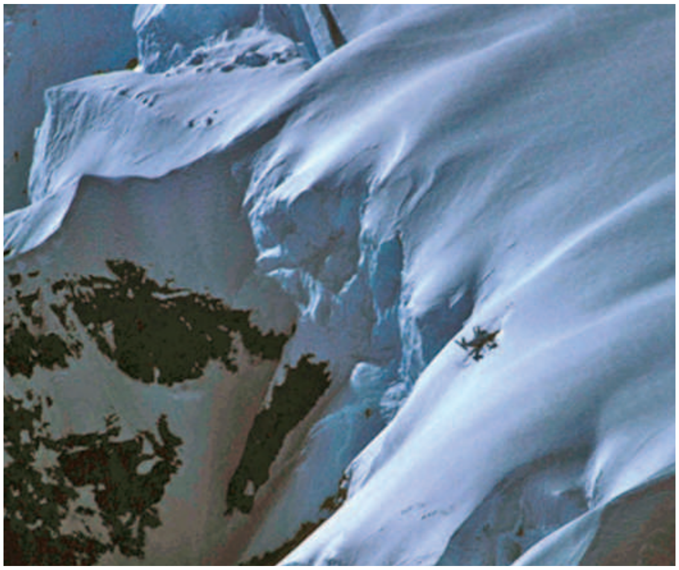

FIGURE 56-1 Plane crash. This fatal plane crash occurred in a remote area of Alaska. Body recovery was considered too dangerous for the rescuers, so the plane and the bodies were left in place. *(Courtesy Ken Zafren.)*

NATURAL HAZARDS

Wilderness travelers should be aware of natural hazards and how to reduce the risks of exposure. This knowledge is even more important for rescuers, especially when they will be exposed to the same hazards that caused or contributed to the need for rescue.

HIGH ALTITUDE

At high altitudes, aircraft performance is impaired. This may result in unacceptably low margins of safety for both fixed-wing and helicopter operations, especially above 2500 m (8200 feet). In addition, human performance and judgment are impaired at high altitude, even in the absence of high-altitude illness. These effects become more important as altitude increases, and they may contribute to injuries.[48,75] High-altitude illness can have serious effects on the performance of unacclimatized travelers, including rescuers. High altitude is often associated with cold, wind, and storms, further limiting the performance of humans and equipment.[49] High-altitude illness is the subject of Chapters 1, 2, and 3.

EXTREMES OF TEMPERATURE AND HUMIDITY

Human performance is impaired by cold and wind. Tasks that require dexterity can take a long time in cold and windy conditions. Human performance is also impaired by hot conditions, especially if the humidity is high. Extremes of temperature and humidity may be limiting factors in wilderness travel and rescue.

Performance of equipment, especially electronic equipment, may also be degraded at extremes of temperature and humidity. Cold decreases battery power and increases power requirements. Heat causes overheating of electronic equipment that can lead to failure with permanent damage. Aircraft tend to perform better in cold conditions as a result of higher air density, but aircraft maintenance is much more difficult in cold conditions. At very low temperatures, motors may not start. Even properly maintained aircraft with special low-temperature lubricants have temperature limits below which safe operation is not possible.

WEATHER

Wilderness travelers should be aware of local weather patterns and general principles of weather prediction. In many parts of the world, weather forecasts may be vague, unreliable, or completely nonexistent.

While focusing on the actual operation, rescuers and rescue leaders should keep an eye on the sky. Storms can often be predicted in mountainous terrain without the help of forecasts. As clouds get bigger and darker, a storm builds. In temperate and tropical areas with frequent afternoon thunderstorms, rescuers should expect storm activity by midday.

Rescue leaders should consider the weather forecast as well as current weather conditions before deciding whether to use airborne resources. It is critical that a helicopter or airplane with a patient onboard be able to complete the mission and deliver the patient to an appropriate health care facility or to a ground ambulance. In areas with highly developed weather forecasting, rescue leaders might benefit from communicating directly with forecasters who can give updated forecasts for specific altitudes and locations. Prerecorded weather forecasts, websites, hotlines, and media forecasts may be unreliable.

Helicopter and fixed-wing pilots will want to know current weather conditions and weather forecasts when they are dispatched to a rescue scene. They will usually contact aviation weather forecasters for current information.

Rescue leaders should understand how weather affects the use of aviation support in mountain rescue. Fog and rainy conditions can lead to reduced visibility, a serious problem for pilots. A clear sky can be replaced by very hazardous flight conditions within minutes.[135] Service ceilings can decrease quickly, especially on sunny days. Turbulence is also a major potential hazard for helicopter operations.

LIGHTNING

Lightning is a hazard in most areas of the world, and is especially common and dangerous in mountain areas. Even in mountainous terrain, most lightning injuries can be prevented.[31,135]

Hikers and mountaineers should avoid summits and ridges, not only during ongoing thunderstorms, but also during periods that have a high likelihood of lightning activity, such as summer afternoons in temperate and tropical mountains. The interiors of mountain refuges and huts, away from open doors and windows, may be safe, but small open structures offer no protection, and may increase risk of side flashes. Tents provide no protection. Metal tent poles may act as lightning rods and increase the risk of a lightning strike. Large valleys and large caves are relatively safe, but wet streambeds, small caves, and areas under overhangs are dangerous locations during lightning activity.

The *triangle of safety* near a cliff or wall is a myth. There are no completely safe areas during a lightning storm, only areas of relative safety. It is still best to avoid being the tallest object in an open area. It is also best to stay a short distance away from cliffs and other vertical objects to minimize the risk of ground currents. Sitting or crouching on a dry pack or dry rope may offer protection from ground currents.

Metal objects do not attract lightning, but they are good conductors. They can function as lightning rods and can cause burns as well as direct lightning injuries. Metal objects, such as skis, ski poles, and ice axes, should not be carried above shoulder level. Antennae present the same risk and also increase the risk of damage to mobile phones and radios. Communications devices should be protected in the center of a rucksack, as should metal objects, such as carabiners and crampons. Watches, rings, and other metal jewelry should be removed.

Ropes, especially when wet, can also provide a path for lightning current. A *via ferrata* is a climbing route that uses metal aids, such as ladders and cable ropes, to provide security on technical terrain. Such routes, and especially the metal aids, should be avoided during a lightning storm.

Anyone who feels skin tingling or hair standing on end may be in danger of being struck by lightning and should immediately crouch with feet touching each other.

Lightning poses special risks for rescuers. If the subject and rescuers are in a relatively safe area, evacuation should be postponed. Otherwise, rapid evacuation to a location with lower risk is probably the best strategy. Helicopters can be struck by lightning while in flight, resulting in crashes. Helicopter operations should be delayed until after lightning danger has passed. Lightning is discussed in Chapter 5.

ROCKFALL

Rockfall can be a major hazard in technical terrain and is particularly dangerous for rescuers who have to perform a rescue in steep terrain. Rescuers must stay alert and be aware that they can trigger rockfall during technical rescue efforts. It is prudent to limit the number of rescuers in any area in which rockfall may occur. Natural rockfall is common during rainstorms and during freeze-thaw cycles that often occur in springtime.

Many fatal rockfall accidents occur when members of a party trigger the event. Rescuers should always wear helmets certified by the International Mountaineering and Climbing Federation (UIAA). They should equip any rescue subject with a helmet. Litter shields that have been designed to protect a subject's face from rockfall are essential elements of any mountain rescue. Another risk of rockfall is that ropes may be cut by the impact of rock against rock.

Large rockfall events generate considerable dust. This can limit visibility, preventing helicopter operations, and can be an inhalation hazard for rescuers as well as persons in the vicinity.[94]

FROZEN WATERFALLS (ICE)

Climbing is often far more hazardous on ice than on rock. Ice is generally less stable than rock. Icefall is a hazard for rescuers as well as for climbers. Rescuers who work in areas that are popular among ice climbers must be aware of objective and subjective hazards. Use of helmets is mandatory for climbers and rescuers. Helmets can mitigate the impact of falls and protect against small pieces of falling ice, but they offer little protection against the impact of larger ice blocks.

Climbers and rescuers on ice use tools that are generally very sharp. Ice axes, crampon points, and ice tools can all cause serious injury in the event of a fall.

Ice in the sun is more prone to decay during certain times of the year. Spring conditions cause increased risk. Warm temperatures cause ice structures to be more hazardous and also more prone to decay. Water runoff on ice routes is a good indication that the hazard of icefall is increasing. Routes with horizontal cracks are showing early signs of collapse.

AVALANCHES

Avalanches are discussed in detail in Chapter 4.

CORNICE FAILURES

When snow falls on mountains, windblown snow can accumulate on the leeward sides of ridges to form a vertical or overhanging edge, termed a *cornice*. Because snow has structural integrity up to a point, cornices can be many meters thick and can overhang 10 m (30 feet) or more in areas with heavy snowfall. It is hazardous to climb under a cornice, because it may fail catastrophically as a result of wind or increased loading and fall on the climber, or it may fall on a snow slope and cause an avalanche. It is even more hazardous to climb on a cornice, because the climber's weight may cause the cornice to fail.[3] Cornices may not be apparent to a climber who is approaching the top of a ridge on the windward side. It is easy to walk on relatively flat snow on top of a ridge without realizing that below the snow there is only air. Climbers should avoid walking on the overhanging part of the cornice at all costs. They should attempt to stay at least 10 m (30 feet) back from the overhanging part, because the fracture line formed by cornice failure may not be vertical, but rather may veer toward the windward side. Climbers have been injured or killed by walking on a cornice that collapsed.

TERRAIN FEATURES

Many terrain features are potentially hazardous, even in nontechnical terrain. These include steep slopes and cliffs as well as rivers and other bodies of water. Even a short stream crossing can be hazardous. These hazards are usually obvious, and technical skills may be necessary for safe travel or rescue when these hazards cannot be avoided.

GLACIER HAZARDS

Many mountain areas are glaciated. *Glaciers* are bodies of ice that move slowly downhill under the influence of gravity. Glaciers present unique hazards for travel. Large glaciers may be the equivalent of slowly flowing rivers. The surface of a glacier may be ice, which necessitates use of crampons, even on gentle slopes. If the glacier is covered with snow, efficient movement may require flotation aids, such as skis or snowshoes.

Crevasses are cracks in a glacier that form as a result of slow movement of the glacier over underlying terrain features. Ice is very plastic, but crevasses form when ice reaches the limits of its plasticity. The width of crevasses varies from centimeters to tens of meters. A person cannot fall into a very narrow crevasse, but one can easily fall into a crevasse that is a meter or more across. If the surface of the glacier is ice, the crevasses will be visible. However, on snow-covered glaciers, crevasses can be impossible or nearly impossible to detect. A crevasse may reveal itself only when a climber falls into it through the snow. Sometimes crevasses can be crossed on snow or ice bridges. However, snow bridges in particular can be prone to fail with the added weight of a climber.

A climber who falls into a crevasse can end up hanging on a rope, possibly free and away from the edges, or can land on the bottom of the crevasse, which may be filled with snow or water.[88] There are special techniques for safe travel on glaciers, including roping climbers together. There are also special rescue techniques for extracting climbers from crevasses.[107] On glaciers without hidden crevasses, climbers are usually safer traveling unroped, except when overcoming obstacles that require technical climbing skills. When overcoming these obstacles, climbers should use a safety line or be belayed.

When a glacier goes over steep underlying terrain (e.g., a cliff), it may form an icefall. In an icefall, crevasses often run not only across the glacier but also in any other direction. Snow-covered icefalls are particularly dangerous to cross, partly because the crevasses may be oriented in unexpected directions. In larger glaciers, icefalls contain blocks of ice known as *seracs,* which may be as large as buildings. Seracs can fall over as the glacier moves imperceptibly. In extreme cases, blocks of ice fall over a visible cliff from a "hanging glacier." It is extremely hazardous to be anywhere in a zone where ice blocks might land. An accident in the Khumbu Icefall on Mt Everest in 2014 occurred when ice blocks from steep slopes above the climbing route fell without warning, causing an ice avalanche that killed 16 people (Figures 56-2 and 56-3).

Other hazardous features of glaciers are known as *bergschrunds*. These are openings at the top of a glacier formed by glacier ice movement away from stationary ice that is stuck to the mountain. The sides are composed of ice and snow, and the bottom is made of rock. Another hazard, called a *randkluft*, is similar to a bergschrund, but one side is rock and the other is snow. A randkluft can form at the top or on the sides of a snowfield or glacier. A randkluft is usually quite narrow, and may have snow bridging the top that does not fill the opening below. Climbers who fall into a randkluft can easily become wedged into place.

FIGURE 56-2 Serac falling onto the Khumbu Icefall on Mt Everest. This icefall hit the main climbing route when no climbers were in the vicinity, in contrast to the icefall in 2014 that caused multiple fatalities. *(Courtesy Ken Zafren.)*

FIGURE 56-3 Aftermath of icefall on the Khumbu Icefall on Mt Everest shown in Figure 56-2. Note the climbers on the route (*in circle*). *(Courtesy Ken Zafren.)*

Streams running on the surface of ice-covered glaciers may present stream-crossing problems. A unique glacier feature is a *moulin*, or glacier mill, a hole into which a glacial stream drains, often completely through to the bottom of the glacier. Moulins are attractive nuisances, usually with steep, icy sides. Climbers who fall into a moulin can be injured, drowned, or carried into the glacier, with predictably fatal results. Large moulins are best viewed from a safe distance.

HAZARDS CAUSED BY EQUIPMENT FAILURE

Even in nontechnical situations, equipment may be important for survival. For example, wilderness travelers, and rescuers depend on clothing and other equipment to stay warm in cold conditions. Clothing is necessary for protection from cold, wind, rain, and sun. Stoves may be necessary to melt water when it is only available in the form of snow. In technical situations, clothing, including protective items such as helmets, and specialized equipment, such as crampons, ice axes, ropes, and anchors, may be critical for safe travel. In some cases, equipment failure can be fatal. Equipment failure may be caused by improper use, such as failure to secure a harness properly, or it may be the result of physical equipment failure. If a climber or rescuer is hanging free (i.e., not touching the ground at all), failure of a single rope will cause a fall. This will result in injury or death if the fall is long enough. The use of redundant equipment, in this case a second rope, can prevent such consequences if the first piece of equipment fails.

Personal and group equipment should be in good condition and ready to use before each wilderness trip or rescue mission. For rescue work, equipment should be checked for damage, inventoried, and repacked at the end of each operation so that it is ready for the next mission. Gear is often packed or organized in modular form (e.g., as a rock rescue kit, glacier rescue kit, or medical kit [for an example of a medical kit for technical rescue, see the Appendix]). A *bash kit* that contains enough equipment to start a rescue can be useful for the first team to go into the field.

Damaged equipment should be repaired or replaced. Fabrics and fibers have a limited lifespan and cannot always be adequately assessed for damage. Ropes and slings should be replaced if there is any known or suspected damage, as well as after a certain time span or number of uses. Any helmet that has sustained a significant impact should be retired. Rescue teams should have an equipment manager to oversee safety and maintenance of equipment. Some equipment, such as radios and avalanche beacons, should be tested every time prior to field use.

HAZARDS RESULTING FROM HUMAN FACTORS OF RESCUERS

Human factors for rescue in technical terrain are the same as human factors in all activities in which errors can result in bad outcomes (e.g., driving a car, piloting an airplane, practicing medicine). Physical and mental performance may both be critical to survival. The following discussion is not intended as a complete discussion of human factors. Rather, it is intended to highlight areas of particular interest in technical climbing and rescue. Ultimately, wilderness travel or rescue in technical terrain safety depends on the judgment of climbers and rescuers.

Training

Effective climbing and rescue teams must train to be familiar with the equipment and techniques to be used in technical terrain. Rescue groups should have classroom and field training, including simulated missions. Experienced mountain rescue teams can break each rescue down into small components. Team members who are responsible for each component must be thoroughly familiar with necessary equipment and techniques. This familiarity can only be achieved and maintained with regular practice.

Physical Conditioning and Skills

Technical climbing and rescues are often very strenuous. Climbers and rescuers should be in excellent physical condition. Rescuers must be careful not to exhaust themselves during their approach to the rescue scene. Rushing to the scene when carrying heavy equipment can result in having no reserve energy for the actual rescue effort. Experienced rescuers know how to pace themselves.

Climbing and mountain rescue require physical skills that must be learned and practiced. Climbers and rescuers must not only understand and be experienced in the use of climbing and rescue systems, they must also possess the physical skills necessary to operate the systems. For example, in a vertical rescue operation, rescuers must know how to maneuver the litter and themselves to move safely past obstacles (e.g., overhangs) while being lowered or raised. Climbers and rescuers should know their limits with regard to both skills and endurance. They should not operate systems with which they are not thoroughly familiar and should not continue activities (e.g., carrying a litter) beyond the safe limits of their endurance.

Food, Water, and Sleep

Climbers sometimes go beyond their usual limits of endurance. On long and difficult climbs, climbers may intentionally deprive themselves of food and water to decrease carried weight so they move more quickly. Speed may increase safety by decreasing time spent exposed to objective hazards, including high altitude. Climbers may also deprive themselves of sleep in an effort to minimize time spent in a hazardous environment or to avoid having to bivouac overnight.

Rescuers may also need to move rapidly, but they must consider increased risks and decreased performance that may result from lack of adequate food, water, or sleep. Lack of sleep may lead to poor judgment that can jeopardize the safety of a rescue operation. If there are enough rescuers, members can rotate in and out of active roles so that they can eat, drink, and rest. Sleep deprivation is especially dangerous after a rescue has been completed. Rescuers have been injured or killed in car crashes driving home after a mission.

Experience in the Environment

Because rescuer safety is the first priority during rescue, mountain rescue personnel must be experienced mountaineers and climbers. Experience with mountaineering and climbing comes from repeated trips in the mountains and technical ascents, traditionally with more experienced mountaineers and climbers as mentors. This experience builds confidence as well as the ability to deal with adversity in mountainous terrain. However, experience can also promote a loss of attention to detail and a casual approach to hazards, decreasing the perceived risk and increasing the likelihood of accidents.

Mission Planning and Risk Assessment

Mission planning and risk assessment during organized rescue are essentially the same as during companion rescue. With organized rescue, plans tend to be more elaborate and resources greater. Rescues in which the subject has died are referred to as *body recoveries*. If it is known that a mission is a body recovery, the degree of tolerable risk to rescuers is usually less than that for a mission in which the subject is known or believed to be alive. There should be no time pressure to recover a body. Body recoveries can be postponed until conditions are safe. Some body recoveries, because of location, are considered too hazardous for rescuers ever to attempt, and the mission is cancelled. Examples of such locations are under hanging glaciers and on steep faces of unstable rock.

Team Safety. Planning and risk assessment in organized rescue are mostly the responsibility of team leaders, but every team member should be aware of safety hazards and not assume that leaders have noticed them. Many accidents, especially in technical rescue, can be prevented if team members look out for potential hazards and communicate their concerns to the leaders. Technical systems should be checked and rechecked by each participant before and during use to make sure an unsafe situation has not developed. Team members should be careful not to act beyond their comfort zones and not to perform tasks for which they are not qualified based on training and experience, especially during the operation of technical rescue systems.

Aircraft Safety. Rescuers on board fixed-wing aircraft or helicopters should be aware that everyone on board represents an extra set of eyes and ears. Rescuers should never assume that the pilot or crew has seen something that they have seen, such as an obstacle to flight or something out of place in the aircraft. Rescuers should know how to use the intercom system and should point out any hazards they notice. In many helicopter crashes, someone on board saw something that appeared wrong but said nothing to the pilot. In one crash, a passenger noticed that the fuel gauge read "empty" but said nothing. The helicopter later crashed as a result of lack of fuel.[109]

EXTERNAL INFLUENCES ON RESCUE ATTEMPTS

During organized rescue, external influences can increase risk. Rescue groups must sometimes resist pressure from outside agencies to deviate from rescue plans. In one example, the successful rescue of four subjects of an airplane crash almost failed when the lead rescue organization decided incorrectly that avalanche conditions were too dangerous for rescuers. It was only through the persistence of rescuers that rescue efforts were not prematurely terminated.

Government agencies and nongovernmental organizations may have their own agendas that conflict with the objective of rescuing subjects in as safe a manner as possible. Family and friends of subjects may exert pressure on rescue leaders. External influences may be amplified by involvement of news media. All of these influences should be managed by rescue leaders and used to the advantage of rescue efforts.

A major problem can be the presence of representatives of government agencies, such as emergency service personnel and law-enforcement officers, who are usually not qualified or suitably equipped to operate in these environments, especially in technical terrain. Other unqualified or unprepared individuals, such as friends and family of subjects and representatives of news media, may also reach or attempt to reach the rescue site. Whatever their motivation for being on scene, all of these individuals can cause great risk to themselves as well as to rescuers, and they can interfere with rescue operations when rescuers attempt to protect them from harm.[61]

HAZARDS RESULTING FROM HUMAN FACTORS OF SUBJECTS

It is essential that rescue teams manage the movement of subjects during technical rescue. Rescue teams should seldom allow a subject to control ascent or descent, unless the subject is an uninjured stranded climber. Subjects in a technical rescue should be placed on systems that are as independent of the subject's control as possible. Rescuers should monitor and stay with the subject as much as possible.

If possible, rescue teams should approach a subject on technical terrain from above or by traversing rather than from below. This reduces the risk of additional rock or debris falling on rescuers. Subjects may cause objects to fall accidentally or intentionally. Rescue teams approaching from above should attempt to choose a line that does not place the subject in danger of rockfall.

The condition of a subject may deteriorate after the arrival of rescuers. The concept of *rescue shock* implies that some subjects have succumbed after the arrival of rescuers because they gave up the fight to survive when rescue seemed assured. Although this concept is currently often found among rescuers, the only evidence seems to be anecdotal and unpublished. However, it is well established that rescuers' actions can cause deterioration of subjects. Movement of hypothermic patients can precipitate *rescue collapse* due to ventricular fibrillation.[137] Placing some patients in an upright position rather than horizontal can cause decreased venous return to the heart, which can lead to hypotension or cardiac arrest.[62,63] Horizontal positioning during rescue is especially important for immersion subjects.[41,64,68,116,117]

Subjects may be mentally ill, under the influence of drugs, or agitated as a result of illness (e.g., hypoglycemia) or injury (especially head injury). In all these cases, there is an increased risk of injury to rescuers from patients striking out or even throwing rocks. Subjects may also have weapons, including knives and guns, although this is a rare issue during a technical rescue.

PLANNING FOR RESCUE

Anyone who ventures into the wilderness should be prepared to assume significant personal responsibility. This is true even for participants in activities that are organized by others. The more remote and inaccessible the destination, the more wilderness travelers must rely on themselves to provide self-rescue or their own party to provide companion rescue. A certain degree of responsibility is also placed on the organizers to provide care in remote settings.

Expeditions and special events (e.g., guided climbing, adventure racing) in remote environments may have both local and traveling guides who provide additional expertise. Guides have the responsibility to lead technical rescue and evacuation of members of their group in case of injury or illness. Local rescue and medical resources may be minimal or entirely lacking. However, if there are local resources, the expedition should have plans to gain access to them in case they are needed.

Organized search and rescue teams have a different purpose than other groups engaged in wilderness activities. They are trained to provide rescue to others, while avoiding the need to rescue their own members. Training includes formal policies and procedures, often involving highly orchestrated responses to specific problems, such as rescue from technical climbing routes and avalanche rescue. There are often specific plans for certain high-risk locations, such as individual climbing routes and known avalanche slopes. Rescue teams have access to specialized equipment, and most have a high degree of technical (but often not medical) expertise. There is wide variation in the degree of medical training of mountain rescuers.[39]

In highly developed areas such as the European Alps, mountain rescue may be fully integrated into an emergency medical services system. Aeromedical helicopters in these areas bring a high level of technical rescue and medical expertise into areas that are otherwise inaccessible, although they may be near major population centers. Most helicopters carry a physician and have advanced life support capabilities, including advanced airway equipment and cardiorespiratory monitoring.[18] Even with these advantages, the level of care is limited when compared with that offered in a hospital emergency department or an intensive care unit.

TEAM TRAINING

Ideally, any organized group that is going to a wilderness location should train together before departure. This applies especially to expeditions and organized search and rescue teams. For packaged expeditions and adventure races, this may not be possible, because group members often come from disparate geographic areas. Training and practice can occur after the group assembles in a remote location, either in a nonwilderness location before going to the wilderness or during the trip itself before encountering specific technical risks.

For organized search and rescue, members are expected to possess standard skill sets based on their roles and responsibilities. Members acquire these skill sets and are usually tested for competency in practice environments before they are involved in actual missions. The structure and sponsorship of search and rescue organizations vary widely among and often within countries.

ROLE OF THE MEDICAL DIRECTOR

Medical oversight of technical rescue is best performed by a medical professional, usually a physician, who is knowledgeable about wilderness medicine and also understands the technical situations in which care will be provided.[76] Ideally, the medical director will train with and be an integral member of the team. In some situations, the medical director might be on scene and provide or coordinate medical care[97]; in others, the medical director may provide consultation remotely. However, because communication problems are inherent in technical rescue, most medical direction will be offline in the forms of guidelines, protocols, and standing orders. The medical director is responsible for quality assurance and improvement. These processes include training and retrospective evaluation of the decisions and care that occurred during a rescue. Missions are usually followed by an immediate debriefing and later by a formal critique.

PATIENT CARE IN WILDERNESS AND TECHNICAL ENVIRONMENTS

PRIORITIES

Priorities of wilderness and mountain rescuers are to provide the best possible patient care while limiting risk to themselves and their patients. Often the best possible care will be to stabilize a patient and treat pain. Rapidly reaching and evacuating patients may also be important, but these should be secondary priorities after safety and adequately stabilizing patients for transport. After they reach a patient, rescuers should assess and treat the patient, and plan evacuation based on patient condition and resources available. Rescuers on scene may have to wait for better weather conditions or for more personnel and equipment before an evacuation can be safely attempted. Use of a litter or other specialized equipment may be desirable or sometimes mandatory for patient safety and comfort, but will increase resources required for evacuation.

LIMITATIONS

Participants on wilderness trips should be aware of the risks of wilderness travel and should realize that medical care will be limited. It has often been stated that medical care in the wilderness is the "art of the possible." Medical providers, no matter how well trained and qualified, will not be able to provide the same level of care in a wilderness environment as they can in less austere settings. This applies even to highly trained rescue physicians on aeromedical helicopters in Europe.

Because diagnostic and therapeutic equipment is limited in the wilderness, medical judgment and decision making are more difficult and more crucial than in the usual urban medical settings. Safety concerns may limit treatment. As in all prehospital care, rescuers may need to remove patients and themselves from a hazardous environment before they can provide even the most emergent medical care. In this way, medical care in the technical environment resembles combat casualty care. Only a few interventions (e.g., opening the airway, stopping extremity bleeding with a tourniquet) may be feasible during the initial rescue.

INITIAL PATIENT ASSESSMENT AND TREATMENT

Patient assessment is a critical skill, but in austere technical environments must be modified from usual practice. As in combat casualty care,[20] diagnosis of hypovolemic shock should be based on mental status rather than measurement of blood pressure. If a patient is conscious and coherent, cerebral circulation is acceptable. There is no need to check carotid, femoral, or radial pulses to estimate blood pressure. The patient should seldom be exposed in technical environments. To remove clothing involves the risk of hypothermia except in very warm conditions. The history and a limited physical examination are used for diagnosis until the patient is placed in a heated aeromedical aircraft or brought to a clinic or hospital.

Initial assessment is usually limited to finding problems that require emergency treatment, including airway compromise, breathing problems, external bleeding, and limb-threatening injuries such as fractures and dislocations. Initial treatment is directed at treating life- and limb-threatening problems. Although advanced life support prioritizes airway, breathing, and circulation, in that order, it is generally better to stop active, brisk bleeding during initial examination before addressing the airway. Direct pressure or a tourniquet can be applied in a few seconds to stop blood loss and increase survival. This is seldom useful in technical environments, because care is not usually immediate. A subject equipped with a tourniquet could apply the tourniquet and then self-rescue or assist with companion rescue or organized rescue.

Resuscitation

During mountain rescue, resuscitating patients without vital signs is usually futile, with the exception of hypothermic patients in whom asphyxia did not precede hypothermia.[16,17,58,83,136,137]

Airway and Breathing

Airway management in technical terrain is usually more difficult than in less austere settings. Initial ventilation by bystanders can be mouth-to-mouth ventilation. This may be all that is necessary to treat patients with respiratory arrest caused by lightning strikes.[31,135] Rescuers can use bag-valve-mask ventilation, but unless they have sufficient training and regular practice, they will be more effective at using mouth-to-mask ventilation.[84]

The use of alternative airways, such as the Combitube, King LT, Laryngeal Tube, and laryngeal mask airway (e.g., LMA, LMA Supreme), is revolutionizing airway management in emergency medical services and is assuming a greater role in technical environments.[91] Recognition that protection from aspiration may not be significantly different between these airways and the “definitive” endotracheal tube (in combination with the known difficulties and hazards of endotracheal intubation in prehospital settings) may continue to drive the transition away from endotracheal intubation and toward the use of alternative airways.[24] At the same time, video laryngoscopy (e.g., GlideScope) may slow or reverse this trend in aeromedical care.[10]

There are a number of maneuvers to improve endotracheal intubation using a standard laryngoscope. One position that can be useful in confined areas (e.g., a rock ledge) is for a rescuer to kneel over the patient’s chest and intubate with the laryngoscope while straddling the patient. This is sometimes referred to as the *ice-axe technique* or *inverse intubation* (Figure 56-4). When intubating on snow, a useful technique is to put a blanket or another cover over the rescuer’s head and let the eyes adapt to the relative darkness before intubating.[120]

FIGURE 56-4 “Ice axe” intubation technique. *(Courtesy Will Smith.)*

Changes in endotracheal tube cuff pressure with changes in altitude can lead to excessive pressure or underinflation, especially during air medical evacuation. This problem is solved by inflating the cuff normally with a measured volume of air at any altitude, withdrawing the air, and inflating the cuff with an equal volume of saline[13] or water. Cuff pressure will then be constant even with changes in altitude. Some manufacturers of endotracheal tubes warn against inflation with saline solution, but there is no clear contraindication.

Circulation and Control of Bleeding

Driven by military experience in Afghanistan and Iraq, use of tourniquets[35] and hemostatic dressings[14,141] has become widespread in civilian prehospital care for controlling external bleeding. Although tourniquets can be improvised, it is difficult to make an effective tourniquet quickly. Commercially made tourniquets approved for military use are small and lightweight and should be included in all but the most basic medical kits on wilderness trips. A tourniquet can be self-applied by a bleeding subject. Hemostatic agents can be beneficial in civilian practice as well as in certain wilderness situations. The U.S. military evaluates and approves hemostatic agents. Only agents that are currently approved by the U.S. Armed Forces should be used.[8,9]

Another device that has been used successfully for controlling external hemorrhage is the iTClamp.[5,56] The iTClamp is a sterile plastic clip about 5 cm (2 inches) long with curved needles, like suture needles, on both jaws. The clip is placed parallel to the wound and then activated. As the clamp springs closed, the needles bring the edges together, everting them. This confines ongoing bleeding to the space deep to the skin where it theoeretically tamponades the bleeding vessel. The iTClamp can be applied very quickly, by a rescuer or by a subject, and stays in place on its own until it is released. This frees the rescuer or subject for other tasks. The iTClamp can be used on extremities if a tourniquet is not available or in areas such as the trunk or neck in which tourniquets cannot be used.

A new type of device, known as a junctional tourniquet, has been developed and is quickly making the transition from battlefield to civilian prehospital practice. Junctional tourniquets use either a belt or rigid apparatus to apply external pressure to a compressible artery by means of a structure such as a ball head or wedge that concentrates pressure at the desired location. The most common application is to control femoral artery bleeding in the inguinal region,[28,57] but pressure can be applied to the axillary,[28] brachial,[67] or popliteal[67] arteries by some models. Regular tourniquets cannot be used at these locations. At least one model uses a belt that can also function as a pelvic binder.[57] Another model is marketed as a device for external compression of the abdominal aorta as well as junctional and peripheral sites.[27]

Manual external aortic compression has been employed successfully to control external hemorrhage from penetrating trauma without use of a special device.[34] Use of this technique is likely possible only for heavy rescuers. In a simulation, rescuers had to weigh more than 92 kg (203 lb) to achieve target pressure for 2 minutes. Only rescuers weighing at least 115 kg (255 lb) were able to maintain the target pressure for 20 minutes.[33]

Traumatic internal bleeding in the abdomen or thorax severe enough to require specific treatment is treated surgically or by interventional radiology. Internal bleeding from pelvic and femoral fractures may also require treatment by surgery or, in the case of pelvic fractures, by endovascular therapy, most commonly embolization. In the field there is little that can be done to control internal bleeding, but stabilization of fractures is helpful to limit additional hemorrhage.

Pelvic fractures should be stabilized by a pelvic wrap[38] or a pelvic binder. When checking for pelvic instability, rescuers should remember that increased bleeding is caused by "opening" the pelvis (i.e., like an open book). The safest method for checking pelvic stability is to gently apply pressure on the iliac crests directed medially; that is, to "close the book" rather than open it and risk causing additional bleeding. Only a single check should be performed to avoid further trauma to the circulation in an unstable pelvis.

Femoral fractures can be stabilized by traction devices. If the femur fragments are overriding, there is theoretically a globular space into which hemorrhage can occur. If the femur is straightened, this space is converted to a cylinder with a much lower volume. Femoral fracture reduction has traditionally been thought to tamponade bleeding and limit further blood loss. However, it may be quite difficult to apply improvised traction in the field. The Kendrick Traction Device is a commercially available lightweight device for providing femur traction. Traction devices require an ankle hitch that should be applied carefully, because they can cause skin necrosis if applied incorrectly and left in place for a duration of time that can cause damaging soft tissue ischemia. Although there is no strong evidence, it is still the prevailing opinion that traction devices for femoral fractures are better than simple splinting, in part because they may increase comfort. If a traction device is not used, a patient with a femoral fracture can be treated using a vacuum mattress or another splint.[38]

TREATMENT OF PAIN

> *Analgesia at the scene of an accident is a human right.*
> **—URS WIGET, PAST PRESIDENT OF THE INTERNATIONAL COMMISSION FOR MOUNTAIN EMERGENCY MEDICINE (ICAR MEDCOM)**[121]

Pain management is an important part of patient care in any environment, including combat casualty care and technical rescue.[103,121] In addition to providing comfort for the patient, effective pain management may allow a patient to self-rescue who otherwise would not be able to do so.

Opiates have long been the mainstay of pain control.[121] They have traditionally been given by intravenous, intramuscular, and oral routes, but some agents can now be given by transmucosal routes. Fentanyl can be given through the oral mucosa[126] (i.e., a fentanyl lollipop) or intranasally. Both transmucosal routes offer rapid onset of pain relief.

Ketamine is an alternative to opiates that can be used to produce dissociative anesthesia for procedural sedation.[12,37] It can also be used at lower doses to treat pain.[40] Ketamine can be used alone to treat pain or at very low doses to allow for a reduction in opiate doses (i.e., opiate sparing).[52] Ketamine can be given intravenously, intramuscularly, or intranasally.[53] Ketamine is safer than opiates because it does not produce respiratory or circulatory depression and allows airway reflexes to remain intact, even at higher doses. Ketamine is widely used in prehospital care in Europe.

Staged pain management starts with nonpharmacologic methods and progresses to treatment with increasingly effective medications as needed. Guidelines from the Wilderness Medical Society describe a pain treatment pyramid.[103] Nonpharmacologic methods include comforting patients to relieve pain and anxiety and use of basic interventions such as rest, ice compression, and elevation (RICE). Another formulation adds "protection" of the injury (PRICE). Medications follow a progression from nonopiates to opiates. The opiates are further divided from least to most invasive. Oral opiates should be used first, if suitable, and then intramuscular, intranasal, and intradermal opiates.

The military have developed a simplified approach to analgesia in tactical combat casualty care.[21] Meloxicam and paracetamol (acetaminophen in the United States and Canada) can be given for casualties with minor pain who are still functioning as combatants. There is a risk of platelet inhibition with meloxicam, as with all nonsteroidal antiinflammatory drugs, but this should not be important in casualties with minor injuries. Oral transmucosal fentanyl is given to casualties with moderate to severe pain unless they are in hemorrhagic shock or respiratory distress or at risk for developing either condition. The protocol's authors chose transmucosal fentanyl rather than intramuscular morphine because it is easier to administer and because fentanyl has a more rapid onset of action. They also noted that intramuscular morphine can worsen hemorrhagic shock. Fentanyl is less likely to produce or worsen hypotension. Ketamine is used in casualties who have moderate to severe pain and are in hemorrhagic shock or respiratory distress or at risk for either condition. Ketamine can also be used to increase analgesia in casualties who have already received opiates.

Use of regional anesthesia to control pain and facilitate reduction of dislocations in the field is more widespread in Europe than elsewhere. Many "emergency doctors" in Europe are anesthesiologists whose training includes use of regional blocks. Wider use of regional anesthesia in mountain rescue has the potential to offer greater pain relief than do opiates, with fewer side effects.[30] For example, a femoral block could markedly reduce pain from a lower-extremity fracture during a prolonged evacuation. Prehospital use of wrist block for digital frostbite has been reported.[86] A wrist block could have the additional benefit of concomitant sympathetic blockade, thereby promoting vasodilatation and theoretically ameliorating frostbite.

PROLONGED CARE AND TRANSPORT

Prolonged care of seriously ill or injured patients with limited medical resources poses a unique set of problems and an increased risk of complications and death compared with care in a well-equipped critical care setting, whether or not the care is in technical rescue terrain. Even if the airway, breathing, and circulation can be stabilized, it may be a challenge to maintain vital functions. Supplies of oxygen and medications, including medication to relieve pain, may be limited. Injuries that cause ischemia of an extremity (e.g., vascular injuries, compartment syndromes) can cause loss of digits, hands, feet, or an entire limb if not corrected within hours. The common advice for life- and limb-threatening problems in wilderness settings is to evacuate rapidly to definitive care. However, this is not always possible (Figure 56-5).

Unconscious patients without airway protection provided by endotracheal intubation or by alternative airways should be placed in recovery position (i.e., the lateral decubitus position with the head turned so that vomiting will not result in aspiration). An oral or nasal airway may be helpful to prevent hypoventilation caused by obstructed breathing. Neither endotracheal intubation nor alternative airways completely eliminate the risk of aspiration, but there is evidence that all provide similar degrees of protection.[24] For patients who are not breathing spontaneously, it can be a challenge to maintain adequate ventilation. Hypoventilation, hyperventilation, and inadequate oxygenation are all hazards of ventilation, especially if mechanical ventilation and monitoring capabilities are not available. A nasogastric or orogastric tube is helpful and sometimes essential to decompress the stomach. Otherwise, ventilation may be severely limited by stomach distension.

External bleeding can be controlled by direct pressure or by using a tourniquet or iTClamp,[56] but hemorrhage from internal

FIGURE 56-5 Multiple trauma. Caring for a patient with multiple trauma during a 6-hour flight from Antarctica to South America in a large turboprop plane. The rescuers reached the subject 40 hours after the plane crash that injured the patient. *(Courtesy Ken Zafren.)*

organs, such as the liver and spleen, is not amenable to nonsurgical intervention. Limited volume resuscitation to maintain blood pressure at low but life-sustaining levels has the potential to limit internal bleeding.[119]

For patients with head injuries, hypotension can be as deleterious as hypoxemia to the outcome of traumatic brain injury. Fluid resuscitation may be essential to prevent hypotension. The use of small-volume intravenous or intraosseous therapy with hypertonic fluids may be beneficial.[119] Although the advantages of small-volume therapy remain controversial, limiting the weight of fluids to be carried is an advantage in most wilderness settings. Unconscious head-injured patients should be protected from hypoxemia as well as hypotension and should be maintained if possible with the head elevated to 30 degrees. This helps maintain cerebral perfusion by decreasing the risk of elevated intracranial pressure without significantly decreasing cerebral blood flow.

Intravenous and intraosseous fluids are the best options for preventing hypovolemia in unconscious patients. Intravenous lines can be difficult to place, especially in cold conditions. Intraosseous line placement is an alternative method of access. In desperate situations, fluid can be given and absorbed rectally (i.e., proctoclysis) through any suitable tube.[15] Unconscious patients will also require bladder drainage, preferably using an indwelling catheter.

For patients without head injuries, permissive hypotension has the potential to limit internal hemorrhage by preventing dislodgment of intravascular thrombi by increased hemodynamic pressure. In theory, these thrombi may prevent hemorrhage from an injured vessel. This is a controversial area that has not been well studied, but many case reports suggest a survival benefit.[113]

If at all possible, fluid administered in wilderness settings should be heated to 40° C (104° F) or at least to normal body temperature. A number of methods are available to accomplish this in cold wilderness environments.[93] Fluid should be given in boluses that have been titrated to effect, especially in the acute setting. Intravenous lines (i.e., maintenance fluids or drips) are difficult to keep warm, although specialized fluid warmers and insulated tubing are available for wilderness use. Even with the best precautions, intravenous fluids may freeze in the tubing in cold environments. It is best to give boluses of warmed fluids and to preserve intravenous or intraosseous access sites between boluses using saline locks.

Limb-threatening injuries should be addressed by attempting to limit ischemia. Fractured bones should be realigned as well as possible, and dislocations should be reduced. Patients with open fractures should receive intravenous antibiotics, if available. Compartment syndrome often complicates these injuries, and may require fasciotomy despite increased risk of infection. If bleeding must be controlled with a tourniquet, there is a risk that the limb will be lost as a result of ischemia. The time usually quoted for irreversible ischemia is 6 hours, but the limb may remain viable longer. If alternatives are fatal hemorrhage or loss of limb, the choice is clearly to maintain the tourniquet for as long as necessary to prevent fatal hemorrhage.

Patients with surgical conditions are usually not allowed to eat or drink anything (NPO) to prepare them for surgery. NPO status maintained over the course of prolonged transport, however, may lead to inadequate caloric intake and hypovolemia. If intravenous fluids are available, they can be used to prevent hypovolemia, but they will not provide sufficient calories to avoid hypothermia. If there is no contraindication (e.g., bowel perforation), patients may be allowed to eat and drink during prolonged transports.

To prevent skin ischemia leading to decubitus ulcers, patients should not be maintained on backboards, even padded ones, for any length of time. Safe parameters are not known, but 1 hour is almost certainly too long. Unconscious patients who are not being actively transported can be maintained on soft surfaces with frequent turning, which is how they would be managed in an intensive care setting. During active transport, a vacuum mattress is the best solution currently available,[96] especially if there is a question of unstable spinal injury.

Ill and injured patients who are immobile lose heat rapidly and should be carefully protected from hypothermia even in warm conditions through use of insulation and, if possible, by warming methods such as large chemical or electric heating pads.[137] This is especially important for unconscious patients and those with neurogenic shock. In neurogenic shock, autonomic control of lower extremities is lost, resulting in vasodilatation, which in turn causes hypotension and heat loss. Patients with severe trauma lose the ability to shiver. Because shivering is the primary mechanism by which humans can generate heat, these patients rapidly become hypothermic without insulation and application of exogenous heat sources.[137] The U.S. military has developed the Hypothermia Prevention Management Kit, which includes insulation and large chemical heat packs. The kit is practical for organized rescue but is relatively heavy, which limits its use in many wilderness settings.

Other details of care for unconscious patients include eye protection with removal of contact lenses, and protection of the cervical spine. Cervical collars can cause localized pressure necrosis of skin if they are maintained for several days.[78] During transport, a cervical collar may not be necessary if a properly applied vacuum mattress is used. A risk of not using a dedicated cervical collar is that spine protection may not be maintained by a receiving hospital when the vacuum mattress is removed. During prolonged waiting, cervical spine protection should be maintained with a padded rigid cervical collar or with an improvised collar that is repositioned on a regular basis. A cervical collar improvised from a SAM Splint is practical for this purpose.

ALTITUDE CONSIDERATIONS DURING RESCUE

When technical terrain occurs at high altitude, there is an increased risk to rescue personnel. Both human and helicopter performance are decreased at high altitudes (Figure 56-6). The reduced performance of helicopters may severely limit payloads as compared with sea level, limiting the ability to carry medical personnel, equipment, and supplies. The service ceilings of helicopters and margins of safety can be improved by removing unnecessary equipment to decrease payload weight. Unfortunately, "unnecessary" equipment and personnel may be medical

FIGURE 56-6 Crashed helicopter near Everest Base Camp, Nepal. *(Courtesy Ken Zafren.)*

equipment and personnel. Many helicopters that are suitable for rescue at low altitudes are dangerous at high altitudes, especially when carrying a full complement of crew and equipment. The crash of a Pave Hawk helicopter during a rescue on Mt Hood in 2002 is an example of the danger of using certain helicopters at high altitudes.

In addition to human performance being decreased at high altitude,[48] there is a risk of high-altitude illness for unacclimatized rescuers[65] who must occasionally respond to rescues above 2500 m (8200 feet). In such cases, it is advisable to limit the amount of time spent by unacclimatized rescuers at high altitudes and to have a contingency plan for descent.[138] In most rescue situations, gradual ascent is impractical. For areas in which ground rescues occur at high altitude, rescue personnel should be based at high altitude. In Denali National Park, where the majority of rescues take place above 4500 m (14,800 feet),[45] rescuers are based at a 4300-m (14,100-foot) camp. However, the helicopter pilots and other crew are based near sea level. Pilots and crew breathe supplemental oxygen when flying higher than 3000 m (9800 feet). Oxygen sets can be removed from the aircraft in case the pilot or another member of the crew needs to leave the helicopter. Rarely, when special technical skills are needed and there is no qualified person at the high camp, short-haul rescues have been carried out by a rescuer based at low altitude. In case the helicopter cannot return to low altitude promptly as a result of technical difficulties or weather, there is an "escape plan" for personnel who are based at low altitude; this plan involves use of oxygen, prophylactic medications, and descent by ground, if possible, during a specified time period.[138]

SUSPENSION TRAUMA

If a climber falls and is held upright by a climbing harness, blood pools in the lower extremities. This problem is referred to as *suspension trauma* or *harness hang syndrome,* and can lead to loss of consciousness and death.[59,80,101] Much has been written about suspension trauma, based on little research. A climber who is able to move while suspended in the harnesses can hang upright in a free position (i.e., suspended in air) for an indefinite period without ill effects. Unconscious fallen climbers who are suspended vertically have died, presumably from circulatory collapse caused by reduced central venous return.[106] An alternative mechanism that involves mechanoelectrical feedback causing a fatal dysrhythmia[23,98] has also been proposed; this has reportedly occurred in a matter of minutes in some cases.

Prompt rescue is considered essential in cases of suspension trauma.[89,100] Rescue is generally accomplished by lowering the patient to the ground, if possible. Some clinicians recommend against placing patients in a horizontal position because of the theoretical risk of acute heart failure caused by sudden volume overload or acute cardiac dysrhythmia. There is no evidence that placing a patient in a horizontal position is dangerous.[80,122] On the contrary, in addition to the fact that it is difficult to manage patients in an upright position, some patients may be hypovolemic as a result of internal injuries and require volume resuscitation. Keeping a hypovolemic patient in an upright position would be contraindicated.[80] There is a case report of an industrial worker who was rescued alive after 20 minutes of suspension in a safety harness who reportedly died in the hospital as a result of internal hemorrhage.[122] Rhabdomyolysis has also been reported in suspension trauma,[128] although the cause is controversial.[99]

USE OF EXTRICATION DEVICES FOR CREVASSE RESCUE

Glacier travelers can be injured by falling into crevasses. When a patient who has fallen into a crevasse has a suspected spinal injury, the best method of extrication is horizontal immobilization on a litter using a vacuum mattress and cervical collar.[133] Use of cervical collars for distraction cervical injuries (i.e., injuries in which ligamentous disruption allows widening of the intervertebral joints) is potentially dangerous.[7] When horizontal stabilization cannot be accomplished in a narrow crevasse, the patient should be stabilized in a vertical position. The Kendrick Extrication Device has been tested for use in crevasse extrication. It maintains support of the head, neck, and torso.[133] The patient is lifted using the patient's climbing harness rather than the straps attached to the extrication device. An extra suspension line at the top of the device may reduce pressure on the spine. This line should be attached to the main line with an adjustable system (e.g., an ascender or a Prusik) that may need to be adjusted during the extrication. The patient should be repositioned from an upright to a horizontal position as soon as possible after extrication.

COMPANION RESCUE

DECISION MAKING IN COMPANION RESCUE

After a problem has been recognized, the group will attempt to solve it. Preplanning can help streamline this process and can make the difference between a successful outcome and a tragic one. If there is an ill or injured participant who requires rescue, some or all of the other participants may be required to accomplish the rescue. Outside resources may be available in some circumstances. Criteria for using outside resources and the means by which they are activated are important parts of the preplan. In some areas, rescue can be as simple as calling a helicopter; however, in many wilderness areas, the initial phase, if not all phases, of rescue will be performed by others in the patient's party. In technical terrain, it may take only a few people to lower a subject down a steep face or snow slope, because gravity can do some of the work. Alternatively, it may take a large group to overcome complex technical problems. On easy terrain, it can take many people to carry a subject who is not ambulatory.

Although there should be a general preplan, when a rescue is about to be started the team should agree about a specific plan of action. Time spent discussing the plan is usually time well spent, especially if there are questions about the best response.

IMPROVISED SEARCHES

In organized search and rescue, the first step is often a search for the subject or subjects. Searching for avalanche victims is discussed in Chapter 4. On a trip with a small team that stays together, searches are not usually necessary. On larger trips and expeditions, if a team fails to arrive at a destination when expected and is unable to communicate with another team, a search will be necessary to find the missing team. This may be the first step in rescue if the missing team is stranded or if it has one or more members who are ill or injured. See Chapter 55 for information on search strategy.

Large groups can limit the need for potential searches by frequent radio contact with moving parties or with passive global positioning system tracking. Most newer cell phones support this application in areas with cell phone service.

It is important to be aware that a search is an emergency. The more capable an individual or group, the more likely it is that there is a problem when the person or group fails to arrive as expected at a destination. Experienced climbers are likely to know how long it will take them to complete a given itinerary and can overcome many unexpected obstacles. If they are overdue, it is more likely that a serious problem has occurred than when less experienced climbers are late.

PLANNING FOR WILDERNESS MEDICINE TECHNICAL RESCUE

Survival of an injured person may depend on rapidity of rescue and care given during and after the rescue. Any group planning to travel in remote, steep, or technical terrain should have specific plans for potential emergencies, assess possible scenarios, and prepare in advance for rescues. Rescue plans should include clearly defined leadership roles and sufficient technical capabilities. Ideally, there should be a plan to ensure that help would be provided promptly to anyone needing it and that specific rescue equipment and a medical kit would be available to deal with any problem. However, ideal conditions seldom occur in the wilderness; rescue equipment can be heavy, and no medical kit can deal with all possible illnesses and injuries. If group resources or capabilities are not adequate to conduct a rescue safely and outside resources can be activated, it may be necessary to call and wait for assistance. If the group cannot conduct a rescue safely and outside resources are not available, the group should not attempt the rescue, because attempting a rescue in these circumstances would jeopardize additional members.

BASIC CONCEPTS OF TECHNICAL RESCUE

Every technical rescue operation involves a certain amount of improvisation, because every rescue is different. This variability demands thought and creativity when developing a solution, and it often includes technical rigging. Most technical rescue operations have a few basic concepts in common: anchors, descent, ascent, raising, and lowering. The ability to apply principles related to all of these concepts in low-angle, high-angle, vertical, and overhanging terrain, whether hanging or with feet planted firmly on the ground, is an essential part of the rescuer's tool kit.

ANCHORS

Anchors for rescue are similar to climbing anchors except they are implemented with the understanding that they may be subject to the loading force of multiple people (i.e., some combination of rescuers, a patient, and equipment). Rescue anchors need to be stronger than normal climbing anchors.

The simplest single-point anchor consists of wrapping a piece of webbing or rope around a "bomb-proof" anchor point, such as a tree or a rock. In this case, anchor strength will depend on anchor point strength and the connecting components, which may include webbing, rope, and carabiners.

Rope offers advantages over webbing in rescue anchors because it is more resistant to abrasion and is usually stronger. One method of anchoring a rope is to wrap the end of the descent line three or more times around a substantial object such as a tree and then clip it back onto itself (Figure 56-7). This method, known as a *tensionless anchor,* provides an anchor that is as almost as strong as the rope itself. Other methods include tying the main line to a substantial anchor using an *end knot* or using a separate rope to sling around a tree. More information on knots can be found in Chapter 108.

It is also possible to use a shorter length of rope to connect to an anchor and then clip the descent line directly to it. Some

FIGURE 56-7 Tensionless anchor. *(Courtesy Loui H. McCurley.)*

mountaineers use a length of cordage, usually 6 to 8 m (20 to 25 feet) long, as a versatile rigging accessory suitable for a variety of applications, including as an anchor. This length of cordage, which may be referred to as a *cordellette,* is generally of a smaller diameter (7 to 8 mm [0.2 to 0.3 inches]). If strength is a consideration, it may need to be doubled.

Webbing may also be appropriate for an anchor if the rescuer understands its capabilities and limitations. A single strand of 25-mm (1-inch) nylon webbing (sling) is rated at about 18 kN (4000 lb); a single strand of 11-mm (0.4-inch) nylon static or low-stretch rope is rated at about 27 kN (6000 lb). High-modulus fibers such as aramid (Kevlar) and ultrahigh-molecular-weight polyethylene (Spectra), available in both webbing and cordage forms, are even stronger. Before using these materials under tension, users should understand their limitations. For example, aramid fibers are very brittle and sharp. Although this is not apparent externally, it can result in self-destructive action internally to the rope. Ultrahigh-molecular-weight polyethylene does not share this characteristic, but its disadvantages include slipperiness, resulting in poor ability to retain knots, and a low melting point. Both fibers offer little or no elongation (stretch).

Elongation is an important part of rope-based systems. When a shock load occurs, stretch in ropes and webbing decreases sudden impact on the anchor and on persons who are in the system. High-modulus fibers increase the risk of anchor failure and injury caused by shock loading. They should only be used with great caution in rescue work.

Webbing used for climbing and mountaineering is often presewn into a continuous loop. Webbing loops may be used in a *basket hitch* configuration (Figure 56-8) or a girth hitch configuration (Figure 56-9) around an anchor point. When using a *girth hitch,* care should be taken to align the load properly, as shown in the figures.

Some climbers and mountaineers prefer to use a version of 25-mm (1-inch) tubular nylon webbing that is not presewn. This allows for greater customization and adaptability, because it may be tied to whatever length is needed for a given situation. Ends of nylon webbing should always be joined with a *water knot;* this is also known as a *ring bend.*

Spectra is a very slippery fiber that does not hold knots well. Spectra webbing should only be used if it is presewn. If Spectra

FIGURE 56-8 Webbing basket hitch anchor. *(Courtesy Loui H. McCurley.)*

FIGURE 56-10 "Wrap three, pull two" anchor. When using tied webbing, the knot should be positioned on the back of the anchor. *(Courtesy Loui H. McCurley.)*

webbing must be tied in an emergency situation, a pretensioned *triple fisherman's knot* with plenty of excess tail has the greatest chance of holding.

When webbing is tied around an anchor point such as a tree, the most secure method is to wrap the webbing three times around the anchor and then to pull two of the strands out as clip-in points (Figure 56-10). The water knot joining the two ends of the webbing should be positioned on the back side of the strand that is left tensioned around the anchor point.

Artificial anchors are also appropriate for rescue when they are used properly. Examples of artificial anchors include chocks, nuts, bolts, mechanical cams, ice screws, removable bolts, pickets, and ground stakes. The strength of artificial anchors directly depends upon the nature and quality of material (e.g., rock, snow, ice) into which they are placed and the nature and quality of the placement itself. For this reason, only competent, experienced climbers should place artificial anchors.

Because a key premise of rescue, as of medicine, is to do no harm, placing two anchors rather than one is often desirable. There are many strategies for rigging multipoint anchors. The first decision is whether one anchor will provide *backup* to the other or if the load will be shared between the two. If one anchor provides backup to the other, keeping the two anchors in line with one another and the fall line, and pretensioning between the two, if necessary, will help prevent catastrophic swing or shock load in the event of a failure. No anchor should ever be used unless it can be reasonably expected not to fail, so in principle this should not be a problem.

Because rigging two anchors is desirable, sharing the load between the two anchors from the outset may also be a good plan; this type of anchor system is known as a *load-sharing anchor.* A load-sharing anchor shares the load between multiple points (Figure 56-11). One concern with a load-sharing anchor

FIGURE 56-9 Webbing girth hitch anchor. *(Courtesy Loui H. McCurley.)*

FIGURE 56-11 Load-sharing anchor. *(Courtesy Loui H. McCurley.)*

is that, unless the fall line is completely consistent, there will be times at which the points of one or the other anchor will bear most or even all of the load. For this reason, a load-sharing anchor should not be used to justify multiple weak anchor points.

One method for avoiding uneven loading between anchor points is to rig the load-sharing anchor so that it is allowed to *self-equalize*. This allows the load to remain distributed more consistently by multiple anchor points, even as the load moves across the fall line. The risks of self-equalizing anchors are often debated in climbing and rescue circles. If a sling that is too long is used to connect the anchor points, the failure of one of the points could create an excessive fall distance and a potentially high-impact load. Another useful technique is to use individual anchor slings (e.g., rope) with some force-absorbing qualities (e.g., elasticity) to extend outward from the anchors to a very short Spectra sling. The slipperiness of Spectra allows for better equalization of the load. In addition, using a short sling helps to prevent a long fall.

With any multipoint anchor system, the angle formed by the lines between two anchors should be as acute as possible. As the angle increases, so does the amount of force placed on each anchor point. Generally, the maximum angle should be 90 degrees. The angle should never exceed 120 degrees. If circumstances demand use of an angle of more than 90 degrees, increased forces at the anchors, at the anchor line terminations, and on other components in the system should be considered.

When an anchor is attached to a structure that clearly has more than adequate strength, it is still advisable to anchor each line separately by using two slings or two connectors, even if both slings or connectors are placed around the same anchor point. Ideal anchors should be unquestionably reliable, be placed so that the rescuer can maintain a working position without difficulty, and be designed so that rescuers can connect to or disconnect from the rope system in an area where there is no risk of a high fall.

It is usually best to rig anchors low because this provides the greatest strength when connecting to natural anchors such as rocks or trees. However, a low anchor can make edge transitions difficult. For this reason, a *high-directional* is sometimes used to redirect the load. In a high directional, the anchor is still set relatively low but the line is passed through a high point before it goes over the edge. In this way, the strength of the low anchor is maintained while the advantages of a high anchor are realized.

Natural features that may be used as high directionals include trees and large boulders. Where natural features are not available, artificial high directionals, such as tripods, bipods, and monopods, may be used. High directionals should only be used by experienced rigging professionals, because the angles and vectors involved can result in excessively high forces or inappropriate directional loading.

DESCENT

The term *pickoff* refers to the rescue of a person who is in technical terrain, usually on a cliff. The person may be an injured climber or a climber who is uninjured but needs to be removed from a vertical or near vertical setting, usually as a result of inability to self-rescue safely or in a timely manner. Basic descending techniques provide the foundation for a rescue pickoff.

Basic descending techniques are important for maintaining personal safety in steep or vertical terrain. Colloquial terms for descending are *rappelling* and *abseiling*. The same concepts that apply to rappelling, or descending down a fixed rope, also apply to lowering a load from above. In the pickoff, a rescuer uses a rope to reach a subject and connects to the subject to descend or be lowered, or raised to safety. Necessary equipment for descent includes an anchored rope, harness, descending device, and carabiners to connect the system together.

Although using a harness can be avoided in some terrain with the *dulfersitz* rappel technique, this method is useful only for very short descents. Even then, the dulfersitz technique is usually limited to desperate circumstances. It involves wrapping the rope between the legs and around the body to provide friction (Figure 56-12). This technique can be painful to use, even under one's own weight; it is certainly not suited to carrying another person. Another method, the arm wrap (Figure 56-13), is less uncomfortable, but also less effective, and does not provide enough friction to be used in vertical terrain.

FIGURE 56-12 Dulfersitz rappel. *(Courtesy Loui H. McCurley.)*

The Swiss seat harness (Figure 56-14) is an improvised method of connecting oneself to a rope that is better than a dulfersitz. It requires about 6 m (21 feet) of webbing, depending on person size. It is much more secure than a simple diaper-style improvisation. Although this method of tying a harness is not easy to remember, the *Swiss seat* can be mastered with practice.

The best method of connecting oneself to a rope is to use a professionally manufactured harness with fully functional straps and buckles for adjustment and a specific attachment point. Regardless of the type of harness or body-holding mechanism, an adequate descender is also necessary. Any descender that provides sufficient friction on the rope may be used. *Figure-eight descenders* are common, but have major disadvantages of not providing sufficient friction for a heavy load and of twisting and kinking the rope. Figure-eight descenders can be double wrapped to increase friction (Figure 56-15). *Brake racks* have traditionally been used by cavers and rescuers in North America. Manipulating the bars allows for easy adjustment of the amount of friction; the straight-line design does not twist the rope. Some professional rescue teams use a tubular device, which facilitates knot passes and is especially useful for lowering a load from the top.

All of these devices share one key characteristic: They rely on the hand grip of the person controlling them to stop a load. They do not offer autolocking or panic lock mechanisms.

FIGURE 56-13 Arm-wrap rappel. *(Courtesy Loui H. McCurley.)*

FIGURE 56-14 "Swiss" seat harness; a tied harness using webbing. *(Courtesy Loui H. McCurley.)*

An *autolocking mechanism* is one that automatically locks off in the event that the user lets go. This is usually accomplished by means of a handle or other mechanical action that requires the user to hold the device open to operate it. The downside of an autolocking mechanism is that a user who panics can easily lose control of the descent. To compensate for this, some devices also offer a panic lock. A *panic lock* is a feature that causes the device to lock off in the event that the user overactivates the *go* mechanism.

Most climbing belay devices may also be used as descenders. Although some devices may not provide sufficient friction for lowering a heavy load, additional friction may be gained by "stacking" devices (Figure 56-16) or by adding carabiners to assist with the braking action. The *Munter hitch* (also known as the *Italian hitch*) is an improvised technique that provides a reasonable amount of friction for a single climber, requiring only a rope and a carabiner.

Lowering a load may be accomplished either by a rappel-style friction descent (i.e., with the descending person controlling descent) at the point of the load or by a lowering system in which the load is controlled by another person from an anchor above. One person at a time may descend (Figure 56-17) or be lowered (Figure 56-18), a rescuer may descend with a subject (Figure 56-19), or a rescuer may be lowered with a subject (Figure 56-20). Although it may be necessary for the rescuer to rappel with the subject due to lack of manpower or for other reasons, being lowered has the advantage of permitting the rescuer to focus on the subject.

FIGURE 56-15 Double wrapped figure-eight ascender. The double wrap increases friction, enabling control of a rescue load. *(Courtesy Loui H. McCurley.)*

FIGURE 56-16 Stacked figure-eight brake. The two figure-eight brakes can be stacked using a carabiner (as shown) or webbing to provide enough friction to control a rescue load. *(Courtesy Loui H. McCurley.)*

ASCENT

Any person who intends to descend a rope should also be able to ascend, even if only for a meter or so, to self-extricate if necessary. Something as simple as catching a shirtsleeve or not having effectively planned an exit point could become a catastrophic event for a person unable to ascend.

Ascending may be accomplished with the use of an ascending device or soft cams (i.e., slings or ropes that grab the main rope as a result of friction) rigged into a system that ensures that if either ascender should become dislodged the user will be caught in a seated position by the other ascender.

Mechanical ascenders are more efficient than *soft cams.* A mechanical ascender generally consists of a shell that wraps around the rope and a toothed cam device to grip the rope. Some mechanical ascenders have handles and some are designed to attach to the harness to allow progress only in the forward direction. Some ascenders are more sturdily constructed than

FIGURE 56-17 Climber on rappel. In rescue situations, the climber would either be belayed from above or be using a self-belay. *(Courtesy Loui H. McCurley.)*

FIGURE 56-18 Climber being lowered. *(Courtesy Loui H. McCurley.)*

others. Others have less aggressive teeth for use with heavier loads. *Prusiks* are the most common type of soft cams. A Prusik consists of a pretied loop of rope that is at least 2 mm (0.08 inch) smaller in diameter than the main line. When wrapped around the main line, a Prusik grips the rope firmly. If more friction is desired, an additional wrap can be made around the main line.

An ascending system may be as simple as Prusiks that are rigged with one as a foot loop to provide a movable "step" and the other at the harness to capture progress. Climbers, including most rescuers, usually choose mechanical ascenders (Figure 56-21). Other systems exist that allow use of both legs to ascend longer distances more efficiently. These are especially favored by cavers, who often ascend long, free-hanging ropes.

HAUL SYSTEMS

Ascending is a one-person activity. When the rescuer reaches the subject, it is difficult or even impossible to ascend with the

FIGURE 56-19 Climber on rappel with subject. *(Courtesy Loui H. McCurley.)*

FIGURE 56-20 Rescuer being lowered with subject. *(Courtesy Loui H. McCurley.)*

FIGURE 56-21 Ascending a rope. The climber initially sits in the harness, putting his entire weight on the upper ascender while bending one leg and moving the lower ascender up to just below the upper ascender. The climber stands up on one leg, unweighting the upper ascender and allowing him to move it up the rope to capture the upward progress. The climber repeats the process as many times as necessary to reach the top of the rope. *(Courtesy Ken Zafren.)*

FIGURE 56-22 Prusik-minding pulley. The haul system can only move the load a certain distance before it needs to be reset. Before resetting the system, the Prusik is "set" to grip the rope and holds the load, taking tension off the haul system so that it can be reset. The Prusik will also set automatically, preventing the load from being dropped if there is a failure in the haul system. *(Courtesy Loui H. McCurley.)*

patient connected to the rescuer's system. For this situation, the rescuer must create a mechanical advantage system to provide greater lifting force. Haul systems used by rescuers can be complex and technically challenging. However, most of the time such complexity is unnecessary. The same tasks can be accomplished with simple systems.

The most common, and generally most useful, haul system configuration is the *Z-system*, which is also known as a 3:1 advantage system. In a 3:1 system, the working end of the haul rope is connected to the load, runs to a pulley at the anchor, and then runs back to another pulley that is connected (by Prusik or other rope grab) to the working end of the haul rope. Using some sort of ratcheting device on the side of the first pulley closest to the working end of the haul rope will help capture progress and prevent catastrophic failure. Prusiks are often used in this progress-capture position. This can be facilitated by a *Prusik-minding pulley* (Figure 56-22). Mechanical advantage can be increased further by using additional pulleys (Figures 56-23 and 56-24).

A Z-system, or any other haul system, may also be piggybacked onto a main line for raising a load. In this case, the ratchet

FIGURE 56-23 Five-to-one advantage haul system on a glacier. Note the load-sharing anchor. The pulley closest to the rescuer is a direction-change pulley that allows the rescuers to pull parallel to the crevasse from which they plan to raise the subject in a litter. *(Courtesy Ken Zafren.)*

FIGURE 56-24 Five-to-one advantage haul system that shows the litter in the system shown in the previous figure. *(Courtesy Ken Zafren.)*

or progress-capture device should be placed on the main line, and an attendant should set the ratchet to maintain progress when the system must be reset.

KNOT PASS

The ability to pass a knot while on descent or ascent is a basic skill for any potential rescuer. A spare ascender with a short lanyard connected to the harness at the waist is a useful tool for this purpose.

To pass a knot while on descent, the rappeller should stop several inches above the knot and *lock off* high enough so the descender does not jam into the knot. An autolocking descender is especially useful. Once tied off, the rappeller connects an ascender (either mechanical or a soft cam) to the rope above the descender and continues to rappel until the ascender is under tension and the descender can be removed from the rope. After reattaching the descender below the knot, the rappeller needs to remove tension from the ascender and reload the descender. This can be accomplished either by attaching another ascender with a foot loop to the rope and stepping up (Figure 56-25) or by making a loop with the rope itself and stepping up. The rappeller should always have a secure attachment from rope to harness at waist level.

Passing a knot on ascent is much easier. The climber ascends to the knot, removes the foot loop ascender from the rope, and replaces it above the knot. The climber continues to ascend until the waist ascender is as close as possible to the knot. Next, the spare ascender (which is also attached at the waist) can be placed above the knot, and the rescuer can continue to ascend until the lower waist ascender can be removed from the rope. If a spare ascender is not available, the climber can temporarily change over to the descender while repositioning the ascender above the knot. This technique can also be useful at the top of an ascent, where pulling oneself over an edge can be difficult.

BACKUP SYSTEMS WITH BELAY

A backup system is any system used to prevent a catastrophic fall in the event of main-line failure. A secondary braking device or an autolocking system (e.g., commercial rope grab device or Prusiks) may be used. For self-rescue, using a secondary system for belay or backup purposes may be difficult. However, a backup belay should always be considered with particular attention to the probability and likely consequences of failure of the primary system. There may be a higher probability of failure when working with inexperienced rescuers. A backup system is especially desirable if the rescue system does not incorporate an autolocking descender. However, multiple systems add complexity, which may interfere with the rescue.

FIGURE 56-25 Knot pass on rappel. The technique is similar to that used to ascend a rope. *(Courtesy Loui H. McCurley.)*

PERSONAL ESCAPE

Any person working at height should be capable of self-rescue. Compact rope descent systems that can be carried in a pocket or small bag are now commonly available. Small-diameter nylon or aramid (Kevlar) ropes are typically used. Nylon ropes are desirable for shock absorption and reliable performance. Aramid escape lines have become popular because of aramid's high strength-to-weight ratio and its resistance to high temperatures. Great care should be taken when aramid ropes are used, because they have virtually no shock absorption capability. Aramid is also especially prone to self-destructive internal damage under repeated bending abuse, such as that which might occur over time when the material is stored in a pocket or bag. Small-diameter ropes used for egress require a descender with extra friction. These may be custom-designed devices, or may resemble small brake racks or figure-eight–type devices. Autolocking devices should be considered for less experienced personnel.

ONE-ON-ONE PICKOFF

One-on-one pickoff is a useful skill for extricating a person who is suspended from a rope. Although it is possible to perform this maneuver using only the subject's rope, it is preferable for the rescuer to reach the subject using a separate rescue rope.

If enough rescuers are available and if communications are adequate, the entire operation can be controlled from above. This allows the descending rescuer to have both hands available to manage and care for the patient. A key decision when preparing for a pickoff is whether the rescuer will descend with the subject or remain stationary while lowering the subject to the ground. It is usually better to descend with the subject; this provides added protection and control as well as reassurance.

To perform a pickoff that is controlled from above, the descending rescuer ties into the end of the rescue rope using an appropriate end knot (e.g., *figure-eight knot, bowline knot*). A descender is anchored to a secure anchor at the top of the drop, and an experienced brakeman controls the lowering process (Figure 56-26). A secondary system may be used as a belay if resources permit. Communications between rescuer and brakeman are critical. All actions are initiated by the rescuer. In other words, the rescuer is in the command role. The exact commands vary by region and training, but it is crucial that brakeman and rescuer agree about them in advance. The following is a good example of appropriate communications.

Rescuer: *On belay? (question)*
Brakeman: *Belay is on. (statement)*

Rescuer: *Down slow. / Up slow.*
Brakeman: *Down slow. / Up slow. (repeats rescuer's command)*

Rescuer: *Slower. / Faster. (or Down slower. / Down faster.)*
Brakeman: *Slower. / Faster. (repeats rescuer's command)*

Rescuer: *Off belay. (command)*
Brakeman: *Belay is off. (statement)*

One method of performing a pickoff that is controlled from above is for the rescuer to be lowered to just within reach, about 1 m (3.3 feet), from the subject. The rescuer then asks the brakeman for a "stop." The rescuer attaches a lanyard (i.e., a sling or rope) to the rope just above the rescuer's own connection using a carabiner or an ascender. The ascender can be either a mechanical ascender or a soft cam (e.g., a Prusik). The rescuer then connects the other end of the lanyard to the subject's harness. If the lanyard is adjustable, slack may be removed by tugging on the tail end of the lanyard. A subject who is attached to a rope by a descender may be removed from the rope by lowering the subject onto the rescuer's system using the descender. Otherwise, the brakeman at the top will need to build a haul system to raise the subject's rope until the rescuer can take up enough slack to transition the subject to the rescuer's rope.

Cutting the subject's rope should only be done as a last resort. This method introduces the potential hazard of shock loading the rescuer's rope or cutting the wrong rope, creating a catastrophic failure.

FIGURE 56-26 Friction brake load lowering. The rescuer is using a friction brake to lower a rescue load down a vertical face. *(Courtesy Loui H. McCurley.)*

A one-on-one rescue can also be accomplished with the rescuer using the rescue rope to ascend or descend to the subject. The rescuer then connects the subject to his own system so that they can descend together to the ground. This method is difficult and should only be attempted by experienced rescuers. It requires rigging systems and using raising and lowering techniques either on a vertical surface or on the rope itself while also trying to manage the subject.

In this scenario, the rescuer rappels down or ascends up to the subject using the rescuer's own rope. Stopping just above but within reach of the subject, the rescuer uses an adjustable lanyard to connect to the subject, with the connection usually being from the subject's seat harness attachment directly into the carabiner that holds the rescuer's descender. Attaching the subject to the descender rather than to the rescuer's harness allows the rescuer more mobility and helps to prevent unsafe cross-loading of the rescuer's harness.

If the subject is suspended from a descender attached to a rope, the rescuer may simply use the descender to lower the subject onto the rescue system. If the subject does not have a descender in place, the rescuer may need to build a miniature haul system by using the rescuer's own rope as an anchor and then raising the subject to disengage the subject from his or her own system.

Another option is for the rescuer to ascend or descend to the subject and anchor at that location and lower the subject to the ground. After lowering the subject, the rescuer descends alone. This method is only feasible if the subject is able to steer clear of obstructions and maintain distance from the slope. If two persons are descending simultaneously, this method might be hazardous.

A one-on-one pickoff rescue may be used to lower a subject all the way to the ground or to load a subject into a litter midwall. This method should not be used to lower the subject very far unless the subject is in relatively stable condition and will not be further injured by the lowering. A badly injured subject or one who is not fully conscious or alert should be loaded into a pickoff seat or litter before movement occurs.

BELAYS

Belaying is protecting a climber by means of a rope. In steep terrain, a climber who falls without a belay might fall a long distance and sustain serious injuries but a climber who is belayed is more likely to fall a short distance, if at all, until caught by the rope. In most organized rescue situations, any system should be belayed, either by a separate rope safeguarding the subject and rescuers or by a double-rope system. This may not be practical in companion rescue. Belay systems require additional time, equipment, personnel, and other resources that may not be available.

A useful approach when deciding whether to belay a rescue system is to balance the probability of failure against the likely consequences. The acceptable level of probability of failure is difficult to determine. It is usually best evaluated by an experienced rescue leader. The level of acceptable risk for any given operation depends on many factors, including resources on hand, available alternatives, the subject's condition, and consequences of failure.

The consequences of failure are the likely effects on rescuers and subjects. If a failure were to occur, would rescuers and subjects skin their knees or would they plunge to their deaths? After the probability and consequences of failure have been evaluated, the leader should consider whether benefits of a belay outweigh increased risks caused by a time delay and use of resources necessary to set up and operate the belay system.

There are many examples in which use of a belay may jeopardize the success of an operation. In the case of a critically injured patient, the time required to put necessary resources in place may be a determining factor in the decision to not use a belay. In unstable terrain, a belay may increase the risk of rockfall from movement of additional personnel and equipment. In that case, belaying might increase rather than decrease the overall risk. On a free-hanging lower, a belay can introduce the potential hazard of tangling lines.

Belay systems can be defined as *active* or *passive,* based on the actions required for them to function. An active belay requires participation of a belayer to work effectively. An example might be a bottom belay for a rappeller or a second brakeman behind the primary brakeman on a lowering device. Running a separate belay line with a lowering device operated by a second brakeman is another example of an active belay.

Active belays offer disadvantages as well as advantages. The greatest disadvantage is that the probability of human failure is generally higher than the probability of mechanical failure. By including a human action in the chain of required responses to a failure, the probability of failure of the belay may be increased. However, an active belay can be effectively adapted to the situation (e.g., when changing from lowering to raising).

Passive belays activate automatically in the event of failure. Advantages of passive belays are that they can sometimes be operated with fewer personnel and they eliminate the possibility of human failure. However, they often require personnel to operate and can sometimes engage when they should not do so. This can significantly slow and complicate an operation. Special care must be taken to not overload an automatic belay when the load consists of more than one person. It is best to keep rescue loads as light as possible in all cases to reduce potential for failure. Whatever belay is applied must be capable of withstanding the load that might be placed on it.

If a belay is introduced into a system, the question sometimes arises regarding which anchor should be stronger: the primary anchor or the belay anchor. The answer is that both anchors must be capable of withstanding any anticipated force, with a degree of safety that is acceptable to rescuers.

HIGHLINES

Highlines are sometimes referred to as *tyroleans, tyrolean traverses, telphers,* or *cableways*. All of these terms refer to a rope or cable suspended from one point to another along which people, equipment, and other loads can be moved.

Highlines may be used to transport rescuers, subjects, and equipment across a barrier, such as a waterway or other difficult terrain. Highlines can be used to cross deep canyons or gorges, to avoid hazardous or difficult terrain, or to evacuate persons from a hazardous area in which there is no other practical alternative. Highlines are particularly useful for areas in which there is a lot of loose rock on steep faces, because they can keep ropes, rescuers, and subjects out of the line of rockfall.

When rigging a highline, consideration should be given to selecting a location with as narrow a span as possible, with sufficiently high anchorages, and with room to work on both sides of the span. Horizontal highlines are suspended from two points that are close to the same level, and steep-angle highlines are suspended between two points, one at a much higher level than the other. Highlines may also be suspended from points that result in an intermediate angle. Separate lines *(tag lines)* are used to pull loads along the highline (Figure 56-27). Special rigging can be added to a highline, making it possible to raise and lower loads from the span.

Highlines should be used with great caution. More than any other rope-rescue system, highlines can overstress rope, equipment, and anchors, causing the system to fail. Highlines also require a great deal of teamwork and communications. They are especially problematic for groups that have not practiced together frequently.

ESTABLISHING A MAIN LINE

The initial step in rigging a horizontal highline is to place at least one rescuer on the far side and to get the rope and equipment across to them. If there is a person on the far side who is at least somewhat mobile, they may be enlisted to assist with this process. There are several available line-throwing devices for sending a pilot line across a chasm. These include professional rope guns, throw bags, and softballs fitted with line connectors.

When a person on the far side has an end of the pilot line, a rescuer can attach a more substantial rope to the pilot line with

FIGURE 56-27 Highline. A special highline pulley can be used to decrease friction. The rescue load (not shown) hangs from the pulley. The lines on either side of the rescue load are tag lines that are used to pull the load along the highline. *(Courtesy Loui H. McCurley.)*

a knot and carabiner and ask the person to pull this across the chasm. This rope will then become the main line. The person on the far side can be asked to wrap this rope two or three times as high as possible around a substantial anchor (e.g., a tree) and clip the carabiner back to the rope.

The main line supports most of the load weight on the highline. Although it may be a single line, rigging a double highline may be desirable when higher loads are anticipated. Using a static kernmantle life safety rope as the main line helps rescuers calculate and maintain an appropriate amount of sag in the main-line rope to prevent overloading the system.

Because of high forces that can be generated in highlines, main-line anchors must be extremely reliable. In a horizontal highline, both main-line anchors will be subjected to similar forces. With steep-angle highlines, the upper anchor will be subject to much higher force than the lower anchor. The tangential forces introduced by a midspan load will result in higher forces at each anchor.

The near-side anchor where the main-line rope is initially anchored is usually the point from which operation of the highline is initiated and controlled. It is also usually the anchor nearest to arriving rescue personnel. The far-side anchor is the anchor to which the main-line rope is attached, and it must be at least as strong as the near-side anchor. For a steep-angle highline, the far-side anchor will receive less stress while the load remains near the top. As the load approaches the bottom, the far-side anchor will be subjected to greater stress.

The forces to which anchors and equipment are subjected are determined by the load to be transported by the highline, and angle or sag in the system. The load could be one person or a subject in a litter or attached to a rescuer with a substantial amount of equipment.

TENSIONING A MAIN LINE

One of the most critical safety measures when rigging a rope for a highline is to include an appropriate amount of sag in the main line. Although a tightly tensioned main line provides an easier path across which to move loads, it is sag in the line that prevents overloading. A highline system must never be stretched very tight and then loaded. This could cause the rope, equipment, or anchors to become overstressed and fail.

There are several theories and complex mathematical equations for working out the appropriate amount of sag. To simplify calculations, many people use the *10% rule*. This is a conservative method of tensioning a highline. According to the 10% rule, for every 100 kg (225 lb) of load and every 30 m (100 feet) of span in the rope, there should be a sag of 3 m (10 feet).[71] Other methods may not be sufficiently conservative, especially for ropes with minimal elongation characteristics. Unless a rescuer incorporates some sort of force measurement system and is thoroughly experienced with rigging, a very conservative approach is recommended.

To tension the main line, rescuers rig a haul system to a substantial anchor on the near side and use this to tension the main line after the main line has been secured on the far side. After a line is established and tensioned, one or more rescuers can cross to the subject's side to provide medical care and continue the rigging. When crossing over water, personal flotation devices should be worn by all rescuers and subjects. Additional ropes or rigging gear may be transported across by rescuers to provide a partial belay for the first crossing, a tag line for controlling the load, or another main line.

THE LOAD

Rescuers, subjects, and equipment may be secured with a harness or in a litter with a spider; this is similar to the spider used for vertical evacuation. The moving load may be attached to the main line with a carabiner, but using a pulley will reduce friction and make the trip more efficient. Large pulleys specifically designed for this purpose are available from several manufacturers.

When rigging a litter onto a horizontal highline, it should be set to minimize the patient's exposure to a head-down configuration. Depending on the highline length and intended application, this may mean that the litter should be positioned head-first.

TAG LINES AND HAUL LINES

An additional non–load-bearing line may be used to connect the load with either side of the highline. A tag line may be used just to maintain contact with the load or it may double as a belay or haul line.

Beyond the center point of a horizontal highline, the load must be pulled upward to overcome the sag in the system. This can be quite an effort and require the use of a mechanical advantage system. Similarly, friction may be needed to control a load on the downward slope of a highline. This can be accomplished by running the tag line through a rescue brake system.

SAFETY FACTORS

A rescue system should be capable of withstanding higher forces than those that can reasonably be expected. Some people think of safety factors in relation to individual components, but the concept applies to the system as a whole. A system safety factor (SSF) is the ratio between the strength of the weakest point of a system and the foreseeable maximum potential force at that point. It is calculated by dividing the system strength by the potential force.

Determination of the safety factor in a given system requires that personnel understand the strengths of components as they are rigged together in the system as well as the manner in which forces are exerted in the system. A common misperception is that if all the components in a system are rated to a strength 10 times greater than the load weight, the resulting SSF will be 10 : 1. This is incorrect because the strength of connections between components is often weaker than the components themselves and forces within the system will be different than the load weight due to vectors, friction, and other factors.

As an example, the rated breaking strength of a static rope that is 10 mm (0.4 inch) in diameter may be over 22,500 Newtons (N) (5000 lb) force, but when a knot is tied in the rope, the strength may be reduced by as much as 30%, to about 15,600 N (3500 lb). A similar reduction in strength can be assumed for a carabiner when it is loaded in three directions. The weakest point in a system will often be either the interface between two components or between a component and an external force (such as an edge).

On the load side of the equation, the mass of a rescuer with equipment may only be about 90 kg. This corresponds to a force of 900 N (≈200 lb), but the effects of acceleration can increase the effective force by as much as a factor of 2 even with uneventful, simple movement on the line.

Calculating the SSF based on component strengths and user mass, one might consider the ratio between rope strength (≈ 22,500 N [5000 lb]) and user weight (≈ 900 N [200 lb]) and come up with a SSF of 25:1. However, taking into account the strength of rigging (≈ 15,600 N [3500 lb]) and increased force of the load in motion (1800 N [400 lb]), a more accurate SSF would be about 8.75.

Load ratios vary throughout the system, so rescuers should consider the ratio between the breaking strength of each point in the system against the maximum anticipated load at that point. The point at which load ratio is narrowest dictates the entire SSF.

The target SSF for a given system varies based on circumstances and should be determined by the most qualified person. Probability of failure and consequences of failure are the two most important considerations in determining an appropriate safety factor. A situation in which failure is unlikely and the consequence of failure would be minimal may justify a low safety factor. In contrast, a higher safety factor is required for a system subject to conditions that are more likely to cause it to fail or in a situation where system failure is likely to be catastrophic to personnel.

If necessary, the safety factor of a given system can be adjusted by making changes within the system, such as using stronger components, improving the relationships between components, or minimizing loading on the system. Loading can be decreased by using one person instead of two or decreasing the length of a potential fall.

FIGURE 56-28 Rucksack stretcher. If the subject has a suitable rucksack, it should be used when constructing the stretcher. *(Courtesy Ken Zafren.)*

GENERAL PRINCIPLES OF ROPE RESCUE

With a good foundation of knowledge and skills, rescuers can adapt to almost any terrain in almost any environment. Regardless of the system used, there are several rules to keep in mind when building rope rescue systems:

- There should be an appreciable SSF. Most alpine search and rescue systems use a 10:1 SSF.
- Ropes should be protected over all sharp or abrasive edges.
- Equipment should be inspected before use to ensure that it is adequate and in good repair.
- Appropriate precautions should be taken to prevent damage to equipment both when it is in use and when it is in storage.
- Ropes should be rigged to reduce the likelihood of a shock load or a pendulum in the event of a fall.
- Ropes should be configured so that users cannot inadvertently descend off the end of the rope.
- Slack in the safety line should be avoided to minimize the length of any potential fall.
- Using the techniques described in this section, with sufficient training and practice, resourceful rescuers can resolve most rescue situations.

IMPROVISED METHODS FOR CARRYING AN ILL OR INJURED PATIENT

Except in organized rescue, use of special rescue equipment is generally impractical. Even if special rescue equipment is available, it is unlikely to be located at the site of initial rescue. In remote areas, supplies for improvised techniques are more likely to be available where and when they are needed.

THE RUCKSACK STRETCHER

Improvised litters are described in Chapters 46 and 57. Although many of the techniques shown have been widely taught in rescue courses, most have significant disadvantages. Many types of improvised litters are difficult to construct or require special materials (e.g., ski poles) that may not be available. None of the commonly taught techniques provides good support for the subject, especially one who may have a spinal injury. An alternative method that is practical and requires only commonly available materials is the rucksack stretcher, which gives good support to the subject's spine and can be constructed in minutes.[140]

A rucksack stretcher is made from three or four rucksacks, preferably with internal stays. Rucksacks should be filled with gear and clothing as if they were going to be carried. The optimal number of rucksacks depends on their size and the subject's height. Rescuers unfasten the shoulder straps of the middle (or middle two) rucksacks and run the shoulder straps of each rucksack (except the "top" one) through the shoulder straps of the one above it. They reattach the shoulder straps in their original positions (Figure 56-28).

Without tightening the straps and with the hip belts of the rucksacks open and off to the sides, rescuers place the subject on the stretcher, using the subject's clothing as handles to lift the subject if needed. If the subject is in a sleeping bag, the bag itself can be used for handles. The subject's head can be stabilized by the hip belt of the "bottom" rucksack. If the subject has a suspected cervical spine injury, the neck should be stabilized before lifting occurs. An excellent improvised method for cervical spine stabilization is a SAM splint (see Chapter 46).

When the subject is lying on the stretcher, rescuers fasten the hip belts snugly around the patient, with care taken not to constrict the chest or go directly over the knees. The shoulder straps are tightened under the subject. One drawback of the loaded rucksack stretcher it is that it has a high center of gravity. When rescuers put the stretcher on the ground, they should make sure that it does not roll over with the subject on it.

IMPROVISED TRANSPORT OVER SNOW

The high center of gravity of a rucksack stretcher limits its use for sliding on snow. On soft snow, a subject without spinal injuries can be dragged in a sleeping bag that has been placed in a durable bivouac sack with a sleeping pad under the sleeping bag. If the snow is harder or the subject has spinal injuries, a rigid litter or vacuum mattress inside a durable bivouac sack can be used as a makeshift sled. This method will usually work for short distances only, because snow is generally abrasive on the fabric of any bivouac sack.

LITTERS AND VACUUM MATTRESSES FOR ORGANIZED RESCUE

VACUUM MATTRESSES

Vacuum mattresses, which are also known as *full-body vacuum splints,* are currently the best method for immobilizing patients for transport, especially prolonged transport.[38,96] They are especially useful in conjunction with rigid litters. Vacuum mattresses are more comfortable than backboards[22,26] and less likely to cause decubitus ulcers,[108] because they conform to the back and minimize pressure points. The mattress is filled with small pellets, like a beanbag. Evacuating air from inside the mattress creates a vacuum so that atmospheric pressure outside the mattress forces it into a rigid shape. The patient must be lying on the mattress during air evacuation so the shape will conform to the body. The patient can be placed in a sleeping bag for additional comfort prior to being placed on the mattress, but before air is evacuated. Vacuum mattresses can be carried or used with a flexible litter, but usually they are placed inside a rigid litter.

The patient should be firmly secured in the vacuum mattress, because the mattress's rigidity has the potential to produce large forces on injured areas if the patient moves during transport.[60] Leaks can occur, but in practice they can be fixed by patching, usually with duct tape. Unlike a rubber raft or other pressurized container in which the patch must withstand the high force of increased pressure in the container, atmospheric pressure works to hold the patch in place on a vacuum mattress. Theoretically, a more uniform padded mattress with a rigid backing might be preferable to a vacuum mattress,[46,55] but this solution would have to overcome potential problems such as bulk and weight to be considered a superior solution for patient transport.

If a vacuum mattress is not available, a patient on a backboard or commercial litter should be placed in or on a sleeping bag with sleeping pads to decrease discomfort and prevent decubitus ulcers. This method of packaging should also be used with improvised rucksack stretchers, if possible.

FIGURE 56-29 Vertical evacuation in a practice scenario. Note that the rescuer is tied into the lowering ropes and not just the litter. *(Courtesy Loui H. McCurley.)*

COMMERCIAL LITTERS

In the United States, mountain rescuers usually use the term *litter* rather than *stretcher*, but the terms are generally interchangeable. Many litters are marketed for organized rescue teams, including basket litters and flexible litters. Commercial litters designed for specific rescue situations such as caving rescue or canyoneering rescue are available. Many types of litters are presented in detail in Chapter 57.

When selecting the type of litter for a given rescue, priorities are the safety and protection of the patient. The lightness and compact size of flexible litters make them attractive choices for the initial response in organized rescue, especially for ground teams that must carry all of their own equipment. They can also be convenient solutions in confined spaces, caves, mines, and canyons. Many flexible litters give little spinal support and are not by themselves well suited to high-angle rope rescue, although they can be adapted for use in high-angle rescue or hoisting operations.[87] There are also devices designed to provide spinal stabilization for a patient in a flexible litter. A flexible litter can be placed inside a larger rigid-frame litter after the patient is removed from a confined space for quicker lowering and raising operations without complete repackaging.

Rigid-frame litters are generally sturdy basket-style litters that are designed to connect to a rope system for safety. They can be lowered or negotiated through almost any terrain. They may consist of an open framework (e.g., a Stokes-style litter [see Figures 57-18 and 57-20 in Chapter 57]), or may be of a closed construction of modern composites that provide more patient protection. Some closed-construction litters can slide on snow. Sleds designed to be towed by snowmobiles and specialized toboggans designed for use by rescuers on skis are also available. The best litter depends on the specific needs of a given rescue. A perfect litter does not exist.[47]

For ground evacuation, many litters can be fitted with a wheel. Wheeling a litter over trails and other suitable terrain is often much easier and requires fewer people than carrying.

Litters can be rigged for high-angle evacuation in either a horizontal or a vertical configuration. Vertical configurations offer a lower profile for rockfall, but can be quite disconcerting for the patient. High-angle rescue in North America is usually performed with the litter in a horizontal configuration (Figure 56-29), but in some countries, vertical orientation is common.

The litter is supported and connected to the end of the lowering line by means of a litter bridle or *spider*. Spiders are available in different forms, which range from those with four litter attachment points and a single main-line connection to those with six litter attachment points and dual main lines. Commercial spiders are available, but spiders can also be easily improvised.

Four-point litter spiders with a single litter attendant are quite common and use minimal gear. A simple nonadjustable four-point litter spider may be improvised by connecting lengths of webbing to four different locations on the litter, providing a stable platform. Making the litter legs adjustable in length, by using Prusiks or straps with buckles, can be help with litter positioning.

With a four-point spider, the litter attendant and litter are both suspended on the rope from a single main attachment point. The job of the litter attendant is to keep the litter away from the rock face, to guide it over terrain, and to mind the patient. A litter attendant who is attached to the same system as the litter has an ergonomic advantage when it comes to moving and manipulating a suspended litter. It can be quite difficult for one suspended body to effectively direct, move, and manage another. A four-point spider with a single litter attendant works particularly well on simple, vertical faces and where the litter need not be maneuvered through chimneys, over boulders, or in other complex types of terrain.

If litter manipulation will be more difficult, due to terrain features or patient factors, or when a patient needs to be loaded into a litter suspended in midface, it may be preferable to use a system with two litter attendants and a six-point spider. With two attendants, there are usually two main attachment points, each of which suspends half the litter and one rescuer. The legs of the spider are spread a little further apart than with a single attachment point. One leg at a time may even be removed to help with loading the patient. Two litter attendants have more muscle power than one to wrestle a litter over difficult terrain, guiding it away from obstacles and providing a smooth ride.

A bowline on a bight is a knot that results in three loops at the end of a rope. A 15-m (50-foot) rope can be made into two bowlines on bights connected in the middle to provide a four- or six-point attachment to the litter for one lowering and one or two main lines (Figure 56-30). This method uses very little equipment.

The patient and rescuers should be attached directly to the lowering line and independently to a belay line, if one is being used. Litter attendants should wear helmets. They should wear their own backpacks to avoid being separated from their gear when they reach the bottom of the descent and also to protect their backs from rockfall. If debris falls from above, attendants should attempt to lean over the litter to protect the patient and to take advantage of the protection provided by their backpacks.

FIGURE 56-30 Improvised spider in a practice scenario. *(Courtesy Ken Zafren.)*

PATIENT PACKAGING

The first priority is protecting the patient from further injury. Dressings and splints are used to stabilize injuries.[38] If spinal injury cannot be excluded, spinal stabilization methods, such as a cervical collar, should be used. However, spinal stabilization can cause increased complications or death. If not medically indicated, spinal stabilization can unnecessarily complicate rescue.[95] Rescuers should be trained to identify awake patients who are at such low risk for an unstable cervical spine injury that they do not need cervical spine stabilization.[118] The NEXUS criteria and the Canadian C-spine rule are decision instruments that can be used to identify patients who do not require cervical spine imaging after injury and by inference may have a lesser need for immobilization. Both guidelines have been validated for prehospital use.[32,125] Guidelines for selective stabilization of the thoracic or lumbar spine have not been validated, but it is unlikely that a subject who is ambulatory in the field would need spinal stabilization.[139] Splints and cervical collars can be improvised using various materials or SAM splints. Improvised techniques are discussed in Chapter 46.

It is very important to keep the patient warm. Because the patient is immobile, excessive cooling is possible, even in warm weather. In cold weather, especially in the presence of wind, it can be very challenging to protect a patient from cooling. Severely injured patients are unable to shiver and lose heat especially rapidly, even in warm conditions. Special hypothermia bags can be helpful to prevent heat loss.[42] Active rewarming methods can be used to prevent cooling, including use of large battery-powered or chemical heat pads, or the Norwegian charcoal-burning HeatPac. If available, active rewarming should be used in any patient who is cold stressed or hypothermic regardless of ambient temperature.[137] The system should be arranged so that injuries can be reassessed with minimal interruptions during transport.

A patient in a litter must have protection from falling or wind-blown objects, especially during evacuation from steep or vertical terrain, during helicopter rescues, and from objects that might protrude and snag the litter during transport, such as rock projections or tree branches. The face and head of a supine patient are particularly vulnerable. The patient should wear a helmet with a face mask, if available, or a litter shield can be used. If a face mask is not available, protective glasses are another means of protecting the eyes. Litter shields that cover the head, face, and neck of the patient are commercially available or can be fashioned from Plexiglas or other materials.

Because tipping or inversion of the litter is always a possibility, the patient should be secured with straps against side-to-side movement when the litter is tilted and jostled, and should be prevented from sliding up or down in the litter and prevented from coming out of either end. Many older basket-style litters had foot dividers to keep the patient from shifting toward the foot end, but these did not protect against shifting toward the head end. Few of these litters remain in use.

The patient can be secured with foot and shoulder loops in addition to the patient's climbing harness. Most commercially available litters are fitted with at least three or four simple straps that go across the patient. For greater security, particularly in technical rescue, a more secure means of lashing the patient into the litter can be used, such as a commercial device or one improvised with webbing. Improvised straps may be especially helpful in protecting injured areas and preventing lengthwise sliding. Straps should not cross the neck and should avoid bony joints, especially the knees. Padding can be placed under the knees to increase comfort, and can also help prevent the patient from sliding longitudinally in the litter. In technical terrain, the patient should always wear a harness secured to the main lowering or belay line.

Vacuum mattresses conform to the contours of the patient's back and can be secured in the litter. The patient should be secured first into the vacuum mattress, and then the vacuum mattress should be placed into the litter.[66] Padding can be placed under the knees or the mattress can be set with the knees flexed. With rucksack stretchers, the hip belts can be used as tie-in straps. One hip belt can go around the patient's forehead, one around the chest, and one around the legs, with care taken not to fasten chest straps too tightly or to cross the knees with the leg straps.

Theoretically, a patient should be transported on one side (i.e., left or right lateral decubitus) in the recovery position to prevent aspiration should the patient vomit. However, it can be difficult to stabilize a patient in that position, even with a vacuum mattress. Because the patient will almost always be transported supine and will be well secured in the litter, close monitoring is crucial. The litter and patient should be turned to one side to protect the airway if vomiting is imminent.

Transferring a patient onto a litter or vacuum mattress can be difficult. Patients who are not injured or who have only minor injuries may be able to transfer themselves without assistance. In most technical situations, an efficient method of transferring an injured patient onto a litter is to have two or more rescuers pick up the patient while another rescuer slides the litter into place underneath from one end. Extrication devices can be useful to help stabilize the spine during transfer, especially in technical terrain (Figure 56-31). Rescuers can use the patient's clothes or sleeping bag as handles to lift the patient. Alternatively, if it is

FIGURE 56-31 Extrication device in a mass-casualty mountain rescue operation in Alaska. The patient was subsequently placed on the vacuum mattress and then in a rigid litter. Bystanders who hiked up to the scene can be excused for not wearing helmets, but professional rescuers who were flown in by helicopter either did not have helmets or removed them, placing themselves in danger from falling rocks. Only the volunteer rescuer is shown wearing proper head protection. *(Courtesy Ken Zafren.)*

easier to load the litter from the side (e.g., when on a narrow ledge), the patient can be turned to rest on one side and then rolled onto the litter. This can be difficult, because the patient must be levered over the edge of the litter.

USE OF AIRCRAFT IN MOUNTAIN RESCUE

Rescuers should never board an aircraft of any type without their personal packs and survival gear. Sometimes rescuers are encouraged to put packs and other equipment on a second aircraft or a later flight of the same aircraft to put more rescuers on the first aircraft or first flight. This is a dangerous practice. Rescuers who are given this choice before flying into a mission should refuse to board the aircraft until it is guaranteed that all rescuers will not be separated from their personal packs and survival gear during the flight. Rescuers should also guarantee that they will not be flown out from a mission without their personal packs and survival gear. The second helicopter or second flight may not arrive as a result of changes in weather, changes in plans, or a crash. None of these circumstances can be controlled by rescuers, so they should never be separated from their personal packs and survival gear.

FIXED-WING AIRCRAFT IN MOUNTAIN RESCUE

In many parts of the world, rescue has become nearly synonymous with use of helicopters. This is especially true in Western and Central Europe,[18] in mountainous terrain near urban areas in other developed countries, and in many national or provincial parks popular with climbers. Although it is not feasible to execute a technical rescue from an airplane, fixed-wing aircraft can sometimes provide important support for technical rescue, including transportation of equipment and personnel to and from the scene as well as evacuation of a subject who has been rescued. Fixed-wing aircraft (i.e., airplanes) can be useful, especially when distances from bases are more than 160 km (100 miles), which is the usual range of helicopters. Some military helicopters are equipped with in-flight refueling capabilities that can greatly extend their useful range. These helicopters depend on fixed-wing refueling airplanes for extended-range operations.

Airplanes can be adapted with skis for snow landings (Figure 56-32) and with floats for water landings. If they are unable to land, airplanes can often be used to airdrop medical equipment, survival equipment, or supplies. Airplanes are frequently used for technical rescues, especially in remote glaciated areas that are far from helicopter bases. Medical care in airplanes is discussed in more detail in Chapter 58.

FIGURE 56-32 Ski-equipped Helio Courier landing on a glacier in Alaska. *(Courtesy Ken Zafren.)*

FIGURE 56-33 Aerospatiale Lama helicopter operated by Air Zermatt, Switzerland. The Lama has limited aeromedical capabilities, but is capable of rescue at altitudes of more than 4000 m (13,100 feet). *(Courtesy Ken Zafren.)*

HELICOPTER RESCUE IN THE WILDERNESS

The sight of a horse makes the strong man lame.
—OLD AFGHAN PROVERB

The sight of a helicopter makes the strong rescuer lame.
—NEW PROVERB

Few changes in the last few decades have affected search and rescue more than the use of helicopters. In emergency and disaster response, helicopters combine versatility as search and reconnaissance platforms with unparalleled rescue and extrication capabilities (Figure 56-33). With rotor tips that turn at more than 250 km/hr (155 mph), this uniquely valuable asset is also potentially dangerous.[109] Helicopters present real hazards to rescuers. In the United States, data from the National Park Service show that rescuers are more likely to die from aviation-related causes, primarily crashes, than from all other causes combined.[109]

HELICOPTER CAPABILITIES

Helicopters are multiuse aircraft that can perform a variety of missions, including:

- Searching for or attracting a subject
- Evacuating ill or injured subjects
- Transporting or extricating field members
- Short hauling or helirappelling to the site of a subject
- Aerially surveying topography

Although fixed-wing aircraft are generally used for searching large open areas for obvious clues (e.g., ski tracks, tents, downed aircraft), helicopters can be used to search areas such as cliffs, gullies, and cliff bottoms that are more difficult to scan from airplanes. Helicopter noise may attract the subject of a search who, in turn, may attempt to attract the attention of those on board the helicopter.

Helicopters are often used in rescue situations to transport ill or injured subjects to medical care. There are a number of methods used by rescue teams to evacuate injured subjects; these methods include external loads, including use of hoist systems or long lines with a fixed external load. Helicopters can also assist with logistic support by transporting rescuers and their gear. This can be especially helpful for speeding up a rescue and for decreasing rescuer fatigue. Helicopters often enable completion of otherwise impossible missions.

SAFE USE OF HELICOPTERS

To use helicopters safely in a search or rescue operation, the rescue leader must understand risks associated with helicopters and rescue operations and perform a risk-benefit analysis. For example, the risk for a helicopter to evacuate a healthy search subject to avoid a 1-hour walkout with rescuers in easy terrain is dubious at best. Conversely, the potential benefit of air rescue is significant if a subject is unconscious with a head injury. The decision to activate a helicopter depends on a combination of rescue circumstances and flight and safety conditions.[43,124]

In Western Europe, where the number of mountain accidents dwarfs the number in the United States, helicopters are constantly responding to calls for help in the mountains. Without helicopter rescue programs, many ground search and rescue teams would be overwhelmed by the number of callouts and would be unable to meet the demand. Risk-benefit analyses must take into account the entire rescue environment. Regardless of location and urgency, helicopters should not be used for missions that are beyond the capabilities of the equipment or crew training. Many accidents have occurred when these capabilities have been exceeded.

TYPES OF HELICOPTERS

Many types of helicopters are capable of responding to search and rescue operations, but not all are suited to the tasks that their crews may be willing to undertake. Search and rescue personnel should maintain a healthy skepticism about the capabilities and safety of any helicopter and crew with which they have not worked in training or on previous missions.

Aeromedical Helicopters

In North America, most search and rescue teams in developed areas have access to local aeromedical helicopters, because many rescue missions occur within the proximity of an urban trauma hospital. Flight nurses or paramedics who are specially qualified in critical care medicine usually accompany each flight. Aeromedical helicopters carry one or more supine adult patients, depending on the aircraft type and internal configuration. In other areas, such as most of Western Europe, aeromedical helicopters with physicians on board are widely available.[18]

Emergency medical equipment, including cardiac monitors and defibrillators, airway management equipment, oxygen, and emergency drugs, are standard on most aeromedical helicopters. "Air ambulance" services provide a rapid response by an emergency medical team to begin stabilizing the patient on scene and rapidly transport the patient to an appropriate hospital for definitive care.

Search and rescue team members should be aware of the methods by which aeromedical helicopters are dispatched. In North America, this is usually controlled by a local emergency operations manager. Some search and rescue teams may be able to request these helicopters directly. If a rescue description indicates that an aeromedical helicopter may be necessary, these specially equipped helicopters should be put on standby before rescuers are on scene. This allows the pilot and flight crew an opportunity to familiarize themselves with the terrain, weather conditions, and type of emergency before they are actually dispatched.

In Europe, aeromedical helicopters are often equipped for technical rescue and have crews with highly trained rescue personnel who are capable of technical rescue and external load operations[69] (Figure 56-34). In the United States, most aeromedical helicopters do not have these capabilities and the crew is not trained to operate in technical terrain. It is a dangerous practice to use aeromedical helicopters for technical rescue unless the helicopter is equipped for technical rescue and the crews are specially trained. In some cases, aeromedical helicopters can land in nontechnical terrain to bring rescuers closer to a scene and to receive patients who have been rescued from technical terrain by qualified personnel.[43]

Law-Enforcement Helicopters

In many countries, law-enforcement agencies operate helicopters, especially near large cities. Some law-enforcement helicopters have search and rescue as one of their missions and are capable of rescue operations in technical terrain. Others have no

FIGURE 56-34 Eurocopter EC 135 operated by Austrian Air Rescue shown performing a short-haul operation. This is a fully equipped aeromedical helicopter capable of performing mountain rescue operations, including hoist and short-haul operations. The crew includes an "emergency physician" *(Notarzt)*, who may be an anesthesiologist, an orthopedic surgeon, a general practitioner, or another specialist with additional training for mountain rescue. *(Courtesy Ken Zafren.)*

training for mountain operations and sometimes have altitude limitations. Rescue teams should know the limitations of local law-enforcement helicopters and their pilots.

Commercial Helicopters

Commercial helicopters may be available to rescuers on an occasional basis or on contract. These may be a valuable resource, although there may be a fee for their services. A preplan should be made with rescue authorities and the company operating the helicopters. Rescuers must be aware of the limitations of helicopters and crews and should not use commercial helicopters for technical rescue unless the helicopters are capable and crews properly trained.

Media Helicopters

Search and rescue teams close to large cities with television stations may be fortunate to have at their disposal one or more media helicopters. Although these may be a valuable resource for transporting rescuers and gear, they are seldom capable of technical operations.

Military Helicopters

Civilian rescue teams are sometimes involved in rescues with military helicopters. Many of these helicopters are not suitable for high-altitude terrain and should not be used above their service ceilings (i.e., safe working altitudes). In the United States, military rescue teams operated by the Air National Guard, and in coastal areas by the Coast Guard, are highly capable in technical terrain, but the helicopters that they use (e.g., Pave Hawk, Jayhawk) have very limited high-altitude capabilities. Specially equipped turbo-Chinook twin-rotor helicopters are operated by the Air Force in the interior of Alaska. These always travel in pairs and, although they may take hours or days to launch, are capable of high-altitude operations as high as 6200 m (20,300 feet) in the Alaska Range. Rescue operations at very high altitudes, especially above 6500 m (21,300 feet) in the Karakorum Range in Pakistan and in the Himalayas (particularly in Nepal) operate with very little margin for error and are justified only in desperate situations.

LIMITATIONS OF HELICOPTERS

The advantages of helicopter use during emergency operations must be weighed against the risks. Rescuers should be aware of the limitations of helicopters. Conditions such as altitude, weather, and terrain all affect the usefulness of helicopters in search and rescue operations. All aircraft are limited by their service ceilings, which can change based on temperature and humidity. Rescuers must be prepared to say that the mission is a "no go" when the risk assessment indicates that risks outweigh benefits.

Visibility Minimums

Rules governing visibility minimums in helicopter operations vary widely by country. Although night helicopter operation for rescue with night-vision goggles is common in countries such as Switzerland and Austria, it is illegal in Italy. In the United States, there are specific minimums that have been clearly delineated by the Federal Aviation Administration (FAA) for day and night helicopter operations for cases in which visibility is limited. Under FAA rules, smaller helicopters generally do not have *instrument flight rules* (IFRs) capability and must fly under *visual flight rules.* Visual flight rules for helicopters mean that flight conditions must be clear of clouds, and operations must not exceed an airspeed that enables the pilot to see and avoid collision.

No matter what the local or national rules are, visibility minimums are important to rescuers and crews who operate rescue helicopters. A large number of helicopter crashes are caused by pilots flying into adverse weather conditions, resulting in uncontrolled flights into terrain. Rescuers must be particularly cautious when weather conditions limit visibility.

IFRs apply to aircraft with special navigational instruments that give the pilot greater capability in otherwise difficult flying conditions. IFRs allow for flying in conditions in which electronics provide the pilot with information that is not available to the naked eye. Larger helicopters, such as most of those used in search and rescue operations, can be equipped with instrument flight capability. Still, rescuers should carefully balance the benefits of using a helicopter in a rescue setting with the increased risk of flying the rescue under IFRs.

Weather Conditions

Turbulence can be a serious problem for helicopters. Mornings are usually the best time for helicopter flight, because there is less turbulence than during afternoons. Afternoon turbulence results from heating by the sun later in the day. Cumulus clouds indicate turbulence with strong updrafts and downdrafts. In addition, there are often downdrafts over the central portions of valleys. Downdrafts are especially dangerous at high altitudes because of reduced engine power. Updrafts often form directly above or on the sunny sides of ridges. Leeward sides of ridges may have severe downdrafts.

For areas in which ground-based operations are possible, even if a helicopter is on its way to evacuate a subject, ground personnel should still be dispatched to the scene with necessary equipment to transport the subject. The helicopter may not reach the subject as a result of malfunction, changes in weather, or other unexpected complications. One should never assume that a helicopter en route will become a helicopter on scene.

Fuel

Each helicopter has a range limited by its fuel supply. In many regions, this is important because helicopters may be based far from a mountain search and rescue mission. In some areas, a mobile fuel tanker can be stationed at a heliport that can be accessed by road. In more remote areas, fuel caches at a forward heliport can enable a mission to continue with limited interruptions for refueling. Otherwise, a helicopter may have to fly a long distance to refuel, losing valuable time and limiting use of a crucial resource.

Safety Precautions on the Ground

Safety training for rescue ground personnel must include procedures that require special care in and around helicopters, either on the ground or in the air. Whenever possible, helicopter operations should occur during daylight hours, usually defined as 30 minutes before sunrise to 30 minutes after sunset. Rescue personnel must be aware of wind velocity and visibility and not dispatch helicopters when predicted wind velocity exceeds helicopter limitations.

Helicopter hand signals should be used whenever possible, but only by personnel trained in their use. All personnel should stay at least 30 m (100 feet) away from helicopters, except when loading or unloading.

Landing Zones (Helispots)

Contrary to popular belief, helicopters do not normally land "on a dime." Pilots require, or at least prefer, sizable landing zones, particularly at high elevations. Helicopter pilots generally will not take off or land vertically. Rather, they require a *landing zone* (often called an *LZ* or a *helispot*) that may be more than 100 m (330 feet) long. The ideal helispot is a flat strip that is at least 30 m (100 feet) wide and 90 m (300 feet) long; roughly the size of an American football field. In the field, flat ridges and saddles may provide the best helispots. The primary reason helicopters need large landing zones is that a helicopter with engine failure needs extra room to land safely. Engine failure most commonly occurs during takeoff or landing.

Landing Zones in Confined Spaces

Helispots should be designed in such a way that the helicopter can land and take off into the wind to increase lift. Only as a last resort should a *hover-hole* helispot be chosen. This is a landing zone where, due to size restrictions, the pilot must slow to a hover above the landing area and then descend to the ground. When taking off, the pilot must use all available engine power, which leaves little room for error.

Because helicopters can generate rotor wash in excess of 160 km/hr (100 mph) during takeoffs and landings (and significantly more for very large helicopters such as Chinooks), the helispot should be free of objects that can blow away. Tall dry grass and shrubs should be avoided to prevent possible damage to the sensitive tail rotor, and tree stumps should be less than 0.3 m (1 foot) high. A snowfield can make a good helispot. Markers such as backpacks and garbage bags filled with rocks or snow should be placed near the helispot to give the pilot a frame of reference for depth perception.

Night operations are becoming more common with availability of IFR and night-vision goggles. Because night landings and takeoffs are significantly more dangerous than similar maneuvers during the day, rescue leaders must consider the risks and benefits of performing night operations. The pilot must be aware of optimal flight paths to avoid hazards such as trees, peaks, ridges, and power lines.

Landings and Takeoffs

Landings and takeoffs are generally easier in the presence of a light, steady breeze of about 20 km/hr (10 knots or 12 mph) than they are in still air. In addition, pilots may choose not to take off or land in a wind of more than 80 km/hr (45 knots or 50 mph) or with a gust spread of more than 37 km/hr (20 knots or 23 mph).

When landing, a pilot will often make a high-level pass over the helispot to observe obstacles and wind indicators and then will come in on a final approach. Despite the tendency to watch during this approach, all personnel who are not in the helispot should look away to avoid injury caused by flying debris kicked up by the rotor wash. Ground personnel must hold down any loose gear.

During the final approach, only one ground person should be near the helispot. This person is sometimes referred to as the *ground contact* or the *parking tender*. With the helicopter some distance away, the touchdown point is indicated by the ground contact standing upwind, back to the wind and arms facing the desired landing spot.

During landings on snow, no rescuer should be in the landing zone at any time. The helicopter's weight can cause it to settle in the snow, which could be dangerous for any rescuer in the helispot.

The ground contact should be the person most familiar with helicopter operations, including landing zones, ground-to-air communications, and helicopter safety. When the helicopter is within radio range, the ground contact should make radio contact with the pilot. Knowing that a knowledgeable ground contact is available will be helpful for most pilots flying into mountainous

FIGURE 56-35 Helicopter loading. *(Courtesy Will Smith.)*

terrain. Medical providers at the scene should generally not also be ground contacts; they should focus on patient care.

LOADING AND UNLOADING

Approaching the Helicopter

Before approaching a helicopter, rescuers must be sure that the pilot is finished landing. Often the pilot will need to jockey the helicopter around before being able to ease off on power. At this point, there will be a noticeable change in the engine sound. The pilot might give a thumbs-up sign to indicate that it is safe for a rescuer to approach. Many helicopters can come to a full rotor stop in a few minutes, so approaching a helicopter with turning rotors may be an unnecessary risk.

Only one person should approach a helicopter after it lands. This person should approach only when signaled by the pilot or crew chief. No one should approach the helicopter unless specifically instructed to do so. When approaching, all equipment such as packs, skis, snowshoes, and ice axes should be carried horizontally below waist level and never upright or over a shoulder. Skis are especially dangerous, because mountaineers often carry them upright and over one shoulder.

With very few exceptions, rescuers should approach the helicopter only at an angle that is visible to the pilot. There is never reason to go back past the skids or side doors, except in the case of helicopters with rear-entry doors (Figure 56-35).

Rescuers approaching a helicopter should squat in a low profile to maximize head-to-rotor clearance. Rescuers should bend down, but they should always look at the pilot. Depending on the helispot and other flight factors, the pilot may have to maintain some power. If this is the case, the helicopter may pull off suddenly as a result of precarious positioning or because of ground resonance, which happens when the helicopter begins to vibrate as a result of harmonic imbalance between landing gear and rotor blades. In either of these cases, the helicopter must become airborne.

In an ideal situation, the pilot will bring the helicopter to a full rotor stop (i.e., "cold" loading and unloading). In this case, no rescuer should approach until the rotors have come to a complete stop. It usually takes at least 2 minutes for the engine to cool down.

Loading and Unloading Safety Procedures

Each of the loading and unloading guidelines listed in this section assumes that the helicopter must maintain rotor power (i.e., "hot" loading and unloading). This markedly increases the hazard as compared with loading and unloading a helicopter in which the rotor is stopped (i.e., "cold" loading and unloading).

All loading and unloading must take place on the downhill side of the helicopter, because the rotor blade may be as close as 1.5 m (5 feet) from the ground in many helicopters, even on level ground (Figure 56-36).

The tail rotor should be avoided at all times. This rotor may not be visible while turning at high speed. Serious injuries and deaths have resulted from careless personnel coming into contact with the tail rotor. The pilot should see all personnel who are within reach of the tail rotor so as not turn the tail around in their direction.

As the rescuer approaches the helicopter, a backpack should be carried rather than worn. Once onboard, the rescuer should immediately buckle in to the seat belt and secure all equipment.

Helicopter crashes are uncommon, but it is best to be prepared. Rescuers should make every effort to keep their backpacks within reach. Small packs can sometimes be stowed between the feet while larger packs may often be placed on the laps of the rescuers. It is best to have one's survival gear, including a handheld radio, nearby in case of a crash.

One-Skid Landings

Usually a helicopter will be fully on the ground when rescuers enter or exit. However, there are conditions in which the pilot is only able to put one skid down and may be in a semihovering state while rescuers board or exit. This situation is called a *one-skid landing*. The helicopter maintains a high rotor speed to keep itself level in the air. Extra caution is required for one-skid or hover boarding and exiting. It is best for rescuers to train for these operations with the pilots. At a minimum, the pilot should brief rescuers about procedures, including hand signals.

Helicopters are very sensitive to weight and balance. Stepping in or out of a helicopter that is balancing on one skid should be done very gingerly to avoid sudden weight change on one side of the helicopter. The probability of a downdraft, power settling, or recirculation effect occurring is high during a hover or one-skid landing. In the case of one-skid unloading, communication between pilot and rescuers is essential. The pilot needs time to adjust the controls for the increased or decreased load coming onto or off of one side of the helicopter. The last thing that the pilot wants is for a heavy, clumsy rescuer to jump from the ship.

To exit a helicopter that is in a one-skid landing position, the rescuer should not open the door until told to do so by the pilot. When the door is open, the rescuer first puts the backpack on the ground. It is important for the rescuer to let the pilot know when this is about to happen. Shifting weight, especially in a small helicopter, can have a major effect on balance and center of gravity, so the pilot must be prepared. With the headset still on, the rescuer tells the pilot, "On the count of three, I will put my pack down: one, two, three." Occasionally, the rescuer actually has to drop the pack out. The rescuer then prepares to exit the ship.

With the headset still on, the rescuer completes all communications with the pilot. It is pointless to attempt to yell at the pilot without a radio headset. The rescuer tells the pilot, "I will step smoothly from the ship after the count of three. Do you understand?" The pilot will either agree or advise otherwise. At this point, after approval from the pilot, the rescuer removes the headset and then removes the seat belt and refastens it behind himself or herself while staying in the seat. The rescuer counts to three with fingers in view of the pilot and gently exits the

FIGURE 56-36 Helicopter unloading. Note the crouched positions of the rescuers who are carrying rather than wearing their packs. *(Courtesy Will Smith.)*

ship. Frequently, the area in which a one-skid landing takes place is steep and complicated terrain. It may be impossible to move away from the helicopter. Once on the ground, the rescuer stays next to the helicopter and as low to the ground as possible. Alternatively, if instructed to do so by the pilot in advance, the rescuer will move quickly away from the helicopter toward the front and on the downhill side so that the pilot can leave the area as rapidly as possible.

If there is more than one rescuer offloading via a one-skid landing, rescuers exit one at a time. Communication is especially critical for any rescuers in the back seat of small helicopters, because the pilot may not be able to see them. Once on the ground, rescuers should hold their positions and stay crouched as low as possible, or, if instructed to do so by the pilot, they should quickly move away from the helicopter toward the front and on the downhill side so that the pilot can leave the area as quickly as possible.

Loading and Unloading Without Moving Toward or Away from the Helicopter

In technical terrain, the safest method of unloading is often for the helicopter to land and for rescuers to disembark but not to move away from the helicopter. This technique can be used with a one-skid landing or a full landing, but it is usually only done when the helicopter will not shut down (i.e., "hot" unloading). In the case of a one-skid landing, the rescuers exit the helicopter on the side of the skid that is on the ground after being cleared to do so by the pilot. Rescuers should still move slowly and gently as they shift positions in the helicopter, as well as when putting their packs on the ground and exiting themselves, because each movement changes the weight and balance of the helicopter. It is much easier for the pilot to compensate for gradual changes than for sudden ones. Like all the techniques in this chapter, it is best to practice loading and unloading in training, before an actual mission occurs.

The reverse procedure of the helicopter landing right next to the rescuers may also be the safest method of loading. In the case of reloading in the same place that one has unloaded, the pilot will usually want rescuers in the same spot in which they unloaded. The unloading procedure is then reversed. The techniques of unloading and loading the helicopter with the rescuers and any subjects next to the helicopter and not moving toward or away from it keeps rescuers and subjects away from the rotors. Like all helicopter operations in technical terrain, these should only be performed by pilots who are trained, experienced, and highly qualified to fly in mountainous terrain.

Hover Load and Hover Jump Operations

An even more risky loading technique occurs when the helicopter hovers very near but does not touch the ground while rescuers and subjects either enter or exit the aircraft. This situation is referred to as a *hover load* or *hover jump*. This is a very dangerous operation that should be avoided unless it is absolutely necessary. Center of gravity variations add to the risk of hover operations, because helicopters are very sensitive to changes in weight and balance. Jumping out of a hovering helicopter causes a dramatic shift in the center of gravity and must be coordinated with the pilot. It is preferable to try to find or make a place to land rather than performing one-skid or hover routines.

EXTERNAL LOADS

In some situations, terrain or other circumstances dictate a technical rescue in which the helicopter is unable to land or to perform a one-skid or hover operation. Rescuers can be inserted or rescuers and subjects can be extracted using external load operations. Such operations include hoist and long-line operations.

Hoist Operations

Hoist (or *winch*) operations occur when rescue personnel aboard the helicopter either insert or extract personnel or gear using an electric hoist and cable setup. During a hoist insertion operation, a load consisting of a rescuer, litter, other gear, or some combination is attached by a specialized rescue harness to the end of the hoist cable and then lowered to the ground by a hoist operator on board the helicopter. The hoist operator communicates with the pilot to ensure that the rescuer is placed at a suitable ground location (Figure 56-37).

FIGURE 56-37 Pave Hawk hoist operation. The Pave Hawk is a version of the Black Hawk helicopter that is especially equipped for rescue operations. Shown here are two rescuers who are about to be inserted into a rescue scene. *(Courtesy Ken Zafren.)*

Litters being lowered often start to spin, so the insertion point should not be directly above rescuers or subjects on the ground if at all possible and any rescuers on the ground should use extreme caution. Rescuers on the ground should not contact any load hanging from a helicopter until it has touched the ground. Loads may carry a large static charge that can cause injury to a rescuer if not discharged by ground contact.

A hoist extraction uses the same system. A load, which may be a rescuer, subject, litter, gear, or some combination, is attached to the cable at the ground. The hoist operator raises the load to the aircraft using the hoist. A light rope called a *tag line* is usually attached to a litter while it is being raised to prevent it from spinning (Figure 56-38).

In most cases, rescuers and subjects are hoisted up and brought inside the aircraft. In some cases, however, the hoist operator brings its human cargo only as far as the skid, where these individuals remain until the pilot finds a suitable helispot to transfer them on board. A subject who does not require spinal stabilization and who is not already wearing a harness can be placed in an extra harness carried by rescuers or in an improvised harness for hoisting or for short-haul operations, which are described in the next section. An alternative is a Bauman Screamer Suit or similar device that can be placed quickly on the subject to provide a secure means of suspending the patient during lifting and lowering. Horse-collar–type harnesses are extremely dangerous and should never be used because they can put pressure on the brachial plexus. Subjects and rescuers have fallen out of horse-collar–type harnesses, sometimes with fatal consequences.

Short-Haul (or Long-Line) Operations

Short-haul operations are similar to hoist operations in that cargo, including people, hangs below the aircraft (Figure 56-39). The difference in a short-haul operation is that the line hanging below the aircraft is not attached to a winch, and the cargo is transported while hanging below the aircraft. The term *short haul* usually refers to live loads, whereas *long line* is applied to body recovery or other nonliving cargo.

FIGURE 56-38 Preparing to hoist. The rescuers are preparing to hoist a litter with a subject into a Pave Hawk helicopter. A tag line was used to prevent the litter from spinning. *(Courtesy Ken Zafren.)*

Short-haul operations may be the most suitable rescue technique for an injured or uninjured climber who is unable to ascend or descend. A rescuer can be inserted by short haul and can proceed to rescue the subject in a pickoff.

Short-haul and hoist operations are dangerous and difficult for subjects. Although rescuers may be familiar with and experienced in such operations, subjects may become quite anxious when being suspended from a helicopter. The same precautions regarding spinning loads and avoiding contact with charged objects apply to both short-haul and hoist operations.

Helirappel

A final method of external operations in technical terrain involves rescuers rappelling from a helicopter while the aircraft maintains a full-power hover above the scene. A common method of insertion in military operations, a *helirappel* involves significant risks. The helicopter must operate at full power, often in a confined space, with little margin for error and minimal room for the pilot to make a controlled landing if there is a problem. Rescuers planning to do helirappels should be experienced at free rappels (i.e., rappels in which their feet cannot touch the terrain), should be able to rappel smoothly at a controlled speed, and should be able to remove all connections with the rope rapidly after establishing a safe stance on the ground. Rescuers should not attempt to rappel down a rope that has been tangled by rotor wash, and under no circumstances should they rappel down a rope that is not touching the ground. It is helpful to tie a large knot on the end of the rope to avoid rappelling off the end if the helicopter has to increase altitude during the rappel. Short-haul operations have largely replaced helirappels for civilian operations.

FIGURE 56-39 Short-haul operation. *(Courtesy Will Smith.)*

PATIENT CARE IN HELICOPTER OPERATIONS

Even in well-equipped aeromedical helicopters, patient care can be compromised by noise, vibration, and cramped conditions. Unless there is no other option, only the most stable patients should be transported without an attendant who is capable of medical interventions. If there is any question that the patient's airway may become compromised and if it is possible to secure it, this should be done before transport.

Use of aircraft in wilderness medicine is discussed in more detail in Chapter 58.

UNMANNED AERIAL VEHICLES

Unmanned aerial vehicles (UAVs) are multiuse aircraft, commonly called *drones,* which can perform a variety of missions, including:

- Searching for or attracting the attention of a victim
- Aerially surveying topography
- Transporting medical or technical materials

UAVs have been used in simulations to support assessment and decision making for search and rescue operations in wilderness areas, including avalanche rescue[2] and mass casualty incidents.[1] Although some studies have shown limitations, advances in video enhancement and mapping of search progress, as well as ongoing work to model the likely location of a missing person, could lead to improvements in UAV path planning, search quality, and likelihood of finding a moving missing person.[29] UAVs can also be used to assist with logistic support by transporting various materials and gear. This could be especially helpful for self-rescue when conditions are not safe for other rescuers.

CANYON RESCUE

CANYON HAZARDS

Canyons have dangerous hazards, including confined spaces, often without an easily accessible exit; water dangers, such as whitewater, strong currents, hydraulics, potholes, strainers, waterfalls, and flash floods; hazardous surfaces; and cliffs with rockfall (Figure 56-40). Environmental risks include accidental hypothermia and heat-related illnesses, sometimes occurring during the same trip.[130] Canyon hazards are discussed in more detail in Chapter 98.

There are few epidemiologic studies to date on canyoneering injuries and canyon rescue. One web survey identified heat illness and dehydration as the most common major problems; hypothermia was the next most common.[114] Major orthopedic injuries, falls, drowning, and animal bites, including snakebites, also occurred. Most injuries were minor, predominantly cuts and scrapes. A recent study of canyon rescue from Aragon, Spain, identified 520 patients.[112] Most rescues (63%) involved difficult terrain, often requiring technical skills. Ninety percent of rescued subjects were injured or had a medical condition or disability related to exposure. Most patients (81%) were injured; 74% of injuries involved the lower extremities.

Preplanning and preventive measures are important during canyoneering and canyon rescue to avoid technical failures and human error. Canyoneers should consider the consequences of technical or human lapses in order to develop backup plans. A careful evaluation of water flow is crucial during canyoneering and canyon rescue operations. Water level and flow can change dramatically, often without warning.

FIGURE 56-40 Complex rescue in a canyon. *(Courtesy Michael Kammerer. Copyright KONG [kong.it/].)*

FIGURE 56-41 Standard canyon anchor expansion bolt *(right)* and glue-in bolt *(left)*. *(Courtesy Giacomo Strapazzon.)*

CANYON ANCHORS

Canyoneers work below anchors, reducing the need for shock absorption in the system. For this reason, they often use static and low-stretch ropes. Rescuers must be aware of high potential forces that can be transmitted through the system and to the anchor when using static ropes. High forces generated by rescue loads in rescue systems, especially highlines, can be especially problematic in a canyon environment. Natural anchors include trees, boulders, chockstones in cracks and holes, rock arches, columns, horns, and holes, either natural or drilled into the rock.[11,51] Artificial anchors include climbers' chocks or nuts, deadmen, pickets, pitons, and bolts. Both expansion and glue-in bolts can be used[51,92] (Figure 56-41). Anchor placement may be affected by water-level variation, especially for rescue. Anchors are often connected in a load-sharing system using stainless steel "chains" formed by chain links, rings, and carabiners. These hard goods are less susceptible to environmental damage than are slings, ropes, and other soft goods. Sand (or cobble) bags can provide a temporary anchor for single-rescuer descent, but are not suitable for rescue operations with a litter or large load.

CANYON DESCENT

Rope techniques for progression down a canyon are based on releasable rappels. More detail on descent techniques is given in Chapter 98. Rappel and rope handling techniques used by climbers and canyoneers have similarities and differences. In a dry canyon, rope is threaded through the anchor and canyoneers rappel on both strands, with security provided by an autoblock knot. This is the same method usually used by climbers. Rappelling around or near flowing water is very different than rappelling on a climb. Especially in wet canyons, canyoneers commonly rappel on a single strand without an autoblock to avoid drowning if they are stuck on the rope under a waterfall or in a hydraulic. A knot block, or a blocked figure-eight descender, is placed against the metal rappel ring and secured with a carabiner at the midway point of the rope[4] (Figure 56-42). The strand opposite the block is used for descent, and the other strand is carried down by the last canyoneer to descend. The second strand is then pulled down to retrieve the rope. Special techniques have been developed so canyoneers can move safely and quickly in canyons with slippery rocks, waterfalls, and swift water. Accessing the anchors can be more dangerous than the actual rappel. The leader can reach a lower anchor by self-lowering from the anchor above or be belayed by a party member[4] (Figure 56-43). Once attached to the chain, the rope acts as a fixed line for the rest of the party (Figure 56-44). Floating anchors use the force of water current to tension a rope so that a party can pass whitewater and hydraulic obstacles at the bottom of a waterfall.

FIGURE 56-42 Knot block in a closed system. A knot block is placed against a glue-in bolt and secured with a carabiner *(left)*. After removing the lanyard (pink rope), the canyoneer can descend on the opposite strand *(right)*. *(Courtesy Giacomo Strapazzon.)*

FIGURE 56-43 The leader of a party reaches the lower anchor belayed by a party member. *(Courtesy Inigo Soteras.)*

CANYON ASCENT

Ascending techniques are used to reverse the route out of the canyon or to bypass a knot in the rope. At least one group member should bring mechanical ascenders. Every canyoneer should carry a few slings, usually made from Kevlar, to make soft cams such as Prusiks, Klemheists (also known as Machards or French Prusiks), or Bachman knots, to be used in an emergency.

CANYON SELF-RESCUE AND COMPANION RESCUE

Accidents in canyoneering are often related to being stuck under water. Self-rescue emergency techniques may allow a canyoneer to release jammed gear or body parts. To free clothing, hair, or straps caught in the belay device, or a hand or fingers caught by the rope, take the load off long enough to pull up some slack and remove the object or body part. This technique, called a *step-up above the jam,* is the way to release from a weighted rope. Step-up tools include mechanical or soft cams and foot loops. Due to the potential hazards of using sharp instruments in the vicinity of safety ropes, cutting jammed clothing, hair, or straps should be considered only as a last resort. Cutting the harness attachment to the descender is another emergency technique.[4] Some harnesses have a metal ring at the point where the descender attaches. In that case, the harness itself must be cut. This technique should be used only when a canyoneer is stuck on the descending rope and does not have a mechanical or soft descender.

If self-rescue is not possible, companions should use emergency rescue techniques. Rescue by descent should be used only where the route is vertical and without obstacles, and the suspended canyoneer is conscious.

Special precautions are necessary for rescue pickoff of an unconscious subject in flowing water or a waterfall, both of which are common in canyons.[4] The rescuer must avoid becoming stuck and increasing the risk of drowning. A rescuer usually reaches the subject by descending. Once the subject is reached, the rescuer secures the subject to the rescuer's lanyard and performs the pickoff; after rappelling, but before entering the water, the rescuer blocks the descender and attaches the subject to the end of the emergency rope. The rescuer removes the subject from the lanyard and cuts the emergency rope under the descender. By holding the emergency rope but not being attached, the rescuer maintains control over the subject but eliminates the risk of becoming caught with the subject in hydraulics.

If having a companion rescuer descend to a canyoneer is too dangerous, as with a canyoneer in a waterfall, a rescue pickoff can be done with a "cut and lower" technique using a second rope.[4] The multianchor (which may be a hardware chain) is replaced and secured with quickdraw extenders using screwgate carabiners, each of which is attached to one of the two bolts or rappel rings. The canyoneering rope strand above the block is secured with a Munter hitch knot to one of the carabiners, and the webbing of the previous anchor system is cut or the hardware chain removed. When the risk is acceptable, rappel and rope handling procedures on a single strand offer great advantages for rescuing a canyoneer stuck on a descent with obstacles or who is unconscious. A rescue pickoff *cut and rappel* is a procedure using the other strand of the rope (or another rope) by the rescuer. *Rig-on-the-rope* with a rebelay (e.g., using a Klemheist knot) is an option for high-angle rescue pickoff when the rope might run over sharp edges, when the emergency rope is relatively thin, or when it is necessary to back up the rappel.[4]

The methods above apply when the subject is trapped while rappelling, but rescue may be necessary when the subject is moving through flat or flowing water. Water rescue techniques include use of a throw bag if the canyoneer is conscious. Otherwise one rescuer enters the water belayed by a second rescuer and performs the rescue (Figure 56-45). Water rescue techniques are outlined in more detail in Chapter 62.

FIGURE 56-44 A fixed line for safety of rescue party members on an exposed anchor in a canyon. *(Courtesy Oskar Piazza.)*

FIGURE 56-45 Water rescue of an unconscious patient in a hydraulic. One rescuer enters the water belayed by a second rescuer. *(Courtesy Erwin Kob.)*

When companion rescuers are below a stranded canyoneer who cannot self-rescue, there is no choice but to rescue from below. If the distance is less than 10 m (33 feet) and there is no waterfall, the rescuer should ascend the rope. Once the rescuer is above the subject, the rope is used to lower the subject with a *rig-on-the-rope* rescue pickoff.[4] Only expert canyoneers should consider using this technique if the distance is greater than 10 m, as longer distances take more time and increase the risk of damage to the rope. This technique is not recommended for thin ropes.

CANYON LITTERS

The evacuation and transport of subjects in canyon rescue are strongly influenced by environmental and logistic factors, mainly narrow or vertical passages, including streams, potholes and waterfalls, and water or ice exposure. Canyon litters may have specific features, such as buoyancy and the ability to keep a subject dry using a waterproof bag, and they can be positioned horizontally, vertically, or at any angle to adapt to the terrain. A rigid shell protects the subject from impact; face protection is provided by a transparent polycarbonate shield. A float valve allows transport in water. Although a watertight seal is designed to allow relatively easy access to the subject, it can induce claustrophobia and prevent continuous communication. Litter attendants should continuously monitor the subject through the transparent dome, a radio should be provided to the subject, and the sealed zipper should be opened periodically for reevaluation of the subject's clinical status.[4]

When using a canyon litter that is sealed and enclosed, water transport, including direct lowering through waterfalls, is preferable to use of highlines. The characteristics of the canyon litter allow a more rapid rescue by water transport. One rope is attached to the head end for belay and another to the foot end as a backup. Special care should be taken when lowering a litter in a waterfall with hanging potholes. Avoid positioning the litter under a high-flow waterfall in a horizontal position, keep the litter from sliding through a tight passage or through curves where it could become stuck, and avoid potholes. These are all places where a litter may become trapped due to stream flow.[4]

ORGANIZED CANYON RESCUE AND EVACUATION

There are specialized canyon search and rescue teams in many popular canyoneering areas of North America and Europe. Rescue activation may be delayed because canyon walls can interfere with electronic requests for assistance. There is often no exit point through which to send a party member for help. There may also be no alternative entrance to the canyon, so rescuers must start from the beginning of the canyon to reach the subject. After stabilization and packaging of the patient, evacuation is usually horizontal and by descent. In rare cases, such as an accident at the beginning of a canyon, ascending techniques can be used. Cave rescue techniques such as highlines and haul systems are required to keep the litter out of waterfalls and to prevent it from getting hung up on cliffs (Figure 56-46). (Cave rescue is discussed in more detail in Chapter 63.)

Horizontal evacuation can be performed by nontechnical evacuation or low-angle evacuation (described in Chapter 57) or by floating transport. Nontechnical evacuation is performed when there is easy walking over level ground. Four to six attendants in pairs carry the litter facing the direction of travel, usually with a team leader in front. A rope can be attached to the head of the litter for belaying, if necessary. A low-angle, or *scree,* evacuation (Figure 56-47) is performed in a similar fashion over debris or rough terrain with the litter belayed as described in Chapter 57.[4] A floating transport is performed in water-filled passages where attendants may have to wade in deep water or swim. Two to four attendants in pairs guide the floating litter while a litter team leader in front manages a rope attached to the head to keep the patient's head above water[4] (Figure 56-48). If the litter rolls, attendants can right it.

FIGURE 56-46 A highline is used to keep the litter out of a waterfall and a pool. A human anchor is used to speed up rescue operations. *(Courtesy Oskar Piazza.)*

Short descent is used on short jumps and slides. The litter is belayed by a "human anchor" using a rope attached to the head of the litter. The other attendants are placed according to the terrain.

Vertical descent of the litter in a horizontal position is the preferred technique for a seriously injured subject when there is a complicated technical descent (Figure 56-49) (see the technical rescue section earlier in this chapter). Descent with a vertical litter hastens operations but risks the litter being caught in hanging potholes (Figure 56-50).

Vertical descent in a waterfall is supported by litter attendants only if there is no danger from water or if there are hanging potholes that must be passed (Figure 56-50). As a general rule

FIGURE 56-47 Low-angle evacuation over debris in canyon rescue. *(Courtesy Michael Kammerer. Copyright KONG [kong.it/].)*

FIGURE 56-48 Floating transport in a water-filled passage during canyon rescue. *(Courtesy Michael Kammerer. Copyright KONG [kong.it/].)*

FIGURE 56-50 Vertical evacuation with an attendant. The litter is in a vertical position. A second attendant waits in the pool to secure the litter. *(Courtesy Michael Kammerer. Copyright KONG [kong.it/].)*

in rescue operations, all rescuers not needed for technical operation at the anchors should stay behind the litter. After each waterfall descent, rescuers should quickly move to establish anchors for the next jump with material available in rigging bags (Figure 56-51).

HELICOPTER CANYON RESCUE

Evacuation by ground transport in canyon rescue is technically complex even when supported by air rescue. Appropriate use of air rescue is determined by the pilot, medical personnel, and rescue technicians based on patient condition, terrain, and weather. Helicopters equipped with a winch can often transport a rescue team by bringing necessary rescue and medical equipment directly to the accident or to an access site, usually the nearest canyon drop-in point. Helicopters operating in canyon areas should be equipped with appropriate extrication options. Such items my include short-haul or long-line configurations with a cable or rope that is ideally at least 50 m (164 feet) long and capable of carrying two persons.[123] There should be a provision for quick release of anchors in case a helicopter needs to

FIGURE 56-49 Vertical evacuation with an attendant. The litter is in a horizontal position. *(Courtesy Oskar Piazza.)*

FIGURE 56-51 Organization of technical equipment according to standards of the Italian CNSAS canyon rescue team. From left to right: litter bag, rigging bag, rope, and swiftwater progression bag. *(Courtesy Giacomo Strapazzon.)*

FIGURE 56-52 Rescue medical kit. *(Courtesy Will Smith.)*

abandon a hover. Measures should be taken to avoid litter rotation during winch or long-line operations.

TECHNICAL RESCUE RESOURCES FOR MOUNTAIN RESCUE

Online resources for mountain technical rescue include the International Commission for Alpine Rescue (ikar-cisa.org), International Society of Mountain Medicine (ismmed.org), and Mountain Rescue Association (North America) (mra.org).

TECHNICAL RESCUE MEDICAL KIT

The technical rescue medical kit shown in the Appendix is used by Will Smith, MD, paramedic, and medical director/team leader for Teton County Search and Rescue, Jackson, Wyoming, United States. The contents of a medical kit are matters of personal and institutional preferences. No single set of contents can be appropriate for all providers in all practice settings.

The kit is modular. Various components can be quickly sorted and assembled to make an appropriate kit for the anticipated rescue situation. It is designed to be carried in a rescue pack, and the entire kit may be used during a helicopter insertion. A long walk-in or technical insertion will limit the amount of medical gear that can be carried in addition to personal and technical gear (Figures 56-52 to 56-55).

AFTERWORD

There have been joys too great to be described in words, and there have been griefs upon which I have not dared to dwell; and with these in mind I say, Climb if you will, but remember that courage and strength are nought without prudence, and that a momentary negligence may destroy the happiness of a lifetime. Do nothing in haste; look well to each step; and from the beginning think what may be the end.

—EDWARD WHYMPER[129]

FIGURE 56-53 Airway module from rescue medical kit. *(Courtesy Will Smith.)*

FIGURE 56-54 Intravenous module from rescue medical kit. *(Courtesy Will Smith.)*

FIGURE 56-55 Medications module from rescue medical kit. *(Courtesy Will Smith.)*

REFERENCES

Complete references used in this text are available online at expertconsult.inkling.com.

APPENDIX

Technical Rescue Medical Kit*

MEDICATION BAG

Epinephrine 1:1000 (1 mg/mL): 2 ampoules
Prednisone 20 mg: 3 tablets
Diphenhydramine 50 mg/mL: 1 vial
Etomidate 20 mg/10 mL intravenous formulation: 2 vials
Ketamine 500 mg/5 mL: 1 vial
Midazolam 50 mg/10 mL: 1 vial
Succinylcholine 200 mg/10 mL: 1 vial (stored in refrigerator)
Rocuronium 50 mg/5 mL: 1 vial (stored in refrigerator)
Vecuronium 10 mg: 2 vials
Dexamethasone 20 mg/4 mL: 1 vial
Cefazolin 1 g: 2 vials
Ceftriaxone 1 g: 1 vial
Ketorolac 30 mg/mL: 2 vials
Chewable aspirin 81 mg: 4 tablets
Hydromorphone 2 mg/mL: 2 vials
Fentanyl 100 mcg/mL: 2 ampoules
Naloxone 4 mg/10 mL: 1 vial
Metoclopramide 10 mg/2 mL: 1 vial
Ondansetron 4 mg/2 mL: 1 vial
Ondansetron 4 mg sublingual dissolving tablets: 2 tablets
Albuterol 3 mg/ipratropium 0.5 mg/3 mL for nebulizers: 2 units
10-mL saline flushes: 5 syringes
Alcohol prep pads: 10 pads
Assorted syringes: 1 mL (with needle): 3 syringes; 3 mL (with needle): 4 syringes; 10 mL: 1 syringe; 20 mL: 1 syringe
Nasal mucosal atomizer device: 2 devices
18-gauge needles: 10 needles
Syringe caps: 10 caps

INTRAVENOUS BAG

1000-mL normal saline intravenous solution: 1 bag
10-drip intravenous drip tubing: 1 piece of tubing
Intravenous catheters: 2 each of 14-gauge, 16-gauge, 18-gauge, and 20-gauge catheters
EZ-IO handheld driver and adult needles (15 gauge × 25 mm): 1 set
Saline lock tubing: 2 pieces of tubing
10-mL normal saline flushes: 2 syringes
Sharps shuttle container: 1 container
Nonlatex intravenous tourniquets: 2 tourniquets
Adhesive bandage strips (Band-Aids): 4 bandage strips
Alcohol prep pads: 10 pads
Roll of 1-inch (2.5-cm) tape: 1 roll
Occlusive dressing for intravenous site: 1 dressing
Intravenous pressure bag: 1 bag

MISCELLANEOUS BAG

Lidocaine 2%, 30 mL: 1 vial
Lidocaine 2% with epinephrine 1:100,000, 30 mL: 1 vial
Bupivacaine 0.5%, 50 mL: 1 vial
Scalpel No. 11 blade: 1 blade
Rolls of 1-inch (2.5-cm) tape: 2 rolls
1-inch (2.5-cm) Coban nonstick bandages: 2 bandages
Cavit tube, 7 g (dental): 1 tube
Dental cement kit: 1 kit
Steri-Strips: 1 each of 0.25-inch (0.6-cm) and 0.5-inch (1.2-cm) Steri-Strips
Stapler with No. 5 staples: 1 stapler
Burn gel package (small): 1 package
Rhino Rocket, 7.5 cm for epistaxis: 1 Rhino Rocket
18-gauge intravenous catheters: 2 catheters
OpSite occlusive adhesive bandage: 2 bandages
Tetracaine eye anesthetic drops: 1 bottle
10-mL normal saline flushes: 3 syringes
18-gauge needles: 5 needles
27-gauge needles; 5 needles
Assorted syringes: 10 mL: 3 syringes; 1 mL: 3 syringes; 20 mL: 2 syringes

FRONT AND TOP POCKETS

Notepad and pencils, pens, or markers: 1 of each
Headlamp: 1 headlamp
Ibuprofen 200-mg tablets: 1 bottle of 100 tablets
Roll of 1-inch tape: 1 roll
Charcoal hand warmers: 5 hand warmers
Alcohol hand sanitizer: 2 bottles
Nonsterile gloves (nonlatex): 10 pairs
Benzoin swabs: 3 swabs
Triple antibiotic packets: 10 packets
Small, clear, zip-top bags; 4 bags
Wooden tongue blades: 4 blades
Emesis bags; 2 bags
Trauma shears or scissors: 2 pairs
Pocket mask (NuMask): 1 mask
Package of 20 triage tags: 1 package
Package of sanitary wipes: 1 package

BANDAGING SIDE POCKET

4-inch (10-cm) elastic bandages: 2 bandages
4-inch (10-cm) Kerlix bandages: 2 bandages
Gauze pads (10-packs), 4 × 4 inch (10 × 10 cm): 2 10-packs
Absorbable pads, 5 × 9 inch (13 × 23 cm): 2 pads
Triangle bandage: 1 bandage
Commercial tourniquet: 1 tourniquet

MISCELLANEOUS SIDE POCKET

Adult blood pressure cuff: 1 cuff
SAM Splint: 1 splint
Handheld nebulizer: 1 nebulizer
Intravenous pressure bag: 1 bag
Strobe light signal device: 1 device

MAIN COMPARTMENT

1000-mL normal saline intravenous bag: 1 bag
10-drip intravenous tubing: 1 piece of tubing
Size 4 King LTS-D supraglottic airway: 1 airway
Halo Chest Seal: 1 seal
16F Foley catheter: 1 catheter
Foley leg bag: 1 bag
Adult diapers: 2 diapers
Cervical collar (adjustable adult size): 1 collar
Pocket bag-valve-mask device: 1 device
Adult EZ-IO battery driver with 2 needles (15 gauge × 25 mm): 1 driver
Handheld suction device (e.g., "Squid" Telescoping Suction Device; Suction Easy): 1 device

*The technical rescue medical kit weighs 15 kg (33 lb).

AIRWAY BAG

Gum elastic bougie: 1 bougie
Comfit endotracheal tube holder: 1 tube holder
Stethoscope: 1 stethoscope
Pocket pulse oximeter with extra batteries: 1 oximeter
Magill forceps (large): 1 pair
Adult endotracheal tube stylet: 1 stylet
Endotracheal tubes: 1 each of 5.0, 6.0, 7.0, 7.5, and 8.0 sizes
Nasogastric tube (18F): 1 tube
End-tidal carbon dioxide colorimetric intubation confirmation device: 1 device
Eye protection shield or face mask: 1 shield or mask
3-0 silk suture on straight needle (SC-2): 1 suture on needle
Ventilator tubing with one-way valve for remote ventilation: 1 piece of tubing
14-gauge, 3.25-inch needles for chest decompression: 2 needles
Oropharyngeal airways (assorted adult sizes): 3 airways
Nasopharyngeal airways (30F and 32F): 3 airways of each size
10-mL syringes: 2 syringes
Laryngoscope handle with AA batteries: 1 handle
Macintosh No. 4 stainless steel blade: 1 blade
Miller No. 3 stainless steel blade: 1 blade
Scalpel No. 11 blade: 1 blade
Chloraseptic swab: 1 swab
Povidone-iodine swab: 1 swab
BAAM whistle device for nasal intubation facilitation: 1 device
Petrolatum Vaseline gauze pads, 3 × 9 inches: 2 pads
Heimlich valve and tubing: 2 sets

OXYGEN KIT†

Carbon Fiber DD-lite oxygen tank (up to 3000 psi): 1 tank
Adult nasal cannula: 1 cannula
Oxymizer nasal cannula: 1 cannula
Nonrebreather face mask: 1 mask
Extension tubing and adapter: 1 set
Pelvic binder (e.g., T-POD Pelvic Stabilization Device): 1 binder
Spider Straps (litter securing system): 1 system
Oropharyngeal airways (adult sizes): 2 airways
Large charcoal blanket (Ready-Heat): 1 blanket
Size 4 King LTS-D supraglottic airway: 1 airway
Bag-valve-mask device (traditional): 1 device
Bag of nitrile gloves (appropriate provider size): 1 bag
Handheld nebulizer: 1 nebulizer
SAM Splint: 1 splint
Kerlix gauze, 4 inch: 1 gauze
Triangle bandage: 1 bandage
Pocket mask: 1 mask
Trauma shears or scissors: 1 pair

†The oxygen kit weighs 10 kg (22 lb).

CHAPTER 57

Litters and Carries

DONALD C. COOPER

Every search and rescue event goes through a series of four consecutive phases. These phases are illustrated by the acronym LAST (locate, access, stabilize, and transport). This process ends with movement of the patient (or patients) from the scene to a transfer-of-care point, medical facility, or area of comfort and safety (transport)[7] (see Chapter 55, Search and Rescue).

In the United States, the term *stretcher* suggests a flat, unsophisticated frame covered with canvas and used for carrying nonambulatory patients short distances. The term *litter* can mean the same thing but usually suggests an apparatus specifically designed to immobilize and carry a patient longer distances. Over the years, the subtle differences in the terms have been lost, and users have gravitated to one or the other. For example, in the United States, the term *litter* is often used to describe all manner of rescue conveyances, but in Great Britain the preference is to use the term *stretcher* to describe the same devices. In this chapter, the two terms are used interchangeably.

SIZE-UP

To select the best method for getting a patient to definitive care, the rescuer must make a realistic assessment of several factors. Scene safety is the initial priority. The necessary evaluation, called the *size-up* (Box 57-1), involves a (usually hasty) determination of whether the victim or rescuer, or both, is immediately threatened by either the environment or the situation. Proper immobilization and patient packaging are always preferable, but sometimes the risk for aggravating existing injuries is outweighed by the immediate danger presented by the physical environment. In such a situation, the rescuer has little choice but to immediately move the patient to a place of safety before definitive care is provided or packaging is completed.

Evacuation options are limited by three rescuer-related variables: (1) number of rescuers, (2) their levels of fitness, and (3) their technical abilities. Carrying a victim, even over level ground, is an arduous task. At an altitude where just walking requires great effort, carrying a victim may be impossible. The specific rescue situation or environment encountered may present challenges beyond the capability of the available rescuers. Complex rescue scenarios requiring specially trained personnel and special equipment are called *technical rescues* and often involve dangerous environments, such as severe terrain, crevasses, avalanche chutes, caves, or swift water. To avoid becoming victims themselves, rescuers must be realistic when evaluating their abilities to perform these types of rescues.

BOX 57-1 Evacuation Size-Up Factors

What are the scope and the magnitude of the overall situation?
Are there immediate life-threatening hazards?
What is the location, and how many victims are there?
What is the patient's condition? Is the subject able to assist rescuers?
- No injury (able to walk unassisted)
- Slight injury (able to walk unassisted)
- Slight injury (assistance required to walk)
- Major injury (requires considerable attention and assistance)
- Deceased

Is there a need for technical rescue?
Is the scene readily accessible?
What rescue resources (including rescuers and equipment) are available?
How far must the patient (or patients) be transported?
Are ground or air transport assets available?

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FIGURE 57-1 **A,** Blanket drag. **B,** Fireman's drag. Both techniques are intended to be used when expeditious transport over a short distance is required. *(From Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

DRAGS AND CARRIES

The most fundamental and expedient method of transporting an ill or injured person is by dragging or carrying him or her. Although these methods of transportation are far less than ideal and may not meet standard care criteria, urgency of the situation may outweigh the risks involved. The process can be physically demanding, and rescuers can quickly become fatigued to the point of hazard. Therefore, other options should often be considered before a victim is moved, especially over a long distance. A drag or carry may be the best option when a person cannot move under his or her own power, injuries will not be aggravated by transport, resources and time are limited, the need for immediate transport outweighs the desire to apply standard care criteria, travel distance is short, or the terrain makes the use of multiple rescuers or bulky equipment impractical.

A *blanket* drag (Figure 57-1A) can be performed on relatively smooth terrain by one or more rescuers rolling the victim onto a blanket, tarp, or even large coat and pulling it along the ground. This simple technique is especially effective for rapidly moving a person with a spinal injury to safety, because the victim is pulled along the long axis of the body. In extreme circumstances, the fireman's drag (see Figure 57-1B) can be used. In this type of drag, the rescuer places the bound wrists of the victim around his or her neck or shoulders, or both, and crawls to safety.

A carry should be considered only after it is confirmed that the victim cannot assist rescuers or travel on his or her own. Beyond simply lifting a person over one's shoulder in a *fireman's carry* (Figure 57-2) or acting as a human crutch, a more efficient one-person carry can be accomplished by using equipment such as webbing, backpacks, coils of rope, or commercial harnesses. Equipment-assisted carries are particularly effective when an injured climber or hiker must be evacuated across a short distance over rough terrain or when a person must be quickly removed from a hazardous environment. In the simplest equipment-assisted carry, 4.5 to 6 m (14.8 to 19.7 feet) of webbing is wrapped around the victim, who is then "worn" like a backpack by the rescuer (Figure 57-3).

Similarly, a split coil of climbing rope or a backpack (also called a rucksack) can be fashioned into a seat in which the patient sits while carried by the rescuer. A single-rescuer split-coil carry (Figure 57-4) requires only equipment already carried by a climber or mountaineering group and works well for conscious patients without severe injuries. However, the patient's legs hang close to the ground, especially during downhill carries and when the rescuer is shorter than the patient, and together the rescuer and patient can carry only one rucksack.

A similar method, the rucksack carry, simply uses a rucksack as the slinging device (Figure 57-5). The rucksack is placed on the patient with the patient's legs through the shoulder straps and over the waist straps if these are present. The rescuer positions the patient on his back (generally with assistance), positions the shoulder straps of the pack over his shoulders, and then stands. This method places a victim high relative to the rescuer's center of gravity; stability of both patient and rescuer can be a factor. This method is particularly useful for a patient with a lower limb injury or other situation where he or she is conscious and able to sit up and hold onto the rescuer. It also allows both the rescuer and patient to carry rucksacks.

Methods and/or devices that attach a patient in a sitting position to the back of a rescuer are sometimes referred to as *Tragsitz* (German for "carry seat") methods and/or devices.[13] Although original Tragsitz devices were made from canvas and specifically designed to carry a patient securely and comfortably, they can also be improvised, as in the split-coil and rucksack carries, or commercially produced using modern, stronger, and more robust fabrics (Figure 57-6).

For carrying infants and small children, a papoose-style sling works well and can easily be constructed by the rescuer, who ties a rectangular piece of material around his or her waist and neck to form a pouch. The infant or child is then placed inside the pouch, which can be worn on the front or back of the rescuer's body.

If two rescuers are available, additional and often superior options for carrying a patient are possible. One option consists of two rescuers forming a seat by joining their hands or arms together. The patient sits on the "platform" and holds onto the rescuers for support (Figure 57-7). It is difficult to cover a long distance or rough terrain when using this technique, and the patient must be conscious and able to sit up and hold on.

A coil of climbing or rescue rope can be used to form a two-rescuer split-coil seat, with each rescuer slipping a side of the rope coil around his or her outside shoulder (Figure 57-8). The patient sits on the "seat" formed by the rope. A similar approach involves using padded ski poles or stout limbs tied together and supported by backpacks worn by rescuers. The victim sits on the supported poles with his or her arms around the rescuers' shoulders. If the poles are properly padded and securely attached to sturdy rescuers, this technique can be quite comfortable for both

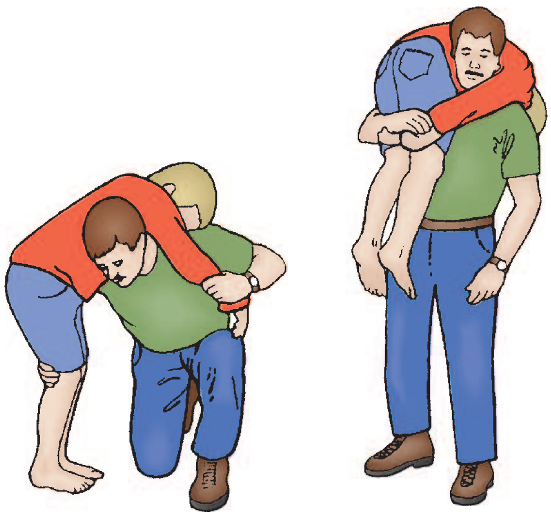

FIGURE 57-2 Classic fireman's carry: a single-rescuer technique for short-distance transport only. The rescuer must use his or her legs for lifting. *(From Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

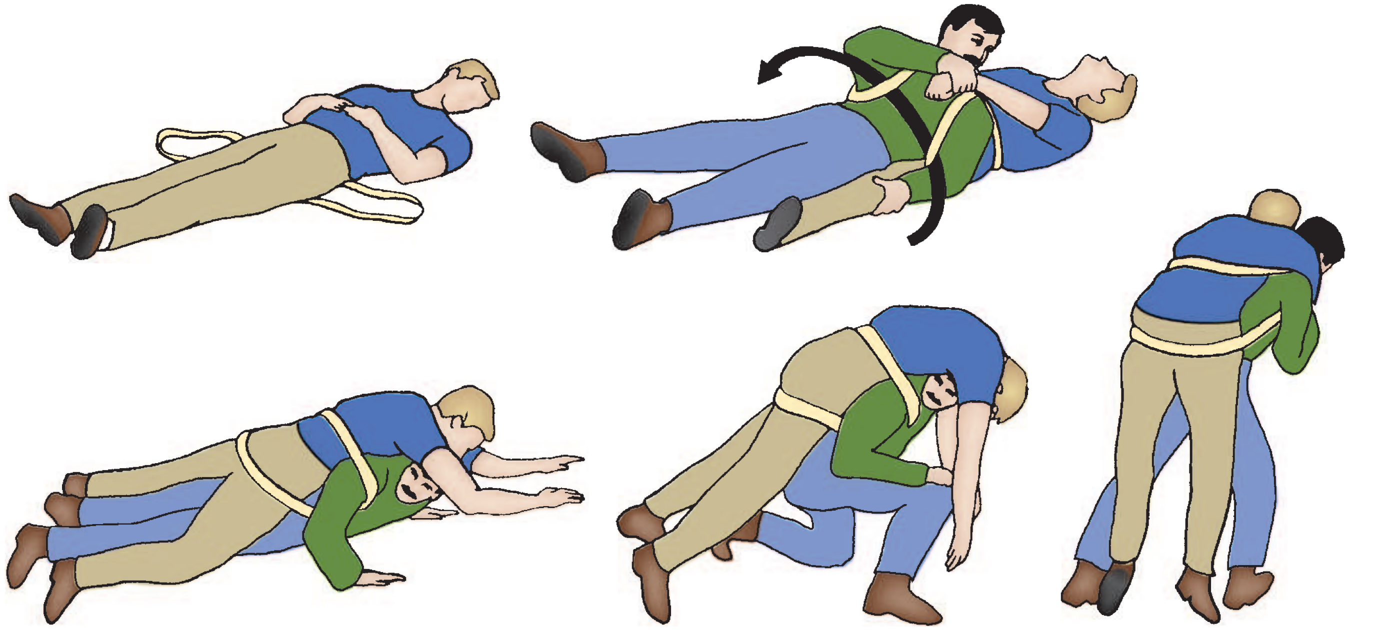

FIGURE 57-3 Web sling (tied into a loop) used to carry a victim. The rescuer must use his or her legs for lifting.

the rescuers and victim. This approach requires gentle terrain without narrow trails.

Spine injuries generally prohibit the use of drags or carries because the victim cannot be properly immobilized, but drags or carries may be acceptable when immediate danger outweighs the risk for aggravating existing injuries. Drags are particularly useful for victims who are unconscious or incapacitated and unable to assist their rescuer (or rescuers) but may be uncomfortable for conscious victims. When a drag is used, padding should be placed beneath the victim, especially when long distances are involved. The high fatigue rate of rescuers makes carries less attractive options when long distances are involved.

LITTER IMPROVISATION

The simplest improvised litter is made from a heavy plastic tarpaulin, tent material, or large polyethylene bag (Figure 57-9). By wrapping the material around a rock, wadded sock, or glove and securing it with rope or twine, the rescuer can fashion handles in the corners and sides to facilitate carrying. The beauty of this device is its simplicity, but it can be fragile, so care must be taken not to exceed the capability of the materials used. As an additional precaution, all improvised litters should be tested with an uninjured person before being loaded with a victim. This type of nonrigid, "soft" litter can often be dragged over snow, mud, or flat terrain but should be generously padded, with extra clothing or blankets placed beneath the victim.

Three or four filled rucksacks (depending on the size and shape of the patient) can also be laid end-to-end—carrying/strap side up—to serve as an improvised litter. Lay the packs on the ground in a straight line with the tops of all packs oriented in the same direction, and use the shoulder straps to tie them together. Open the waist straps wide and place the patient flat on his or her back (lifted flat by clothes, neck immobilized if necessary) on the packs before tightening the waist straps. The patient's head should be placed at the end with the top of the packs. Moving the patient safely in this device takes a coordinated effort, one leader, and at least four rescuers. The full rucksacks offer support beyond that which is provided by only the packs and their straps, but their weight when full and added

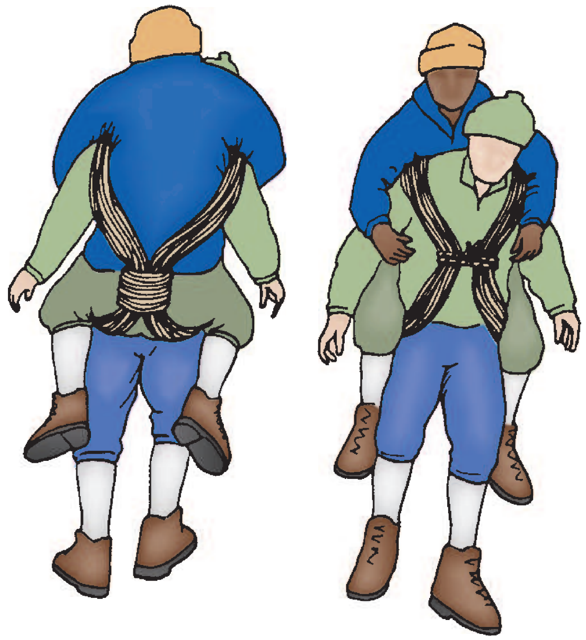

FIGURE 57-4 Single-rescuer split-coil carry. Note that the coil can be tied in front of the rescuer, and the wrists of the victim can be bound and wrapped around the rescuer's neck for more stability.

FIGURE 57-5 Backpack or rucksack carry.

FIGURE 57-6 Manufactured Tragsitz harness in use.

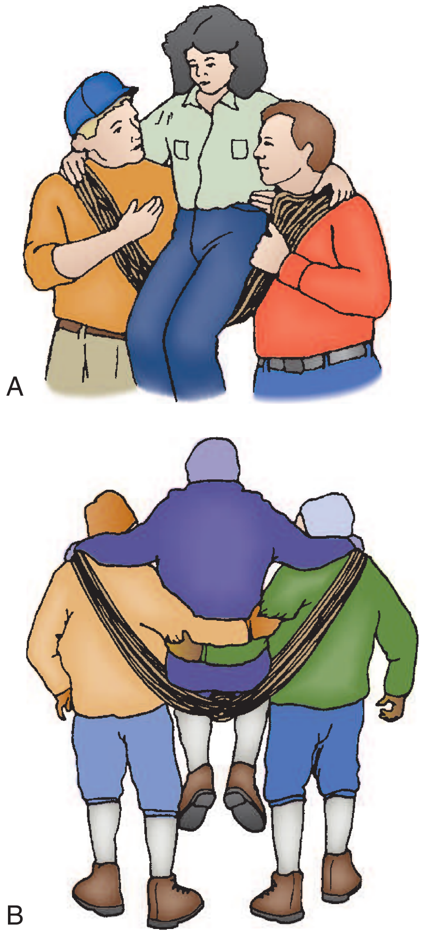

FIGURE 57-8 Two-rescuer split-coil seat.

to the patient's weight can be demanding on rescuers. When stopping to rest, rescuers must be sure not to allow the patient to roll over. This method works well for patients who require transport in a supine position, including those who are unconscious or have femur, pelvis, or spine injuries. It also provides superior stabilization in the body axis compared with most other improvised litter options, and is unlikely to allow the patient to fall out, even if a rescuer slips while carrying.

A coil of rope can be fashioned into a litter, called a *rope litter* or *clove hitch stretcher*; a 46- to 61-m (150.9- to 200.1-foot) climbing or rescue rope is required (Figure 57-10). The rescuer constructs the litter by laying out 16 to 20 180-degree loops of rope in the middle of the length of rope (8 to 10 on each side of center) across an area the desired width of the finished litter (Figure 57-11). The running ends of the rope are used to tie a clove hitch around each of the loops (Figure 57-12), and then the unused portion of rope is passed through the loops and tied off to form a handhold around the peripheral edge of the resulting device (Figure 57-13). The litter can then be padded with clothing, sleeping pads, or similar material. Lateral stability can be added by tying skis or poles to the finished product. Because of its nonrigid construction, this litter offers virtually no back support, can be uncomfortable for patients, and is best suited for patients with injuries that do not require mechanical stabilization or immobilization. One advantage of this device is that items commonly carried on a wilderness or climbing trip are all that

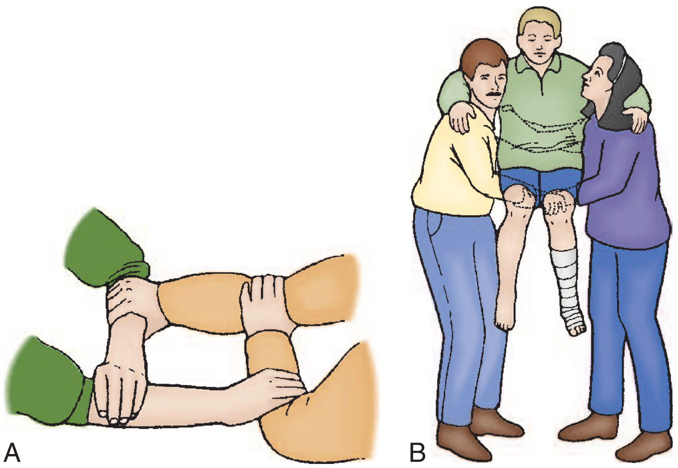

FIGURE 57-7 **A,** Four-hand seat used to carry a person. In this technique, the upper body is not supported. **B,** Alternative four-hand seat that helps support the victim's back. *(From Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

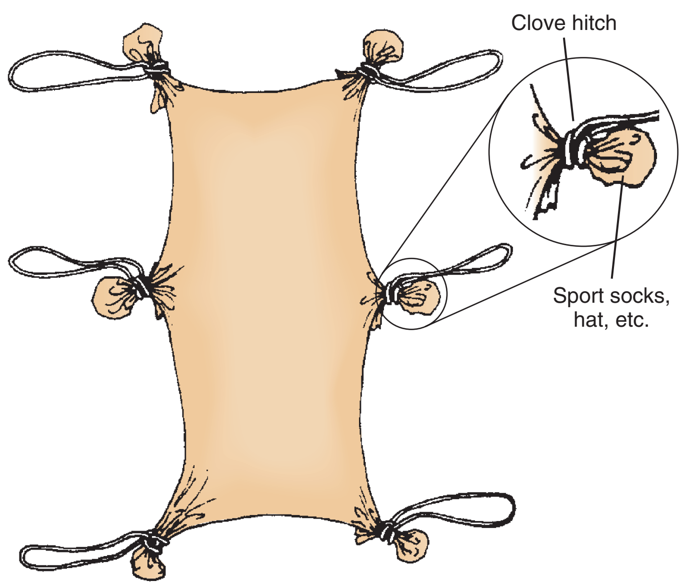

FIGURE 57-9 Improvised handled soft stretcher.

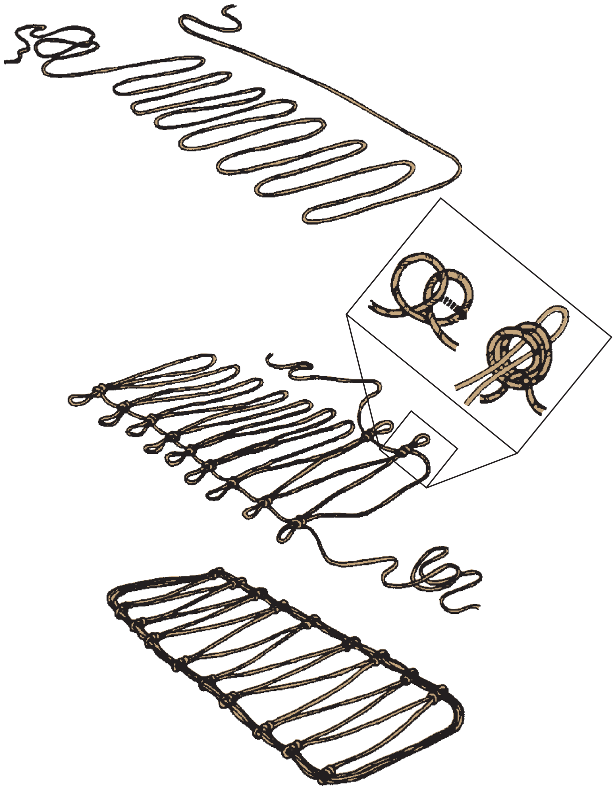

FIGURE 57-10 Tying an improvised rope (nonrigid) stretcher.

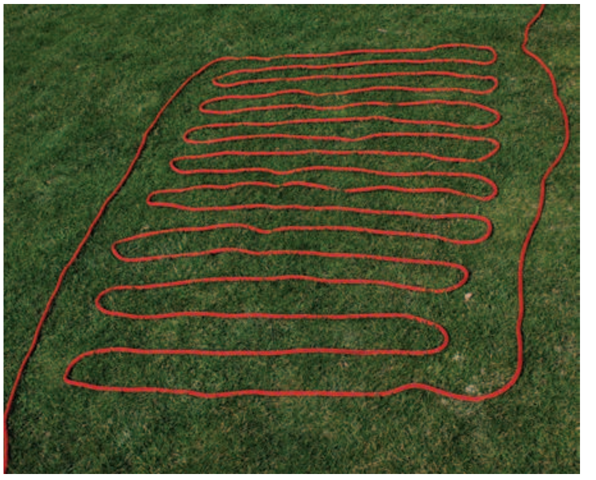

FIGURE 57-11 Laying out the rope for an improvised rope stretcher. *(Courtesy Timothy Mier.)*

FIGURE 57-12 Tie clove hitches around each loop. *(Courtesy Timothy Mier.)*

are needed to configure it. However, it can take 30 to 45 minutes to construct and can be difficult to get properly proportioned (length and width) unless rescuers are well practiced. Comfort for the victim is limited at best, and therefore use of this litter is best suited for carries over a short distance. Although the idea of this device may initially seem attractive and relatively easy, in reality it takes quite a long time to construct, is easily tied incorrectly (taking even longer to re-tie), and is uncomfortable for most patients.

A sturdy blanket or tarp can be used in combination with ski poles or stout tree branches. The blanket or tarp is stretched over the top of two poles, which are held about 1 m (3.3 feet) apart; tucked around the far pole; and folded back around the other pole. The remaining material lies over the first layer to complete the litter (Figure 57-14). The weight of the patient holds the blanket in place, but the weight of the patient also tends to force the poles together so that the blanket wraps tightly around the patient. This quickly becomes uncomfortable for the patient and is best used only for short periods of time. A similar, and in some ways superior, device can be improvised by passing the poles through the sleeves of two heavy, zipped (closed) parkas.

It may be necessary to transport victims with certain injuries (e.g., spine injury; unstable pelvis, knee, or hip dislocation) on a more rigid litter. Ski poles, stout tree limbs, or pack frames can provide a rigid support framework for such a device. For example, three curved backpack frames can be lashed together to form a platform (Figure 57-15). Ski poles or sturdy branches then can be fastened to the frames for use as carrying handles, and the platform can be padded with ground pads, sleeping bags, or a similar material.

Combining a rope litter with a rigid litter can provide more strength and versatility. The rescuer fashions this type of litter by first building a platform of poles or limbs, using a blanket as in a rigid litter, and placing the victim in a sleeping bag on the platform. The patient and platform are wrapped and secured with

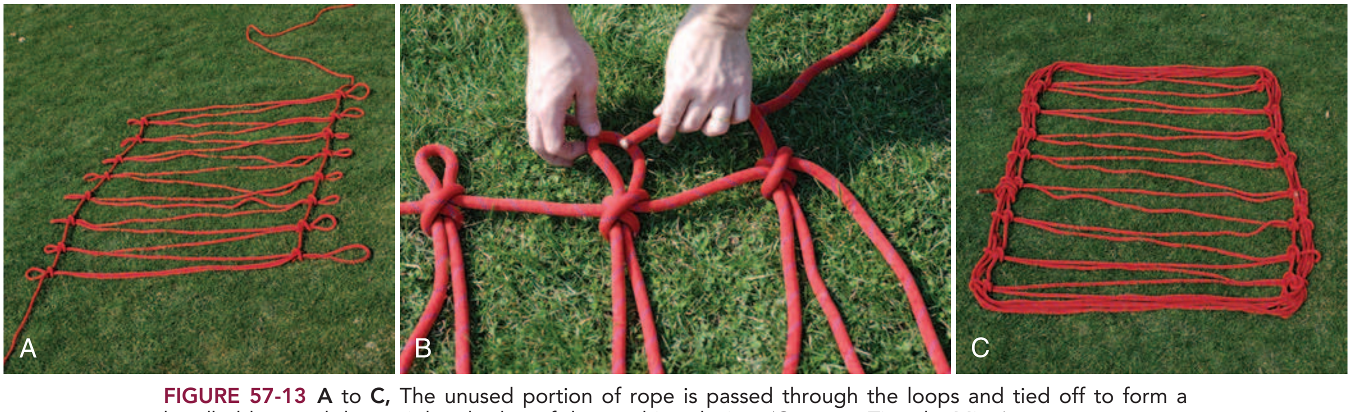

FIGURE 57-13 **A** to **C,** The unused portion of rope is passed through the loops and tied off to form a handhold around the peripheral edge of the resulting device. *(Courtesy Timothy Mier.)*

FIGURE 57-14 Improvising a stretcher from two rigid poles and a blanket or tarp.

a length of rope. Because a mummy sleeping bag is used to encapsulate the victim, this device is sometimes called a *mummy litter*. Although this type of litter offers improved support, strength, and thermal protection, careful thought must be given to the physical and psychological effects that such a restrictive enclosure may have on the victim (Figure 57-16).

If long distances must be traveled or if pack animals are available, a litter may be constructed so that it can be dragged or slid along the ground like a sled. One such device is known as a *sledge* (Figure 57-17). This litter is fashioned out of two forked tree limbs, with one side of each fork broken off. The limbs form a pair of sled-like runners lashed together with cross members to form a patient platform. The sledge offers a solid platform for victim support and stabilization. If sufficient effort is put into fashioning a smooth, curved leading edge to the runners, a sledge can be dragged easily over smooth ground, mud, ice, or snow. Ropes also can be attached to the front of the platform for hauling and to the rear for use as a brake when traveling downhill.

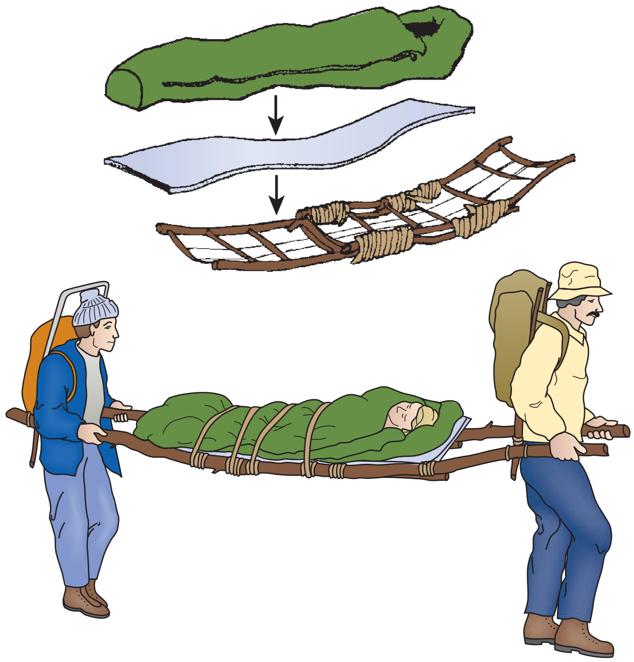

FIGURE 57-15 Pack frame litter. Note that the sapling poles on the litter can be attached to the rescuer's pack frames to help support the victim's weight.

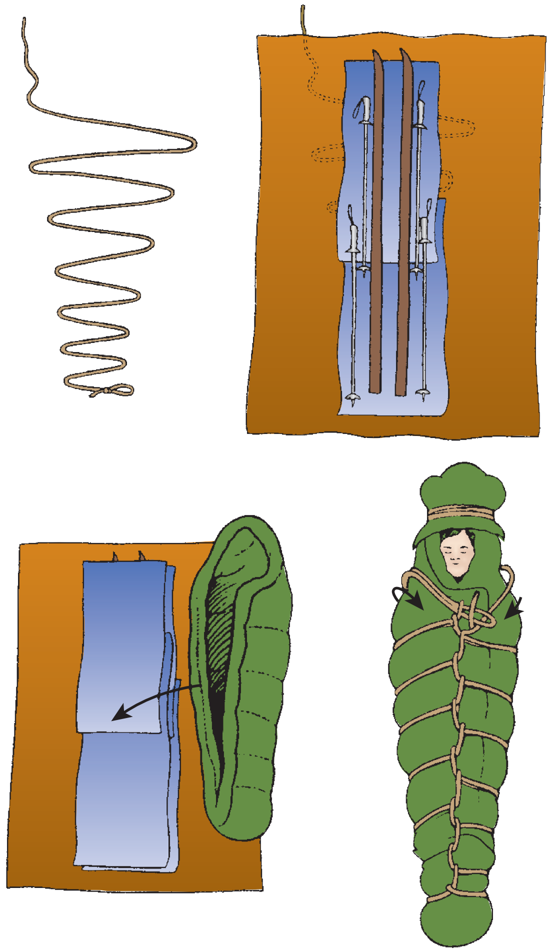

FIGURE 57-16 Mummy litter. *(From Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

A *travois* is a similar device that is less like a sled and more like a travel trailer (without wheels). A travois is a V-shaped platform constructed out of sturdy limbs or poles that are lashed together with cross members or connected with rope or netting. The open end of the V is dragged along the ground, with the apex lashed to a pack animal or pulled by rescuers. Although the travois can be dragged over rough terrain, the less smooth the ground, the more padding and support necessary for comfort and stabilization. A long pole can be passed through the middle of the platform and used for lifting and stabilization by rescuers when rough terrain is encountered.

When victims are transported in improvised litters, especially over rough terrain, they should be kept in a comfortable position, with injured limbs elevated to limit pressure and movement. To

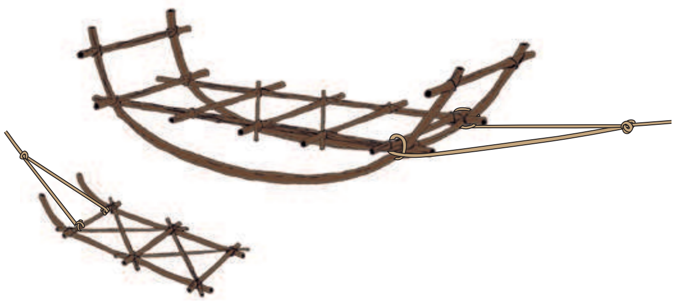

FIGURE 57-17 A "sledge."

splint the chest wall and allow full expansion of the unaffected lung, victims with chest injuries generally should be positioned so that they are lying on the injured side during transport. For a person with a head injury, the head should be elevated slightly, and for persons with dyspnea, pulmonary edema, or myocardial infarction, the upper body should be elevated. Conversely, when the victim is in shock, the legs should be elevated and the knees slightly flexed. Whenever possible, unconscious patients with unprotected airways should be positioned so that they are lying on their side during transport to prevent aspiration.[1]

RESCUE LITTERS AND STRETCHERS

The image most often associated with rescue immobilization and transportation devices in the United States is that of a traditional tubular steel and chicken wire–netted basket, which came to be known as the *Stokes basket*. Although this apparatus is ubiquitous, many may recall the Thomas, Duff, Mariner, Brancard Piguillem, Perche Barnarde, Neil Robertson, MacInnes, and Bell stretchers for their evolutionary and robust designs. There is a variety of devices in current use that meet the following two primary wilderness medical needs:

1. Immobilization and protection of a patient during transportation
2. Safe, comfortable, and stabilized transportation of a patient to definitive care

DESIRABLE CHARACTERISTICS OF A WILDERNESS STRETCHER

Peter Bell,[2] rescue equipment historian and developer of Bell stretchers in the United Kingdom, described several specific characteristics of a high-quality, useful rescue stretcher. Bell claims that a good stretcher should have the following characteristics:

- Be as strong and robust as possible, with materials compatible with the rescue environment
- Be as lightweight as possible
- Have smooth edges that will not snag
- Be devoid of small spaces that will trap or pinch rescuers' or patients' fingers
- Be large enough to provide strength, security, and comfort for the largest of persons when the device is in any position (e.g., horizontal, vertical, on its side, upside down)
- Prevent worsening of injuries
- Provide security for the victim regardless of environmental conditions (e.g., slippery, wet, muddy)
- Be comforting to the conscious victim
- Be easy to use in the dark and in environmental temperature extremes
- Protect the victim from the environment (e.g., heat, cold, brush, rocks)
- Be reliable for many years after many uses in extreme conditions
- Be easy to carry and use when carrying a heavy, large person
- Be portable (can be carried in a car, boat, plane, helicopter, etc.)
- Be impossible to use improperly
- Be easy to clean and sterilize

STRETCHERS

This discussion describes stretchers in five categories: basket-style, flat, wrap-around, mountain rescue, and hybrid.

BASKET-STYLE STRETCHERS

The basket-style stretcher derives its name from its shape. The sides curve upward to protect the victim's sides and to prevent him or her from rolling out. Most basket-style stretchers combine a steel frame (solid or tubular, or both) with a shell of either steel wire netting (e.g., chicken wire) or plastic. Many include wooden slats in the bottom to provide additional protection and support.

Most likely, basket-style stretchers were initially adopted by wilderness rescue organizations because they met fundamental needs and were sufficiently robust to endure great abuse in severe terrain. The seminal basket-style stretcher, called the Stokes, first appeared in the late 1800s and likely got its name from the fact that it was designed to be used on naval and commercial ships to remove casualties from the "stokehold," a room in which the boilers were stoked (Figure 57-18). However, at least one source makes an unverified claim that the device was invented in 1895 by Charles Stokes.[9] The significant influence of this device is reflected in the fact that the Stokes was the first commercially available basket-style stretcher in the United States.

The original Stokes design included a leg divider meant to separate and support each leg individually. Many came to consider this configuration counterproductive when use of long (0.4 × 1.8 m [16 × 72 inch]) backboards and other spinal, full-body immobilization devices became widespread, especially for early treatment of trauma. Most current designs of the Stokes basket-style stretcher have eliminated the leg divider to allow full immobilization of a patient on a long backboard or vacuum mattress, which can be inserted into the basket. The Junkin Safety Appliance Company manufactures several Stokes basket-style stretchers, including models that break into two pieces (Figure 57-19) and models with and without wooden slats or leg dividers that meet more robust military specifications (MIL-L-37957 and RR-L-1997) (Figure 57-20).

FIGURE 57-18 Traditional tapered Stokes litter with leg divider. *(Courtesy Junkin Safety Appliance Company.)*

FIGURE 57-19 Split-apart rescue litter. The two parts of this type of litter can be nested, one on top of the other, and packed into the backcountry. The two pieces "hinge" together at the bottom, and are secured by integral threaded collars on the top rail that lock into place, eliminating the need for pins. The stainless steel version weighs 16 kg (35 lb), and the titanium version weighs 7.26 kg (16 lb). *(Courtesy CMC Rescue, Inc.)*

FIGURE 57-20 Break-apart Stokes litter with wood slats. Accessory straps and/or a backpack device that allows a rescuer to carry the litter halves on his or her back are also available. *(Courtesy Junkin Safety Appliance Company.)*

FIGURE 57-21 Lifesaving Systems Corporation's Model 404-F Medevac II stainless steel basket litter with optional flotation. *(Courtesy Lifesaving Systems Corporation.)*

Although the traditional materials and design (i.e., tubular and flat, welded steel with a steel chicken wire covering) are still in use today, basket-style stretchers are most often constructed from tubular stainless steel, aluminum, and titanium because of added corrosion resistance, increased strength, and reduced weight. Manufacturers, such as Junkin and Ferno, offer basket-style devices in full rectangular and tapered rectangular shapes. Both are also available in break-apart versions for easy carrying. Narrower versions (usually 0.5 m [19 inches] wide, instead of 0.6 m [24 inches]) are available for use in confined spaces or caves, although cave rescuers rarely prefer any type of chicken-wire litter.

Because of the importance of portability in wilderness areas, the break-apart capability is an adaptation to nearly all styles and types of litters. Junkin manufactures a version of the Stokes stretcher completely coated with a plastic material called plastisol, which provides nonsparking, nonconductive, and antistatic properties. Junkin suggests that this coating allows improved purchase (handgrip) on the litter and offers insulation from the temperature of the metal. A collateral benefit of the coating is that it extends the life and integrity of the steel chicken-wire netting.

Lifesaving Systems Corporation of Florida markets the Medevac II series of Stokes-style litters used widely by the U.S. Coast Guard and all branches of the U.S. military. These are built with the marine environment in mind, made from either powder-coated 304 stainless steel or titanium, the latter of which is 40% lighter (9 kg [20 lb] versus 14.5 kg [32 lb]). It also comes in a break-apart version (Medevac IIA) designed to include flotation for use in and around the marine environment (Figure 57-21). In this device, the wood slats used on the original Stokes litter have been replaced with stainless steel reinforcements that run the full length of the litter; smooth, plastic net mesh (with 13-mm [0.5-inch] openings) replaces the chicken-wire liner. Visit lifesaving-systems.com for more information.

Taking advantage of substantial improvements in polymer research, some manufacturers began producing a stretcher shell composed of rigid plastic instead of steel mesh. Ferno's Model 71 stretcher has an orange plastic shell wrapped around an aluminum frame and secured with aluminum rivets. Brass grommets in the plastic serve as attachment points for a lifting harness (Figure 57-22) and a replaceable closed-cell foam pad is attached inside the stretcher for patient comfort. At half the weight of a traditional steel Stokes, this device offers protection from snags and obstacle penetration that cannot be provided by the wire netting of the Stokes. In addition, the plastic used is chemical resistant, and the molded underside runners make it slide smoothly over flat ground, ice, and snow. Ferno offers a version with tow handles and a chain brake that is designed specifically for ski patrol applications, so that a packaged victim can be "skied" down a slope or pulled along a snow-covered trail. The orange Ferno litter has a load limit of 272.2 kg (600 lb), but its usefulness in a vertical raise configuration depends on the integrity of the aluminum frame and the plastic shell; if one is compromised, both may fail. Because of this limitation and because of the lightweight materials used, bending or twisting the device should be avoided. Visit fernoems.com for more information on all Ferno products.

International Stretcher Systems (ISS) also builds a basket-style stretcher called the Yellow Jacket. It has a lightweight aluminum frame but uses a different approach for combining the frame with the shell. Its high-density polyethylene shell is similar to the shell in the Ferno Model 71 (except it is yellow), but it is placed outside a full aluminum skeleton to facilitate sliding over the ground. Inside the stretcher, a spring-suspended victim "bed" that doubles as the victim retention system has been added to protect the victim from the internal frame members. This bed minimizes transport shock and features built-in shoulder straps, pelvic padding, a head and chin immobilizing harness, foot and ankle straps, and a large "double-security" Velcro body restraint flap that wraps around the victim. This allows the patient to be moved in any position (vertically, horizontally, on the side, or even upside down) while being safely secured in the restraint system. The stretcher weighs 18.1 kg (40 lb), has an engineered load rating of 1134 kg (2,500 lb) (Figure 57-23), and due to its robustness and high durability, is used widely in urban search and rescue environments. Visit rescuestretchers.com for more information.

The Junkin Model JSA-200-B includes parallel stainless steel top rails. The top tube is larger to allow comfortable handgripping and to provide an attachment for lifting bridles, and the smaller solid steel lower rail allows attachment of patient retention straps. The twin rail configuration keeps patient straps and

FIGURE 57-22 Ferno Model 71 Stretcher. *(Courtesy Ferno.)*

FIGURE 57-23 International Stretcher Systems' Yellow Jacket Basket Litter with flotation added. *(Courtesy International Stretcher Systems.)*

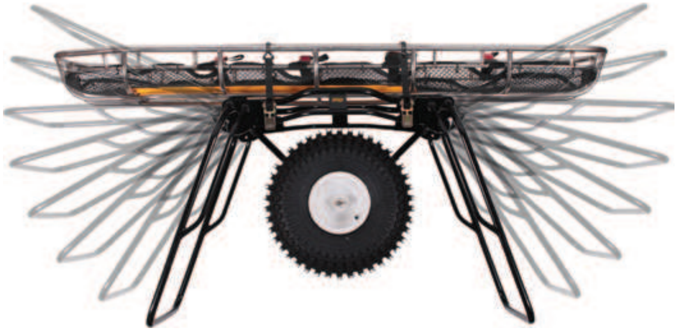

FIGURE 57-25 CMC Rescue Mule II Litter Wheel with handles (manufactured by Traverse Rescue) showing all positions of the handles. This versatile device allows the wheel to be removed and stored inside the frame and is available without the handles. *(Courtesy CMC Rescue, Inc.)*

lifting systems from interfering with each other and helps protect the attached materials from abrasion during use. Unlike the International Stretcher Systems device, the stainless steel frame in the Junkin stretcher wraps around the exterior of the basket, which is lined with a smooth-surfaced, permanently padded plastic shell. This design offers comfort for the victim but makes it difficult to slide on the ground because of the external, exposed steel frame members. Although a bit lighter than the ISS Yellow Jacket, the unit is heavy (14.5 kg [32 lb]) but breaks apart for packing and marries well with a litter wheel to allow easier handling. Visit junkinsafety.com for more information.

Cascade Toboggan manufactures the Model 200 Advance Series of rescue litters (Figure 57-24). These robust devices, common sights at many recreational ski areas, have a 16-mm (0.6-inch) stainless steel top rail that attaches to a composite basket. It is available in a break-apart version and integrates four 25-mm (1-inch) patient restraint straps into the basket. The device is compatible with both the CMC Rescue Litter Shield and Litter Wheel (Figure 57-25) and weighs less than 8.2 kg (18 lb) for the one-piece version. The two-piece version is just a bit heavier. Cascade Toboggan also developed and manufactures the Litter Skin, an abrasion-resistant shell that can be quickly attached to many types of rescue litters to make sliding across any surface easier (Figure 57-26). Visit cascade-rescue.com for more information.

Bell Rescue Stretchers offers the Series 2 Ludlow stretcher, which is their strongest flat stretcher with deep basket sides added. This strong, stainless steel–framed design has fold-down sides, which simplify access with a backboard. The sides can be completely removed to revert the device back to a flat stretcher. Other available variations on this theme from Bell include versions with shorter sides (the Otterburn), an open foot end (the Newark), and a steel plate welded into the bottom of the stretcher to help protect the victim (the Manchester). The Manchester weighs nearly 22.7 kg (50 lb). The manufacturer claims that the Series 2 models can all accommodate a long spine board and have been "proof tested" to between 500 and 720 kg (1102.3 and 1587.3 lb). The "bed" of Bell's Series 2 stretchers is made of 14 interlaced polypropylene web straps that cross between steel frame members. This webbing also passes through two movable stainless steel spinal supports (flat steel frame members that run the length of the caudal two-thirds of the litter). Four patient retention straps attached to the outermost rails, a patient shoulder strap, and integral lifting rings are supplied with the device. A slightly smaller, lighter, and less robust version, called the Bell Emergency Stretcher (discussed in the next section), is also available. Peter Bell no longer manufacturers the Bell line of rescue stretchers, but after 35 years of production, many are still in use and likely to remain so for many years to come. At least one company in the United Kingdom (lyon.co.uk) still services and load tests select Bell Stretchers commonly used in fire and rescue services.

FIGURE 57-24 Cascade Toboggan's Model 200 Advance Series Rescue Litter with optional snow handles. *(Courtesy Cascade Toboggan Rescue Equipment Company.)*

FLAT STRETCHERS

Flat stretchers are generally flat and have very short or no sides. Restraint straps or built-in tie downs serve as the physical means by which the victim is secured in the litter. Although the specific characteristics of these types of stretchers vary greatly (from extremely lightweight to high strength), generally they are used when specific benefit is derived from their low-profile shape. Although this style of stretcher has been modified to allow dragging or sliding (e.g., mountain rescue stretchers), the primary purpose of the flat design is to reduce weight and profile for carrying or for specific applications, such as loading into an aircraft.

Although a simple, two-pole canvas litter is fine for use over short distances, uncomplicated terrain, or the battlefield (where speed is paramount), lack of patient protection and immobilization capability limit its usefulness outside of the hospital or battlefield setting. A more modern version of this simple device is made of aluminum, folds for easy storage, and doubles as a long backboard. Another version is hinged at one end so that it can be spread along its long axis and slid under a patient on the ground with little movement or rolling. This "scoop" stretcher was commonly used by emergency medical service providers but has been supplanted by long backboards. In the final analysis, both military and aluminum iterations of the flat stretcher are intended for carrying a person short distances in an environment

FIGURE 57-26 Cascade Toboggan's Professional Series Litter Skin that can be attached to many types of rescue litters for easy sliding across any rough or abusive surface. *(Courtesy Cascade Toboggan Rescue Equipment Company.)*

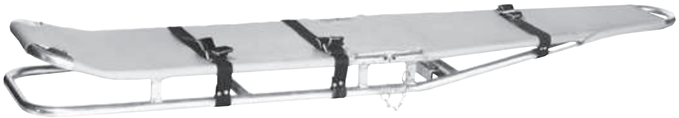

FIGURE 57-27 The Junkin Air Rescue Stretcher (SAF-350) was designed for use in Bell JetRanger (206) helicopters. This lightweight, flat stretcher folds for easy storage but is not designed for long carries. *(Courtesy Junkin Safety Appliance Company.)*

with few terrain obstacles or where complete security and immobilization are not required.

Several successful varieties of flat stretchers have evolved over the years, including the Brancard Piguillem, Junkin Air Rescue Stretcher (Figure 57-27), and a few of the Bell stretchers that are categorized as flat for the purposes of this discussion.

The Brancard Piguillem (*Brancard* is French for "stretcher," and Piguillem is a proper name) is a flat, old-style stretcher consisting of a canvas patient bed lashed to a steel and aluminum frame, weighs 13.6 kg (30 lb), and folds in half for easy carrying by one person. The design, which has evolved over the years in the European and British mountain rescue communities, includes a patient bed with a permanently attached, integral casualty bag lashed to the frame to protect and secure the victim. Full-length runners raise the stretcher a few inches above obstacles and allow for easy bare-handed gripping. This folding, portable design with integral patient protection made the Brancard Piguillem popular with mountain rescuers and served as impetus for evolution of several current styles of mountain rescue stretchers.

An interesting variation on the flat theme is the Rescue Sled Inflatable Rescue Litter manufactured by Switlik and distributed by Life Support International (Figure 57-28). The Rescue Sled is an inflatable, flat litter made of coated ballistic nylon Cordura with a Kevlar bladder that offers 102 kg (225 lb) of buoyancy and weighs less than 9 kg (20 lb). The device can be lifted, paddled, towed, or slid, both in and out of the water. It may be inflated either manually (foot pump) or with a small carbon dioxide canister. Uninflated, it packs easily into a medium-sized backpack or duffle bag. Integrated head restraints and body straps allow securing a patient, and towing and lifting attachments simplify the process of moving the device when loaded. Although this device may not be best for all situations, its unique buoyancy, weight, and design characteristics make it attractive for many ice- and water-related rescues. Visit lifesupportintl.com for more information.

The Kendall Stretcher, from Bell Rescue Stretchers, has the same features as their Ludlow Stretcher without the basket sides (see previous section). The Kendall has a stainless steel frame, integral lifting rings, a bed made of polypropylene web straps that cross between the frame members, color-coded patient retention (38-mm [1.5-inch] web) straps, and a detachable foot loop. A slightly less robust version of Bell's flat stretcher is their Basic Emergency Stretcher. This device is small and light (5.2 kg [11.5 lb]) and works well in commercial and industrial settings, where severe terrain is rarely encountered.

Although the manufacturer considers this stretcher to be a mountain rescue device, the MacInnes Mark 7 Rescue Stretcher

FIGURE 57-28 Life Support International's Rescue Sled (manufactured by Switlik) is a unique, durable, and inflatable device that provides 102 kg (225 lb) of buoyancy and weighs under 9 kg (20 lb). Shown is the Rescue Sled with integral flotation devices inflated (one tube each side). *(Courtesy Life Support International, Inc.)*

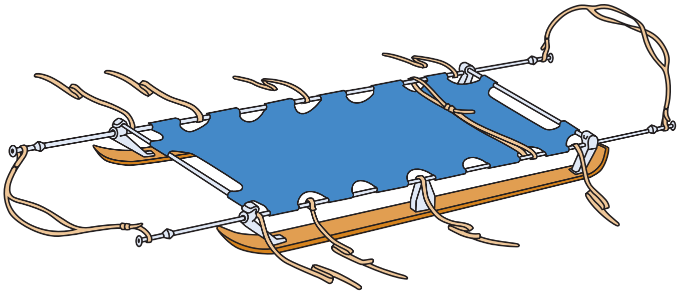

FIGURE 57-29 Thomas Stretcher as used in the United Kingdom circa 1966. It was made from Duralumin tubing (trade name of one of the earliest types of aluminum alloys that harden with age) and had telescoping handles, ash or laminated wood skids, and a Terylene (polyester fabric) net bed. *(From Kirkman NF: Mountain accidents and mountain rescue in Great Britain,* Br Med J *1:162, 1966.)*

is one of the latest in a long line of strong, user-friendly stretchers from Hamish MacInnes, the founder of MacInnes Rescue Stretchers and member of the Glencoe (Scotland) Mountain Rescue Team. The designer's aim was to develop a compact, versatile stretcher made from light, "space-age" materials. The Mark 7 is 10 kg (22 lb) complete, less than 5 cm (2 inches) high (unfolded), constructed of abrasion-resistant titanium and composite materials, and can be folded for easy packing and carrying into isolated areas. It also includes a folding footrest and head protector that double as handles.

MOUNTAIN RESCUE STRETCHERS

Mountain rescue stretchers are essentially stronger, more robust flat litters with runners or skis attached to the bottom for easy movement over rugged terrain. Over the years, engineers and litter designers with mountaineering and rescue backgrounds have adapted rescue litter designs to meet specific practical needs of their environment. The result is the strongest and most robust platform available for patient treatment and transportation, but these benefits come at the cost of weight and size.

The Thomas Stretcher is an early and beautifully simple example of the mountain rescue device (Figure 57-29). Invented in the United Kingdom in the 1930s by Eustace Thomas (no relation to Hugh Owen Thomas, who invented the Thomas "half-ring" splint), it originally included wood (ash) runners, an aluminum alloy frame, a canvas bed, and six or seven patient straps attached to the rails. It also had locking, tubular, retractable handles that stowed in the tubular rails.[10] Until recently, the Thomas Stretcher was being manufactured, with some modifications, by Bell Rescue Stretchers in the United Kingdom. However, this manufacturer has since ceased making the devices.[5]

In the late 1950s, Donald Duff, a pioneer of mountain rescue in Scotland, designed a stretcher with a steel tubular frame and no handles. Channeled steel runners extended along two-thirds of the caudal end of the stretcher. It weighed about 13.6 kg (30 lb) and could be fitted with a wheel and undercarriage for easier movement over rocky terrain. Its profile was low and sleek; the runners could be detached and the remainder folded in two for backpacking.[3] Although these stretchers have almost completely been replaced by more modern designs, two basket-style mountain rescue stretchers that evolved in Britain and Europe over the first half of this century deserve mention. The Perche Barnarde (*Perche* is French for "perch" or "pole," and Barnarde is a proper name) consists of a 2-m (6.6-foot) square section of steel tube from which a canvas casualty bag is suspended. The tube breaks down into three pieces for easy carrying. The bag is attached to the tube at each end. Where the patient's shoulders would fall, a spreader bar is placed to keep the bag open. From each end of the steel tube extend two removable, bicycle-type handlebars fitted with pads so that the handlebars can rest on rescuers' shoulders. Although this device has been used successfully in many difficult mountain evacuations over the years, it has limitations of patient comfort, protection, and immobilization.

The Mariner consists of a canvas bed attached to a steel sled-like frame. The bed functionally resembles a reclining chair in

FIGURE 57-30 MacInnes Mk 6 Mountain Rescue Stretcher. Note the extending handles, folding head guard, and optional twin (solid) tires. *(Courtesy MacInnes Rescue Stretchers.)*

FIGURE 57-31 Quick extrication, ultralight, nylon litters; six handle *(left)* and four handle *(right)*. Designed for rapid movement of casualty by dragging (one person) or lifting and carrying. Note torso straps to secure the patient. *(Courtesy London Bridge Trading Company, Ltd.)*

that the patient sits flexed at the hips and waist with the lower legs supported by a canvas platform. The frame is rounded from end to end and includes two steel runners to deflect obstacles. Two adjustable handles extend from each end of the frame for carrying. Today, the Mariner is used by several U.K. mountain rescue teams and is noted to have contributed significantly to evolution of the mountain rescue stretcher.

The current British standard for mountain rescue stretchers includes two devices that are incredibly strong, durable, and, unfortunately, heavy. The Mark III Bell Rescue Stretcher (24 kg [53 lb]) and the MacInnes MK6 Rescue Stretcher (22 kg [48.5 lb]) (Figure 57-30) are intended to survive years of use in extreme mountainous environments. Both have break-apart versions for easy packing into isolated areas and incorporate lifting rings, skids, and head guards. The MacInnes MK7 Rescue Stretcher (11.3 kg [25 lb]) is the modern and much lighter version of this robust style of stretcher. It is constructed mostly of a light but very strong and radiograph-opaque composite material. Titanium is used for the shafts and some structural elements, a six-point harness can be fitted for lifting/lowering, and a lightweight alloy wheel can be quickly attached. The MK7 also folds up completely and can be attached to a pack frame for carrying into the backcountry.[11]

FLEXIBLE, WRAP-AROUND STRETCHERS

A focus on improving stretchers for particular environments or situations has led to major developments in a number of litter design areas. It is difficult for a single device to excel in every situation because enhancing one capability or characteristic can be detrimental to another. For instance, it can be difficult to achieve a substantial increase in strength while decreasing overall weight. However, new innovative stretcher designs and materials allow structural flexibility to meet specific needs.

Flexible, wrap-around stretchers can be folded, rolled, or otherwise compacted for storage and "wrap around" in that they contain the victim to provide protection, immobilization, and often sufficient support for vertical lifting. The Neil Robertson Stretcher was the impetus for this entire category of device. Adapted from a Japanese design by John Neil Robertson and first produced between 1906 and 1912, this wooden and canvas stretcher was originally made of bamboo and sewn by hand. The "Neil Rob" supplanted the Mansfield military stretcher in the United Kingdom and was first given the name "Hammock for Hoisting Wounded Men from Stokeholds and for Use in Ships whose Hoists are 2 feet, 6 inches in Diameter."[4]

The Neil Rob consists of wooden slats that are covered with semirigid canvas and sewn the length of the stretcher. These slats wrap around the patient in mummy fashion, with arms in or out, providing protection without bulk. Full-body immobilization, protection, and small cross section combine to produce a device well suited for use in small spaces or for situations in which the victim must be moved through a small opening.[12]

The most basic type of flexible, wrap-around stretcher has long been used by the military under combat conditions to quickly move casualties. London Bridge Trading Company manufactures Quick Extraction and Hasty Litters that integrate web handles and torso straps on an ultralight, coated nylon panel (Figure 57-31). While in use by one person, it may look more like a drag sheet than a litter. By passing litter poles through the web handles, the device, which weighs less than 0.9 kg (2 lb) and can almost be packed in a pocket, works well when spinal immobilization is unnecessary or can be provided separately.

The Ferno LifeSaver Stretcher is a modern version of the traditional Neil Robertson Stretcher. It is 152 cm (60 inches) long and uses full-length 5-mm (0.2-inch) ribs interwoven by 1000-denier nylon fabric to provide full-body splinting in a very narrow package. Five built-in restraints with forged steel buckles are integrated into the device, and stainless steel rings are used at the foot and head for vertical attachment points (Figure 57-32).

For situations requiring full-body protection for the victim without complex restraint systems, the Reeves Sleeve and Ferno Traverse Rescue Stretcher almost totally encapsulate the patient. When used in conjunction with a cervical collar and spinal immobilization, these devices provide environmental and mechanical protection, while allowing the victim to be carried through narrow passages.

The Ferno Traverse Rescue Stretcher uses heavyweight Cordura nylon to cover a high-density polyethylene sheet that gives the device rigidity when wrapped around the patient (Figure 57-33). This stretcher has an integrated adjustable, full-body harness to secure the patient in the device, padded straps in the shoulder and groin areas to provide a comfortable fit, and a foot strap that prevents the patient from sliding down during vertical lifts.

FIGURE 57-32 The Ferno LifeSaver Stretcher, a modern version of the Neil Robertson Stretcher. *(Courtesy Ferno.)*

FIGURE 57-33 Ferno Traverse Rescue Stretcher (TRS) configured for horizontal lift. *(Courtesy Ferno.)*

FIGURE 57-35 Sked Rescue System. *(Courtesy Skedco.)*

Alabama-based Reeves EMS offers the Model 122 Reeves Sleeve. The device is constructed of vinyl-coated polyester and designed to fit over a spine board, on which it depends for rigidity. It works well to immobilize patients with spine and neck injuries, lift them out of tight spaces, and move them across multiple terrains. It incorporates both vertical and horizontal lift points for hoisting. The vinyl coating makes it easy to clean with soap and water, impermeable to fluids, and resistant to acids and alkali. Without the spine board, it weighs 6.8 kg (15 lb) and the manufacturer claims a load capacity of 453.6 kg (1000 lb). When rapid immobilization in a tight space is needed, this device offers a compact immobilizing stretcher suitable for hand-carry situations or vertical environments (Figure 57-34). Visit reevesems.com for more information.

Skedco's Sked stretcher (the name is derived from combining "skid" and "sled") provides wrap-around protection similar to the Neil Robinson, but a combination of shape and material, rather than integral slats, provides longitudinal rigidity (Figure 57-35). Light and compact when stored in its packable case, the flexible, low-density polyethylene plastic litter, part of their Basic Rescue System, wraps around the victim to form a rigid sleeve that is superbly compact for maneuvering in tight quarters. The standard litter dimensions are 2.4 m (8 feet) long by 0.9 m (3 feet) wide, and the weight of the standard litter, case, slings, straps, and carabiner in the Basic Rescue System is 7.7 kg (17 lb). A half-length version is available for moving persons from areas that are too confined for a full-length device, when flexing the victim at the hips might facilitate extrication. A bariatric version (2.4 m [8 feet] long by 1.2 m [4 feet] wide; 8.2 kg [18 lb]) and tactical version (2 m [6.6 feet] long by 0.56 m [22 inches] wide; 4.5 kg [10 lb]) are also available. The hard and smooth plastic material can be easily dragged over a variety of surfaces and offers substantial protection from penetrating obstacles. Although the Sked stretcher provides spinal protection, the manufacturer recommends using an Oregon Spine Splint (Skedco) or similar device when cervical spine immobilization is necessary. External lift slings are included with the Sked to allow vertical or horizontal lifting, and flotation is available for use in a marine environment. Visit skedco.com for more information.

The Brooks-Range Mountaineering Equipment Company Eskimo Rescue Sled (Figure 57-36) is designed as a foolproof, one-piece sled or "drag bag" suitable for ski guides, backcountry skiers, and travelers who need a reliable but minimalist means to transport an injured person out of the backcountry. The Eskimo Sled can also be used with a pair of skis positioned underneath the patient for added immobilization, stability, and protection. A water-resistant, breathable snow guard protects the patient from rope abrasion and snow. The patient can be transported in the Eskimo Sled while either prone or sitting. The Eskimo Sled has both front and back tow loops, as well as eight head and side handles to facilitate carrying the patient when

FIGURE 57-34 Reeves Sleeve in use. *(Courtesy Reeves Manufacturing, Inc.)*

FIGURE 57-36 The Brooks-Range Mountaineering Equipment Company Eskimo Rescue Sled. This one-piece sled or "drag bag" can also be used with a pair of skis positioned underneath the patient for added immobilization, stability, and protection. *(Courtesy Brooks-Range Mountaineering Equipment Company.)*

FIGURE 57-37 The Medical Devices International Immobile-Vac Full Body Mattress is a full-body vacuum splint that can be inserted into other litters. *(Courtesy Medical Devices International.)*

needed. The Eskimo Sled is a versatile device that can also be used as a bivouac sack, gear sled, or emergency shelter. It weighs just 850.5 g (30 oz) and is 20.3 × 15.2 × 5 cm (8 × 6 × 2 inches) when packed. Visit brooks-range.com for more information.

Medical Devices International (MDI) makes the Immobile-Vac Full Body Mattress, which is a full-body vacuum splint on which the victim is carried (Figure 57-37). The vinyl-coated, fabric patient bed contains loose polystyrene beads similar to those in a beanbag chair. Once the victim is positioned on the mattress, a small hand pump is used to expel air from within it. This process creates a rigid, full-body splint that conforms to the victim's shape. This "cocoon" immobilizes the spinal column and extremities while providing a comfortable platform. The mattress has integrated web carrying straps that can be used to carry the patient directly, or the mattress can be inserted into a basket-style stretcher for added versatility and strength. Use of a basket stretcher will be necessary for high-angle rescue because the MDI device, like most full-body vacuum mattresses, is not designed for vertical rescue by itself.

Conterra, Inc., in Bellingham, Washington, manufactures a state-of-the-art full-body vacuum mattress (Figure 57-38). In addition to the characteristics of other full-body vacuum splints, the ergonomically designed Conterra VSB (vacuum spine board) has eight moveable and removable handles, so it can also be used as a stretcher, and an integrated pelvic binding system that can be moved to align with the patient's pelvis. Rather than using polystyrene beads, the VSB uses polyethylene beads that the manufacturer claims will not break down over time, as will polystyrene. The design of the VSB also incorporates a series of baffles that keep the beads compartmentalized so the beads do not have to be spread out or distributed before use. Visit conterra-inc.com for more information.

FIGURE 57-38 Conterra VSB Vacuum Immobilizer. *(Copyright 2014 by Conterra, Inc.)*

FIGURE 57-39 The Brooks-Range Mountaineering Equipment Company Ultralite Rescue Sled. The kit is combined with a pair of snow skis and poles to form a stable transport platform suitable for transport of an injured or incapacitated person over snow. *(Courtesy Brooks-Range Mountaineering Equipment Company.)*

Ferno makes a Full-Body Vacuum Mattress with six carry handles that allow the splint to be used as a stretcher. The device has a load limit of 124.7 kg (275 lb), weighs 6.8 kg (15 lb), and uses the same evacuation pump as Ferno's line of vacuum splints.

HYBRID DEVICES

A hybrid of field improvisation and commercially made sleds and litters, the Rescue Sled line produced by the Brooks-Range Mountaineering Equipment Company (Brooks-Range.com) offers a lightweight and compact kit of components that can be easily packed into the backcountry.

The components of the Brooks system will convert a pair of skis of any length between 135 and 205 cm (53.1 and 80.7 inches) into a secure and durable rescue sled using a pair of stretcher bars, backcountry ski straps, and the sled. The sled component, constructed of lightweight, ripstop nylon fabric, binds the components together and forms a secure cocoon around the patient. The sled is easily assembled in under 2 minutes and offers 5.1 cm (2 inches) of patient elevation off the surface of the ground or snow.[6]

The most popular model is the Ultralite Rescue Sled (Figures 57-39 and 57-40). When packed, the kit measures 10.2 × 27.9 × 5 cm (4 × 11 × 2 inches)—not much larger than a one-liter water bottle—and weighs no more than 705.9 g (24.9 oz). In addition, if a Brooks-Range compact snow shovel is packed on the same trip, the stretcher bars can be omitted from the Rescue Sled kit, because the shaft of the shovel doubles as a set of stretcher bars, thereby reducing the package size of the Rescue Sled to approximately 2.5 × 10.2 × 12.7 cm (1 × 4 × 5 inches) and weight to 246.6 g (8.7 oz).

FIGURE 57-40 The Brooks-Range Mountaineering Equipment Company Ultralite Rescue Sled with patient. *(Courtesy Brooks-Range Mountaineering Equipment Company.)*

TRANSPORTATION HARDWARE ACCESSORIES

A number of wheeled devices can be attached to most basket-style stretchers. These devices take the carrying burden off rescuers in nontechnical evacuations and reduce the load on low-angle haul systems. One example is the CMC Rescue Mule II Litter Wheel (see Figure 57-25), which incorporates a large, underinflated all-terrain vehicle tire into a lightweight frame that clamps to the underside of the litter. This single wheel is positioned under the center of gravity, and the rescuers walk alongside, or at each end of, the litter to steady and guide it, with the wheel carrying most of the load. When they encounter large obstructions, such as logs or trenches, rescuers simply lift the litter and continue rolling. One advantage of this device is that it reduces the number of rescuers required to move a litter safely over a long distance. When using this device, only two rescuers (one at each end) are required to control the litter, but more may be used as necessary.

To meet a similar need, International Stretcher Systems employs a collapsible steel-frame trailer, the Anchor Man Trailer, with two all-terrain vehicle wheels. With no axle between the wheels, the tires can be set to the outside of the frame for greater side-to-side stability or to the inside and under the frame to negotiate narrow trails or doorways. The drawbar end of the trailer is set up to receive either the T-bar handle, for pushing by rescuers on foot (facing in the direction of travel), or a hitch adapter for towing behind motorized vehicles. Skis can also be substituted for the wheels.

Junkin markets several useful stretcher accessories, but at least one is particularly notable. Junkin's Comfo-Pad is designed to fit in all Junkin stretchers and is simply a pad on which the patient lies in the litter. It is made of 13-mm (0.5-inch) foam rubber with a durable, orange nylon cover and is held in place with hook-and-loop types of fasteners. Because patient comfort is always an issue, this simple accessory can be quite helpful.

MacInnes and Bell integrate steel wire head protectors in their mountain rescue stretcher designs. This feature is important where falling rock is a hazard. CMC Rescue markets a similar aftermarket device made of clear polycarbonate under the trademark CMC Rescue Litter Shield (Figure 57-41). It protects the victim's face from falling debris; allows for easy, rapid airway access; and can be moved out of the way because it hinges on the end of the litter. The shield stores compactly (upside down) in the litter when not in use.

Flotation systems are available for many litters. Ferno, International Stretcher Systems, and Skedco each offer this option to make their devices safer and more versatile in swift- or open-water rescue situations.

Most litter manufacturers offer specific packaging or methods for carrying their devices into isolated areas. For instance, London Bridge Trading Company's Quick Extraction Litter, the Sked, and Ferno's Traverse Rescue Stretcher can all be compacted and carried by a single rescuer. Other manufacturers sell special backpacks or integral carrying harnesses for carrying one-half of their break-apart litters because of the greater weight.

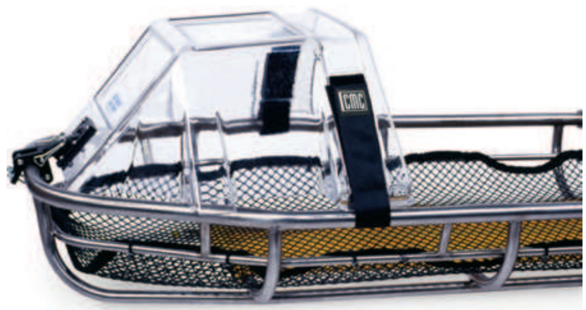

FIGURE 57-41 The CMC Rescue Litter Shield protects the victim from falling debris while allowing access to the head and face. It can also be inverted and placed in the litter to save space during storage. *(Courtesy CMC Rescue, Inc.)*

CARRYING A LOADED LITTER

An evacuation is defined as high angle or vertical when the weight of the stretcher and tenders (stretcher attendants) is primarily supported by a rope and the angle of the rope is 60 degrees or greater.[8] This type of situation is often encountered when a rescue is performed on a cliff or overhang or over the side of a structure, and usually requires only one or two tenders. In high-angle rescues, most often the stretcher is used in the horizontal position to allow only one tender and to keep the victim supine and comfortable. However, when the packaged victim and stretcher must be moved through a narrow passage or when falling rock is a danger, the stretcher may be positioned vertically.

In a scree or low-angle evacuation, the slope is not as steep (< 60 degrees), the tenders support more of the weight of the stretcher, and a rope system is still needed to help move the load. In this type of rescue, more tenders (usually four to six) are required, and the rope is attached to the head of the stretcher. The head of the litter is kept uphill during a low-angle rescue.

In a nontechnical evacuation, tenders completely support the weight of the stretcher during a carry out. Generally, the terrain dictates the type of evacuation. If the stretcher can be carried without the support of a rope, it is a nontechnical evacuation. If rope is needed to support the load or to move the stretcher, it is either a low- or high-angle evacuation, depending on the angle of the slope.

Carrying a litter in the wilderness is difficult and requires many resources. It takes at least six rescuers to carry a person in a litter a short distance (0.4 km [0.2 mile], or less) over relatively flat terrain. With six rescuers, four can carry the litter while the other two clear the area in the direction of travel and assist in any difficult spots. However, depending on the terrain and the weight of the victim, all six rescuers may be needed to safely carry the litter any distance. If the travel distance is longer, many more rescuers are required (Figure 57-42).

PATIENT PACKAGING

Patients on stretchers must be secured, or "packaged," before transport. Packaging consists of stabilization, immobilization, and preparation of a patient for transport. Physically strapping a person into a litter is relatively easy, but making it comfortable and effective in terms of splinting can be a challenge. The needs of a person secured and transported in a litter are great and should not be overlooked or underestimated. The rescuer's goals are to:

- Package the person to avoid causing additional injury
- Ensure the patient's comfort and warmth
- Immobilize the patient's entire body in such a way as to allow continued assessment during transport
- Package the patient neatly so that the litter can be moved easily and safely
- Ensure that the patient is safe during transport by securing him or her within the litter and belaying the litter as necessary

Once packaged in a carrying device, a person feels virtually helpless; thus, transport preparation must focus on alleviating anxiety and providing rock-solid security. With this in mind, rescuers must provide for the patient's ongoing safety, protection, comfort, medical stabilization, and psychological support.[7]

Splinting and spinal immobilization have traditionally used a full or short backboard, but the vacuum mattress offers a much better option. The mattress conforms to the patient. Traditional backboards lead to pressure points and potentially decubitus ulcers (stage 1 after just minutes). When the patient is immobilized in the vacuum mattress, he or she can then be placed into the litter. During transport, patients like to have something in their hands to grasp, to have pressure applied to the bottom of their feet by a footplate or webbing, and to be able to see what is happening around them.[7] Because persons are vulnerable to falling debris when packaged in a litter, especially in a horizontal high-angle configuration, a cover of some type should always be used to protect the patient. A blanket or tarpaulin works well as a cover to protect most of the body, but a helmet and face shield

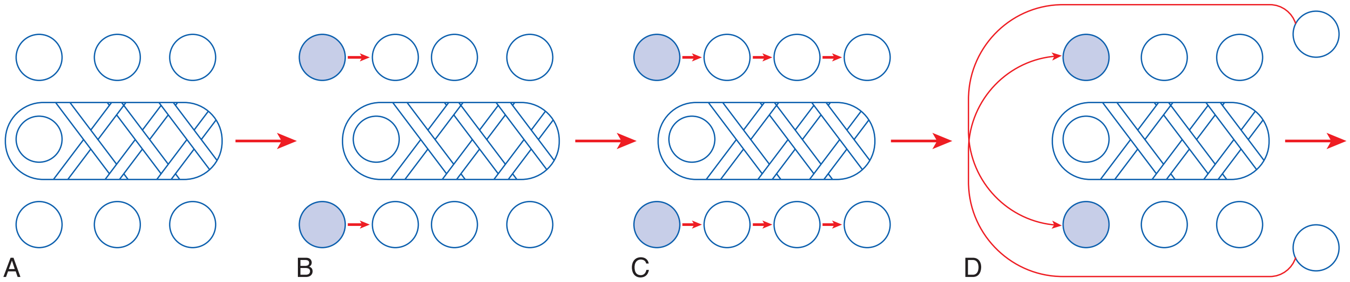

FIGURE 57-42 Litter-carrying sequence. **A,** Six rescuers are usually required to carry a litter, but rescuers may need relief over long distances (> 0.4 km [0.2 mile]). **B,** Relief rescuers can rotate into position while the litter is in motion by approaching from the rear. **C,** As relief rescuers move forward, others progressively move forward. **D,** Eventually, the rescuers who are farthest forward can release the litter (peel out) and move to the rear. Rescuers in the rear can rotate sides so that they alternate carrying arms. Carrying straps (webbing) also can be used to distribute the load over the rescuers' shoulders. In most cases, the litter is carried feet first, with a medical attendant at the head monitoring the patient's airway, breathing, level of consciousness, and so on.

or goggles are also options to protect the head and face from projectiles or falling debris. Alternatively, a commercially available litter shield can be used and allows easy access to the airway, head, and neck (see Figure 57-41). Because the head and neck usually require immobilization, the technique and equipment used to protect them should allow this. Remember also that the conscious patient desires an unobstructed view of his or her surroundings, so being moved feet first is almost always the best approach.

Carrying a person in the wilderness often requires that the litter be tilted, angled, placed on end, or even inverted. In all these situations, the patient must remain effectively immobilized and securely attached to the litter and the immobilizing device within the litter. Any supporting rope must be easily accessible and securely attached. Poor attachment can cause patient shifting, exacerbation of injuries, or even complete failure of the rescue system.

Manufacturers have taken several approaches to securing a person within the litter. Most integrate a retention or harness system directly into the litter. However, a few require external straps to secure the patient to the device. Many users suggest that an independent harness be attached directly to the patient to provide a secondary attachment point in case any link in the attachment chain fails.

When a harness is not available, tubular webbing, strips of sturdy material, or even rope can be used to secure the patient. One approach uses tubular webbing slings in a figure-eight at the pelvis and shoulders to prevent the patient from sliding lengthwise in the litter.

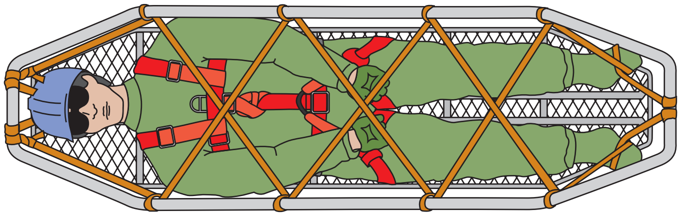

FIGURE 57-43 One 10-m (32.8-foot) web or rope can be used to secure a person into a litter.

A 10-m (32.8-foot) piece of 5-cm (2-inch) webbing or rescue rope can be used to achieve the same goal (Figure 57-43). The rope or web is laced back and forth between the rails of the litter in a diamond pattern until the patient is entirely covered and secure. Such a technique also easily incorporates a protective cover and support of the patient's feet.

Regardless of the techniques and equipment used, frequently checking vital signs (e.g., distal pulses and capillary refill) during transport can help ensure that strapping does not obstruct circulation.

REFERENCES

Complete references used in this text are available online at expertconsult.inkling.com.

CHAPTER 58

Helicopter Rescue and Air Medical Transport

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Prehospital patient access to emergency response, care, and transport is an important component of modern health care systems. In urban areas of developed countries, ground emergency medical services (EMS) tend to be broadly available. However, ground services are not available in all areas and are not always practical. The use of ground services can be impaired by geographic isolation, rough terrain, destruction or congestion of roads, or overwhelming demand. In such cases, air medical transport (AMT) may be the best option for patients who need some combination of a timely emergency response, on-site

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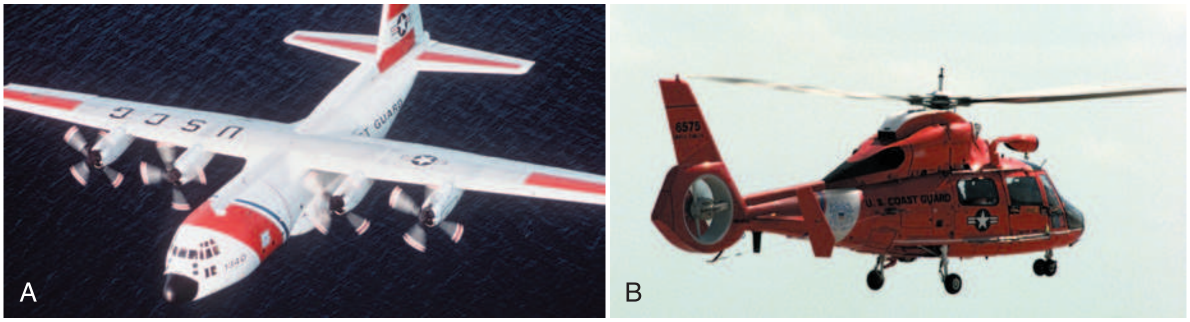


FIGURE 58-1 Airplane and helicopter assets serve different and complementary roles in air medical transport. The U.S. Coast Guard, for example, operates fixed-wing and rotor-wing aircraft for search and rescue, as well as for air medical transport. **A,** U.S. Coast Guard C-130 Hercules aircraft. **B,** Coast Guard HH-65 Dolphin helicopter. *(Courtesy U.S. Coast Guard.)*

stabilization, and early treatment while en route to a receiving medical care facility.

AMT by helicopter or fixed-wing (FW) aircraft can be particularly helpful in wilderness and environmental emergencies because these conditions frequently involve time-sensitive illnesses or injuries in remote locations with challenges in physical access and unfavorable logistics for ground transport (Figure 58-1). This chapter introduces the basic aviation and medical concepts of AMT, emphasizing areas of its potential application in wilderness and environmental emergencies.

EVOLUTION OF AIR MEDICAL TRANSPORT

Although an oft-related story of injured patients' evacuation by hot-air balloon during the 1870 Siege of Paris may be apocryphal,[101] the history of AMT is extensive. Ad hoc use of aircraft to move the ill or injured has doubtless occurred for nearly as long as flying machines have carried passengers. Medical literature traces the formation of dedicated FW AMT services back to the early 20th century; Australia's Royal Flying Doctor Service noted its 50th anniversary in a 1978 *British Medical Journal* publication.[170]

Battlefield medicine has played a major role in the evolution of AMT. In World War I, FW transport of stabilized patients was a major component of care systems for the wounded.[10,66] Helicopter medical evacuation was used in World War II's Burma Theater, with large-scale military rotor-wing (RW) medical operations first undertaken in Korea and Vietnam (Operation DUSTOFF).[134,135]

Early AMT services focused on evacuation rather than in-flight care. Early FW services were able to offer some intratransport care, but in the Korea and Vietnam conflicts, helicopters had neither the physical layout nor the staffing to provide medical care during patient transport.[50]

Despite the rudimentary nature of early AMT and the limited intervention capabilities of helicopter EMS in the 1950s and 1960s, helicopter transport was associated with improved survival of injured soldiers and AMT became firmly established as a military asset.[5] Subsequently, AMT has been extended during wartime situations to include both primary helicopter flights (i.e., from the scene of injury to an initial care facility) and secondary FW transport to a definitive care center that can be hundreds or thousands of miles distant.[53,100]

Facilitation of patient access and rapid helicopter transport during wartime offered obvious lessons for the civilian world.[135] Experiences from Korea and Vietnam led to early adoption of helicopter EMS for nonbattlefield settings in countries such as Germany and the United States.[24,181]

Just as FW aircraft predated helicopters, FW medical transport occurred long before the Korea/Vietnam era. In most areas, FW aircraft have usually been employed for secondary (interfacility) patient transport. Secondary transport, complemented by primary transport in remote regions for which distance renders helicopter transport impossible, remains a critically important role for FW air medical services.[208]

In the past few decades, AMT (particularly, with helicopters) has grown in numbers of aircraft used and geographic regions served. AMT began with a few services in the early 1970s, and by the 1990s there were hundreds of services flying well over 100,000 patients annually.[84] The Association of Air Medical Services Atlas and Database of Air Medical Services (ADAMS) project tracks helicopter and FW medical services using geographic information software. ADAMS data estimate that in the United States, 1020 helicopters transport 400,000 patients annually, with an additional 150,000 patients flown in the country's 346 FW aircraft.[2] Up-to-date information on air medical assets and their U.S. distribution is available on the ADAMS website: adamsairmed.org.

With the burgeoning of air medical services came the realization that an accreditation process was needed to optimize patient safety and the quality of medical care provided. The Commission on Accreditation of Medical Transport Systems (CAMTS; camts.org), founded in 1990, is dedicated to improving these factors. CAMTS counts 21 member organizations (e.g., American College of Emergency Physicians, Air and Surface Transport Nurses Association, National EMS Pilots Association) that participate in generating standards (now in their ninth edition) applicable to helicopter, FW, and ground transport services. CAMTS accreditation is held by approximately 170 U.S. services and about 6 international services.

Air medical services offer advantages of access, critical care, and rapid transport. The many clinical and logistic requirements of wilderness medicine make the field especially well suited to benefit from the strengths of AMT (e.g., time savings, remote patient access, advanced prehospital care).

BUSINESS AND ORGANIZATIONAL MODELS FOR AIR MEDICAL TRANSPORT PROGRAMS

There are myriad business and financing approaches to the operation of AMT aviation and medical components. Categorization of models can be complicated. One hospital-based university helicopter EMS program reports that its five bases are operated by 130 university employees who work alongside an additional 50 or more on-site staff affiliated with the for-profit company that provides aviation services.[85]

A "program" may have a broad range of business models. For example, a single helicopter program, the Air Evac Lifeteam (lifeteam.net), uses a unified corporate structure, including administrative and medical directorship. The Air Evac Lifeteam "single program" operates more than 100 U.S. bases and performs tens of thousands of transports annually (Figure 58-2). Other single programs, such as Vanderbilt University's LifeFlight and the multihospital Boston MedFlight, operate numerous aircraft (and ground vehicles) across a large area.[85] Finally, many single programs consist of one helicopter based at one hospital.[2]

FIGURE 58-2 The Bell 206 LongRanger family has an extensive history of air medical use in civilian and military settings. Skid landing gear facilitates helicopter landing on nonpaved surfaces. *(Courtesy Air Evac Lifeteam, Inc.)*

Differences in helicopter program sizes and definitions make descriptions of "average program" characteristics difficult. For example, the number of programs decreased between 2008 and 2014 from 310 to 300, whereas the number of helicopters in service substantially increased (from 840 to 1020).

Administrative AMT considerations with relevance to wilderness and environmental medicine are limited and straightforward. First, there are considerations relevant to crew staffing (see the section on crew models later in this chapter). Second, there are considerations that fall under the aegis of "knowing one's resources." This section's brief overview of administrative models for AMT services emphasizes implications for wilderness medicine.

Each of the models discussed may include a combination of vehicles (helicopters, FW aircraft, and surface vehicles). Precise numbers for specific model configurations are not provided here because the numbers are always changing, are difficult to interpret (see above), and have limited relevance to wilderness medicine considerations.

HOSPITAL-BASED AIR TRANSPORT SERVICES

Hospital-based AMT services are run by individual medical centers. When multiple hospitals collaboratively operate a program, the term *consortium service* is commonly employed. Most of the early helicopter EMS programs in the United States were hospital based, but these programs are now outnumbered by services with other organizational configurations.[2]

Even within hospital-based services, organizations vary. For example, programs based at hospitals may or may not contract aircraft-related services to specialized aviation companies. Some hospitals base their aircraft at the home hospital, whereas others deploy their aircraft at satellite locations.

Regardless of differences in details, one key component for wilderness medicine understanding of hospital-based helicopter EMS is the case mix of the hospital out of which the aircraft operate. Pediatric centers and heart hospitals are characterized by markedly different patient populations, so units based at these hospitals may bring different types of experience and expertise to the wilderness medicine patient.

COMMUNITY-BASED AIR TRANSPORT SERVICES

Due in large part to the time and resource commitments required to operate helicopter EMS, air medical services are increasingly becoming community based (i.e., not administratively based at a hospital). Aircraft of the community-based services may or may not be stationed at hospitals. Even if they are, the helicopters are often placed at smaller outlying facilities rather than at larger receiving centers. It is therefore quite possible that a community-based helicopter EMS will be the closest air medical asset in many wilderness medical situations.

Community-based helicopter services range from single-aircraft operations to large multistate programs (e.g., Air Evac Lifeteam) with scores of aircraft. Thus, as is the case for hospital-based programs, there is a range of operational capabilities (and potential expertise) within community-based services.

GOVERNMENT-SPONSORED AIR TRANSPORT SERVICES

AMT may be provided by governmental organizations. These operations, which number at least a few dozen in the United States (as outlined at adamsairmed.org), are also seen around the world.[34,155,175] Government aircraft operated by police or military agencies tend to bring additional mission capabilities, particularly in search and rescue (SAR), which can be quite useful in wilderness medicine situations (Figure 58-3).

Some government AMT operations, such as the well-known helicopter unit of the Maryland Institute for EMS Systems, are largely dedicated to patient care and transport.[44] Aircraft of other government agencies, which have primarily nonmedical missions, can be used for civilian AMT on an "as-available" basis. An example of this is the Military Assistance to Safety and Traffic (MAST) program, which has deployed RW and FW assets since the early 1970s.[165] MAST units, which do not compete with civilian helicopter operations, but rather serve as backup options when they are available, have proven to be valuable partners for AMT all over the United States, from the eastern seaboard to the Hawaiian Islands.[6,61,164]

Military aircraft also provide ad hoc assistance in many international settings, particularly in countries lacking well-developed civilian (or national public service–model) helicopter EMS. They include services, such as the U.S. Air Force Critical Care Air Transport team, the capabilities of which highlight the importance of military expertise for worldwide patient transport[125] (Figure 58-4).

AIR TRANSPORT ORGANIZATION: LESSONS FOR WILDERNESS MEDICINE

Whether an AMT program is under the auspices of the military, a public service organization, a hospital, or a community, the key for wilderness medicine is to know the resources available in one's region. Different types of organizations may be characterized by significant variations in aircraft type as well as response capability and speed. For instance, community-based helicopter EMS operations in the United States tend to use smaller, slower helicopters than the large aircraft flown by the military, but military assets are primarily intended for military missions and may not always be able to provide a rapid response for civilian

FIGURE 58-3 An MH-60G Pave Hawk hoists a pararescuer during a search and rescue exercise. The S-60 variant includes modifications such as forward-looking infrared, night vision–compatible cockpit lighting, terrain and navigation radar, auxiliary fuel tanks, and hoist. The aircraft can be refueled while in flight. *(Courtesy of U.S. Air Force.)*

FIGURE 58-4 Military jets play an important role in long-range transport of casualties, as illustrated in a training exercise. **A,** Two burn "victims" (actually manikins) transported by the U.S. Army Burn Transport Team during a training mission aboard a U.S. Air Force C-17 aircraft **(B).** *(Courtesy Robert C. Allen.)*

missions. Wilderness medicine practitioners do not need to immerse themselves in AMT's administrative and corporate organizational minutiae, but good planning and optimal wilderness outcomes are facilitated by knowing regional AMT assets.

CREW MODELS IN AIR MEDICAL TRANSPORT

Differences in crew configurations in AMT programs are more apparent than differences in administrative organization. Staffing variations in different models of helicopter and FW services are myriad. Even for a given AMT service, crew configurations may change depending on the particular mission profile (e.g., different crews for transport of a neonate than for an adult cardiac balloon-pump patient).

Reviews as recently as 2014 continue to address important components of the debate about optimum crew configuration.[64,98] There is not a single definitive model. We outline the staffing types that may be encountered while highlighting areas of potential wilderness medicine relevance.

AIR TRANSPORT CREW WITH A PHYSICIAN

Physicians were not part of the earliest helicopter EMS trauma transports in the 1950s to 1970s, because these early military flights were more focused on evacuation than on treatment.[134,135] On military FW transports during the same era, physicians began accompanying flights over longer distances in larger aircraft.[117] The presence of a physician is now standard in lengthy military FW transports.[100]

Some civilian FW transport operations (e.g., Australia's Royal Flying Doctor Service) have incorporated physicians since their inception.[170] Long-distance FW transport can entail complex cases that commonly require a physician presence.[91] European FW and helicopter transport services have also tended to include physician crews.[26,76,179]

In part because of the emergence of the specialty of emergency medicine in the United States, some early American helicopter units incorporated emergency physicians into their crews.[11,64,72] The practice of using an emergency physician on at least an occasional basis continues at many university-based programs[75] (Figure 58-5). The proportion of U.S. flight crew members who are physicians at any level has remained stable at approximately 5%.[2]

The capability of having emergency medicine residents fly as part of a helicopter unit has been noted to offer substantial advantages to both the physician and nonphysician crew members.[85] Professional societies such as the National Association of EMS Physicians (NAEMSP) have position statements that outline specific components of training recommended for developing expertise as flight physicians.[196]

AIR TRANSPORT CREW WITHOUT A PHYSICIAN

Although the potential advantages of having doctors on the aircraft have been studied and reviewed,[59,62,156,175] most helicopter services in the United States operate without on-board physicians.[2] The growth of emergency medicine residencies has contributed to more physician staffing of these services, but the overall proportion of missions with physician staffing remains at approximately 5% to 6%.[64]

Crew configurations include some combination of nurse, paramedic, respiratory therapist, or other specialty crew members such as perfusionists and advanced-care nurses (e.g., neonatal nurse practitioners). In the United States, most crew members are nurses and paramedics (each ≈ 40% to 45% of all flight crews).[2]

In the past few decades, data have demonstrated the capability of a nonphysician crew in providing advanced medical care. Nonphysician crews treat pain with potent analgesics (e.g., fentanyl),[39,40,97] institute blood transfusions,[33] place intraosseous access devices,[174] decompress pneumothoraces (with needle or tube thoracostomy),[85,219] and execute advanced airway management with success rates rivaling those in hospital emergency departments.[189] Nonphysician crews have adapted to the growing complexity of medical equipment (e.g., AMT crews can provide advanced mechanical ventilation modes with state-of-the-art ventilators that have been downsized for suitability in the transport setting).

As would be expected, not all flight crews are able to execute all advanced interventions. However, existing evidence supports the potential for nonphysician helicopter crews to provide advanced and effective out-of-hospital care. Keys to success in these arenas lie in training and skills maintenance. Helicopter services with a high rate of success in managing airway disorders have outlined the facets of their training programs that contribute to intubation efficacy, including cadaver lab training, advanced medical simulation, and operating room and clinical experiences.[189]

FIGURE 58-5 University-based air medical programs may occasionally be staffed with physicians. Specialized training includes simulation exercises in the helicopter cabin of this Airbus EC135. *(Courtesy Michael Abernethy and Ryan Wubbens, University of Wisconsin Med Flight.)*

Successful helicopter operations devote a great amount of attention to hiring, training, and skills maintenance for nonphysician crew members. Requirements to be considered for a flight nurse position with Vanderbilt University's LifeFlight program include:[85]

- 3 years of experience in tertiary care in an emergency department or intensive care unit
- 640 hours of experience in pediatric care
- Certifications in adult and pediatric resuscitation courses, such as advanced cardiac life support (ACLS), pediatric advanced life support (PALS), and the Neonatal Resuscitation Program (NRP)
- Certification as an emergency nurse *or* critical care registered nurse *or* certified flight registered nurse
- Completion of a trauma nursing core course *or* transport registered nurse advanced trauma course

The Vanderbilt program's minimum hiring criteria for flight paramedics are similarly rigorous. New flight paramedics must have 3 years of adult and pediatric patient care experience, as well as certifications including ACLS, PALS, and NRP. They are additionally required to have certification in either prehospital trauma life support or basic trauma life support.[85]

Not all AMT programs have access to the same crew-hiring pools, and thus crew characteristics tend to vary among services. Furthermore, not all programs have the resources to provide crews with an ideal level of training and skills maintenance education (e.g., cadaver labs, high-fidelity simulation).[85,189] As with so many other aspects of the AMT arena, wilderness medicine providers are advised to become familiar with the characteristics of the resources in their area.

AIR TRANSPORT CREW CONFIGURATION: LESSONS FOR WILDERNESS MEDICINE

Although the optimal crew configuration remains open to debate, there is near-universal agreement that the capabilities and scope of practice of each crew are at least as important as their credentials.[177] The duties depend on the mission types of the transport program. Helicopter EMS scene responses, interfacility transports, SAR missions, hoist operations, and wilderness or disaster medicine evacuations differ from each other, and from FW operations such as transcontinental repatriation. For each of these mission profiles, different skill sets are required.

Wilderness medicine practitioners must be familiar with the air medical provider assets in their area of operation. Accurate assessment of aircraft and crew capabilities to perform different missions should inform planning and decision making. In some instances, specific crew capabilities (e.g., winch rescue training) are far more important than their medical credentials.[144] In an aircraft, tasks that are usually easy to perform, such as auscultation or palpation of a pulse, may become difficult.[79,195,194] Wilderness practitioners should understand that the flight cabin is in some ways an "austere" setting in its own right, and flight crews have specialized knowledge that can contribute to the success of the wilderness medicine air medical response and transport.

As AMT has evolved in recent years, increasingly complex diagnostic and therapeutic modalities (e.g., extracorporeal membrane oxygenation) are being used during helicopter transport.[161] The trend has distinct relevance to wilderness medicine cases. For example, ultrasound has the potential to diagnose a stroke, high-altitude pulmonary edema, increased intracranial pressure, and pneumothorax, even in the wilderness.[217,47,48] To the extent that the clinical care capabilities of AMT continue to expand, it will become even more important to staff helicopters with physicians or with nonphysicians who have extensive training and expertise.

A crew cannot be of help if it cannot get to the patient. Sometimes a crew with lesser medical training is the only one that can actually fly to the patient. An example would be use of a military (including U.S. Coast Guard) helicopter to execute a mission with medical corpsmen as crew when civilian helicopter EMS operators cannot fly (e.g., because of weather).[60] The wilderness medicine provider is advised to know all of the available resources to allow informed decisions about AMT service selection.

PHYSICIAN OVERSIGHT IN AIR MEDICAL TRANSPORT

Regardless of the crew configuration, AMT services must have committed leadership from physicians. The importance of the medical director in wilderness EMS has been highlighted by wilderness medicine experts who point out that remote or inaccessible terrain types often translate into a frequent need for helicopters in emergencies.[212]

DIRECT AND INDIRECT MEDICAL OVERSIGHT

As is the case for all types of prehospital physician oversight, physician direction is categorized as indirect (i.e., off-line) and direct (i.e., on-line). Indirect duties requiring the most time for medical directors include medical protocol development, quality assurance, crew hiring and training, and other administrative functions.[158] Direct duties, such as giving advice or orders during a transport, are additional functions of the position.[158] The amount of direct oversight depends on the situation. Indirect medical oversight is a key component of a successful program. Since the earliest days of military and civilian air transport, it has been known that medical guidance from a physician with transport experience and expertise can be invaluable.[117,181]

CHARACTERISTICS OF THE MEDICAL DIRECTOR

As lessons regarding the importance of air medical direction were learned over decades, the community of AMT directors (including both military and civilian leaders) evolved into a group with well-delineated qualifications and functions.[76,158] These qualifications are illustrated by position statements, such as that from the NAEMSP, that detail the specific background and training preferred for medical directors.[197]

Directors usually have training and interests relevant to wilderness medicine. In the United States, where helicopter EMS directors most likely have a background in emergency medicine, wilderness medicine principles and practices are likely to have been introduced during the emergency residency.[158] Furthermore, U.S.-based organizations' guidelines for flight physician training and medical director qualifications include familiarity with topics related to wilderness medicine.[196,197] Internationally, the specialty background of directors varies widely by country, but there are myriad training programs that include principles relevant to wilderness medicine.[160]

The exposure to wilderness medicine topics that physicians receive during residency training is helpful but incomplete. Experts have therefore included AMT in the core content of recommended topics for wilderness medicine fellowship training.[110]

THE MEDICAL DIRECTOR: LESSONS FOR WILDERNESS MEDICINE

Regardless of their specialty background, the AMT medical director can be an important asset for wilderness medicine planners and providers. The directors will know their crews, aircraft, and service capabilities.

Beyond familiarity with their services' capabilities, medical directors may be of assistance in the particulars of out-of-hospital response and transport. Even if the medical director does not have specific training in wilderness medicine, most individuals have flight medicine and prehospital care experiences that can be extrapolated to care in an austere setting. Medical directors are also quite commonly involved with other aspects of prehospital care, ranging from ground EMS to disaster medicine operations.[85,190] If a wilderness medicine operation is occurring in an area unfamiliar to its participants, the AMT director should be on the pre-mission contact list to aid in planning and preparation.

TYPES OF AIR MEDICAL TRANSPORT MISSIONS

AMT missions range from a helicopter response to a local scene to a transcontinental FW repatriation. Because wilderness medicine patients may use all components of the AMT system, we provide a review of the types of missions from an aviation perspective (medical categories of missions are discussed later in the chapter).

SCENE MISSIONS

Of the several traditional categories of missions, among the most important is a flight to assist a patient at the scene of injury or illness. *Scene transports,* used in the past mostly for trauma patients, are being used increasingly for nontrauma situations, such as a patient with acute coronary syndrome.[129] An AMT service may therefore be dispatched to a trauma scene or a nontrauma scene. In either case, the mission is also known as a *primary mission*.

Most primary missions use helicopters rather than FW aircraft because of the logistics of arranging, deploying, and landing an aircraft and getting to the patient. There are some cases, however, for which FW aircraft will be the initial mode of AMT (usually for a patient who has been stabilized by a ground EMS crew). These cases are particularly likely to occur in rural or remote settings beyond the range of helicopter units.

A helicopter emergency response for a primary mission can be activated by ground EMS, first responders, or others with minimal medical training (e.g., law enforcement officers). The pathways for activation may vary widely in differing jurisdictions.[112]

INTERFACILITY TRANSPORTS

In interfacility transport, or a *secondary mission,* AMT is activated by providers (usually physicians) at a hospital or similar medical care facility. The goal is to move a patient from one facility to another facility with a higher level of care.

In some situations, ground EMS providers may contact the AMT crew and have the flight team meet the ground ambulance at a point other than the initial scene. This point may be along the road from the scene toward the receiving facility or even at the helipad of a community hospital. The term *modified scene mission* is commonly used to describe these situations.

For patients in remote locations, there may be a question as to whether a mission that has originated at an ad hoc referring facility (e.g., seasonal medical care hut) qualifies as a primary or secondary mission (Figure 58-6) with potential associated regulatory implications.

FIGURE 58-6 Helicopters, such as this Airbus EC130, can provide important response and transport capabilities for seasonal clinics associated with wilderness activities. *(Courtesy MedFlight of Ohio.)*

Some interfacility transport missions qualify as specialty transports and so fly with different crew configurations (as compared with standard air medical staff). Neonatal transports are often specialty transports; standard air medical crew are supplemented or partially replaced with persons specializing in neonatal care. Other specialty transports include critical care missions in which specialist physicians or nonphysicians (e.g., respiratory therapists, perfusionists) may be taken along instead of, or in addition to, the regular crew. These types of transports deserve to be considered differently, because they entail different crew, additional transport segment(s) to pick up additional crew, and perhaps even different operational approaches, such as leaving the crew at the referring hospital to stabilize the patient over a period of hours before they return by another flight or transport by ground.

TYPES OF AIR TRANSPORT MISSIONS: LESSONS FOR WILDERNESS MEDICINE

National and international summary data on mission profiles tend to be unrefined in nature and limited in value. Numbers can vary dramatically even within a given country. As a rough estimate, primary missions tend to account for 30% to 50% of all helicopter transports.[82,85] For some services, such as those based at pediatric or cardiac specialty hospitals, scene missions are rare.[2] Other services, such as law enforcement vehicles, rarely perform interfacility transports.[2]

It is critical for wilderness medicine providers to know whether a particular service is accustomed to providing the type of response required for a particular situation. A helicopter service with pediatric specialty training that has never been involved in a scene response may be the closest service to a given wilderness situation, but contingency planners may determine that it is preferable to use a helicopter service with more appropriate training even if it is further away.

AIR TRANSPORT AIRCRAFT

In 2014, U.S. ADAMS data showed that there were a total of 1020 helicopters and 346 FW aircraft used for AMT; many types of helicopters and airplanes were involved.[2] Wilderness medicine providers should have a working knowledge of aircraft capabilities.[83]

Here we highlight selected aircraft used for various mission profiles, and point out specific aviation and logistics principles relevant to wilderness medicine.

AIRPLANES FOR LONG-RANGE AIR MEDICAL TRANSPORT

Airplanes are commonly used for medical transport. Weather and logistics are two common factors that drive the choice of FW rather than RW transport. For a variety of geographic, aviational, and situational reasons, it is not possible to specify a universally applicable distance cutoff beyond which FW aircraft are the only transport option. Although there are reports of long-distance transports by helicopters under exigent circumstances, logistics considerations make FW planes the practical choice when transport distances are longer than a few hundred miles.[71]

An airplane is nearly always the vehicle of choice for transcontinental and similarly long flights. These transports tend to involve patients who have experienced illness or injury while away from their home region. The airplane is used to move the patient from an initial stabilizing hospital back to the patient's domicile. More serious cases require dedicated aircraft for transport, but for stable cases, regularly scheduled commercial flights may be used.[8,42,145] Information pertinent to triaging these cases is presented later in this chapter.

For patients of higher acuity, commercial flights are not an option and dedicated FW transport is needed. Worldwide, there are many long-distance FW services (including military units) with capabilities ranging from straightforward observation to management of specialized equipment such as ventricular-assist devices[128] (see Figures 58-1 and 58-4). In long-distance transports, patients are often categorized as critical and the duration of air

TABLE 58-1 Examples of Airplanes Used in Medical Transport

Manufacturer*	Model (name/type)	Engines	Approximate Cabin Volume (cubic feet)†	Minimum Runway Length (feet)‡	Service Ceiling (feet)	Maximum Cruise Speed (mph)§	Maximum Range (miles)
Lockheed-Martin	C-130 (Hercules J-30)	4 turboprops	5,000	2,000	26,000	410	2,000
Boeing	KC-135 (Stratotanker RT)	4 jets	6,000	7,000	50,000	530	9,000
Boeing	C-17 (Globemaster III)	4 jets	20,000	3,500	45,000	520	3,000
Airbus	A-319 (neo)	2 jets	7,000	5,000	39,000	510	4,800
Boeing	737 (900ER)	2 jets	10,000	5,000	41,000	600	3,700
Dassault	Falcon (50 EX)	3 jets	800	4,700	49,000	570	4,000
Cessna	CitationJet (CJ3)	2 jets	300-400	3,200	45,000	500	2,200
Bombardier	Learjet (Lear 70)	2 jets	400-500	5,000	51,000	535	2,400
DeHavilland	Twin Otter (DHC-6)	2 turboprops	380-400	1,000	25,000	150	800
Beechcraft	King Air (250i)	2 turboprops	300-400	2,100	35,000	360	1,800
Pilatus	PC-12 (NG)	1 turboprop	400-500	2,700	30,000	325	2,100
Cessna	Conquest (441-II)	2 turboprops	400-500	4,000	35,000	300	2,500

*Data are from manufacturers' websites (airbus.com; beechcraft.com; boeing.com; bombardier.com; cessna.com; dassault.com; lockheedmartin.com; pilatus-aircraft.com).
†Differences in cabin configurations can have a marked impact on cabin volume in patient care space.
‡Minimum runway length for takeoff at sea level; different conditions (e.g.,. higher altitude, varying runway surface) will dictate different minima.
§Maximum cruise speed often depends on flight distance; long-range transports may entail need for lower cruise speeds.

medical attendance can exceed 8 to 10 hours.[81,100] For the wilderness medicine practitioner planning a transport, the duration of time patients spend in flight emphasizes the need for some familiarity with aircraft characteristics.

Aircraft speeds and ranges reported herein are provided solely for purposes of a rough overview. Multiple factors, including payload (weight), weather, and individual airplane modifications (e.g., C-130H versus C-130J), contribute to broad variability of speed and range, even for two aircraft of the "same type" operating in the same area. Information regarding individual FW performance characteristics is provided in Table 58-1 as a rough guide, with the caveat that meteorologic, topographic, payload, and other parameters can substantially affect aircraft performance numbers.

Military long-distance flights usually occur in order to move patients from forward-area hospitals near combat zones, or to evacuate patients from remote bases with limited care capabilities (e.g., Guam).[100,142] Military transports tend to occur in larger aircraft, given the resources available to these governmental agencies. Of course, different countries' military assets vary, but in the United States, the airplanes most commonly used include the C-130 Hercules, KC-135 Stratotanker, and C-17 Globemaster. Because the U.S. military has few (if any) airplanes solely allocated for AMT, these large cargo airplanes are repurposed for medical flights. Information on airplanes' capabilities comes from the U.S. Air Force website (af.mil) and from the medical literature outlining operations of the Air Force's Critical Care Air Transport Team.[100]

The C-130 is a turboprop with a cruise speed and range (for the newest models) of approximately 400 mph and 2000 miles (see Figure 58-1). The aircraft is noteworthy for its ability to use austere-setting runways (even simple strips of dirt or gravel) of short distance. Peacetime runway minimal requirements for the Hercules are approximately 2000 to 2500 feet (length) by 60 feet (width). The capability of serving runways in lesser-developed regions, including areas at high altitude, renders the Hercules particularly useful in natural disasters or other mass casualty incidents occurring in remote areas. Despite its rugged flight characteristics, the patient care setting in the Hercules can allow for use of advanced medical devices such as an interventional lung assist.[91]

A step up in size from the C-130, the quad-jet KC-135 Stratotanker's requirement for a long runway (at least 7000 feet) is offset by its markedly increased range. With the standard five-person medical crew complement (two registered nurses and three medical technicians), the KC-135 cruises at 530 mph with a range of over 9000 miles. The extended range has contributed to its frequent use; the Air Force website (af.mil) reports that one KC-135 unit has flown approximately two dozen air medical evacuation missions since 2005.

Some of the most desirable characteristics of the C-130 and the KC-135 are found in the C-17 (see Figure 58-4). Like the C-130, the Globemaster can use an austere runway of short length (minimum, 3500 feet) and narrow width (at least 90 feet). Although the C-17 does not have quite the range of the Stratotanker, the Globemaster's capability of flying 520 mph for 3000 miles (not counting its capability for in-flight refueling) contributes to its high utility in a variety of medical evacuation scenarios with relevance to wilderness medicine.[100]

Other countries' military planes used for long-distance patient transport tend to be similar to aircraft used in the United States. For example, when a large earthquake struck China in 2010, many evacuations were executed by that country's rough equivalent of the C-17, the Ilyushin Il-76.[113]

Whereas military long-distance transports tend to be limited in type, civilian long-distance transports involve many different airplanes. For mass casualty incidents and environmental disasters such as earthquakes or tsunamis, the ad hoc nature of civilian aircraft deployment means that airplanes used for medical evacuation are those that usually operate in regional regularly scheduled commercial air services.[4,113]

Civilian airliners in use for long-range transport are not designed for short runways in austere settings, so their ready availability is offset by their need for a paved runway of sufficient length. Civilian airports wishing to be able to accommodate any aircraft, including wide-bodied planes with enough fuel for intercontinental flight, usually have runways of approximately 10,000 feet in length. At lower altitudes, runways 7000 feet long should suffice for most other long-range aircraft.

In the Yushu earthquake, specific civilian commercial aircraft were used to complement military aircraft for medical evacuations, most notably, the Airbus A-319 (the shorter-fuselage version of the cornerstone Airbus single-aisle A-320 passenger jet).[113] The A-319's shorter fuselage and associated decrease in runway length requirement, combined with its range of well over 4000 miles (data from airbus.com), rendered this aircraft well suited for medical evacuation service after the Chinese earthquake.

The A-319 is but one example of a civilian airliner's having been useful in a temporary air medical evacuation role. In response to a mass casualty incident in Sweden in which there was insufficient capacity to move large numbers of patients long distances, the Scandinavian Airlines System developed the capability of temporarily converting a Boeing 737 passenger jet into a fully outfitted flying hospital (boeing.com/boeing/

FIGURE 58-7 **A,** The Cessna CitationJet III is typical of intermediate-range air medical transport jets. **B,** Interior of the Cessna CitationJet III depicts a layout characteristic of intermediate-range air medical transport jets. *(Courtesy Boston MedFlight.)*

commercial/737family/5000/sas_medical.page). The 737's speed (nearly 600 mph) and range (≈ 3700 miles) are quite well suited to transporting dozens of patients in one flight.

Civilian long-range AMT includes dedicated jet aircraft capable of flights of thousands of miles. For example, the Dassault Falcon 50's flight parameters (range approaching 4000 miles at approximately 570 mph) have enabled it to execute nonstop transports, such as moving a Lassa fever patient from Sierra Leone to Sweden.[114] The Cessna Citation series of jets has also been long used for a variety of civilian long-distance transports on multiple continents[108] (Figure 58-7). This family of aircraft, exemplified by the CJ-2 and CJ-3 (cessna.com), is characterized by a long range (depending on the model, up to 2500 miles at 480 to 520 mph) and the capability of using relatively short (3200-foot) runways. The Lear 70 (bombardier.com) used by some international air medical services has a long-range speed of approximately 500 mph, with a range of nearly 2500 miles and runway requirement of 5500 feet.

Myriad aircraft are used for intercontinental and other long-range patient transports. Whether considering movement of a mildly ill trekker on a commercial flight or planning an air response to a mass casualty earthquake, wilderness medicine physicians benefit from familiarity with the capabilities of long-distance air vehicles.

AIRCRAFT FOR SHORT- AND MEDIUM-LENGTH TRANSPORTS

Although airplanes that are well suited for transoceanic flights may also be used for short medical flights, practicality renders such practices uncommon. For transports of hundreds (not thousands) of miles, long-distance airplanes tend not to be used for reasons of economics, availability, and even runway length. As with long-range transports, myriad types of aircraft are used for shorter-distance transports. The aviation characteristics of these airplanes are exemplified by the commonly used twin-engine (Beechcraft King Air) and single-engine (Pilatus C-12) aircraft.

The twin-engine turboprop Beechcraft King Air (beechcraft.com) is one of the more widely used civilian FW aircraft for transports within a thousand miles' distance (Figure 58-8). As is the case with other planes, King Air models differ with respect to aviation specifications. The performance parameters of the King Air 250 are representative: It can operate from a runway (at sea level) of 2100 feet and cruises at over 350 mph with a range of 1800 miles. Shorter-range aircraft, such as the King Air, tend to carry two medical crew members along with patients. There is often room to accommodate a few family members, as well.

Other twin turboprop aircraft that are generally comparable to the King Air include models by Piper (e.g., Chieftain, Cheyenne) and Cessna (e.g., Conquest). As with the King Air, there are different types within the same model series. These planes may be able to accommodate two or three medical crew (and sometimes additional passengers), and can take off on relatively short runways (in the range of 2500 to 4000 feet). The range varies, but it can be significant (e.g., 2500 miles for the Cessna Conquest II). The twin turboprops generally cruise at 250 to 350 mph.

Perhaps the most broadly used single-engine medical transport airplane worldwide is the Pilatus C-12 (Figure 58-9). The PC-12 cruises at just over 320 mph for a range of over 2000 miles. This versatile aircraft requires 2700 feet of runway in normal conditions, with some models having excellent capabilities at high-altitude airports or those with unimproved surfaces (e.g., grass).

Twin-engine turboprop aircraft and even some single-engine planes (e.g., Pilatus C-12) may be able to accommodate two patients on stretchers. This may depend on the specific airplane and service (even with the same aircraft, not all air medical providers' cabin configurations are the same). The ability to carry more than one patient is noteworthy for its potential applicability to multicasualty wilderness medicine situations.

Another parameter important to confirm is whether the aircraft has a pressurized cabin. Aircraft discussed in this section should generally have cabin pressurization (which is not available on medical transport helicopters). It is prudent to confirm that this capability is present when considering AMT options.

The types of FW aircraft discussed in this section are not practical for AMTs that are very long (e.g., transoceanic). However, the relatively low cost and the versatility (e.g., runway requirements allowing use in austere settings) render these turboprops useful for transports of a few hundred miles to 2000 miles. When circumstances such as weather or topography render helicopter transport impractical, turboprop aircraft can be the appropriate modality, even for transport distances under 200 to 300 miles.

HELICOPTERS FOR WILDERNESS TRANSPORT

The first and most obvious aviation parameter that helicopters offer is the ability to take off and land without a runway. There

FIGURE 58-8 The Beechcraft King Air is commonly used for short-range fixed-wing air medical transport. *(Courtesy Air Evac Lifeteam, Inc. Operated by EagleMed LLC.)*

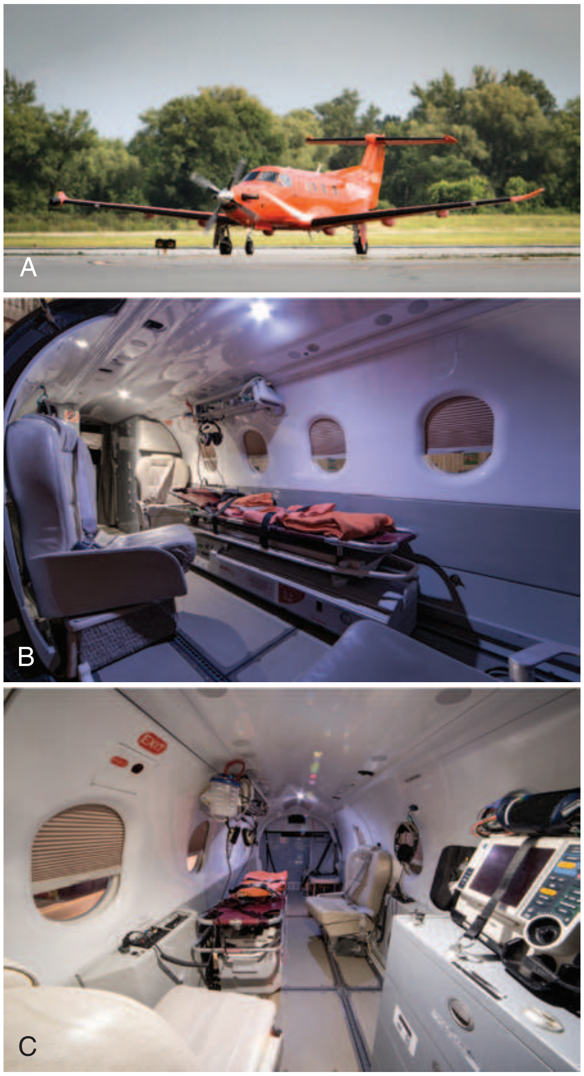


FIGURE 58-9 **A,** The Pilatus C-12 is one of the most commonly used airplanes in medical transport worldwide; it has particularly good performance at high altitudes and on unimproved runway surfaces. **B,** Side entry into the Pilatus C-12 reveals positioning of the patient stretcher. **C,** View toward aft of the Pilatus C-12 patient care cabin reveals positioning of crew seating with respect to the patient stretcher. *(Courtesy Joshua McNamara, Ornge, Ontario, Canada.)*

are a few airplanes with vertical takeoff and landing capability, but decades of theorizing about the potential of tilt-rotor aircraft (e.g., V-22 Osprey) for AMT have not spurred widespread (nonmilitary) use of these special vehicles.[166] If a wilderness situation calls for transport in a setting without a runway, a helicopter will almost always be the sole option.

The ability of a helicopter to take off and land vertically is accompanied by its capability of hovering and slowly circling an area, such as a landing zone (LZ). This allows relatively flexible deployment into rough or unknown terrain (Figure 58-10).

Using the aircraft's hovering and slow-flight characteristics, the EMS crews can scout LZ regions, search for victims, and execute extraction (e.g., hoist) operations over land or water (Figure 58-11). A helicopter's aviation profiles allow a range of applications, from mountain or canyon backcountry evacuations to patient transports after natural disasters such as avalanches or earthquakes.[29,36,63,67,68,77,122,137,150,162]

RW aircraft can be of benefit in wilderness medicine situations even when they do not perform the traditional role of landing to transport patients. For instance, rotor "wash" may be used to cool a patient with heat illness (a situation recounted in helicopter EMS lore and also cited in the Wilderness Medical Society

FIGURE 58-10 The Alouette's light weight and performance at altitude render it well suited for alpine rescue in difficult terrain. *(Courtesy P. Bärtsch, MD, and the Swiss Alpine Club.)*

practice guidelines).[109] More commonly, a helicopter's unique flight characteristics may allow it to pick up a patient from an area in which it cannot land (e.g., in an area with steep terrain, it may provide short-haul transport of a person suspended beneath it).[214] Its flight characteristics also are useful in SAR missions for transporting a team, searching for a victim, or facilitating communications via airborne radio[163,90,148] (Figure 58-12).

As with FW aircraft, capabilities for AMT vary among different helicopters. For instance, some helicopters are better suited for very long distance transports and others may be more appropriate for special functions such as high-altitude rescue (Figure 58-13) or hoist operations (see Figure 58-3). An overview of helicopters in use for AMT highlights some of the differences in flight characteristics. Keeping in mind the tremendous situational variability that can characterize wilderness transports, the distance cut-point for selection of RW rather than FW aircraft is usually defined as a one-way range of 200 to 300 miles.[161]

FIGURE 58-11 U.S. Coast Guard HH-60J Jayhawk helicopter (like the Black Hawk, an S-70 variant) in low hover over water, preparing to lower hoist cable to the rescue swimmer. Note the extensive spray under the aircraft. *(Courtesy U.S. Coast Guard.)*

FIGURE 58-12 The Airbus EC130 **(A)** is noteworthy for superb visibility from the pilot's seat **(B).** *(Courtesy MedFlight of Ohio.)*

FIGURE 58-13 The Bell 407 appears similar to the Bell 206 (see Figure 58-2), but its manufacturer-recommended service ceiling (i.e., maximum operational altitude) is nearly twice as high. *(Eric Swenson, University of Utah AirMed.)*

Categorizing and Comparing Helicopters Used in Air Medical Transport

As is the case for FW aircraft, situational specifics can also substantially affect a helicopter's range, speed, ceiling, and other aviation parameters. Two aircraft with similar performance parameters as assessed near sea level can have markedly disparate capabilities in extreme conditions (e.g., high altitude, hot desert). With this important caveat in mind, Table 58-2 provides a general overview of some characteristics of helicopters used in wilderness rescue around the world. The information in Table 58-2 comes from the ADAMS 2014 database, which reports the types and numbers of RW aircraft in use in the United States to provide a general idea of which are used most often. Other information comes directly from manufacturer websites and corporate representatives: AgustaWestland (agustawestland.com), Airbus (airbushelicopters.com; Jennifer Hardcastle, air medical sales manager), Bell (bellhelicopters.com), and Sikorsky (sikorsky.com). The method of reporting aircraft parameters precludes a true apples-to-apples comparison because various companies frame technical performance data in differing ways. Furthermore, commonly cited reporting services (e.g., Conklin and DeDecker, conklindd.com/cdalibrary) calculate fuel consumption and range using assumptions (e.g., providing range at 90% of maximum cruise speed rather than maximum endurance speed) that differ from those used in reports from aircraft manufacturers. Even for seemingly basic information such as "patient care cabin space," some helicopter manufacturers include "luggage space," which can reasonably be used for medical equipment, while other manufacturers leave out this space. For these reasons, the information provided can be used only for rough approximations and relative comparisons.

There are multiple methods for categorizing various RW aircraft commonly used in AMT. Range is one approach, but differences among helicopters tend to be less clearly delineated than ranges for airplanes. Also, the range of a helicopter can be greatly affected by conditions of wind, weather, fuel access, and other aspects.

Another concern is whether an aircraft can fly in conditions of low visibility by using instrument flight rules (IFRs). In AMT, most FW flights are conducted using IFRs. In helicopter operations, most missions are conducted by visual flight rules (VFRs). Most helicopter missions in the United States involve aircraft that are not capable of IFRs. Furthermore, even if the helicopter itself is capable of supporting IFR operations, the pilot must be appropriately certified. The converse is also true, that is, an IFR-certified pilot may be flying in a helicopter that does not support IFR operations.[15] When IFR operations are possible, the capability

FIGURE 58-14 Instrument flight rules can allow for helicopter flight directly to a hospital helipad. Fog can drastically reduce visibility and is among the meteorologic parameters checked by pilots along the entire planned flight route before any mission. *(Courtesy Michael Abernethy and Ryan Wubbens, University of Wisconsin Med Flight.)*

TABLE 58-2 Examples of Helicopters Used in Medical Transport

Type	Manufacturer*	Model (example nickname)	*n*, 2014 ADAMS†	Type for Which Performance Data Are Provided‡	Patient Care Cabin Volume (cubic feet)	Useful Load (lb)§	*Ceiling:* Hover out of Ground Effect‖	*Ceiling:* Service Ceiling (feet)	Maximum Cruise Speed (mph)	Maximum Range (miles)
Single-engine aircraft	AgustaWestland	AW119 (Koala)	32	119	122	3,014	15,000	15,000	144	520
	Bell	205/UH1 (Huey) series	8	205A-1	220	4,274	5,800	12,400	127	364
		206 (JetRanger, LongRanger)	119	206L4 LongRanger	100	2,119	6,510	10,000	125	374
		407	150	407GX	105	2,558	10,440	18,410	153	380
	Airbus (Eurocopter)	AS350 (A-Star)	161	B3e	106	2,413	9,450	14,950	158	398
		EC130	43	T2	131	2,353	9,675	18,085	146	376
Twin-engine aircraft	AgustaWestland	AW109 (Power, GrandNew)	42	109 GrandNew	139	3,182	20,000	20,000	152	506
		AW139	14	139	283	6,768	13,085	20,000	161	668
	Bell	212 (Twin Huey)	3	212	220	4,985	See note¶	12,900	115	264
		222	6	222B	130	3,321	6,400	15,800	160	345
		230	1	230 (wheel gear)	130	3,303	7,300	15,500	162	346
		412	21	412EPI	220	4,829	6,600	16,460	140	418
		429	9	429	204	3,022	11,290	18,710	173	428
		430	7	430 (wheel gear)	158	3,930	6,200	16,180	165	406
	Airbus (Eurocopter)	AS-332 (Super Puma)	3	L1	474	9,127	7,546	9,500+	162	517
		AS355 (TwinStar)	1	NP	106	2,419	7,080	13,380	138	455
		AS365 (Dolphin)	15	N3+	180	4,246	3,773	15,223	167	491
		BK117	84	C1	177	3,494	6,300	16,700	152	336
		BO105	13	CBS	154	2,761	1,500	10,000	150	345
		EC135	180	P3	173	3,303	8,200	17,200	157	548
		EC145	48	T2	241	3,951	9,700	18,000	153	404
		EC155 (Dolphin)	4	B1	235	5,072	8,000	15,000+	165	487
	McDonnell Douglas	MD900 series	7	MD902	163	3,525	10,400	20,000	154	349
	Sikorsky	S70 (Jayhawk)	3	S70i	396	10,400	4,550	12,790	172	313
		S76	24	S76D	204	4,907	4,930	15,000	178	543

*Data in table are from manufacturers, at sea level, standard atmosphere, maximum takeoff weight (SL, ISA, MTOW); table data from personal communications with Jennifer Andrews (Bell Helicopter-Textron), Michael Bucari (AgustaWestland), Loressa Diaz (McDonnell-Douglas), David Franc (Sikorsky), and Jennifer Hardcastle (Airbus). For all aircraft, the numbers used for U.S. distribution come from recent available data in the ADAMS database.
†Atlas and Database of Air Medical Services *n* (all types of given model) as reported in 2014.
‡Different types of same model have differing performance characteristics.
§Excess potential load above aircraft intrinsic weight.
‖Highest altitude at which helicopter can independently (outside of ground effect) maintain a hover attitude.
¶Aircraft cannot perform hover out of ground effect at takeoff maximum weight; Bell 212 can hover at sea level at 10,000 lb gross weight.

can include guidance to landing at predesignated fixed points such as hospital landing zones, because IFR conditions do not necessarily mean that helicopters can only fly to airports (Figure 58-14). IFR capability is desirable in that it increases a helicopter's likelihood of being able to accept missions, and also provides an additional safety margin in case the weather causes VFRs to become useless and instrument meteorologic conditions to become necessary (Figure 58-15). A pilot's ability to use IFRs comes at a significant increase in cost for equipment and training, and additional personnel are also usually needed (a copilot is often required for IFR operations).

Helicopters differ in the number of pilots needed. Many aircraft can support only one pilot, whereas others are often (or always) flown by an aviation crew of two. This distinction, like IFR versus VFR, is important as an aviation safety consideration for helicopter EMS, but there are gray zones in which an aircraft is sometimes flown by a single pilot but at other times (e.g., in IFR missions) by two pilots.

Perhaps the most common method of categorizing air medical helicopters is by the number of engines. This method, used by the ADAMS database, is simple and objective: Aircraft have either one engine (singles) or two engines (twins).[2,15] Twin aircraft tend to be larger in size, have a longer range, and are more likely to be capable of IFR operations (Figure 58-16). Single-engine aircraft tend to be lighter and potentially more suitable for use at high altitudes[181] (see Figure 58-6). Importantly, singles are less expensive to purchase and operate, so that singles now outnumber twins used for U.S. helicopter EMS. The next subsections discuss various helicopters in AMT use.

Multiple subtypes of helicopters exist within the same family. Helicopter EMS operators in the United States alone use seven different model variants of the AS-350 (see Figure 58-6) and eight

FIGURE 58-15 Moderate rain is not a safety problem for helicopter operations, but changing weather conditions encountered during a flight can prompt route alteration or even mission cancellation. *(Courtesy Michael Abernethy and Ryan Wubbens, University of Wisconsin Med Flight.)*

variants of the Bell 206 (see Figure 58-1). The differences can be as substantial as the differences between completely different helicopter models. Variations in aircraft models, situational issues (e.g., altitude, flight topography, load, wind/weather), and formats by which manufacturers list technical specifications greatly limit "apples-to-apples" comparisons of EMS helicopters. Therefore, the following sections discuss RW aircraft used in wilderness medicine with the goal of highlighting average performance parameters.

Single-Engine Helicopters

Cost and other factors have prompted a move in the United States toward a steadily increasing proportion of single-engine helicopters for EMS. Representative aviation sales websites (e.g., avbuyer.com) illustrate the magnitude of cost differences, even for used helicopters. The single-engine aircraft discussed in this section tend to be priced in the range of one to three million dollars, whereas the "light twin" larger aircraft (e.g., Agusta 109) can be expected to cost twice as much. The cost of larger twins (e.g., Sikorsky S-76D) can exceed 10 million dollars.

Operation DUSTOFF, mentioned earlier, was executed largely with the single-engine Bell Iroquois. The aircraft's initial military designation HU-1 (later changed to UH-1) was responsible for its nickname, Huey. The Huey, along with its military SAR model variant (HH-1) and its civilian version (Bell 205), is still executing missions for approximately six EMS programs, according to ADAMS data in 2014. These aircraft have high service ceilings (20,000 feet) and a relatively slow cruising speed (125 mph), with a range of 300 to 350 miles. They tend to be used in EMS

FIGURE 58-16 **A,** The AgustaWestland 139 is one of the larger aircraft used for civilian helicopter emergency services. Its size, speed, and range make it ideal for a number of mission types. **B,** Forward-facing view of the AgustaWestland 139 interior depicts typical layout for a fore-and-aft stretcher on each side of the cabin, with crew seating in between. Each stretcher has its own associated monitor, ventilator, and other medical equipment. **C,** The AgustaWestland 139 tail rotor's placement offers an increased safety margin. However, in certain wilderness settings (e.g., desert) the aircraft's weight causes settling in soft landing surfaces, and the tail rotor can become a hazard. *(Courtesy Hamad Medical Corporation.)*

transports associated with law enforcement and military units, and bring the advantages of a large amount of cabin space and lift capacity (e.g., to evacuate multiple casualties).

Military roots were also responsible for development of another commonly used single-engine EMS aircraft. The Bell 206 JetRanger was introduced to civilian aviation after a failed attempt to have the airframe selected as a military observation helicopter. The 206 aircraft used by EMS are those of the LongRanger series (including the 206L1, 206L1+, 206L3, 206L3+, and 206L4) (see Figure 58-1). Although law enforcement services (e.g., Delaware State Police, U.S. Park Police) have provided air transport with the LongRanger, most air medical 206 aircraft (over 100) in the United States operate as part of the multistate EMS service Air Evac Lifeteam. The LongRanger's extensive service history (the 206 was developed in the 1960s) and economic attractiveness come with a cruise speed of 120 to 130 mph and range of 350 to 400 miles.

Replacement of the two main rotors on the 206 with a four-rotor system, combined with other modifications, resulted in the Bell 407 (see Figure 58-13). The 407's maximum range is at the longer end of the spectrum seen in 206 models (nearly 400 miles), and its cruise speed is significantly faster at approximately 160 mph. Furthermore, the 407's cabin space of 85 cubic feet is approximately 6% larger than that of the 206. The 407 is seeing increasingly broad use worldwide, with deployment regions including both flat areas (e.g., Texas) and mountainous topography (e.g., Montana, Colorado, and Utah).

Rivaling the Bell 206 as the most commonly used single-engine air medical helicopter is the Airbus AS-350 Ecureuil (Squirrel) (known as Eurocopter/Aerospatiale prior to a 2013 rebranding) (Figure 58-17). Like the 206, the AS-350 can accommodate a single stretcher with two medical attendants. Its aviation performance parameters are slightly improved compared with those of the 206; its cruise speed is 158 mph and range is nearly 400 miles. Included in the many model variants of the AS-350 is the B3 model, which has executed long-line rescue on the world's 8th- and 10th-highest mountains (Mts Manaslu and Annapurna). An AS-350 has landed on top of Mt Everest (29,029 feet).[121] These impressive records illustrate the limitations of the information provided in Table 58-2, which lists 14,950 feet as the manufacturer-provided AS350B3e service ceiling (i.e., the highest altitude for which the aircraft is certified) (Figure 58-18).

Notwithstanding exceptional performances, the general operational envelope for single-engine aircraft encompasses environmental temperatures of approximately −40° C to +40° C, with a manufacturer-recommended altitude ceiling of 15,000 to 18,000 feet. A modification of the AS-350, the Airbus EC-130 (see Figure 58-12), is notable for a slightly higher manufacturer-recommended altitude ceiling (over 18,000 feet); the EC-130 is also noteworthy for its capability, unusual in single-engine helicopters, to potentially accommodate two patient stretchers. The EC-130, which cruises at nearly 150 mph for a range of almost 400 miles, is a derivative of the AS-350 and is thus part of the Ecureuil family. It is used by law enforcement agencies (e.g., California Highway Patrol) that provide AMT, and is also commonly employed in high-altitude areas of the United States (e.g., by Flight for Life Colorado bases in the Rocky Mountains).

The Agusta A-119 Koala is a single-engine aircraft that potentially accommodates two stretchers. Its one-way range and speed are approximately the same as those of the EC-130. The Koala is not commonly encountered in EMS, but areas of operation

FIGURE 58-17 The Airbus 350 A-Star is among the most commonly used helicopters in U.S. air medical transport. *(Courtesy Stephen H. Thomas.)*

FIGURE 58-18 **A,** The AS-350 B3 is particularly well suited to operations at high altitudes. Here and in part **B,** an AS-350 Ecureuil operates at a high-altitude monastery, and approaches for landing at a small high-altitude helipad of the Pasang Lhamu Nicole Niquille Foundation Hospital in Lukla, Nepal. **C,** View of AS-350 B3 from end of a long line. *(Courtesy Monika Brodmann Maeder.)*

FIGURE 58-19 Bell 412 EMS helicopter landing on a low bridge in the Texas hill country. Although small, this landing zone offers good approach and departure paths with minimal obstacles. Traffic over the bridge should be stopped at a minimum of 30.5 m (100 feet), and preferably more, away from the landing zone during approach, landing, and takeoff. *(Courtesy San Antonio AirLife.)*

FIGURE 58-21 The AgustaWestland A-109, noteworthy for its speed and model variants with extended capabilities, is used for air medical transports worldwide. *(Courtesy Reed Brozen, MD.)*

include regions such as Colorado and Arizona, in which wilderness transports are frequent.

Given increasing economic pressures, it is not surprising that more than 50% of U.S. AMTs now occur in single-engine helicopters. For the foreseeable future, these aircraft will likely continue to be a critical component of EMS.

Twin-Engine Helicopters

Some of the earliest twin-engine helicopter EMS missions were executed by a spinoff of the Huey, the dual-engine Bell 212, operated primarily by public services, such as sheriff's and fire departments. The second engine provides improved power and performance (over the Bell 205). The even more advanced Bell 412 features a four-blade main rotor (in comparison with the two-blade rotor of the earlier Huey derivatives) that provides even more aviation benefit (Figure 58-19). The 412's cruise speed is 140 mph, with an extended range exceeding 400 miles.

One of the most important advantages of the 412, and a factor the aircraft has in common with its Huey predecessors, is patient care space. The 412 boasts 220 cubic feet of cabin space, and 7.7-foot sliding doors allow easy access for a variety of advanced equipment. A four-axis autopilot (also available on many other helicopter EMS twins) facilitates SAR operations by enabling the pilot "hands-off" capability. In the United States, most 412 aircraft that execute AMT are operated by public service agencies, ranging from fire departments in Los Angeles and San Diego to SAR agencies in Alaska and Florida.

Although some civilian operators use Bell 412s, most nongovernmental EMS using Bell twins have opted for other models. Among the most common are the Bell 222/230 family, characterized by stub wings into which the landing gear retract (Figure 58-20). Compared with other dual-engine EMS helicopters, the 222 and 230 have a lower manufacturer's recommended operational ceiling (≈ 16,000 feet) but have excellent speed and range (≈ 160 mph and 430 miles, respectively). The Bell 430 is a stretched derivative of the 230 and has increased power, more space, and a four-bladed main rotor (the 222 and 230 are twin-bladed) that contribute to its higher top speed and improved aviation performance envelope. Taken together, these three Bell twins (the 222, 230, and 430) are used by dozens of civilian EMS operators in the United States and are thus likely to be encountered by wilderness medicine practitioners.

FIGURE 58-20 Emergency medical services Bell 222 helicopter landing on a freeway near the Nevada Test Site, 96.6 km (60 miles) north of Las Vegas. Note that traffic in both directions of the freeway has been stopped. *(Courtesy Nevada Test Site Fire-Rescue.)*

One of the newest Bell helicopter twins used in EMS is the 429. This aircraft looks like the previous "Rangers" (206, 407), but its cabin volume (204 cubic feet) is more than double that of the Bell 206 or 407 and its speed and cruise range are similarly improved (173 mph and 470 miles). So far, there are only approximately a half-dozen civilian EMS services using the 429.

AgustaWestland also offers twin-engine options. Their single-engine A-119 Koala is used by approximately a dozen EMS services, with four times as many services using the company's twin-engine A-109 (Figure 58-21). The A-109C MAX model, which is the company's air medical evacuation variant, is notable for its extrawide cabin and access doors that can be hinged at the top and bottom (rather than side by side). Another variant, the A-109 K2, is particularly well suited for high-altitude and high-temperature operations and is usually used by EMS services (e.g., in Idaho and Utah) performing significant numbers of SAR operations. The A-109 is noteworthy for its cruise speed (177 mph) and range (over 500 miles).

AgustaWestland's latest aircraft introduced for AMT is one of the largest and most capable helicopters. For EMS operators with the resources to obtain the AW-139, its combination of space (283 cubic feet), speed (190 mph), and range (> 700 miles) render it suitable for just about any imaginable RW mission (see Figure 58-16). In North America, the major fleets of AW-139s are in Ornge, Ontario, and with the Maryland State Police.

Because helicopter LZs may be small in the wilderness, the safety margin of having no tail rotor renders noteworthy the McDonnell Douglas MD-900 and closely related MD-902. These twin-engine aircraft have the speed (≈ 150 mph) and range (300 to 350 miles) typical of many other twins, but their lack of a tail rotor (they use a directed-flow nozzle instead) causes less noise and increases their safety. The aircraft, which are also noteworthy for having a relatively large cabin size (173 cubic feet), have a lower manufacturer-specified ceiling (14,000 feet) than some of the other twins. They are operated in the United States by civilian EMS providers primarily stationed in California and New York.

Airbus manufactures most of the twin-engine helicopters used for AMT. In the United States, few civilian EMS operate the twin-engine version of the previously discussed AS-350; the AS-355 TwinStar (employed in Europe as the Twin Squirrel) is a single-stretcher aircraft with performance characteristics moderately better than those of the AS-350.

Nearly two dozen variants of the AS-365 Dauphin (Dolphin) are used by U.S. EMS programs. The aircraft, which has a manufacturer-recommended operational ceiling of 15,000 feet, was most notably operated by the Maryland State Police (the first large helicopter EMS fleet in the United States) until their recent

FIGURE 58-22 The AS-365 (N2 variant) is one of the larger, faster twin-engine helicopters used in air medical transport. *(Courtesy Boston MedFlight.)*

transition to the AW-139. Other well-known users of the Dolphin include U.S. Coast Guard units executing SAR and AMT with the HH-65 variant (see Figure 58-1B). The Dolphin has benefited from ongoing improvement through succeeding AS-365 model variants (N1, N2, N3, and N3+) (Figure 58-22). The most recent variant, the EC-155 (initially designated the AS-365 N4), is entering U.S. operations and is currently used by the University of Michigan EMS. The Dolphin has remained a premium EMS aircraft. Its specifications include a large cabin (up to 235 cubic feet or more), rapid speed (cruises at ≈ 170 mph), and long range (approaching 500 miles), providing flexibility that may be useful in many wilderness medicine situations.

The next and most popular series of twin-engine EMS helicopters all arise from the older Messerschmitt-Bolkow-Blohm models BO-105 and BK-117 (Figures 58-23 and 58-24). These aircraft were both introduced in the 1970s and had multiple model variants until their eventual replacement with the EC-135 (see Figure 58-12) and EC-145 (Figure 58-25).

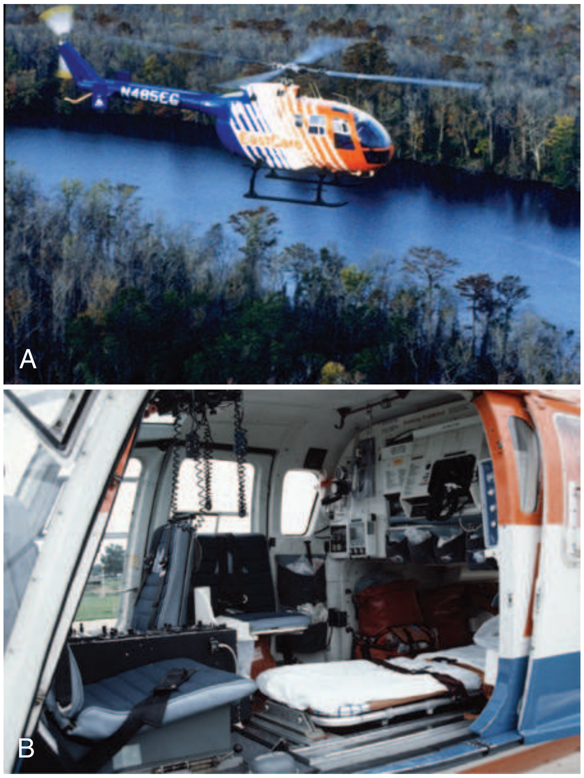


FIGURE 58-23 **A,** The BO-105, historically a workhouse of the U.S. air medical transport fleet, was often equipped with high-skid landing gear that facilitated landing on unimproved surfaces. **B,** Interior of the BO-105 depicts positioning of the patient stretcher and crew seats and gives an idea of patient care space in a light-twin helicopter. *(Courtesy Stephen H. Thomas.)*

FIGURE 58-24 **A,** The BK-117 has historically been one of the most commonly used helicopters in EMS. **B,** BK-117 with rear clamshell doors open. (**A** *Courtesy Geralyn Martinez and Stanford Life Flight.* **B** *Courtesy Susan Lockman and Stanford Life Flight.)*

The BO-105 was one of the first light twins. It was used by scores of EMS and SAR units in the decades after the 1970s. In 2001, the BO-105 production line was replaced by that of the EC-135, which was characterized by an increased speed (160 mph versus 150 mph), range (550 versus 350 miles), and operations ceiling (17,200 versus 10,000 feet). Major users of EC-135s in the United States have included some of the major for-profit EMS operators (e.g., Air Methods, Metro Aviation, Petroleum Helicopters International) as well as tertiary care center fleets, such as the University of Pittsburgh STAT MedEvac.

The BK-117 was introduced in the 1970s as a cooperative effort between Messerschmitt-Bolkow-Blohm and Kawasaki. As compared with the BO-105, the BK-117's larger size rendered it particularly well suited for EMS.[195] In 2004, there were more than 100 BK-117s in EMS use in the United States, but by 2014 this number had declined to 84. The drop in BK-117 numbers was mirrored by increases in numbers of its replacement model, the EC-145 (branded as the BK-117 C2 model in some countries). In the United States, EMS EC-145 numbers increased from 3 (in 2004) to 48 (in 2014). As a medium twin, the EC-145 is noteworthy for speed (155 mph), range (400 miles), and generous cabin space (241 cubic feet). Its manufacturer-recommended operations ceiling is 18,000 feet. EC-145s are used across the United States by law enforcement and civil aviation units.

The largest Airbus EMS aircraft in the United States are found in the fleet of three AS-332L1 Super Puma helicopters operated by the Los Angeles County Sheriff's Department. This aircraft is used worldwide by organizations ranging from the Tokyo Fire Department to Bolivian military disaster/SAR units. The Super Puma, with a cabin volume approaching 500 cubic feet, cruises

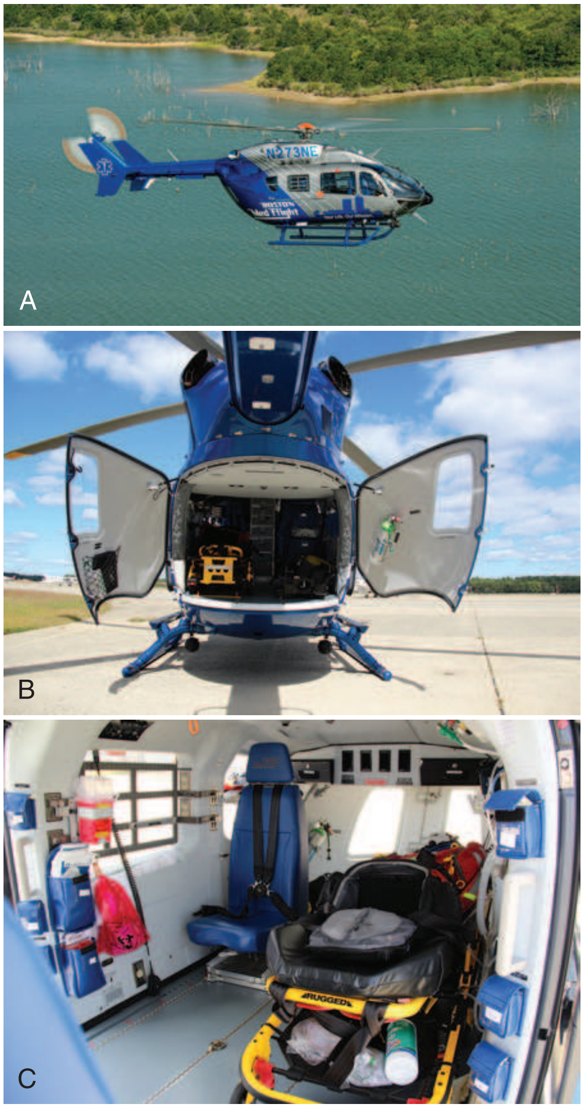


FIGURE 58-25 **A,** The Airbus EC-145 is the latest model of the old BK-117 line. **B,** The Airbus EC-145, depicting clamshell door entry from rear. Patient loading must take into account risk from the tail rotor (fenestron). **C,** The Airbus EC-145 interior. *(Courtesy of Boston MedFlight.)*

at approximately 160 mph with a range exceeding 500 miles and a manufacturer-recommended ceiling of 9500 feet. It has ample power for winch operations and can carry the equivalent of more than a dozen passengers.

The final twins discussed here are those carrying the name of helicopter aviation's pioneer, Sikorsky. The main Sikorsky helicopters used in civilian EMS are the S-76 family (Figure 58-26). Most comparable to the Dauphin and the AW-139, the S-76 is among the largest, fastest, and most capable of EMS aircraft. Although its manufacturer-recommended ceiling (15,000 feet) is a bit lower than that of some other aircraft, the S-76's aviation capabilities are laudable: speed of nearly 180 mph with a range of 470 miles and a cabin size of 204 cubic feet. Like the top-of-the-line RW aircraft of Airbus (EC-155, successor to the Dauphin) and AgustaWestland (AW-139), the S-76's performance comes at a relatively high price (in the range of 10 million dollars). There are a few dozen S-76s in civilian use in North America.

The other Sikorsky helicopters used for EMS are primarily found in the military, although some law enforcement operations also use these large aircraft. The S70, HH60M, and variants (Black Hawk, Pave Hawk, Jayhawk) are used by the U.S. Coast Guard and other armed services for SAR and EMS (see Figures 58-3 and 58-11). Nearly 24 "Hawk" variants are used by the Alaska Coast Guard and the Alaska Air National Guard. These aircraft have an excellent range (> 500 miles with external fuel tanks), cruising speed (≈ 172 mph), and amount of cabin space (up to six stretchers), which combine to render them extremely useful for a breadth of land- and ocean-based SAR and patient evacuation operations.

OTHER AIRCRAFT FACTORS

Aircraft power and lifting capacities are important considerations when assessing the suitability of a particular aircraft for a specific wilderness medicine mission. The need for a vertical takeoff (or even hovering) can place large demands on a helicopter's engine power, especially if it is a single-engine helicopter (Figure 58-27). The ability to rescue and carry heavy patients can be a restricting factor for many aircraft in high altitudes or hot weather (because less-dense air decreases lifting capacity). Similarly, in hot weather or at high altitudes, runway requirements can be longer, even for FW transports.

In both FW and RW transports, balancing weight in the aircraft is a major contributor to safety. Especially in smaller aircraft, the center of gravity can change substantially with the addition or

FIGURE 58-26 **A,** The Sikorsky S-76 is one of the larger twin-engine helicopters used in U.S. air medical transport. **B,** Among the S-76's advantages that may be less obvious is the additional safety margin provided by the high positioning of the tail rotor (see also Figure 58-16C depicting tail rotor height on AgustaWestland 139). It should be noted that the crew would not be in the depicted positions if the rotor were turning. *(Courtesy Boston MedFlight.)*

FIGURE 58-27 In alpine settings, hovering and hoist operations are often the only way to extract patients, rendering the helicopter the only air medical option. *(Courtesy of Urs Pietsch.)*

repositioning of even relatively light equipment. Any repositioning of a patient or of even lightweight equipment in the cabin should occur only after the pilot has confirmed that he or she is aware of and in agreement with it.

AVIATION LOGISTICS AND SELECTION OF A TRANSPORT VEHICLE

Situational specifics drive decisions regarding aircraft selection for a particular mission. Helicopters have greater speed than ground emergency medical vehicles, but with the speed come operational logistics and requirements (e.g., weather, LZ access) that can limit practicality. Airplanes have greater speed than helicopters, but their use entails additional transport legs and runway requirements.

SELECTION OF AN AIRPLANE VERSUS A HELICOPTER FOR TRANSPORT

Myriad aviation and logistic factors contribute to making the best decision about which plane or helicopter is best for a given transport. Situational variations are always a factor, so weighing all aspects of the mission is always important.

The initial factor to consider for all types of aircraft is distance to the patient. Differences in range are less of a factor in choosing among helicopters (although some, such as military helicopters, have a longer range, perhaps 500 miles). Distance is a significant factor when determining which transport missions are appropriate for helicopter transport rather than FW transport.

If a patient is 200 to 300 miles away, a helicopter is probably a good choice for rescue, but if the distance is longer, an airplane becomes more appropriate. The decision also involves weather conditions, model of aircraft available, and weight considerations; a distance of 200 to 300 miles, however, is commonly used to define the point at which an airplane is clearly more desirable.[161,198] Early data, perhaps influenced by aircraft and aviation capabilities of the time, suggested that once the distance reaches 100 miles, an airplane also becomes more economical.[198] As such, early guidelines for helicopter EMS tend to mention 100 miles as the transition zone between RW and FW appropriateness.[199] A 2014 economic modeling data analysis found that a helicopter can be most time-effective up to approximately 300 miles; starting at approximately 200 miles, an airplane begins to become more cost-effective, with airplanes becoming increasingly preferable as distances approach 300 miles.[16]

As a general rule (with caveats as to situational specifics), it is reasonable to consider the range of 200 to 300 miles as the boundary at which an airplane becomes more efficient than a helicopter. Even in states where FW resources and airports may be limited (e.g., Oklahoma), the common practice is to use a helicopter for a one-way distance of up to 200 miles and an airplane (even in a neighboring state) when distances exceed 200 miles.[176] This cutoff is not presented as definitive but, rather, as typical of many settings, and it may be informative for those trying to choose the appropriate transport modality.

Weather is an important factor affecting selection of an airplane over a helicopter because airplanes can generally operate in worse weather conditions than can helicopters and also because airplanes are often able to fly over or around weather systems that would ground helicopters. Of course, when weather is particularly bad, even an airplane can be grounded. When weather is too bad for helicopter transport, the wilderness medicine physician is advised to consider an airplane as an option.

Perhaps the most important remaining aircraft consideration related to vehicle triage is the helicopter's flexibility to divert while en route, in order to land at a local hospital helipad. If the patient situation changes, a helicopter may be able to land at a facility along the way, in an effort to deliver the patient to stabilizing care. A helicopter may also be able to land so that it can serve as an immobile, stable platform for patient care and interventions such as endotracheal intubation, much as an ambulance may pull over to the side of the road during transport. FW aircraft can also divert during transport, but they usually are not able to land at a hospital; the rare exception is a hospital with its own runway, such as Anchorage Regional Hospital in Alaska. Whereas a helicopter can land (if there is a safe LZ) in a few minutes, FW aircraft cannot land on short notice to allow the crew to care for a patient.

The final factor in choosing a helicopter or an airplane is the fact that a helicopter can deliver a patient directly to a receiving facility, so there is no need for additional ground transport between an airport and a hospital. The advantages of delivering critically ill and injured patients directly to a hospital have been clearly and consistently noted in the literature.[103] NAEMSP states in its position statement that it is not in a patient's best interests to have even a short ground EMS transport from a hospital LZ to a hospital patient care area.[184]

The need for an airport should not be an overriding factor in selecting an aircraft. With proper preflight evaluation and planning, many types of patients (e.g., obstetric patients) for whom in-flight deterioration would be least desirable have been safely and effectively transported by an airplane.[140] In certain situations, however, helicopter transport might be beneficial, as when a patient is being transferred from one hospital to another. In extreme cases, the capability of diversion plus the capability of flying from hospital helipad to hospital helipad makes a helicopter the best choice, even when the mission will take 7 hours or more.[71] Even in less extreme cases, when the distance is on the edge of a normal helicopter range, the ability to transport directly from one hospital to another can tip the decision toward a helicopter (e.g., helicopters are used for patients needing extracorporeal membrane oxygenation in the French Caribbean region at distances of up to 310 miles).[161]

Many decisions affect the choice of helicopter or FW aircraft for AMT. If the availability of and landing areas for the two aircraft are equal, aviation parameters and logistics tend to drive the decision. In the wilderness, the situation (e.g., high-angle rescue and evacuation) may be one in which there is little or no real choice, but more commonly there is need for comparison of options. Careful consideration of available resources and situational aviation logistics is an important contributor to optimal outcomes in air medical response to wilderness emergencies.

LOGISTICS AND TRIAGE IN HELICOPTER AIR TRANSPORT

The preceding subsection addressed aviation and logistics parameters informing selection of a vehicle for an air medical response. Often, the more pressing question is whether a patient needs air transport rather than ground transport; the determination as to which patients are appropriate for AMT is complex. Patient factors will be discussed in subsequent sections of this chapter. Aviation and logistics issues informing the decision are addressed here.

The first aviation question asked in deciding on the appropriateness of AMT is: *Is there an available aircraft and can it get to* *where it is needed?* Air transport is an option only if it is available and can get to the patient. However, it is worth noting that in wilderness medicine situations, AMT may be ruled out almost as soon as it is considered because of weather conditions, operational parameters (e.g., range, altitude), or simple logistics. Wilderness medicine planning should include assessment of these types of aviation issues that may remove the air response capability as an option.

When air resources are available and it is reasonable to believe they can reach a patient (e.g., a runway or LZ is nearby), the most important aviation considerations are those of time and distance. We have already noted that evidence does not support a concrete demarcation line of time or distance for choosing helicopter or an airplane. Evidence also does not allow for a precise delineation of transport distance (or time) beyond which helicopter transport is preferable to surface transport. However, the following are general observations that can help inform transport mode decisions. For very long transports exceeding many hundreds of miles, in which time and the patient diagnosis are factors, air transport is almost always preferred. Determination whether it is by airplane or helicopter depends on factors previously discussed.

On the other (short-distance) end of the logistics spectrum, the question becomes: *When should a helicopter be used rather than a ground vehicle?*

A study based in rural Australia (where traffic is not much of an issue) suggested that a helicopter be used when the one-way transport distance reaches 62 miles (100 km).[171] Others have identified an approximately similar threshold of 45 miles.[23,41] However, data suggest that helicopter EMS *can* be significantly preferable at distances within 10 to 50 miles, with 20 miles being the minimum cutoff point at which mortality rates from trauma can be significantly improved.[41,104,154] Others have reported that in situations in which time is truly critical, road traffic in large metropolitan regions can render flight distances of as little as 20 miles reasonable for helicopter EMS.[192]

Air medical logistics recommendations tend to emphasize time savings, not just distance considerations. Various cutoffs have been proposed for the ground transport time at which a helicopter should be used. One group suggested that helicopters should be used if the surface transport time exceeded 45 minutes.[13] Others, however, propose that saving as little as 10 minutes can be clinically important, depending on the situation.[180] In some cases, the most important time end point is bringing advanced care (by a helicopter EMS crew) to the patient. In other cases, it is bringing the patient to definitive intervention, such as the cardiac catheterization laboratory or operating room.

Whatever time savings is judged to be medically important, consideration of transport options should be comprehensive in terms of this factor. It may take more time than expected to get a dispatched air or ground vehicle actually moving; even when the emergency service is stationed at a referring facility, the dispatch-to-departure time can be longer than would be expected.[180] Other areas of time loss are inevitable with air transport. For FW missions, it takes time to get from the airport to the patient's location and back to the transferring airstrip. The same time issues occur at the receiving end. Helicopters are more flexible, unless weather or other issues dictate the need to land at an airport. Even when RW aircraft can respond directly to a patient's location, there is a need for LZ identification and preparation.

Given the many factors to be considered in choosing which type of EMS to use and its clinical impact, there is no universal threshold at which to use a helicopter rather than a ground vehicle. In fact, the literature and the NAEMSP AMT triage guidelines point out that due to many factors, such as limited ground ambulance availability, wilderness medicine situations are "exceptions to the rule" of any set of logistics parameters.[87,199]

AVIATION SAFETY

Safety is the main priority of AMT operations. Ensuring safe aviation operations is one of the fundamental areas of both RW and FW services, but the general subject of safety tends to focus more on helicopter missions because they have long formed the arena with the most notable history of crashes.[115]

Safety involves not only pilots and mechanics but all members of the flight crew. Attention to safety should be prospective. Retrospective analyses of risk and error are necessary and informative but obviously less desirable than accident prevention.[118] The flight crew (including the medical crew) must have initial and ongoing training in safety topics, ranging from how to operate seat belts and secure aircraft doors to how to communicate by radio or manage an emergency fuel cutoff and engine shutdown. The medical crew must be trained to participate in assisting pilots with communications as well as searching for and reporting hazards (e.g., as an aircraft approaches and leaves the LZ).

Even persons who are on the requesting and receiving ends of a given AMT are involved with ensuring that a mission is conducted with full attention to safety. Creating an atmosphere of safety is an ongoing and resource-intensive task, with myriad areas of focus. The subject of safety is too complex to be fully covered in this discussion. Instead, the aim is to address representative topics of particular relevance to wilderness and environmental medicine situations.

Safety starts well before a specific transport. It is part of the overall philosophy of an AMT program, as well as the training and ongoing education for the program. Aviation safety matters, such as the blinding of pilots to medical issues and crew resource management (optimization of cognitive, collaborative, communications, and problem-solving skills to create safe flying), form a significant part of the CAMTS accreditation process. Different programs with varying mission profiles have different areas of emphasis for their safety endeavors. FW services providing transoceanic AMT will have the same broad goals and approaches, but different safety program details, as helicopter programs providing mostly scene responses. Specific areas of training for helicopter crews operating in wilderness or marine settings might include wilderness survival courses and "dunker" simulations (in which an aircraft mockup is immersed in water so the crew can practice egress measures).

The AMT safety environment is constantly being enhanced by increased attention to learning and teaching safe aviation operations. Checklists, premission risk analyses, and encouraging the crew to share concerns without risk of censure all contribute to improved safety.[52] Weather "minimums" (i.e., particular meteorologic conditions that must be present before safe flying can occur) are nonnegotiable, even when a patient is in critical condition. A pilot should not be privy to information exchanged regarding the seriousness of a patient's condition when the pilot is assessing whether the mission can go forward safely.

Unfortunately, wilderness missions involve precisely the sorts of situational risks that are most concerning for aviation safety. Weather, terrain, and spatial disorientation are major areas of focus for safety evaluation.[3,136] Wilderness AMT can obviously be subject to risks in these arenas and others, so safety must be paramount in planning and execution. Pilot and flight crew recommendations regarding safe execution should not be questioned by medical providers. Pressure to evacuate a critical case cannot be allowed to drive decisions to fly in unsafe circumstances. When a mission must be declined for bad weather at either the helicopter unit's starting location or along the flight path to the LZ, it is conceivable that a helicopter from a different location (i.e., with a different directional flight path) might have a safe routing to the evacuation site. Communications must be extremely clear, however, when multiple helicopter services are consulted regarding a specific mission, to avoid the potentially dangerous practice of "helicopter shopping."[73]

Practicing safe aviation does not always mean purchasing the latest technology. Adding equipment adds capabilities, but it also adds financial costs and, sometimes more importantly, weight. Deicing equipment would seem to be an obvious requirement for helicopter services operating in alpine settings. However, the added weight associated with this equipment can offset the advantages in safety. In mountainous regions of Alaska and Utah, for instance, EMS helicopters do not have a deicing capability; they simply do not fly in icing conditions.

The topic of safety overlaps with many other topics discussed in this chapter. Subsections on topics, such as communications and LZ setups, provide information with relevance both to operations and safety.

EFFECTS OF ALTITUDE ON AIR MEDICAL TRANSPORT

Helicopter flights tend to occur within a few thousand feet of ground level. FW flights tend to occur miles above the ground. Even for FW flights executed in pressurized cabins, interior pressures are not brought down to sea-level pressure because this would entail long-term risks to fuselage integrity. Although the physics and physiology of altitude are relevant in both RW and FW transports, the magnitude and clinical relevance of altitude changes tend to be greater for airplane transport. This section is an overview of the laws of physics that relate to AMT.

BOYLE'S LAW: PRESSURE, VOLUME, AND ALTITUDE

As altitude increases, ambient pressure decreases. This means that there is less resistance to gas molecules' natural tendency to expand. With increasing altitude and decreasing atmospheric pressure, the volume of a given number of gas molecules increases. Put simply, an inflated and tied-off balloon expands as it rises and contracts as it descends. At 18,000 feet, atmospheric pressure is only half that at sea level.

The balloon metaphor is particularly apt in cases of medical devices incorporating balloons. Endotracheal tube (ETT) cuffs, intraaortic balloon pumps, and balloon tamponade devices for variceal bleeding are among the devices that have long been known to require careful intratransport attention and adjustment because of altitude and Boyle's law.[130]

Given the frequency with which intubated patients undergo air transport, the ETT cuff issue has received particularly close attention. Most investigators have used a cutoff of 30 cm H_2O (22 mm Hg) as the target for ETT cuff pressures, because higher pressures risk mucosal ischemia and complications ranging from sore throat to tracheal perforation.[9,19,20,123,201] The literature (which covers cuffs from ETTs and other airway devices such as laryngeal mask airways) describes significant risk from high cuff pressures, both high pretransport cuff pressures and altitude-related increases in cuff pressure.[19,20,146,218] Although formulas guiding the change of ETT cuff air volume with changing altitude have been generated, the most practical approaches for flight crews appear to be either employing cuff manometry or filling the ETT cuff with noncompressible saline.[20,57,123]

Air splints can increase in size with higher altitudes, increasing the risk of inducing dangerous tissue compartment pressures. Intravenous tubing, pumps, and infusion devices can malfunction and overmedicate at higher altitudes.[90] Boyle's law is usually presented as the reason glass bottles are prohibited for medication infusions in AMT, but the risk of having them fall and break is probably a more practical reason. Ventilators ranging from continuous positive airway pressure machines to complex multifunction mechanical ventilation devices have long been known to be susceptible to altitude- and pressure-mediated alterations in function.[14,56] As is the case with ETT cuffs, the medical changes subject to Boyle's law do not prevent successful AMT, but they must be considered in the planning and intratransport care phases to prevent unfavorable sequelae.

In addition to medical devices, gas inside closed spaces within the body can be affected according to Boyle's law. The same descent-related squeeze injuries (e.g., barotitis) and ascent-related reverse squeeze phenomena (e.g., sinus pressure and pain) commonly associated with divers can also occur on movement through the atmosphere. More critically, the size of a pneumothorax can expand on ascent or a pneumocephalus may worsen during AMT.

Boyle's law applies to pressure and volume changes with any altitude change, but its clinical relevance is situational. For minor altitude changes, the correspondingly minor changes in pressure differential translate into little change in volume. When changes in altitude are more substantial (more than a few thousand feet), the clinical relevance of the pressure differential is magnified.

Decisions as to the clinical relevance of Boyle's law are made as a part of each transport. In mission planning, the medical crew must take into account the planned flight altitude, in-cabin "altitude" (for pressurized FW flights), patient considerations, and devices in place. Furthermore, while keeping safety as the paramount consideration, the flight crew can also determine whether a given transport can be executed at a low altitude (e.g., most helicopter missions can easily be executed within 1000 to 1500 feet of ground level).

Pneumothorax is a useful exemplar of the effects on body cavities as described by Boyle's law. The diagnosis is sufficiently common, and risks associated with volume changes sufficiently severe, that this illustration is useful both in its specifics and as a general guide to approaching altitude physics. Pneumothoraces can be conceptualized as balloons with particularly rigid encapsulation (i.e., by the chest wall rather than by thin rubber). Like other balloons, pneumothoraces expand with increasing altitude and contract with decreasing altitude. This fundamental understanding has been responsible for decades-long recommendations that any pneumothorax patient undergoing air transport should have preflight chest decompression with thoracostomy (needle or tube).[92]

The problem with the rigid application of Boyle's law in chest decompression is that it has led to unnecessary executions of a procedure (thoracostomy) that comes with its own risk of morbidity.[17,92] A study using mechanical models to simulate lungs with pneumothoraces has shed light on how much larger pneumothoraces can be expected to grow with increases in altitude.[92] In an experimental model, multiple models' results (with high cross-model consistency) suggested a volume increase of approximately 1.5% with each 500-foot increase in altitude. The study was executed in a helicopter with flights of up to 5000 feet above ground level. Clinical studies assessing pneumothorax patients who undergo helicopter transport without preflight decompression have also confirmed a very low rate (6%) of decompensation; in cases where deterioration occurred, it was rapidly recognized and successfully treated.[17]

For patients with pneumothorax who undergo FW transport (for which cabin pressurization usually is in the range of 8000 feet) and for any who are receiving positive pressure ventilation, preflight decompression and thoracostomy is the rule for management. For other cases, in which clinician judgment is appropriately applied, pneumothorax patients transported by helicopter may be able to be flown without thoracostomy if there is close monitoring (which can include modalities such as in-flight ultrasound).[17,120]

For disorders subject to the principles of Boyle's law, such as pneumothorax, clinicians in austere settings must incorporate clinical judgment into peritransport decisions. A patient suspected of having a pneumothorax who will have a long transport by a Coast Guard aircraft with a minimally trained flight crew should have pretransport thoracostomy. Expectant management may be appropriate for a stable patient with early diagnosis (e.g., by imaging such as ultrasound) of a small pneumothorax, who is undergoing precautionary evacuation in a helicopter staffed by a crew with advanced-care training. The wilderness medicine physician needs to be aware of the principles of altitude physics and physiology of Boyle's law, but this awareness should guide considerations of therapeutic risks and benefits rather than dictate the absolute need for preflight treatment due to potential pressure-volume changes.

According to Boyle's law, the volume of a given number of gas molecules increases with altitude. From this principle follows the corollary that increasing altitude translates into fewer gas molecules per unit volume. This principle combines with Dalton's law (i.e., the total barometric pressure of a gas is the sum of the partial pressures of the constituent gasses) to result in altitudinal hypoxemia, because there are fewer oxygen molecules in a given inspired volume of air. In the nonpressurized cabin of a helicopter used for a flight of over 10,000 feet in altitude, supplemental oxygen should be available. If the flight will exceed

12,500 feet in altitude, the pilot must have supplemental oxygen and it should also be available for the medical crew. Understanding when supplemental oxygen should (and must) be used by pilots and flight crews is an important part of training for any service operating nonpressurized aircraft (RW or FW) at high altitudes.

Hypoxemia for a medical crew dictates at least one helicopter EMS practice that is unusual outside of wilderness medicine. When rescue needs to occur at a very high altitude, if there is an acclimatized medical crew (e.g., on-scene with the patient) that can safely replace the unacclimatized regular medical flight crew, the patient is extricated from the scene with the acclimatized crew and flown down to a safer altitude, where the regular medical crew takes control.

The most dramatic AMT relevance of Boyle's law for hypoxemia would be sudden loss of cabin pressure in an airplane transport. Given the altitudes and associated ambient oxygen levels involved (partial pressure of oxygen can drop to 30 to 35 mm Hg at 20,000 feet), such an event would be quite hazardous and potentially fatal unless supplemental oxygen was available. Less substantial, but more common, are altitude-related effects associated with RW flights that occur in high-altitude regions, such as the mountains. A goal of RW flights is to clear any ground obstacles by approximately 2000 feet. Helicopters operating in mountainous areas can easily reach altitudes at which supplemental oxygen use is wise (or required). The ambient air hypoxemia issue is not usually such a pressing one for patients, who nearly always receive additional oxygen by nasal cannula, face mask, or in-dwelling airway.

Just as Boyle's law dictates fewer oxygen molecules per unit of volume with increasing altitude, it is also the case that water vapor is more dispersed. This decrease in humidity with altitude means that secretions can dry (and occlude ETTs). Insensible water loss is also increased.

In some cases (e.g., cerebral arterial gas embolism), there may be a case against AMT at any altitude. This pressure-volume issue, like others with respect to related processes such as decompression sickness, needs to be adjudicated on a case-by-case basis. There may be a portable hyperbaric chamber alternative (for FW transports), but the patient may best be transported by ground.

CHARLES'S LAW: ALTITUDE AND TEMPERATURE

Fewer molecules per unit of volume at higher altitudes mean fewer chances for molecules to collide with each other. This translates into decreased temperature with increased altitude. The temperature drop at altitude tends to be of little clinical significance in heated aircraft cabins during flight. It is more important for flight crews to remember that air medical responses to patients at altitude are likely to involve patients who are already hypothermic.

Aircraft can become cold in certain operational circumstances. Prolonged parking of an aircraft at a high-altitude LZ or runway, or hovering with open doors (as while winching) during SAR missions can cool even a heated cabin (Figure 58-28).

FIGURE 58-28 Helicopters have unique capabilities to work closely with ground-based teams, such as those executing avalanche search and rescue. Among the environmental factors that the crew must keep in mind is the drop in temperature inside the aircraft when sitting in a cold environment, which is an important issue when the aircraft is parked at higher (colder) altitudes. *(Courtesy of Eric Swenson and University of Utah AirMed.)*

Once a patient has been loaded onto an aircraft, Charles's law and altitude-related low temperatures dictate the need for special attention to preservation of body temperature.

HENRY'S LAW: ALTITUDE AND DISSOLVED GAS CONCENTRATIONS

Henry's law is particularly applicable to practitioners of dive medicine. It states that the mass of gas absorbed into a liquid is directly proportional to the partial pressure of the gas in contact with that liquid's surface. In dive medicine, the higher pressures at lower "altitudes" (i.e., greater depth) translate into increased amounts of dissolved gas. Overly rapid ascent is associated with gas transition out of solution and into bubble form, thus causing decompression sickness.

Rapid decompression of pressurized cabins at high altitude can also cause a form of decompression sickness. Air medical providers executing FW missions are therefore trained to respond to emergency loss of cabin pressure. Overall, dysbarism associated with Henry's law is much less likely to be a factor in air transport than in dive medicine because the weight (i.e., ambient pressure) of the atmosphere is so much less than that of water.

MEDICAL CARE IN THE IN-FLIGHT SETTING

In addition to altitude physics, other matters are very pertinent to in-flight care. These include issues of a nonmedical nature, such as how to power medical equipment. Most aircraft systems operate using direct current electricity, but medical instruments tend to require alternating current. This requires use of power inverters. Some in-cabin care constraints with particular relevance to wilderness medicine are discussed in this section.

PATIENT LOADING AND CABIN CONSIDERATIONS

Details of caring for patients in an aircraft are outlined in the following section. Overarching principles should be kept in mind. These are practical guides to patient care in the aircraft.

Safety is the overriding consideration in AMT operations and affects all facets of care, ranging from mission acceptance through patient loading and transport. For example, loading of the patient onto a helicopter as the rotors are turning (hot loading) can save a significant amount of time, but patients must often be cold loaded due to safety concerns with an inexperienced ground crew.

The aircraft cabin is usually smaller than the patient care area of an emergency department, but flight crews can be amazingly adept at executing high-level monitoring and interventions. Providers should consider the breadth of crew capabilities that may be brought to bear in a given situation.

A critical tenet of care by an AMT crew is independence. Crews often operate with minimal external support, and with none if communications and medical oversight are unavailable.

Care in the emergency department can be standardized in a way that care within an aircraft cabin cannot. If it is dark, medical crew members may need to look for LZ sites by searching for the flashing lights of ambulances. Cold weather outside often means a cold cabin, which affects both crew and patient safety. High winds can substantially alter in-flight care capabilities if aircraft movement interferes with patient care and crew comfort.

Care in aircrafts is also time limited in a way that is different from the emergency department setting. Decisions are made based upon what is best for the patient, but those decisions are influenced by the logistics of transport. For example, if the flight is quite lengthy and patient access limited, the crew may start an additional intravenous line. If the patient requires extra transfers (e.g., ground transport legs), extra padding and securing of lines and tubes may be needed.

Aircraft medical crews require flexibility, self-reliance, and attention to weather, logistics, and safety that differ from in-hospital care.

MOTION AND VIBRATIONS

Atmospheric conditions (mostly wind) can cause significant degrees of three-dimensional vehicle movements during AMT. Patients can be medicated, but crews must be careful about side effects of antimotion sickness medications. When conditions are particularly windy or an aircraft is being jostled for other reasons during flight, crews may need to use additional measures to stabilize a patient or otherwise alter their approach to patient care. It is a good idea to have communication during the preflight stages so there is clear understanding of what, if any, limitations may be perceived by crews operating in suboptimal atmospheric conditions.

In addition to large-scale vehicle movement associated with wind, normal engine function may cause vibrations. There is some evidence to show that in-flight vibrations may jar a fractured limb, leading to hemorrhage.[27] Vibrations are among the sources of physical stress to patients and crew.[28] Vibrations may cause difficulties in palpating pulses.[79]

Fortunately, most evidence indicates that other than the real issue of crew and patient muscle fatigue, theoretical problems associated with high-frequency vibrations remain uncorroborated by patient outcomes data. The best examples of reassuring AMT data with respect to vibrations come from the realm of post-thrombolysis patients. Despite rational theoretical risks of hemorrhage in these cases, experience and evidence for both cardiac and stroke patient populations demonstrate no increase in bleeding risk.[18,54,191]

One additional type of motion is the larger-scale translational motion from yawing, pitching, and taking off. Motion sickness is a nontrivial complication for certain patients (e.g., a patient wearing a cervical collar, who is at risk for aspiration). Nausea can be a risk for even the most experienced flight crews if it reduces efficiency in patient care. For FW transports, acceleration associated with takeoff can cause venous pooling sufficient to induce hypotension. The complication may be eliminated by positioning patients feet-forward.

NOISE

Anyone who has flown in an airplane will not be surprised that ambient noise levels can be a problem.[205] Particularly for turboprop planes, noise can prove more than a distraction because it can reach levels that interfere with patient assessment and monitoring. Even in jets such as the Falcon 50 and KC-135 Stratolifter, the need for some form of enhanced stethoscopy has been reported.[51,204,205]

Noise becomes far more of a problem in RW transports. In the early 1990s, reports of inability to auscultate breath sounds were sufficiently notable to warrant publication.[78] Intervening years have seen reports of auscultation solutions such as esophageal stethoscopy or in-flight ultrasound.[25,120,178] The solutions most commonly employed are workarounds, such as monitoring chest excursion and ventilator data (e.g., to evaluate whether high pressures are present, thus possibly indicating pneumothorax).

FIGURE 58-29 Cabin space is not an issue for medical transport in large airplanes, in which many patient interventions can be provided during flight. **A,** Hyperlyte portable hyperbaric chamber being inflated and rigged for a dive aboard a U.S. Air Force C-17 aircraft. At the time this photograph was taken, the aircraft was flying at 4572 m (15,000 feet). **B,** Hyperlyte portable hyperbaric chamber being secured to the deck of a U.S. Air Force C-17 aircraft. Note the gas lines feeding into the near end of the chamber. *(Courtesy Robert C. Allen.)*

Flight crews in most settings cannot rely on aural cues. Critical alarms, such as those on mechanical ventilators, must be visually monitored. Even for communication between medical crew members, headsets are usually required. Communications with patients tend to rely on hand signals or headsets.

CABIN LAYOUT AND SPACE

Space to treat a patient may be a problem in AMT. Except in smaller planes, for FW transport, space is not much of an issue because there are many interventions that can be executed in the in-flight setting (Figure 58-29). For helicopters, though, layout and space in the patient care cabin area can have clinical relevance. All other things being equal, when it comes to helicopters, more space is better. Flight crews have for years demonstrated capabilities to provide excellent patient care in even the smallest of AMT helicopters. Although there are no data supporting better patient outcomes related to larger helicopters, in terms of ease of executing tasks, ranging from chest compression to airway management, available data consistently indicate that in-flight medical care is easier in larger cabins.[193-195] Even in larger aircraft characterized by layout issues that can impair specific procedures, greater available cabin space enables more flexibility in generating workarounds.[94,188] For safety reasons (e.g., to minimize location change in the center of gravity), it is preferable for the medical crew to remain restrained and in position. Regardless of the aircraft size, a medical crew member should inform the pilot when he or she is planning to shift out of restraints or change position.

In addition to their capacity for lifting heavier loads, larger helicopters are much less likely to run into problems with large patients. Patients (and crew members) with a maximum circumference of more than approximately 50 inches cannot fit into smaller single-engine helicopters.

One of the most important issues of cabin space and layout in many helicopters is lack of an interior wall (or curtain) between the patient care area and the area where the pilot is seated. There are at least two important ramifications of the fact that pilots, patients, and crew are all essentially in the same room. First, for purposes of safety, the patient must be absolutely secured; an aircraft cabin is no place for a combative, thrashing patient. Second, for nighttime flights, use of dimmed cabin lighting is necessary to preserve the pilot's night vision. In dimmed lighting (which may be red colored), the ability of the flight crew may definitely be limited when performing certain tasks, particularly those in which distinguishing colors is important (e.g., reading red labels on medications, interpreting color-coded end-tidal carbon dioxide detectors).[70]

As with other in-flight challenges, space considerations are not insurmountable barriers. Instead, they are reasons for the specialized training provided for flight crews. Space issues may cause the crew to execute certain tasks at different times (e.g., preflight rather than in-flight airway management) based on their best judgment.[65]

COMMUNICATIONS AND COORDINATION OF AIR AND GROUND MEDICAL RESOURCES

Information exchange and collaboration of ground and air personnel are key components of safe and effective deployment. Optimal outcomes are achieved when all personnel can easily communicate and exchange information. Much important communication occurs before a mission is ever undertaken. The importance of coordination and planning for wilderness AMT cannot be overemphasized. With regard to communications during a mission, the standard radios with which aircraft are equipped (for aviation purposes) are in the very high frequency (VHF) band. VHF radios must be complemented by other equipment (usually ultrahigh-frequency [UHF-band] radios) for air and ground personnel communications. This section addresses aspects of communications between air medical and ground personnel from the preflight stage through transport to the receiving center.

PREFLIGHT COMMUNICATIONS AND AIR-GROUND COORDINATION

Initial preflight coordination and communications efforts optimally occur long before any actual transport situation. This phase entails the wilderness medicine practitioner's work to establish familiarity and contact with appropriate air medical personnel. An expedition planning process, for example, should include obtaining information regarding available air medical assets. This information encompasses previously discussed aviation points and should also include mechanisms (including redundancies) for contacting air medical assets should the need arise.

The next phase of air and ground communications is the initial call for an air medical response. The method of initial consultation for air evacuation varies depending on the nature of the mission. Far more detail is available (and necessary) for optimal planning for a transcontinental repatriation than for an emergent RW response to a backcountry trauma scene. The initial communications, which can occur either by phone or radio, should include the same medical information recommended for any transport. Evidence suggests that errors in exchange of demographic, medical, and logistics information during initial AMT request communications are quite common, although usually without serious medical consequence.[211] Particular attention to detail, including repeating back critical information, is warranted during the first contact between AMT requestors and providers. The initial conversation between requesting ground personnel and air medical resources should provide information regarding patient location, landing area setup at the airport or LZ to be used, and plans for getting the flight crews to the patient. At this time, flight crews can communicate special needs (e.g., assistance with a stretcher or equipment movement) to ground personnel.

One of the special needs that should be communicated at this early stage is whether the patient is likely to require supplemental oxygen during the flight. Using the flow rate and projected time and distance of the AMT, flight crews can calculate how much oxygen and equipment may be needed for patient support. Most aircraft carry oxygen cylinders, and some carry liquid oxygen.

COMMUNICATIONS AND PREPARATION AS THE AIRCRAFT APPROACHES THE PATIENT'S LOCATION

The initial dispatch of an aircraft usually involves a straightforward exchange of information and may occur by telephone. As the aircraft approaches the LZ, the need for direct communication between the flight crew and ground personnel is critical, but sometimes problematic. Standard radio frequencies should be used, but this may not always be possible due to technical limitations.

Communications are well known to be a major barrier to efficient interservice prehospital care. They are critical in the wilderness setting, when a ground unit may be trying to communicate with a crew in a helicopter hovering overhead. The problem of "narrowbanding" arose with the 2013 Federal Communications Commission mandate for public safety radios (operating in the 150- to 512-MHz range) to transition from 25 kHz to 12.5 kHz.[96] The expert recommendation for maximizing chances of easy communication between a ground unit on the scene and a helicopter overhead is the narrowband frequency 155.3400, as dictated by the National Interoperability Field Operations Guide; this is an FM, no tone code, transmit-and-receive frequency that works with every ground and air narrowband radio.[96]

GROUND AND AIR COORDINATION DURING PATIENT STABILIZATION FOR TRANSPORT

Location of the LZ needs to be communicated clearly to the responding AMT service. Although it is usually not a major issue, knowing the name and location of the receiving airport is obviously important when a metropolitan region has multiple landing strips. For helicopter EMS responses to referring hospitals, the location of the LZ is almost always well known to the area's RW service. The issues of communication are particularly important in helicopter scene responses. Using a Global Positioning System (GPS), knowing the latitude and longitude of the location, and even knowing which roads and other landmarks are nearby can help pinpoint the LZ.

PREPARATION OF THE LANDING ZONE

For FW flights, the "LZ" is an airstrip. The only planning needed by a requesting physician is that related to communications and the arrangement of ground transfer between the airport and hospital. For RW transports, setting up an LZ is critically important for both the safety and the efficiency of the AMT.

A temporary or impromptu LZ is inherently less safe for aviation purposes than a proper airport runway. Multiple steps should be taken to optimize its safety. These steps begin long before transport, with educational efforts directed at any hospital or prehospital provider unit that is likely to receive a call for an EMS scene or interfacility response. LZ classes are an integral part of any RW service's community education and outreach, and should be part of general plans in wilderness medicine. The remainder of this subsection presents information that is contained in a typical LZ class, with the caveat that information about a specific LZ area may change depending on local parameters such as altitude, topography, prevailing winds, and aircraft type. The practical steps entailed in setting up an LZ are outlined in Box 58-1, with further explanation in the remainder of this section.

First, the LZ is identified. This is not usually an issue at hospitals, where there is nearly always a predesignated area with appropriate lighting and known locations of obstructions. At a scene, though, the ground personnel setting up an LZ must learn to be on the lookout for hazards that may not be obvious to the nonaviator. Power lines, for instance, can be nearly invisible at night.

The LZ should be close to the patient in order to save time but not so close as to cause problems (e.g., from rotor wash or noise) (Figure 58-30). For hazardous materials and disaster situations, there may be additional considerations (e.g., avoidance of spills) that dictate the need to distance the LZ from potential problems.[190] In optimal cases, setting up an LZ can be as straightforward as blocking off a section of road (Figure 58-31).

Clear aircraft access is needed, keeping in mind that the helicopter will approach and take off against the wind. Wind indicators that are useful include smoke, flags, or even portable, well-secured wind socks. One configuration often used is the

BOX 58-1 Practical Steps in Setting Up a Helicopter Landing Zone

Communicate with air service to determine specific needs
Identify the landing zone, which should have:
- Minimum size of 100 × 100 feet
- Slope of less than 5 degrees
- Clear visual approaches
- Minimal or no hazards at height (e.g., power lines)
- Appropriate spacing from patient

Mark the landing zone with:
- Indicators of wind direction
- Clear delineation of hazards (e.g., vehicle parked under power lines)

Clear the area of debris (considering strength of rotor wash)
Communicate again with air service
- Describe exact location of landing zone
- Discuss any hazards
- Explain markings
- Arrange and agree upon signals to be used

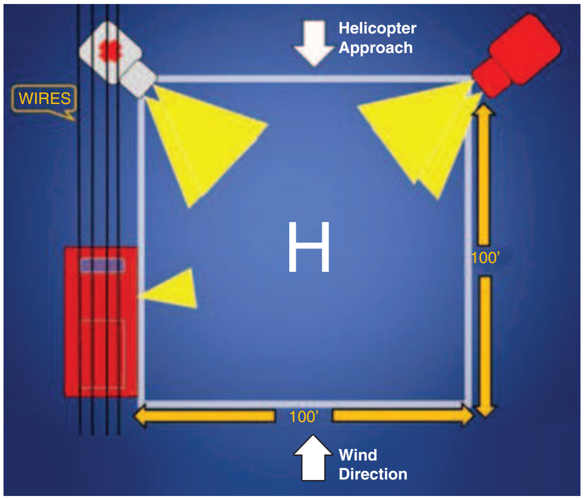


FIGURE 58-32 A temporary helicopter landing zone. Setup of landing zones can vary depending on circumstances. In this diagram, two vehicles have been placed at the upwind corners of a 100-foot square, with headlights crossing at the center of the landing zone. A fire truck is parked underneath the power lines to indicate presence of the hazard. All lights, flares, or clothing should be firmly attached to the ground to prevent them from being blown away by rotor wash. Lighting may need to be changed if night vision instruments are being used by the helicopter crew. *(Courtesy of Boston MedFlight.)*

box-and-one setup, in which a marker is placed at each of the four corners of the LZ square and an additional marker is placed to indicate the wind direction (Figure 58-32). Of course, ground personnel and air personnel must communicate to be sure they are interpreting the wind direction marker in the same way (i.e., the marker indicates where the wind is blowing *from*). Helicopters should be brought into the LZ in such a fashion as to avoid flying directly over the patient or incident scene. Altitude clearance of 500 feet upon aircraft approach and egress is usually necessary, and helicopter services tend to ask for an LZ that is approximately 100 feet on each side. A smaller area may be appropriate for smaller helicopters, whereas the largest (military) helicopters may need a square of at least 120 feet on each side. Because of aircraft performance issues, higher altitudes or hotter temperatures dictate the need for larger LZs. An additional 50-foot buffer between the LZ perimeter and potential hazards is also desirable (Figure 58-33). Because nighttime operations are inherently more dangerous than daylight ones, the LZ should be commensurately larger as requested by the pilot. Debris should be cleared. The surface composition and condition should be considered; tiny pieces of gravel or rocks that may seem fine for automobiles can become dangerous flying objects during a helicopter landing.

Of particular relevance to wilderness medicine is consideration of the slope of the LZ. The ideal situation is a level area surrounded by level terrain. Where this is not possible, other considerations must be taken into account. If a helicopter lands on or hovers slightly above a slope, the side of the rotor disk nearest the slope will be closer to the ground (Figure 58-34). In practical terms, the side of the helicopter that is "uphill" is the

FIGURE 58-30 The helicopter landing zone should be set up with safety as the paramount concern, but the it should also be sufficiently close to the patient to optimize efficiency while managing issues such as rotor wash. *(Courtesy of MedFlight of Ohio.)*

FIGURE 58-31 Often, the safest and easiest landing zone is achieved by blocking off a section of highway. *(Courtesy Michael Abernethy and Ryan Wubbens, University of Wisconsin Med Flight.)*

FIGURE 58-33 Landing zone setup must take careful account of high nearby obstructions. *(Courtesy Michael Abernethy and Ryan Wubbens, University of Wisconsin Med Flight.)*

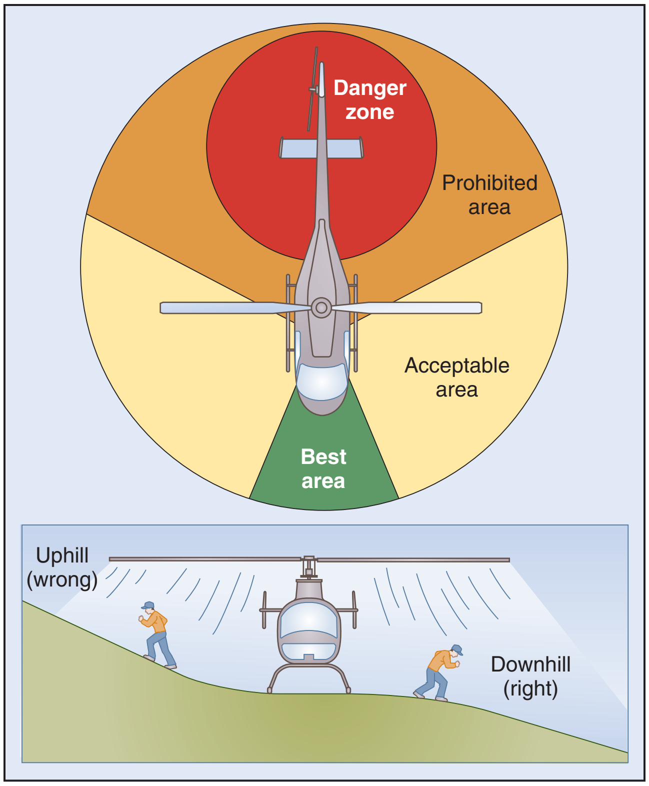


FIGURE 58-34 A helicopter with rotating main rotor should be approached from the downhill side, from the front and side angle, and under direct visualization of the pilot.

risky side. This has implications both for the pilot, who needs to fly the aircraft safely, and for ground personnel, who risk being struck by the rotor. The preference is for no slope; if there is a slope, it should be less than 5 degrees. An angle of slope that is too steep is a common reason for loading a patient with the engines shut down (cold loading).

Scattering material by the wash from aircraft rotors can cause injury. Debris can break windshields, injure eyes, and otherwise cause significant damage or trauma. Policing the LZ to ensure there is no flying object debris is a critical step in preparation; the patient and the ground personnel should be assured that there are no garments or equipment that can become flying object debris. Notable types of flying object debris that should be avoided are objects often found near prehospital scenes, such as road cones, perimeter tapes, or ropes.

The LZ can be indicated in several ways, depending on the terrain, nearby obstacles, available resources, and time of day. For daytime operations, visibility is usually not a problem. Vehicles can be positioned to indicate the borders and delineate obstacles that may not be obvious (e.g., a fire engine might be parked underneath and parallel to power lines).

At night, limited visibility increases the dangers of scene landings. Radio communications should be maintained at all times. Lights can be helpful but can also blind the pilot and should never be aimed directly toward the aircraft. All nonessential lights should be extinguished, and any spotlights used to illuminate the LZ or obstacles should be aimed downward and secured firmly in place. One favored method is to place automobiles at the two corners of the LZ that are upwind. The vehicle lights are shone in criss-cross fashion to generate an X across the LZ, and the helicopter approaches from the downwind direction (i.e., the same direction in which the ground vehicle lights are pointing).

Growing use of advanced equipment, including GPS and night-vision goggles (Figure 58-35), is changing helicopter LZ setup practices. For example, flashing or rotating lights on emergency vehicles have long been useful in guiding a pilot who is trying to find an LZ at night. As GPS becomes more widely used, the flashing-lights “beacon” is becoming less necessary. Furthermore, flashing lights are reported by many pilots (and medical crew) as causing vision problems with their night-vision goggles. Not all zones will be precisely identified with GPS, and not all EMS pilots use night-vision goggles. Thus, it is particularly important for wilderness medicine users of AMT to consider their own situational specifics, and not to assume that practices that worked in the past should be employed on every LZ setup and operation. Wilderness medicine providers likely to use helicopters are urged to work with regional services to obtain appropriate training in LZ setup and related communications.

HELICOPTER LANDING AND ON-SITE INTERACTIONS BETWEEN AIR AND GROUND PERSONNEL

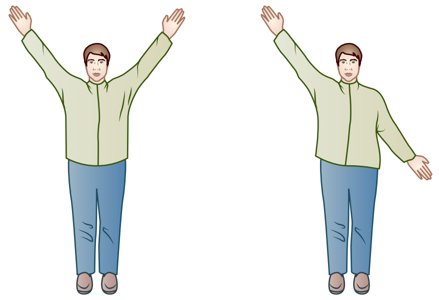
Communications during an approach to an LZ are extremely important. Due to noise levels associated with helicopter engines, direct vocal communication is impossible. Classes on landing a helicopter include hand signals and standardized approaches to identification of hazards. To direct the helicopter, ground personnel may have radio contact but should never count on being able to verbally communicate with the flight crew. Lack of verbal communication is one of many reasons that an LZ should be cleared of personnel prior to the approach of a helicopter.

Given the absence of verbal communications when the helicopter is running, personnel located on the ground must use hand signals and explicitly follow the directions of the flight crew. Previously established signals, such as those learned in a training course, are optimal, but it is important to use whatever communications are available to clarify which hand or nonverbal signals will be used for what purposes. Even if the crew has learned signals in a course, safety dictates that signaling is reviewed prior to landing whenever possible. Basic universal ground-to-helicopter signals should be known by the regular outdoorsman, climber, and trekker in order to communicate with the flight crew upon approach (Figure 58-36A). There are also additional, nonuniversal signals provided as an example (see Figure 58-36B). Flight crew members are trained to know more comprehensive ground signals. Ground-to-air signals can be misinterpreted with devastating results. It is imperative that clear signals between the ground crew and helicopter crew be well defined before the aircraft approaches (see Figure 58-36C).

The aircraft should only be approached after the pilot or flight crew gives permission. Ground personnel should approach from the direction indicated by the flight crew. This will be from the downhill side (if there is one) and usually from the sides of the helicopter (or occasionally the front) rather than from the back. Ground personnel approaching a helicopter are well advised to assume a head-down crouching position, and those walking away from the aircraft should retrace steps in the same direction used to approach the helicopter.

FIGURE 58-35 Many air medical programs now equip pilots and flight crews with night vision goggles. *(Michael Abernethy and Ryan Wubbens, University of Wisconsin Med Flight.)*

International ground-to-air hand signals for communication with helicopter rescue



Nonuniversal examples of ground-to-helicopter or swimmer-to-helicopter hand signals

Intention	Action
Deploy medical kit	Arms above head, wrists crossed
Situation okay	Thumbs up
Lower rescue cable with rescue device	Arm extended over head, fist clenched
Lower rescue cable without rescue device	Climbing-rope motion with both hands
Helicopter move in/out	Wave in/out with both hands
Cease operations	Slashing motion across throat
Deploy litter	Hands cupped, then arms outstretched
Personnel secured, hoist rescue device	Vigorously shake hoist cable or thumb up with vigorous up motion with arm
Team recall	Circle arm over head with fingers skyward

B

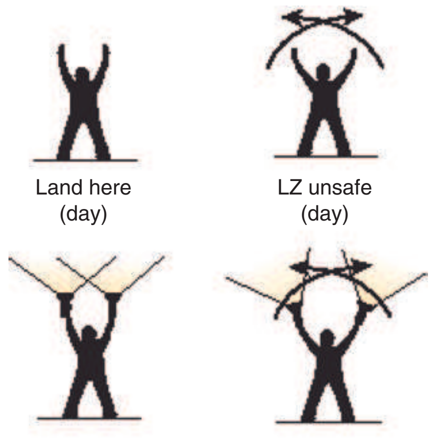


FIGURE 58-36 **A,** Universal international ground-to-air hand signals for helicopter rescue. **B,** Examples of nonuniversal ground-to-air or swimmer-to-air hand signals for helicopter rescue. **C,** Ground guide hand signals. The ground guide should stand in the middle of the helicopter landing zone with arms raised over his or her head (the "safe to land" signal) until the pilot has seen the zone. The ground guide should then immediately exit the landing zone, heading upwind at least 5 to 10 m (16.4 to 33.8 feet) outside the marked zone and maintain the "safe to land" signal. If at any time the ground guide sees a danger or unsafe condition around the landing zone, he or she should immediately give the wave-off signal and continue this signal until the helicopter has aborted the approach/landing.

FIGURE 58-37 A spinning tail rotor is virtually invisible. *(Courtesy Boston MedFlight.)*

Avoiding the main rotor disk, as previously mentioned in the discussion of slope, is critical, even if the zone is flat. Depending on the particular helicopter and wind situation, the main rotor blades can drop significantly as they spin on a parked helicopter. Centrifugal force keeps the rotor disk higher when rotors are turning quickly. During start-up and shut-down, however, rotors can dip lower in response to wind gusts.

The tail rotor is an area of profound danger in helicopter operations. It is not as large and obvious as the main rotor. When it is spinning, the tail rotor may not be easily visible (Figure 58-37). As previously noted in the aircraft section of this chapter, these concerns are moderated in helicopters that have embedded tail rotors (e.g., AS-365 Dauphin, with its fenestron) or no tail rotors (e.g., the MD900 series, with its directed-flow nozzle).

One way to reduce risks to ground crew is to not let them approach until engines are shut down and rotors are not turning. (The FW equivalent to this is to shut off the engine on the side of patient loading.) The decision to allow engine shutdown before transfer of the patient is one that will be made by the flight crew in consultation with the pilot and ground personnel.

Ground personnel who approach the aircraft should have been trained at an LZ class. These personnel should explicitly follow the flight crew's directions, allowing the crew to open and close aircraft doors, move equipment, and position the patient and stretcher for movement. Ground personnel should have eye and ear protection, be attentive to the possibility of creating flying object debris, and secure objects, including personal clothing, before the helicopter arrives.

Before the patient is loaded onto the helicopter, he or she should be provided with hearing and eye protection. Depending on the circumstances, the patient may be given a radio communications headset. Clothing and belongings should be secured to eliminate the risk of flying object debris. Antiemetic therapy is often useful in windy situations or in cases where vomiting would be particularly risky (e.g., a patient wearing cervical collar).

For scene calls, inaccessibility or LZ safety issues may preclude a helicopter EMS response directly to the patient. Ground personnel may therefore move the patient to a safer LZ some distance away, with the helicopter subsequently executing a *modified scene call.* The LZ for a modified scene call is often a location that is well known to the helicopter and ground personnel, having been prespecified by ongoing regional outreach or as part of planning for a particular mission.

The modified scene call can also occur at a hospital helipad. In 2004, the Centers for Medicare and Medicaid Services ruled that when a ground EMS uses a hospital helipad as part of a system effort to get a patient by air to the closest appropriate facility, the provisions of the Emergency Medical Treatment and Active Labor Act (EMTALA) do not attach to the hospital at which the modified scene call occurs.[30]

COMMUNICATIONS AFTER TRANSPORT TO THE RECEIVING CENTER

For wilderness medicine transports, which are likely to represent "special" cases due to issues with topography, communications, or logistics, posttransport loop closure is particularly important. After completion of an AMT, the flight crew should provide feedback to the ground personnel who consulted the helicopter EMS. Follow-up information provided by the flight crew should include intratransport developments and initial receiving center impressions and plans. Two-way communication is important to best utilize the AMT. Without posttransport feedback from both ground and air personnel, important opportunities for system improvement can be missed.

Utilization review for helicopter missions should be conducted based on regional EMS use guidelines, with the understanding that individual cases can often inform decisions as to how triage could be improved for a given area.

PATIENT POPULATIONS THAT MAY BE SUITABLE FOR AIR MEDICAL TRANSPORT

Determination as to which patients may benefit from AMT is a complex and sometimes controversial subject. Because FW transport tends to occur in cases where distance renders ground EMS unsuitable, most debate about AMT use focuses on helicopter EMS. For some patients who need urgent medical attention, surface transport is not an option. For a backcountry trekker with a broken femur or a wilderness canoeist having a heart attack on an island, helicopter EMS is usually preferable. When the choice is not obvious, however, there is room for medical and logistics judgment in determining which type of response would be best.

INTEGRATION OF AIR MEDICAL TRANSPORT INTO REGIONAL SYSTEMS PLANNING

AMT should be part of prehospital and system-based planning in every region in which FW or RW assets are used. The air assets should be integrated into comprehensive EMS plans. AMT should be included in discussions regarding care networks for particular patient populations. Air medical response to disaster incidents has particular relevance in wilderness and environmental medicine.

Detailed listings of potential situations for which helicopter EMS may be useful have been promulgated and endorsed by many professional societies (e.g., NAEMSP).[199] Lists are available (NAEMSP Guidelines for Air Medical Dispatch are located at NAEMSP.org). The lists are most helpful if they are used to serve as guides for system planners who incorporate the recommendations into region-specific AMT triage and utilization plans. The "science" guiding AMT deployment is imperfect. However, every health care system in which AMT is used should set up triage and utilization guidelines.

GENERAL CONSIDERATIONS FOR TRIAGE IN AIR MEDICAL TRANSPORT

From the patient perspective, air medical assets are most likely to be useful when their response results in time savings of potential clinical import. Important time savings may be accrued by rapidly bringing advanced care (flight crews) to patients and/or by rapidly bringing patients to definitive diagnostic or therapeutic interventions (e.g., surgery, cardiac catheterization). Another general medical consideration is the potential capability of air medical crews to provide necessary intratransport monitoring and care that would not be within the practice scope of ground EMS providers.

If time constraints are not a consideration, there is no role for urgently executed AMT. It is conceivable, but rare, that in a situation in which there is no feasible alternative for transport, nonurgently deployed air assets may be the sole practical means of evacuation.

Because there is usually a time component in helicopter transports, time saved in readying the patient for transport might translate into an improved likelihood that AMT will help. Whether the patient has a time-critical stroke, myocardial event, or injury, it is important for hospitals using helicopter EMS to work with regional services to generate protocols for streamlining patient stabilization and handoffs to the flight crew. For instance, intravenous lines should be stabilized, ordered medications given, fractures splinted, and airways secured.[21]

Patient safety in AMT has both aviation considerations and medical issues. With regard to aviation, flight safety is and should be the priority for any transport. Certain general safety issues are addressed elsewhere in this chapter, but the overall subject of aviation safety is far too complex for detailed treatment. In the setting of appropriately operated (e.g., CAMTS-credentialed) EMS operators, safety issues should not inform triage to EMS if a pilot accepts a mission. The "vision zero" campaign of the EMS industry, which has the goal of preventing all helicopter crashes, is both necessary and laudable, but rigorous cost-benefit modeling clearly demonstrates that the risk of a crash causing a patient death is so low as to not have a substantive impact on calculations of helicopter EMS use and overall effectiveness.[37]

Medical risks for various diagnostic groups undergoing AMT have been theorized, but patient studies consistently demonstrate the medical safety of helicopter flights. Pacemaker malfunction, postthrombolysis bleeding, and in-flight airway deterioration (with lack of ability to reintubate) are among the specific areas that have been investigated, with demonstration of EMS safety in terms of medical complications.[54,55,65,95] Available data assessing the overarching patient safety question suggest that after adjustment for patient acuity, transport by helicopter is associated with a lower risk of adverse events than is ground transport.[49,119,206]

Before moving to clinical considerations driving AMT triage, some additional nonclinical parameters deserve mention. Aviation and logistics issues (e.g., weather, aircraft range, patient weight, LZ availability) can render a helicopter response impractical or impossible. The NAEMSP guidelines include a final logistics point about the often-underemphasized issue of whether ground EMS transport of a patient will leave a local (referring) region with an inadequate prehospital response.[199]

Taking an overarching approach to determining AMT appropriateness guidelines within a given region is both complex and critically important. Case-by-case adjudication should be an important part of vehicle triage decisions, but situational specifics should be incorporated into a previously generated set of regional AMT dispatch guidelines. Generation of regional guidelines should include stakeholders from prehospital, hospital, public policy, and public safety arenas. Inevitable imprecision in AMT dispatch guidelines should prompt refinement of, rather than discarding of, the guidelines.

Ensuring that regional providers actually use locally generated guidelines is sometimes a challenge, but meeting the challenge is worthy of effort.[200] Thus, utilization review and feedback must be an integral part of use of any AMT guidelines.

AIR MEDICAL TRANSPORT OUTCOMES LITERATURE: STATE OF THE EVIDENCE

The medical issues addressed in this section are informed by scores of studies assessing the association between AMT and patient outcomes. Because FW AMT is usually executed for repatriation or other missions for which surface transport is impractical, investigators seeking to discern the association between outcomes and the transport mode have focused on helicopter EMS.

Recognizing the controversy attending debate over whether RW transport improved patient outcomes, NAEMSP's Air Medical

Services Task Force set out in 2000 to assemble (and annotate) in one publication all helicopter EMS outcomes studies published since 1980. The large number of studies prompted a need to split the comprehensive outcomes research assessment into two reviews (both published in 2002), one for trauma and one for nontrauma.[186,187] The helicopter EMS outcomes research compendium has since been updated in four publications (each including 3 to 5 years of data) covering the time period 2000 to 2013.[22,102,182,183] The volume of helicopter EMS outcomes studies has grown sufficiently to warrant continuous updating of the overviews. This task is performed by a multicenter collection of helicopter EMS researchers that make up the Critical Care Transport Collaborative Outcomes Research Effort; the annotated reviews of outcomes research from 2014 onward is available at cctcore.org.

Although studies have been imperfect, there is utility in viewing the state of the evidence for certain transport populations summarized in the following subsections.

Patients with Traumatic Injury or Burns

AMT of the injured patient can be classified into FW and RW transports. The FW trauma transport literature tends to focus on movement of patients over large distances. There is clear and consistent demonstration, attended by little or no controversy, of the utility of FW transport in moving patients to higher levels of trauma care hundreds (or thousands) of miles distant.[43,81,100,124,207]

There are dozens of outcomes studies assessing for association between transport mode and outcomes. The more methodologically rigorous analyses are quite consistent in their overall estimates of a 20% to 30% mortality reduction with helicopter transport (versus ground transport).[22,58,102,157,182,183,187] Furthermore, the minority of negative studies in the literature are marked by major flaws, such as residual confounding, selection bias, and inclusion of large numbers of patients transported by helicopter to hospitals that are not trauma centers. Helicopter EMS can consistently optimize patient outcomes only if AMT is part of a regionalized system of care.[22,58,102,182,183,187]

Helicopter EMS neither saves patients with unsurvivable injuries, nor contributes to a better outcomes for patients with trivial injuries. Thus, the decision to dispatch AMT needs to be informed by patient acuity and clinical parameters, such as those in nationally promulgated guidelines for helicopter dispatch.[185,199]

In wilderness medicine situations, logistics benefits of helicopter EMS over ground transport (which may not even be a practical option) are particularly likely to carry weight in triage decision making. A patient with a single-system injury (e.g., broken femur) who would not normally be a candidate for helicopter transport might become an excellent candidate if she or he is in a wilderness backcountry setting, or other situation, where the alternative would be for other trekkers to carry the patient for many miles.

Patients with Cardiac Disease

Most AMT studies of cardiovascular patients focus on ST segment–elevated myocardial infarction (STEMI), because in most systems these cases constitute the largest group of nontrauma air transports. Particularly relevant to wilderness medicine is the evidence supporting helicopter dispatch to scenes of field-diagnosed STEMIs.[80,129,143]

Wilderness medicine often entails a helicopter response to a remote area. Given the evidence supporting the principle that "time is myocardium," use of helicopter EMS to quickly move STEMI patients to specialized cardiac care is an important asset.[38] A properly used helicopter unit can save one to two lives per 100 STEMI missions.[147]

As is the case with other diagnoses, helicopter dispatch for cardiac patients needs to be based on situational characteristics; otherwise, the potential utility of AMT is not realized.[129] The wilderness medicine practitioner faced with a STEMI case would be wise to consider the substantial time savings, with associated clinical benefit, provided by helicopter EMS.

When calls are made for a patient in cardiac arrest, the wisest course is usually to manage AMT decisions expectantly. As a general rule, the literature supports ground transport of patients undergoing active cardiopulmonary resuscitation. Dispatch of AMT resources for patients in cardiac arrest may be rational, but these patients should be loaded for transport only if there is truly a need for transport (i.e., there is some chance of survival) in the absence of a viable surface vehicle alternative. Mechanical chest compression devices are significantly safer (allowing the crew to remain belted) and more preferable (for compression quality and to free hands for other tasks).[99,150,153] For patients who have been successfully resuscitated from cardiac arrest, the literature supports AMT.[215]

Stroke Patients

For hemorrhagic stroke, decreasing neurosurgical coverage in many rural areas has translated into an increased need for AMT to bring patients to centers capable of operative intervention.[116] For patients in rural or isolated (e.g., island) geographic situations, likely in wilderness medicine, AMT is a critical component of the hemorrhagic stroke care network.[88]

The role for helicopters in transporting stroke patients is rooted in the realization that time is just as important for these patients as it is for patients who have suffered trauma or acute coronary syndrome. Rapid transport for patients with stroke is not invariably needed, but early stroke center evaluation is often an important goal for the wilderness medicine provider. Given that outcomes can be improved when a stroke patient is moved rapidly to a center providing specialty care, helicopter EMS has the potential to much improve outcomes.[163,167,192]

Pediatric Patients and Neonates

Use of AMT to allow wider geographic coverage for pediatric care networks is reported from many areas. The common conclusion is that AMT (by either FW or RW) needs to be available for time-critical cases, including those in which it is necessary to get a specially trained crew (e.g., neonatal resuscitation experts) to patients in remote rural locations.[12,74,105,133,149]

Use of AMT for children who are not infants is extensively reported in the wilderness medicine setting. For near-drowning victims in warm-climate locales, teen skiers injured in alpine settings, or children involved in mass casualty natural disasters, helicopter deployment is an important part of ensuring health care access.[7,86,127,168]

The success of any AMT mission partially depends on the expertise of the flight crew that will care for the patient. Children (including neonates) are a special population for which the wilderness medicine provider should consider crew qualifications. Especially in the United States, there are many regions that have dedicated AMT services that focus solely on pediatric patients. The wilderness medicine planner is advised to become familiar with specialized pediatric AMT assets that might be available in a given area.

Obstetric Patients

There is a risk in allowing women to give birth in locations lacking maternal-fetal medicine or neonatal resuscitation capabilities. However, there is also a risk in loading a patient onto an aircraft for transport and having the patient deliver while in flight. As a general rule, the in-flight setting is suboptimal for childbirth. Fortunately, in areas that are very remote, available EMS assets tend to be larger in size (because they must be capable of long-distance flights). In a recent report on a breech delivery in an AS365 transporting a patient in the Finnish Arctic Circle region, the authors noted that the delivery was successful only because the larger aircraft size allowed for patient repositioning.[152]

Fortunately, the AMT mission screening process has proven quite adept at minimizing the risk of an unwanted intratransport delivery. Case series over the past few decades have consistently found an extremely low (usually zero) incidence of in-flight delivery, leading to the conclusion that outcomes for mothers and infants transported by air are just as good as those for pregnant women who present primarily to a specialty center.[34,46,89,141,210]

Wilderness obstetrics cases are most likely to involve a patient in an isolated location with unexpected onset of labor or a patient with expected labor occurring in a situation in which unexpected evacuation is necessary.

Other Disorders for Which Air Medical Transport May Be Useful

AMT can be useful in the form of a 100-mile flight for a pediatric patient with an infectious disease such as meningitis, or in the form of a 5000-mile flight (in an advanced isolation unit) for a patient with life-threatening Ebola virus infection. Similar examples of uncommon but crucial AMT applications can be found wherever there is a combination of time criticality, a life- or limb-threatening situation, and medical needs that exceed the capabilities of the patient's current location.

COST-EFFECTIVENESS OF AIR MEDICAL TRANSPORT

Imprecision regarding effectiveness renders AMT cost effectiveness calculations difficult. Because FW transport is often employed when there is no other option, cost-effectiveness for airplane transport is relatively noncontroversial. For helicopter transport, there is more debate.

Analyses based largely on time savings have demonstrated cost-effectiveness of helicopter EMS as part of the overall care system for trauma, cardiac, and stroke patients.[31,38,69,93,132,147,172] The fact that it is difficult (if not impossible) to parse the contribution of helicopter transport to overall outcomes improvements does not mean that AMT is not a critical part of those systems.

Cost-effectiveness is often unrelated to logistics gains. Helicopter transport of a head-injured patient, reliably demonstrated to be associated with improved outcomes, translates into lower long-term costs for the survivor.[35,151] Large-scale assessment of appropriate use of helicopters for trauma patients also suggests cost-effectiveness. Economics studies have calculated that in order to be cost-effective, helicopter EMS must save at least 1.3 lives per 100 patients.[37] Reviews of literature on trauma have consistently indicated that helicopter transport meets or exceeds this threshold.[1,22,102,182,183]

AIR MEDICAL RESPONSES IN DISASTER AND MASS CASUALTY SITUATIONS

Disasters and mass casualty incidents can pose a number of challenges for which AMT can be of assistance to ground EMS and incident commanders. Areas of air medical application in such situations are centered on response, care provision, patient evacuation, and assistance in other aspects, ranging from communications to distribution of the patient burden across a system.[190]

As previously mentioned in the FW discussion, one mechanism for use of AMT in disasters lies in a long-range response and transport when a natural disaster destroys local health care capabilities. In the aftermath of a 2011 earthquake in Japan, a fleet of physician-staffed helicopters was judged vital to medical assistance and rescue. Fifteen helicopter EMS teams transported 149 patients in the 5 days following the incident.[126]

A more recent earthquake in Yushu, China, provided a further opportunity for AMT in a situation in which local hospitals had been devastated.[113] In this situation, which involved thousands of casualties, both RW and FW assets were employed. Earthquake trauma was the most common diagnosis of transported patients. It is noteworthy that of the 2796 patients who were moved by AMT, some had diagnoses other than trauma (e.g., 166 patients with acute mountain sickness). In Yushu, military helicopters were used for shorter-range flights.[113]

In assessing the AMT response for disasters and mass casualty incidents, the geographic location and extent of local damage need to be considered. The previously mentioned earthquakes resulted in wholesale destruction of local and even regional medical capabilities. Thus, one of the roles of AMT was to assist in transporting medical responders, sometimes for thousands of miles, to facilitate reestablishment of basic health care. This general rule is applicable in many natural disasters. Another example of widespread, long-distance, multifaceted AMT occurred after the 2004 tsunami in Indonesia's Aceh province.[107] Helicopters were also crucial in reaching remote villages affected by the 2015 earthquakes in Nepal.

Air transport assets have long been stationed at mass gatherings (which can turn into mass casualty incidents), ranging from sporting events to air shows.[138] The wisest application of AMT is that which occurs with close communication and cooperation with ground personnel.

Specific disaster-related AMT contributions can include movement of vital equipment and supplies or personnel to incident sites. Aircraft can also serve as airborne repeaters or facilitate communications in other ways. Larger helicopters, with increased carrying capacity for medical attendants and patients, can be particularly useful in disaster or mass casualty situations.[190]

Larger helicopters might need larger LZs. Setting up landing areas for helicopters may be difficult in disaster situations because hazardous material may be present, communications may be impaired, and ground personnel may be inexperienced.[190] These potential problems can combine to create a high-risk situation. For example, in one U.S. chemical explosion disaster, poorly trained personnel did not take into account the hazardous material nearby and failed to tell the helicopter unit about it, creating a situation that was dangerous for both the flight crew and persons at the scene.[32] Any disaster situation involving hazardous materials should be considered a high-risk situation for AMT. Unless aviation and on-scene personnel safety can be assured, the helicopter should land sufficiently far away and proceed to evaluate the situation before deciding on transport appropriateness.

AIR MEDICAL RESPONSES FOR SEARCH AND RESCUE AND ALPINE OPERATIONS

Searches and patient evacuations are common components of wilderness medicine. For both the search phase and the rescue phase, there is a potential role for air medical assets.

A helicopter may be the only practical means for getting a patient out of a given wilderness situation (Figure 58-38). Sometimes a helicopter can land near a patient and the crew can provide the same care as might be given in a traditional scene response. On other occasions, there is nowhere to land and the helicopter must use its unique capability to hover without landing.

AIRPLANES IN SEARCH AND RESCUE MISSIONS

SAR missions executed by FW can be particularly important. It is critical, for example, in long-distance searches, such as those over large areas of the ocean. FW assets can also provide long-term coverage of an area, facilitating communications with helicopter units; the C-130 Hercules is useful for this in the Denali region. An airplane can deploy personnel such as parachutists, who can search for and rescue a person and then be extracted by a helicopter after finding a patient. These missions are nearly always performed by highly trained military units.

SAR contributions by airplanes tend to fall more within the aegis of "aviation" than "medical" transports

HELICOPTERS IN SEARCH AND RESCUE MISSIONS

Helicopters bring the advantage of allowing close inspection of a search area from a low altitude above ground level. They can bring more searchers to the scene and are a readymade source of AMT because they are "on location" if the search is successful. When a patient's location is not known with any precision, they can be useful for movement of equipment, personnel, or supplies.

There can be problems if AMT units not normally used for SAR are employed on an ad hoc basis. In the absence of specially trained helicopter EMS units, issues of coordination of effort and communications can negate the potential advantages or even detract from operational safety. Wilderness medicine planners and practitioners should have a low threshold for using helicopter units for search missions when the units have appropriate

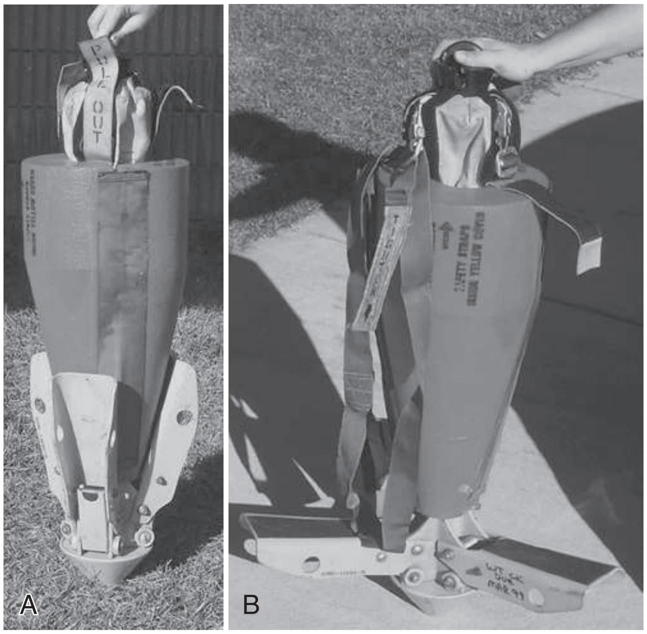


FIGURE 58-38 Occasionally, helicopters are the only viable option for extracting patients in difficult topography. One example of such terrain is dense jungle. **A,** Jungle penetrator used as a hoist device on most military rescue helicopters. The streamlined shape allows it to slip through dense tree canopies to reach the ground. A foam flotation collar can be attached, making the penetrator buoyant. **B,** Jungle penetrator rigged for hoist. The seats are flipped down, and safety straps are pulled out from their stowed position and passed over the head and under the arms of the victim, who then straddles one of the seat paddles. Although the penetrator has three seats, usually only one or two persons are hoisted at a time. *(Courtesy Robert C. Allen.)*

training and expertise. When such training is absent, the wilderness medicine decision maker should carefully weigh the risks and benefits of helicopter involvement.

Almost any RW aircraft can be pressed into SAR service, but most helicopters used in the United States are much better suited for patient transport than they are for search operations. In other countries, helicopter EMS tend to be more likely associated with law enforcement or military units. Some of the earliest reports of RW involvement in SAR come from military units (including those with dedicated on-board physicians).[173,179,209,213,216] Over 10 years in the 1980s, a Royal Air Force helicopter EMS unit conducted nearly 1500 SAR missions along the coasts and in the mountains of the United Kingdom.[111]

In the United States, most civilian helicopter units lack standard SAR equipment (e.g., winches, infrared imaging devices, bright searchlights). Furthermore, the special training required for effective SAR operations is not usually part of the education program. A 2013 review of hoist operations by a civilian helicopter operator in the United States noted that the study program was the only nonmilitary, non–law enforcement helicopter service in the country providing hoist operations.[29] It is not surprising that many civilian programs (excluding those affiliated with law enforcement units) are not well suited for SAR.

There are multiple important exceptions to the general rule that civilian programs are often not optimally suited for SAR. These exceptions tend to involve programs operating in rural and particularly alpine settings. The previously mentioned U.S. civilian helicopter EMS program providing hoist operations has executed hundreds of such missions in the Utah-area backcountry.[29] Swiss helicopter services operating in that country's mountains have long reported success in alpine SAR operations[121,131,150] (see Figure 58-27).

Mountain settings provide an illustration of how helicopter units can help in SAR when a patient location is known only in a general sense. In these cases, a helicopter can transport medical personnel, who make their way on foot to the suspected position.[29] A helicopter that is unable to get all the way to the top of a mountain can land as high up as possible (e.g., ascending to just below the cloud line). Even if medical care cannot be delivered directly to the patient, the savings in time is significant compared with having responders hike to the site.

HELICOPTERS AND AVALANCHE RESPONSE

Avalanche response warrants mention because of its frequency and the blend of aviation and medical issues involved. RW assets have long been used to respond to such situations and contribute to successful outcomes even when patients are in cardiac arrest.[150]

Close collaboration between ground and air EMS wilderness providers has resulted in streamlining of operations and elucidation of important lessons (e.g., the utility of mechanical compression devices for avalanche victims in arrest). These devices have been judged necessary by wilderness medicine personnel who have taken into account the need for prolonged "hands-off" time associated with helicopter loading from a steep-slope setting.[150] When helicopters may be employed in the wilderness, the flight crew and referring ground providers should discuss how to best execute the particular mission type.

HELICOPTERS AND HOIST OPERATIONS

Lifting patients onto hovering helicopters is commonly referred to as a hoist operation or winch operation. Short transports, as in alpine rescues, are discussed elsewhere in this chapter (see long-line operations). The term hoist operation is used here to encompass hoist operations, winch operations, and long-line operations. Hoist operations are provided from alpine settings to oceanic archipelagos.[29,45,106,150]

Helicopters capable of providing hoist operations can be invaluable at a wilderness medicine scene. A study from the United Kingdom assessing wilderness regional evacuations by surface transport concluded that for approximately a third of cases, a helicopter hoist rescue would have saved valuable prehospital time.[45] These authors and others have concluded that valuable prehospital time can be saved with hoist operations and that helicopter units in mountainous regions should aim to have this capability.[45,203]

Equipment for technical rescues and medical material must be reduced to the lightest weight and volume possible. Whenever possible, a victim should be hoisted in his or her own harness, which should be first checked for its ability to hold the victim's weight. This is feasible when injuries are less severe or there are medical issues without the need for spinal immobilization (Figure 58-39). For evacuation of a patient in a horizontal position, the so-called horizontal net (Figure 58-40) has proved to be light in weight, very useful, and easy for a single rescuer to apply. Because of the variation in equipment suitability and availability, training needs to include multiple techniques. The training must be hands-on and repetitive, because even during "busy" times, long-line operations may not be sufficiently common to ensure that skills can be maintained. The special case of long-line operations at extreme altitude is addressed later in this section.

As previously noted, most civilian helicopter EMS programs do not provide this SAR expertise because their resources tend to be directed more toward transport than "rescue." However, hoist operations are practiced by some civilian units and such rescues are well within the capabilities of most military/governmental RW services.

Hoist operations can be limited to lowering of a rescuer (or multiple rescuers) to the patient (Figure 58-41). After stabilization, the patient may be transported by a surface vehicle. More commonly, the rescuer is initially lowered for patient stabilization and then the patient (and rescuer) are lifted into the hovering aircraft using a basket or harness.[29] In short-haul situations, the patient and/or rescuer may be transported for a very short distance while still suspended from the aircraft (Figure 58-42). The preference for a hoist or a short haul may be related to pilot experience or comfort levels; a helicopter EMS program may choose a short haul because it requires less equipment and one fewer crew member. A short haul can therefore save the weight of one crew member and at least 100 pounds of additional equipment.

FIGURE 58-39 When there is no requirement for spinal immobilization, patients can be evacuated in a harness. *(Courtesy Monika Brodmann Maeder.)*

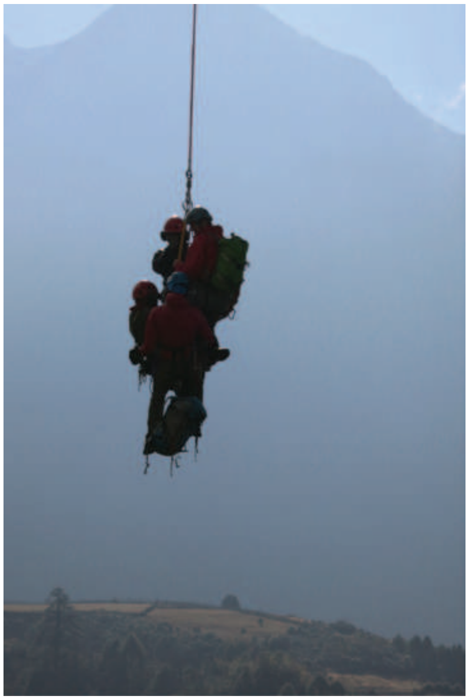


FIGURE 58-41 A long-line device can be used to deliver multiple search and rescue team members. *(Courtesy Monika Brodmann Maeder.)*

Specially designed equipment must be used to extract patients via hoist operations. Rescue nets or baskets (often called Stokes litters) are used by helicopter operators in SAR (see Figure 58-40). These special litters allow for safe accommodation and movement (including in a vertical direction) of a patient, while maintaining spinal immobilization.

Execution of hoist operations requires proper training. Preparation and collaborative exercises are a *sine qua non* of successful combined air medical evacuation operations (Figure 58-43). A few examples of pertinent safety considerations are provided here. Rescue personnel must avoid touching the end of the hoist (or rescue device) before it can first touch the ground. A helicopter can build up a substantial static electricity charge, and by touching the hoist before it is grounded, rescue personnel may receive potentially dangerous shocks. Other points of importance include the need to use a tag line to prevent a person from spinning while being hoisted, and the avoidance of any looping of lines around those being lifted (to avoid injury when slack is taken up during lifting). These tips are offered only to emphasize the critical importance of appropriate training before engaging in hoist operations (Box 58-2).

FIGURE 58-40 Horizontal net used for helicopter hoist operations. *(Courtesy Monika Brodmann Maeder.)*

HELICOPTERS AND HIGH-ALTITUDE SEARCH AND RESCUE IN LESSER-DEVELOPED COUNTRIES

A growing number of tourists visit remote mountainous regions of the world. Compared with a few decades ago, these tourists are likely to be older and to have preexisting medical conditions. As a consequence, there are increasing demands for rescue in the event of medical emergency situations that develop in isolated regions.

Some of the most rapid growth in wilderness AMT is occurring in trekking and alpine settings in less-developed countries in which the helicopter transport system is the only realistic means of rapid evacuation. For many developing countries, tourism is an important part of the national income. Governments are thus interested in investing in the development of rescue structures that include AMT.

Increased availability of rescue allows governments to attract tourists in greater numbers. In countries such as Nepal, growing rescue capabilities are associated with increasing tourist numbers in high-altitude areas. The ability to retrieve tourists who are trekking or climbing becomes a priority.

Not only Nepal is depending on AMT. Almost all peaks over 6000 m are located in the Andes, Himalayas, or Karakorum. SAR structures are rarely available in many of these regions and existing capabilities are often conducted by (or under the control of) governmental organizations. The experience of some helicopter crews in conducting challenging rescue operations at high altitude is often limited. Pilots are rarely experienced in hoist and long-line operations, and landings and takeoffs at high altitude are challenging. Operations therefore tend to be delegated to mountain-savvy services based out of Western countries, which spend a few weeks per year in countries where they are needed.

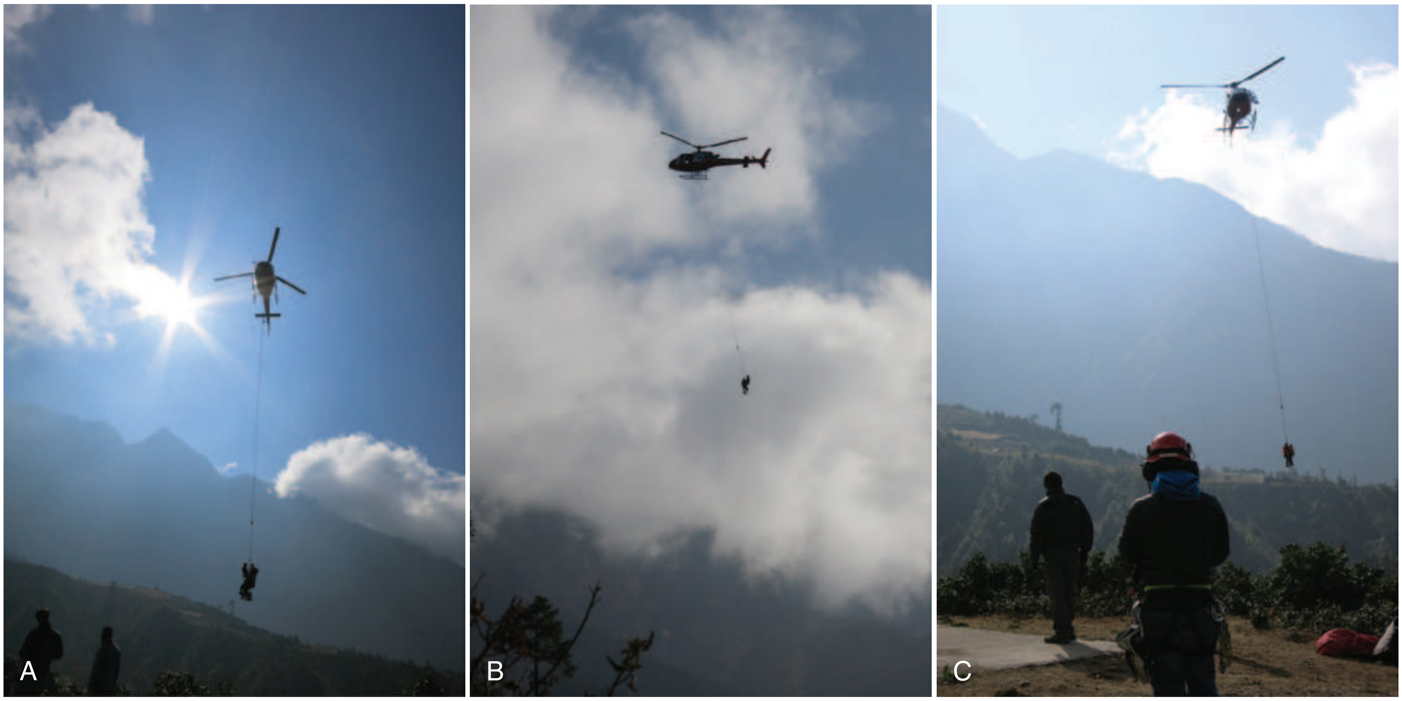


FIGURE 58-42 A long-line device can be used for a "short-haul" of a patient **(A)** from the rescue site for a short distance **(B)** to a stabilization area **(C).** *(Courtesy Monika Brodmann Maeder.)*

Public health issues surround deployment of a resource-intensive air rescue service in areas with little wealth and poor overall health care capabilities. Efforts to establish a high-quality rescue system aim to attract more tourists, who will be willing to pay high fees for a rescue. On the other hand, local people might have little access to basic medical care. This gap is obvious and raises criticism about inequities. Helicopter organizations can mitigate this problem in part by undertaking rescue missions in extreme altitude regardless of a patient's ability to pay.

For countries with minimal intrinsic helicopter services, the goal should be development of sustainable capacity through education of local crews. The teaching goal is for the local unit to be able to conduct rescue missions with high-quality performance and outstanding safety.

As another possibility for overcoming the imbalance in health care assets, more projects for transporting medical teams by helicopter to remote areas in a country should be established.[121] This allows the local population to share the benefits of proliferation of helicopter SAR in developing countries with high mountains (Figure 58-44).

FIGURE 58-43 Collaborative training that includes flight crews and personnel who will call for (and assist with) helicopter evacuation is a paramount step for optimizing air transport resource use. *(Courtesy Stephen H. Thomas.)*

BOX 58-2 Steps in Helicopter Safety

- Approach and depart downhill
- Use crouched position
- Approach after approval from pilot
- Await directions of flight crew
- Secure area of people and debris
- Do not shine lights toward aircraft
- Use tag line to prevent spinning of hoist
- Ground the hoist line to prevent electric shock

FIGURE 58-44 **A,** Patient waiting zone for consultation at the health camp served by the Lukla Helicopter Medical Assistance unit in Bung, Nepal. **B,** Patients waiting for the consultation. *(Courtesy Monika Brodmann Maeder.)*

HELICOPTER FLIGHT AT HIGH ALTITUDE

High altitude poses unique issues for RW aviation operations. Besides rapidly changing weather conditions, strong winds, and low temperatures, "thin air" and hypoxic conditions pose risks for pilots and crew. In order to minimize these risks and optimize safety, the choice of helicopter and the technical and medical equipment must take high-altitude parameters into account. The higher the altitude for the potential operation, the less forgiving the terrain will be in the event of poor planning or execution of the rescue mission.

The weight and power of the helicopter must be adapted for rescues at extreme altitude. In many rescues (and also in commercial operations) in the Himalayas, the Airbus AS-350 Ecureuil B3 has proved effective. This aircraft has been useful for extreme operations ranging from long-line rescues above 7000 m to a landing on the summit of Mt Everest. Modifying the AS-350 B3 for high-altitude operations is achieved through such measures as removing aircraft doors. Removal of doors reduces weight and also provides space for a "cabin security" backup system for the cargo hook used in long-line operations. Because of these weight limits, the crew usually consists of the pilot and one rescuer only.

At high altitudes, the physics of helicopter flight become more challenging. Air is less dense, so there is more difficulty in lifting off and hovering above the ground. The problem is rendered more serious if there is a need for a helicopter to hover while executing SAR tasks such as winching. Special expertise has been developed by pilots and medical crews who operate in alpine settings in Europe (particularly, Switzerland) and other areas of the world with even higher mountains. Lessons learned have been successfully applied to render high-altitude missions safer and more effective.[150] Even with improvements in mountain-based wilderness medical provision in areas with (relatively) adequate resources, such as Denali, helicopter evacuations remain an important asset as part of the prehospital care and evacuation system.[159]

LONG-LINE OPERATIONS AT EXTREME ALTITUDE

Due to the fact that starting a helicopter and hovering is nearly impossible at extreme altitude, most mountain rescue evacuations at high elevation are long-line operations. Such operations have some noteworthy differences from operations at sea level; a typical alpine operation at extreme altitude is outlined here. The first leg of the alpine mission to a high-altitude site involves repositioning the aircraft from its base to the general area of the patient, at a lower altitude than the patient's suspected location. During this flight, the patient position is being localized and the environment checked for safety. The helicopter lands in the lower-altitude LZ and the crew prepares for the operation.

In the next step, a static line is hooked into the cargo hook. The cabin security system is installed, and the rescuer attaches to a special hook at the other end of the line, which is usually 20 to 30 m long. The helicopter starts and slowly lifts the rescuer from the ground. During the approach to the patient, the rescuer is responsible for indicating the direction and height of the helicopter in relation to the place where the rescuer is supposed to land. After landing, the rescuer unhooks from the line. The helicopter flies to the lower LZ and waits until the rescuer has prepared the victim. When this is done, the helicopter returns to the site. The patient and the rescuer are hooked to the line and flown out (under the helicopter) to the lower LZ. After a short check, the patient is placed into the helicopter and the team departs for definitive care.

MEDICAL INTERVENTIONS DURING HELICOPTER SEARCH AND RESCUE MISSIONS

In SAR or extrication missions, the timing of medical interventions is driven by scenario-specific factors. Sometimes scene safety dictates a need for initial evacuation before execution of any medical care. In hoist operations, patient acuity and scene stability often combine to constitute a situation in which the patient is first moved (with spinal stabilization as appropriate) to a more controlled environment and then undergoes medical care.

FIGURE 58-45 Ankle splinting in a Nepalese search and rescue operation; timing of provision of medical interventions depends on situational specifics. *(Courtesy Monika Brodmann Maeder.)*

Initial rescuers may have a limited medical background. The expected practice scope for these individuals should be focused and minimal. The timing of medical interventions is driven by situational elements (Figure 58-45). Immobilization techniques with special evacuation systems, such as a horizontal net or splinting techniques with flexible aluminum splints, are useful because they are easy to handle, lightweight, and small.

Reasons for evacuation from an extreme altitude, besides trauma, are often related to the altitude itself. Even if the initial rescuer is not trained to a high medical level, the initial evaluation should include assessment in a basic fashion.

The rescuer must assess for any signs of altitude illness that can be life-threatening. When there is a question of serious injury or illness (e.g., high-altitude cerebral edema), the goal should be to quickly and safely move the patient to a lower altitude for evaluation by appropriately qualified medical professionals. Some patients with minor problems can easily be flown to a base camp, where expedition doctors are available. In all other cases, it is crucial to define a local hospital with a helicopter LZ that has medical competence in emergency medicine.

High-altitude operations and rescues frequently involve relatively young, active, physically fit victims of trauma ranging from falls to avalanches. High-altitude units need to train for avalanche rescues and transports, because helicopter transport for core rewarming is a well-reported component of improved survival.[139] In addition to the "traditional" high-altitude operations for avalanches, ski accidents, and similar situations, units must also be able to respond to the unusual case, such as the Himalayan climber (at 5900-m elevation) who is diagnosed with stroke and needs transport to Kathmandu.[217]

Regardless of the patient type, the helicopter unit must integrate with the regional health care assets. Existing recommendations of medical standards for mountain rescue operations using helicopters must be adapted to the local possibilities and competence of the rescuers.[202]

HELICOPTER PROGRAM SAFETY AND HIGH-ALTITUDE OPERATIONS

The wilderness medicine practitioner considering helicopter deployment in a high-altitude setting may need to consider the additional risk posed by operations in a demanding environment. In some wilderness settings, the extreme altitude of potential rescue targets can contribute to a safety calculus more conservative than in other settings. In Alaska's Denali region, for instance, helicopters are not deployed unless there is risk to life, limb, or eyesight.

The usual safety considerations (e.g., weather, fuel/distance) attendant to any helicopter mission are applicable at high altitudes. An additional consideration may be that if something happens to the aircraft, there are few (if any) options for rescuing the rescuers (Figure 58-46). In Denali National Park, for instance, the primary unit is an Airbus AS350B3 (A-Star), which is flown up to 24,000 feet in that mountainous area. The Denali aircraft may have backup from a Sikorsky S70 Pave Hawk, but the Pave Hawk can fly only to 14,000 feet. Only one other aircraft in the Denali region, the Boeing CH47 Chinook out of Fairbanks, can be deployed to the higher altitudes that can be reached by the AS350B3. If the Chinook is not available, there is no airborne backup in case of a problem with the A-Star.

The low oxygen partial pressure at extreme altitude poses another challenge for the helicopter crew. Pilots who fly to extreme altitude are obliged (by regulation) to use supplemental oxygen, which sometimes interferes with the communication system in the helicopter. Special masks that deliver the oxygen and enable the pilot to communicate via radio are very useful during high-altitude operations.

Supplemental oxygen is only rarely available for rescuers after they leave the aircraft; acute hypoxia is thus a risk. If the rescuers are deployed for a long enough period of time, they may be vulnerable to high-altitude illness. For this reason, unless the mission is certain to be very short in duration (in which case the risk is low), rescuers may be instructed to take medications intended to decrease high-altitude complications.

PUTTING IT ALL TOGETHER: KEYS TO JUDICIOUS USE OF AIR MEDICAL TRANSPORT

AMT has the capability of contributing to improved patient outcomes and system performance. For FW transports, which tend to entail repatriation and other mission profiles that are simply not an option for surface vehicles, there is relatively little controversy. For helicopter transports, on the other hand, discussions about outcomes benefits and appropriate utilization sometimes bring debate.

With helicopters, the argument is less about whether transport can improve outcomes, but rather, for whom the asset should be used. Sometimes, if a patient needs urgent health care, the helicopter option is the only option (Figure 58-47). However, the decision is not always straightforward.

While helicopter EMS outcomes research barriers are being addressed, helicopters continue to execute hundreds of thousands of transports each year. The recommendation for regional EMS systems is to begin by examining the "standard" NAEMSP helicopter dispatch guidelines, which have been endorsed by many of the relevant prehospital and physician groups in the United States.[199] Those standard guidelines should be discussed by stakeholders in a given EMS region, with adaptation dictated by local needs. As far-fetched as it seems, there are reports in relatively recent times describing metropolitan regions in the United States without guidelines directing helicopter EMS dispatch.[169]

Guidelines are important because they provide a starting place for ongoing utilization review and optimization of triage. Data suggest that even within a single region, there can be substantial heterogeneity between the appropriateness of use by different entities requesting helicopter EMS.[200] To accomplish review and improvement, it is important to provide feedback to the ground EMS or referring hospital entities who called for the helicopter.

FIGURE 58-46 In mountainous remote terrain, there is limited backup in case of adverse events involving the helicopter rescue team. *(Courtesy Monika Brodmann Maeder.)*

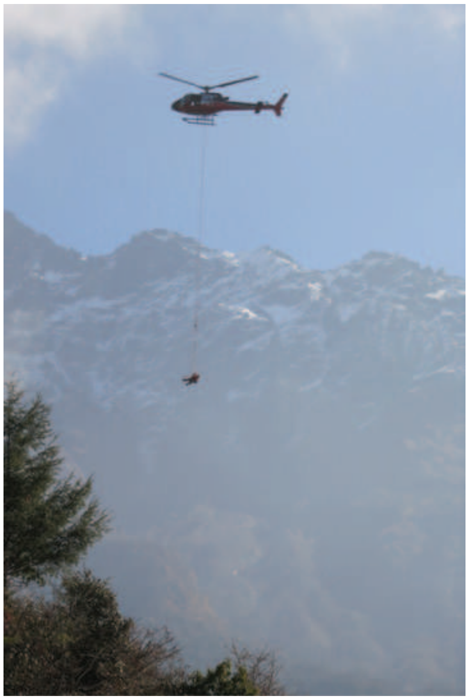


FIGURE 58-47 In some terrain, a helicopter offers the only realistic option for timely access and evacuation. *(Courtesy Monika Brodmann Maeder.)*

TABLE 58-3 Air Medical Services Internet Resources

Air Medical Physician Association (AMPA): ampa.org
Air and Surface Transport Nurses Association (ASTNA): astna.org
Association of Air Medical Services (AAMS): aams.org
Atlas and Database of Air Medical Services (ADAMS): adamsairmed.org
International Association of Flight and Critical Care Paramedics (IAFCCP): iafccp.org
Critical Care Transport Collaborative Outcomes Research Effort (CCT CORE): cctcore.org
National Association of EMS Physicians (NAEMSP): naemsp.org
National EMS Pilots Association (NEMSPA): nemspa.org

AIR MEDICAL SERVICES INTERNET RESOURCES

Resources listed in Table 58-3 may prove useful to those seeking further information regarding AMT.

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CHAPTER 59
Essentials of Wilderness Survival

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This chapter discusses the general principles of wilderness survival, particularly in temperate and moderately cold (i.e., nonpolar) environments such as the mountains of the American West. For additional information, especially about other environments, please refer to Chapter 1 for high-altitude medicine, Chapter 9 for polar medicine, Chapter 60 for jungle survival, Chapter 61 for desert survival, Chapter 90 for how to live off the land, Chapter 106 for wilderness navigation techniques, and Chapter 121 for certain aspects of environmental changes (e.g., global warming).

According to *Webster's College Dictionary,* the word *survive* means to "continue to function or manage in spite of some adverse circumstance or hardship," and it implies the presence of conditions that make this more difficult than usual. "*The ability and the desire to keep yourself alive, all alone, under adverse conditions until rescued"* is a more practical definition. These conditions may—and frequently do—include a lack of oxygen, food, or water; the presence of rain, snow, high winds, or temperature extremes without shelter; the complicating presence of illnesses or injuries; and the necessity to rely completely on the physical, mental, and material resources that are immediately at hand. Physicians who participate in wilderness recreation or who treat such participants need to be aware of the physical, physiologic, and psychological hazards of environmental stress and how related deleterious effects can be prevented and treated in themselves and their patients.

Increased leisure time and growing interest in outdoor activities place more people into settings in which survival situations may develop. The increasing use of all-terrain vehicles and snowmobiles has made it easier to get lost or stranded far from help. In addition, the rise in sedentary lifestyles with inattention to healthy diets, decreased emphasis on physical conditioning, and increasing prevalence of obesity have led to decreased fitness in developed nations, particularly the United States. With modern communications and tactics (e.g., the use of combined helicopter and ground teams), search and rescue operations have become more efficient. At the same time, electronic devices such as cellular and satellite phones, global positioning system (GPS) locators, emergency locater transmitters for aircraft, and personal locator beacons have made it easier to get assistance, but these are accompanied by increased risk taking, false sense of security, decrease in a healthy respect for wilderness, neglect of survival training, failure to carry survival equipment, and less-effective use of simple nonelectronic tools such as maps and compasses. An especially egregious practice is the "Yuppie 9-1-1," when a personal locator beacon that sends a "help" message to a satellite is used for a nonemergency situation. In some cases, carrying such equipment tempts wilderness travelers to take chances that common sense would otherwise prevent. According to the *Billings Gazette,* in one recent episode, an inexperienced party made three calls in three days from the Grand Canyon, thus "mobilizing helicopters for dangerous, lifesaving rescues inside the steep canyon walls. What was that emergency? The water they had found to quench their thirst 'tasted salty.'"

Societal "progress," then, has made it easier to get assistance when there is trouble, but it is now also easier to get into trouble. This chapter's main thrust is prevention and successful initial definitive management of such trouble. By paying heed to the recommendations discussed here, the reader will be more apt not only to live through the stress of a survival emergency but also perhaps to do so in relative comfort.

A Story of Survival

A recent episode in Montana illustrates the types of problems that wilderness travelers such as hunters can experience, and emphasizes both the penalties for risk taking and the role of technology in the softening of these penalties. Glenn Eschenko, who was 51 years old, ran a bowling alley and supper club in Big Timber, Montana. A longtime hunter and mule owner, he had returned to the same camp near Anderson Mountain in the Absaroka-Beartooth Wilderness for 20 years. He packed in enough gear to spend a week hunting elk next to the border of Yellowstone National Park. In 2005, he had been hunting for 6 days with four friends. They had harvested a six-point bull elk when the weather started to turn nasty on Saturday, September 17. After four of them had lunch, two of them (Eschenko and Chad Cochran) saddled up to look for the fifth hunter (Courtney Ayers), who had not returned.

Eschenko was riding one of his older mule colts when he came around a corner in the rain and saw Ayers up ahead. Ayers was riding down a mountain toward him, wearing a yellow rain slicker. The slicker startled Eschenko's mule, who whirled and started bucking, throwing his rider after about five jumps. Eschenko was thrown down an embankment, sliding on a skiff of snow on the grass, hitting a rock, and then sliding on his belly farther downhill before crashing into a boulder.

Eschenko was able to stagger to his feet, but the wind was knocked out of him, and he could feel loose and moving broken ribs on his left side. His friends loaded him onto another mule and got him back to camp, but he could not move because of his dyspnea.

Cochran had a cell phone and called 9-1-1. A helicopter was dispatched from St Vincent's Hospital in Billings, about 160 km (100 miles) away, but it was unable to land because of bad weather. Cochran rode to a nearby outfitters camp and asked a nurse for advice. She told him that if Eschenko was still alive when he got back, then the injured hunter would probably survive.

The party spent a cold night by a roaring campfire; Eschenko was still alive the next morning. A helicopter from Idaho was set to make a rescue run, but again the weather was too severe. Finally, a helicopter from Mammoth, Wyoming, was dispatched; the camp was found as a result of the pilot's use of GPS coordinates that the hunters had called in, and the aircraft was able to land at a mountain meadow above camp and drop off two emergency medical technicians. Fearful of getting fogged in, the craft departed down the mountain around 8:30 AM.

The emergency medical technicians noted extreme tenderness in Eschenko's left upper quadrant and felt that his spleen was probably ruptured. Because extreme pain limited Eschenko's movement and ability to walk, his companions managed to transport him by mule 0.8 km (0.5 miles) to a place where the helicopter could safely land. Eschenko was flown back to Mammoth, where an ambulance was waiting to take him to Livingston Memorial Hospital in Livingston, Montana. A doctor told Eschenko that he had cheated death because his spleen was "pulverized" although not freely bleeding. Once he was out of the hospital, Eschenko sold the mule that had bucked him off. He then planned to show his other mules yellow raincoats to get them used to the sight. He also said that he had acquired an appreciation for cell phones and GPS receivers.

GENERAL CONSIDERATIONS IN SURVIVAL

The exact type of environmental stress depends on the type, location, and duration of the wilderness experience. Cross-country skiers, winter mountaineers, and winter campers may be exposed to extremes of cold and storm. Expeditionary mountaineers may explore regions in which winter exists year round and where ambient oxygen is low. Desert or tropical travelers may be exposed to extremes of heat and humidity. Passengers in aircraft, sea craft, or land vehicles may be stranded in almost any type of environment.

Requirements for survival, which are discussed in detail later in this chapter, are similar whether the subject becomes lost with few resources during a simple day hike or whether injury occurs or severe environmental conditions develop during a well-planned wilderness expedition. Although traveling alone in the wilderness is universally condemned, one must always assume that he or she may be alone and possibly injured when in a survival scenario. Therefore, emergency equipment must be familiar, sturdy, uncomplicated, easy to assemble, and—most importantly—available immediately. Necessary skills cannot be learned on the job but must be anticipated, acquired, and practiced beforehand so that essential tasks can be accomplished with minimal delay and effort should an emergency arise. Although improvisation and the ability to live off the land are important, anticipation, prevention, and especially preplanning and carrying emergency equipment are vital. Consider examples taken from polar exploration: Roald Amundsen's style of thorough preparation and the use of familiar equipment should be emulated, whereas Robert Scott's careless, arbitrary, and stubborn approach should be rejected. Both of these explorers had extensive polar experience, but Scott elected to use European clothing rather than Eskimo furs and unproved motor sledges and ponies rather than Eskimo dogs. He relied excessively on sled hauling by men on foot, rejected the use of skis, failed to establish enough supply depots for his return, and died of cold, exhaustion, and starvation on the way back from the South Pole. Amundsen, who used Eskimo clothing, well-tested Greenland sled dogs, and experienced skiers, won the race to the South Pole and made it back alive.

The outcome of an encounter that involves severe environmental stress varies with the stressed person's resources and the type, magnitude, and duration of the stress. These resources include the state of acclimatization; physical integrity (particularly conditioning and the presence of illness or injury); experience; equipment on hand plus the ability to improvise intelligently; and such intangibles as good judgment and "backcountry common sense." A common judgment error is to insist on traveling during a storm or other stressful environmental situation, when more prudent persons would stay put in a comfortable bivouac. Excuses for this include wanting to reach a predetermined (but not essential) goal on time so that others will not worry. Recall the old adage, which has been attributed to Will Rogers, that "good judgment comes from experience; experience comes from bad judgment." To this, we should add, "… provided that you survive the bad judgment." The most important resource, however, may be the will to survive. This may be inbred in some persons, can be established through training and experience in many, and is impossible to acquire in a few. With a strong will to survive, some persons have withstood incredible hardships. Without such will, the best training and resources may be useless. It should also be noted that the need for a strong will to survive might not be as important for those who are prepared to spend an unexpected night out. However, for those who have never prepared and then found themselves in a survival event without appropriate training or equipment, a strong will to survive is critical—it is all they have to bring them through.

Although it is based on science, the study and practice of survival is more a craft or learned skill than an exact science. The recommendations in this chapter are based on the opinions of survival experts, research, analysis of actual survival situations, and personal experience. General principles are emphasized, but "tricks of the trade," which are usually acquired through experience, may hold the key to life or death. Unfortunately, much of the lay literature emphasizes tales of misfortune, hazardous adventures, and mindless bravado in the face of unnecessary hardships that are brought on by the errors of the participants, whereas great deeds go unrecorded or forgotten because the experience and competence of the adventurers kept catastrophic "newsworthy" experiences to a minimum. In the words of Corneille, "To vanquish without risk is to triumph without glory." It is also unfortunate that the popular genre of television survival shows is the source of much of today's "what to do in an emergency" information. The viewers forget that the protagonists in the shows are young, highly skilled, trained individuals, some with military survival training backgrounds. They are carefully selected people who do not represent the typical survivor. These shows should be viewed as entertainment and not as de facto sources of legitimate survival techniques or procedures.

Travelers should always plan for the unusual and unexpected. Tools include familiarity with weather forecasts, strategizing worst-case scenarios, carrying emergency items, avoiding solo travel, and leaving notice of the projected route and the expected time of return. With good planning, deteriorating weather or an injury-forced bivouac becomes more of an inconvenience than a life-threatening ordeal. However, chance always plays a part in survival. Serious but unforeseen or unavoidable hazards or environmental stresses can become so severe that survival is impossible regardless of preparations. Anyone who ventures into the wilderness must accept the possibility—however remote—of death or serious injury.

For survival, the body requires a constant supply of oxygen; a core temperature that is regulated within relatively narrow limits (about 24° to 42°C [75° to 107°F]); water and food; and self-confidence, faith, and the will to live. For comfort and optimum performance, however, the body temperature must be close to normal, and the body must be rested, well nourished, in top physical condition, and free from disease and injury. The most immediate of these latter requirements are maintenance of body integrity (through accident prevention) and regulation of body temperature. Dehydration, starvation, and exhaustion make temperature maintenance more difficult and interfere with the rational thought and agility required to prevent accidents. Insufficient oxygen becomes a contributing factor at extreme altitudes or in such mishaps as suffocation caused by avalanche burial or carbon monoxide poisoning from cooking in an unventilated shelter. Abundant food and water are of little value to a hypothermic person with insufficient clothing and shelter or to the victim of heat stroke, although lack of food and water will eventually weaken and kill an otherwise healthy individual. Lack of self-confidence, faith, and the will to live may cause an attitude of panic and defeatism that prevents a person from taking timely survival actions, such as conserving energy, preparing shelter, or lighting a fire. Poor physical conditioning or the presence of illness or injury may interfere with the body's ability to produce heat by shivering or to lose heat by sweating and increasing skin perfusion; this can hamper wood gathering, shelter building, and other necessary tasks.

The most important organ for survival is the human brain, because voluntary actions, such as preparedness, regulation of energy expenditure, adjustment of clothing, and provision of shelter, are more important than are involuntary mechanisms of adaptation to environmental stress.

OXYGEN

As a human ascends from sea level, the body is subjected to increasing cold, decreasing oxygen, increasing solar radiation, and decreasing atmospheric pressure. For every 305 m (1000 feet) of altitude gain, ambient temperature drops by about 2.2°C (4°F), barometric pressure drops by about 20 mm Hg (27 millibars or roughly 0.1 millibar drop per meter of altitude gain), and the amount of ultraviolet radiation increases by about 5%. The percentage of oxygen in the atmosphere remains constant, but partial pressure of oxygen diminishes with altitude so that, at 3077 m (10,000 feet), it is only two-thirds of that at sea level; at 5488 m (18,000 feet), it is only one-half of that at sea level.

During acute exposure to high altitude, effects of hypoxia can initially cause fatigue, weakness, headache, anorexia, nausea, vomiting, dyspnea on exertion, insomnia, and Cheyne-Stokes respirations. These symptoms are probably present to some degree in everyone who goes rapidly from sea level to 2462 m (8000 feet) or above. The clinical effects of hypoxia are often difficult to distinguish from those of cold, high winds, dehydration, and exhaustion. Serious degrees of acute mountain sickness are unusual below 3692 to 4308 m (12,000 to 14,000 feet), but they have been reported in trekkers as low as 2308 m (7500 feet). As noted during one author's experience as a periodic summer physician in Yellowstone National Park, mild acute mountain sickness is occasionally seen in visitors at just over 1829 m (6000 feet) at the north entrance. At any height, oxygen in ambient air may be prevented from reaching the cellular level because of interruption of normal transport pathways, generally by illness or injury. Carbon monoxide poisoning is probably a greater hazard than is generally appreciated. Many famous polar explorers, including Byrd, Andree, and Stefansson, were killed by or had narrow escapes from the toxic effects of stoves operated in tightly enclosed spaces.

REGULATION OF BODY TEMPERATURE

Humans are considered homeotherms because, as warm-blooded animals, they maintain a body temperature that varies within very narrow limits despite changes in environmental temperature. In poikilotherms, which are cold-blooded animals, body temperature varies with the temperature of the environment. Homeothermy is necessary to support the enzyme systems of the human body, which function best at 37° to 37.5° C (98.6° to 100° F). The human body can be viewed as a heat-generating and heat-dissipating machine, where internal temperature is the net result of opposing mechanisms that tend to increase or decrease body heat production, increase or decrease body heat loss, and increase or decrease addition of heat from the outside. With use of these mechanisms, internal body temperature can usually be regulated successfully, despite ambient temperatures that vary by more than 55° C (100° F) from the coldest to the hottest seasons in temperate climates.

Basal body heat production is about 50 kcal/m^2/hr. This can be increased by muscular activity (both involuntary [shivering] and voluntary), eating, inflammation, and infection (fever), and in response to cold exposure. Shivering can increase heat production up to 5 times the basal rate, and vigorous exercise can increase it up to 10 times. Cold exposure increases hunger; secretion of epinephrine, norepinephrine, and thyroxin; and semiconscious activity, such as foot stamping and dancing in place. Eating provides both needed calories and the temporary increase in basal metabolic rate that occurs during digestion alone; this is *specific dynamic action* (SDA). The SDA of protein is five to seven times higher than that of fat and carbohydrates, and it lasts longer. However, onset of the SDA is much faster with carbohydrates than with protein or fat. Therefore, the person who is cold inside a sleeping bag at bedtime should eat carbohydrates for quicker warming and protein to stay warm all night. In hot weather, body heat production can be decreased by slowing muscular activity and avoiding foods with a high SDA.

In cold weather, heat can be added to the body by exposure to a fire or another heat source (e.g., sunlight) and by ingesting hot food and drink. In hot weather, external heat addition can be decreased by staying in the shade, wearing clothing that blocks the sun's rays, and avoiding hot objects and hot food and drink.

The body loses heat to the environment by conduction, convection, evaporation, radiation, and respiration; it may gain heat from the environment by the same mechanisms (except for evaporation). The relative importance of these mechanisms depends on temperature, humidity, wind velocity, cloud cover, insulation, contact with hot or cold objects, sweating, and muscular exercise. With a resting body in still air at 21° C (70° F), radiation, conduction, and convection account for about 70% of total heat loss; evaporation accounts for about 27%; and urination, defecation, and respiration account for only 3%. During work, however, evaporation may account for up to 85% of heat loss.

It is useful to think of the body as being composed of a core (i.e., the heart, lungs, liver, adrenal glands, central nervous system, and other vital organs) and a shell (i.e., the skin, muscles, and extremities). Most of the physiologic adjustments in response to cold or heat exposure occur in the shell. These adjustments are intended to maintain a relatively constant core temperature; in below-freezing weather, these adjustments may predispose parts of the shell to frostbite and other types of localized cold injury.

The importance of avoiding travel and seeking shelter during storms and extreme cold cannot be overemphasized. The additive chilling effect of wind when added to cold is impressive. Wind-chill charts (Figure 59-1) show the relationship between actual temperature, wind velocity, and "effective" temperature at the body surface. The term *wind chill* refers to the rate of cooling; the actual temperature reached is no lower than it would be if wind were absent (unless evaporation of liquid is occurring at the body surface). The increase in heat loss as the wind rises is not linear; rather, it is more proportional to the square root of the wind speed.

At moderate ambient temperatures, the body's core temperature is kept stable by constant small adjustments in metabolic rate, muscular activity, sweating, and skin circulation. When the body is chilled, automatic and semiautomatic mechanisms increase internal heat production by slightly increasing metabolic rate, shivering, and semiconscious activities (e.g., foot stamping), and they reduce heat loss by diminishing sweat production and shell circulation. The person has a strong urge to curl up into a ball, thereby reducing the body's surface area. At the same time, the brain tells the body to decrease heat loss by adding insulation

Wind (mph)	Temperature (° F)																	
Calm	40	35	30	25	20	15	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40	−45
5	36	31	25	19	13	7	1	−5	−11	−16	−22	−28	−34	−40	−46	−52	−57	−63
10	34	27	21	15	9	3	−4	−10	−16	−22	−28	−35	−41	−47	−53	−59	−66	−72
15	32	25	19	13	6	0	−7	−13	−19	−26	−32	−39	−45	−51	−58	−64	−71	−77
20	30	24	17	11	4	−2	−9	−15	−22	−29	−35	−42	−48	−55	−61	−68	−74	−81
25	29	23	16	9	3	−4	−11	−17	−24	−31	−37	−44	−51	−58	−64	−71	−78	−84
30	28	22	15	8	1	−5	−12	−19	−26	−33	−39	−46	−53	−60	−67	−73	−80	−87
35	28	21	14	7	0	−7	−14	−21	−27	−34	−41	−48	−55	−62	−69	−76	−82	−89
40	27	20	13	6	−1	−8	−15	−22	−29	−36	−43	−50	−57	−64	−71	−78	−84	−91
45	26	19	12	5	−2	−9	−16	−23	−30	−37	−44	−51	−58	−65	−72	−79	−86	−93
50	26	19	12	4	−3	−10	−17	−24	−31	−38	−45	−52	−60	−67	−74	−81	−88	−95
55	25	18	11	4	−3	−11	−18	−25	−32	−39	−46	−54	−61	−68	−75	−82	−89	−97
60	25	17	10	3	−4	−11	−19	−26	−33	−40	−48	−55	−62	−69	−76	−84	−91	−98

Frost bite in >> 30 min | 10 min | 5 min

FIGURE 59-1 Wind chill chart. *(From Bowman WD, Johe DH, American Academy of Orthopaedic Surgeons, National Ski Patrol System [United States]:* Outdoor emergency care: comprehensive prehospital care for nonurban settings, *ed 4, Boston, 2003, Jones & Bartlett.)*

and wind protection, seeking shelter, and increasing heat gain by increasing muscular activity, building a fire, seeking sunlight, and eating.

When the body overheats, these actions are reversed. The body increases heat loss by increasing circulation to the skin and extremities and by increasing sweating. These mechanisms require more water, which stimulates the thirst response. Heat production is decreased as a result of a feeling of sluggishness and languor, which leads to reduction in physical activity and in the amount of heat produced by the muscles. The brain tells the body to decrease heat gain and to increase heat loss by providing shelter from the sun, removing clothing, and fanning itself.

COLD WEATHER SURVIVAL

Body temperature in a cold environment is maintained by decreasing body heat loss, increasing internal body heat production, or adding heat from the outside. The most efficient of these methods is conservation of body heat by decreasing heat loss, generally with the use of clothing and shelter.

DECREASING BODY HEAT LOSS

Heat loss from conduction and convection can be prevented by interposing substances of low thermal conductivity, such as clothing made of insulating materials, between the body and the outside air. Clothing creates a microclimate of warmed, still air next to the skin surface. Clothing's value depends on how well it traps air, the thickness of the air layer, and whether these qualities are reduced by wetting (Table 59-1). Traditional insulating materials are wool, down, foam, and older synthetics such as Orlon, Dacron, and polyester. Wool retains warmth when wet because of a moderately low wicking action and its ability to suspend water vapor within its fibers without affecting its low thermal conductance. It can absorb a considerable amount of water without feeling wet, but is heavier than synthetics, "itchy," and more difficult to dry. However, its toughness and durability make it a good choice for garments that are subject to hard wear, such as trousers, mittens, and socks. Cotton, particularly denim and corduroy, is a poor insulator. It dries slowly because of its low evaporative ability; high thermal conductance is further increased by wetting. Cotton has no place in the backcountry in cold weather.

Orlon, Dacron, acrylic, and polyester were developed to duplicate wool's properties without wool's high cost and other perceived drawbacks. They traditionally have been used for hats, shirts, sweaters, and long underwear. They are almost as warm and not as itchy as wool, and evaporate moisture better. A number of newer fabrics are woven from fibers that have lower thermal conductance, greater insulating ability, and better wicking action than do traditional fibers. Examples include polypropylene and treated polyesters such as Capilene, Thermax, and ThermaStat. Polyester is also made into pile and fleece; these are light, dry easily, trap air well, and stay warm when wet because the fibers do not absorb water. Examples include Polartec, Borglite, PolarPlus, and Synchilla. Fibers used as fillers in quilted garments, such as parkas, include hollow synthetics, such as Hollofil II and Quallofil, which were designed on the basis of the principles of reindeer hair. Microfibers that provide good insulating ability with less bulk include Thinsulate, Thermoloft, and Thermolite. One of the newer fibers, Microloft, is supposed to be warmer than down of the same weight. New synthetics become available frequently, so one should consult trade journals and "gear" issues of outdoor magazines.

The layering principle of clothing is effective for preventing both chilling and overheating. Multiple layers of clothing provide multiple layers of microclimate. Layers are added as necessary to prevent chilling or subtracted to prevent overheating that would cause perspiring. Because water conducts heat 25 to 32 times faster than air at the same temperature, clothing that is wet with perspiration or water may cause rapid heat loss from conduction and evaporation. The need to add or subtract layers should be anticipated before either chilling or heavy perspiring occurs.

Clothing should be easily adjustable, sweaters should be closeable from the waist to the neck with a sturdy zipper, and outer layers should be cut full enough to allow for the expansion of inner layers to their full thicknesses. Zippers in the axillary, lateral chest, and lateral thigh areas are useful for ventilation.

Loss of heat from convection can be prevented by wearing windproof outer garments. Typical examples include a parka with a hood and a pair of windproof pants (regular or bib style) or ski warm-up pants.

Loss of heat from infrared radiation can also be prevented by insulation and emphasizing the proper covering of body parts with a large surface area–to–volume ratio. The uncovered head can dissipate up to 70% of body heat production at an ambient temperature of −16° C (5° F), partly because the body does not reduce the blood supply to the head and neck in cold weather as it does to the extremities. High heat loss through radiation during cold nights can be decreased by sleeping in a tent or under a tarpaulin instead of out in the open.

Coverage for the head, ears, hands, and feet should not restrict circulation. Developed initially for skiers, a tubular neck gaiter can be pulled up over the back of the head to form a hood or up over the lower face to form a mask. In addition to head and neck protection, this device also blocks some of the heat that would otherwise be lost by the bellows action of clothing that is caused by body motion.

Heat loss from the respiratory tract can be diminished by avoiding overexertion and overheating that occur with excessively heavy breathing. When it is extremely cold, inspired air can be warmed by pulling the parka hood out in front of the face to form a "frost tunnel."

Heat loss from conduction occurs as a result of direct contact with a colder object. Sitting on a pack, a foam pad, a log, or another object of lower heat conductivity is preferable to sitting in the snow or on a cold rock. At low temperatures, bare skin freezes to metal; avoid this by wearing light gloves when handling metal objects. Gasoline and other liquids with freezing

TABLE 59-1 Fiber Characteristics of Natural and Synthetic Fibers

Fabric	Specific Gravity* (ratio to water)	Thermal Conductance† (cal/m^2)	Evaporative Ability‡	Wicking Ability	Moisture Regain§
Wool	1.32	2.1	Low	Moderate	17
Cotton	1.54	6.1	Low	High	7.9
Nylon	1.14	2.4	High	Low	4
Polyester	1.38	2.4	High	Low	1
Acrylic	1.15	2.4	High	High	1
Polypropylene	0.91	1.2	High	High	5

*The lower the specific gravity, the better the insulating ability.
†The lower the thermal conductance, the slower the flow of heat from the body.
‡The higher the evaporative ability, the shorter the amount of time that a fiber will be wet (i.e., in a reduced insulative state).
§Moisture regain is the amount of moisture that a fiber can absorb before it feels wet.
Modified from Davis AK: *Nordic skiing: a scientific approach,* Minneapolis, 1980, University of Minnesota.

points lower than that of water can cause frostbite if they are accidentally poured on the skin at low temperatures. During bivouacs in snow shelters, avoid contact with the snow by sitting on a foam pad or backpack or by improvising a mattress of evergreen boughs, grass, or dry leaves. In cold or windy weather, an injured person needs windproof insulating material under as well as over and around the body.

Heat loss from conduction and evaporation can be lessened by avoiding wetting and by changing to dry clothes or drying out quickly when wet. Ideally, outer clothing should be windproof, and it should not collect snow. It should shed water but not be waterproof, because waterproof garments prevent evaporation of sweat; laminated fabrics such as Gore-Tex and its relatives are designed for this purpose.

DRESSING FOR COLD WEATHER

Anyone who ventures outdoors in cold weather should have enough clothing of the proper kind, either on the body or in the backpack, for the most extreme environmental conditions that are likely to be experienced. Although building fires, carrying emergency shelters, and improvising survival shelters are discussed at length later in this chapter, the process of dressing for cold weather should be approached with the idea that clothing may become the only shelter and endogenous heat production the only heat available. Clothing and other types of insulating materials should be selected with the idea that they need to keep the body warm and dry, even during periods of inactivity.

First Layer

Long Underwear. Wool is an excellent choice for long underwear, but it is itchy and expensive, and may be difficult to find. Merino wool is less itchy. Polypropylene, acrylic, and the newer polyesters may be preferable because of their lower cost, good insulating ability, and outstanding evaporative ability (see Table 59-1). Avoid cotton. Synthetics, more than wool, tend to retain body odor after washing.

Socks. One or two pairs of moderate to heavy wool or wool/nylon-blend socks are excellent, preferably with an additional pair of light polypropylene socks worn underneath next to the skin. Consider carrying at least one spare pair of wool socks.

Thin Gloves (Glove Liners). Light propylene, wool, silk, or fingerless wool or pile gloves are useful for moderately cold conditions or when finger dexterity is required, as when adjusting ski bindings. Polyester/Lycra gloves provide a tighter but more stretchable fit, which enhances fine finger movements.

Second Layer

Shirt. Shirts should be made of light, soft wool or a durable synthetic such as acrylic, and they should have long sleeves. Large breast pockets with buttons or Velcro fasteners are handy to carry such items as sunglasses and a compass. For ventilation, the front of the shirt should open completely (i.e., it should have a button or zipper closure). A turtleneck feature protects the neck, as do neck warmers and mufflers that can be pulled up to protect the lower face.

Pants. Wool or pile pants are best and should have pockets that are easily accessible for hand warming. Pile pants should have reinforcements at the knees and buttocks and a zipper or Velcro fly for males. Full or partial lateral leg zippers are convenient, especially for removing pants without removing boots.

Foot Gear. The type of boot chosen depends on the type of activity and the expected environmental temperatures. For moderate conditions, sturdy leather climbing boots made of full-thickness leather and that are 15 to 20 cm (6 to 8 inches) in height, that have rubber lug soles, and are roomy enough to accommodate the desired numbers of socks are ideal. Boots made of leather and fabric (e.g., Gore-Tex) are lighter and suitable for trail hiking, but may not be as durable for rough terrain.

Boots must be long enough, their toes high enough, and laces tight enough so that the wearer's toes do not strike the inside of the front of the boot during downhill walking. Laces should also be tight enough to prevent the heel from moving up and down during walking, but not so tight that circulation is restricted and the toes cannot wiggle easily.

For colder temperatures, double boots are preferable. These can be all-leather boots, or they can have outer shells of plastic or nylon with inner boots of felt or foam. All-leather versions may be hard to find. The Canadian type of shoe pack with a removable inner felt liner is a good choice for light snowshoeing and other nontechnical outdoor activities in the cold. Special double ski boots are available for ski touring, Telemark skiing, and ski mountaineering, depending on the type of binding selected.

Hat. Hats should be of the stocking variety; made of wool, pile, Orlon, polypropylene, or wool/polypropylene; and large enough to cover the ears. A small bill feature is desirable to shade the eyes. "Bomber" caps with bills and pull-down earflaps or "Andean" caps with ear coverings are preferred by some. Some arrangement should be provided to protect the face from cold wind, as with a balaclava configuration or a separate face mask. A useful combination for very cold and windy weather is a ski hat together with a neck gaiter that can be pulled up to cover most of the lower face; the parka hood can then be pulled over the head from behind.

Third Layer

Parka. The parka can be a standard ski or mountain parka filled with down, Dacron, Quallofil, Thinsulate, or another lofting material. A more versatile combination is two separate garments: a pile jacket plus a water-resistant shell. For snow camping, a pile jacket with a thin outer cover of nylon (i.e., three-season, squall, or warm-up jacket) may be preferred, because, unlike an uncovered pile jacket, it does not collect snow when it is worn without the shell. The shell should have a hood with a drawstring, a two-way zipper with an overlying weather flap closed with full-length Velcro (in case of zipper failure, very cold hands, or upper extremity injury), a cloth flap to protect the chin from the metal zipper pull, armpit or lateral chest zippers for ventilation, and at least four outer pockets plus one or two inside pockets to contain frequently needed items (e.g., gloves, compass, map, sunglasses, neck gaiter). Outer pockets should be located where they can be reached while wearing a backpack with a fastened waist belt. The shell should be fingertip length unless bibs are worn. Zippers should have extra-long tabs added to facilitate closure with cold or mittened hands.

Pockets with horizontal openings may close with Velcro, but those with vertical openings should close with zippers. Because the parka is anchored by the shoulders, when using one hand, it is generally easier to pull a vertical zipper down rather than up. In some brands of parkas, vertical zippers are pulled down to close the pockets; in other brands, they are pulled up. The authors prefer the former type: the danger of losing pocket contents as a result of difficulty with closing a zipper is worse than any perceived delay caused by difficulty with opening a zipper.

For ventilation, there should be zippered openings at the armpits. These should be large enough so that the parka can be converted into a vest-like garment during warm conditions by inserting the wearer's arms through the openings and tucking the sleeves inside the parka. Because these zippers usually perform more easily when they are pulled from the distal to the proximal direction, this direction should close them; increasing wind protection is usually more urgent than decreasing it (i.e., freezing is more dangerous than sweating).

Wind Pants. Wind pants should be light and water repellent; a laminated garment such as Gore-Tex is a good choice. Long and zippered side openings at the bottoms are useful to permit the donning of pants without removing boots, as well as for ventilation and access to inner pants' pockets.

Hand Gear. Mittens and gloves provide hand protection from trauma and cold. Because survival depends to some extent on normal hand dexterity, gloves or mittens should be available to protect the hands from cuts, bruises, blisters, and possible resulting infections. In temperate weather, these can be light and unlined leather gloves.

One of the more serious and still unsolved cold weather problems is how to keep fingers warm while leaving them sufficiently unhampered to do work. Mittens are warmer than gloves, because fingers that touch each other warm each other. Additionally, unlike gloves where each finger is isolated in a "tube," thereby increasing the surface area of the hand from which heat may be lost, mittens reduce the surface area because each finger lies beside the next. However, even thin mittens do not allow for delicate finger movements. An important part of the cold-finger solution is to prevent core cooling and compensatory extremity vasoconstriction by addressing core temperature stabilization through exercise, eating, and wearing enough layers on the trunk.

A common method is to wear a pair of thin gloves of polypropylene, silk, thin wool, or polyester/Lycra inside a wool or pile mitten covered with a windproof and water-resistant shell. For delicate finger work, the gloved hand is removed from the mitten, the work done as fast as possible, and then the hand returned to the mitten. However, because insulating materials insulate in both directions, when inside a warm mitten, cold fingers wearing gloves will not rewarm as fast as cold, bare fingers. Therefore, another solution is to use bare fingers, which will perform faster than gloved fingers, work as fast as possible, and then return them to warm mittens periodically until the task is done. However, this is not practical when working in very cold weather, especially with metal. Another approach is to keep a pair of gloves warm in a pocket and put them on after removing the hands from mittens. Polyester/Lycra gloves are easier to don than are many other types of thin gloves.

Excellent three-layer mitten sets include windproof shells with leather palms and two sets of removable pile mittens, at least one of which is fastened to the inner shell with Velcro. Another good system is a thin glove liner inside a heavy wool mitten (e.g., Dachstein mitt, rag wool, wool/polypropylene) inside a Gore-Tex shell.

An option that provides more finger dexterity in moderately cold conditions is a polypropylene glove liner inside a fingerless wool glove inside a shell. A newer combination is a fingerless wool glove inside a wool mitten that has a horizontal slit in the distal palm (i.e., Cordova's ragg wool convertible gloves). The distal tip of the mitten can be folded backward dorsally and secured with a Velcro patch, thereby allowing the hand that is covered with the fingerless wool glove to be exposed through the slit. However, more layers and increasing complexity mean more difficulty doing delicate hand tasks.

Shells should have easily accessible nose warmers of pile or mouton on their backs, be long enough to cover the wrists, and have palms of soft leather or sticky fabric for securely holding ice axes and ski poles.

Gaiters and Overboots. Gaiters, which are long nylon tubes that cover the lower leg and upper part of the boot, are designed to keep snow, sand, and gravel out of boots and socks. They extend upward to just below the knee, open at the side or in front with a zipper or Velcro, have a strap that fits under the boot sole to keep them snug on the boots, and have a drawstring at the top to hold them up. Gaiters with a front opening that is closed by a wide Velcro strap are the easiest to put on and take off. Shorter versions that extend to just above the ankle are adequate for summer mountaineering and may be preferable for cross-country skiers who need access for tightening boot buckles before descents. High-altitude mountaineering requires special insulated overboots or lined gaiters.

Fourth Layer

The previous three layers are usually worn on the body. A fourth layer should be easily available in the pack; this layer should include quilted or pile pants and a jacket or vest.

Raingear. In moderate climates or in spring conditions, when rain and wet snow may be encountered, outer garments of Gore-Tex or a similar material should be used. For maritime climates and during seasons of heavy rain, it may be better to have two separate sets of outer garments: a light, thin, windproof nylon jacket and pants and a waterproof (i.e., coated nylon) jacket and pants.

Vapor Barrier Systems. Waterproof garments and sleeping bag liners worn close to the skin are favored by many because they can prevent the wetting of outer clothing by sweat that might result in decreased insulating capacity. Some reduction in water consumption requirements with such items is also claimed. These types of vapor barriers seem to work better in very cold weather than at moderate temperatures. A light garment of polypropylene or a similar material should be worn next to the skin, with the waterproof garment worn over this. Vapor barrier systems probably should be tried out in the field in nonsurvival conditions before being relied on in severe weather. Persons with hyperhidrosis and those who dislike clammy skin may not feel comfortable with such garments.

SHELTER

SUMMER EMERGENCY SHELTERS

For an emergency shelter to be useful it must be easy to use, quick to erect, serve its purpose (i.e., keep one out of the wind and protected from precipitation), be durable, trap heat, and be convenient to carry. Most commonly, persons in trouble will not acknowledge the need for a shelter until it is too late. The sun is setting, the wind is picking up, and it is beginning to rain. The person facing a night out is probably already dehydrated and may be hypothermic and possibly injured. To ask this person to build a windproof, waterproof shelter from the available natural materials makes no sense. It is better to carry any shelter that might be needed with you.

When faced with an unplanned night out, one's first step should be to locate a place out of the wind. Getting behind a rock, moving to the lee side of a ridge, going down into the tree line, or even turning one's back to the wind can make a difference. Eliminating wind chill allows one to concentrate on dealing with the ambient air temperature by using spare clothing and natural insulation and by starting a fire. Look for a space into which you can crawl, such as a rocky overhang or a space under dense evergreens or fallen logs. Experienced and prepared individuals will have some type of waterproof material (e.g., plastic bag, tube tent, tarpaulin) into or under which they can crawl, as well. Bright-colored (i.e., orange, royal blue, or fluorescent green) materials are easier for searchers to spot. Getting out of the wind, rain, or snow quickly and being able to stay as warm and dry as possible are vital. When one is wet and cold, it may be very difficult—and sometimes impossible—to rewarm and dry out.

SPACE BLANKETS AND BAGS

Space blankets and bags are lightweight, inexpensive, and compact, but they are of limited value in an emergency. Consider a typical scenario in which it is late in the day; it is cold, rainy, and windy; and the survivor is injured or hypothermic, or both. In these conditions, it is difficult to get a space blanket out of its package, unfold it, and manage it. Blankets also demand constant use of one hand to keep the blanket secured. Depending on the brand, space blankets are usually too small to fully encase an adult. With the head covered, the survivor will find that a space blanket creates a shelter that is so noisy that even an approaching aircraft or ground search party may not be heard. The noise can be so great that the survivor will be tempted not to cover the head to escape the constant noise and inadvertently increase heat loss. Space blankets also tear easily when they are nicked or punctured.

The space *bag* has the same flaws as does the space blanket except that it is easier to use to encase an individual and for that person to stay enclosed.

Similar bags and blankets sold under the SOL brand name are much tougher and do not tear when punctured.

THERMAL BLANKETS

Thermal blankets are similar to space blankets, but they are made from much heavier material that is reinforced with fiberglass threads and that has a grommet in each corner. They can be used as body wraps, but again, depending on the size of the person, they are often too small to encase an adult. Some survivors have attempted to use a thermal blanket as a shelter roof by tying lines to each corner and then stretching the blanket between various anchor points. In benign conditions, this may work; however, with any wind or snow loading, the grommets quickly tear or pull out.

TUBE TENTS

Tube tents are usually about 2.4 m (8 feet) long and provide a tubular shelter that is 0.9 to 1.5 m (3 to 5 feet) high, depending on the brand. They can be pulled over the body to provide a quick shelter or pitched as a "pup tent." To do this, find two anchors (e.g., rocks, trees) that are the proper distance apart, tie a line to one of them, spread the tent out along the length of the line, run the line through it, and then tie off the other end of the line. The height of the line should be such that the tent can be spread out to accommodate the occupant. To avoid ripping, the tent plastic should be 3 to 4 mils thick (1 mil = 0.0251 mm [0.001 inch]). Tube tents can be improvised from two plastic 55-gallon drum liners, which are 3 to 4 mil thick, or from large, heavy-grade, household trash bags by opening up the closed end of one bag, sliding it into the open end of the second bag, and then duct taping the bags together (Figure 59-2).

TARPAULINS

Sheets of Visqueen plastic, painters' drop cloths, large pieces of canvas, or other similar materials can be used to erect a wide variety of effective survival shelters. "Blue crinkly" plastic tarps made of a laminated polyethylene weave are readily available and inexpensive; they can be purchased from most hardware stores, come in a variety of sizes, and have grommets inserted along the edges. A tarp, no smaller than 2.4 × 3 m (8 × 10 feet), is needed to protect an adult. Tarps of this size weigh about 0.7 kg (26 oz) and roll up into a tube that is 15 cm (6 inches) in diameter by 30 cm (12 inches) long, which is convenient to carry tied to the outside of a daypack or a fanny pack. To save valuable time in a survival situation, tie 3 m (10 feet) of parachute cord to each corner grommet ahead of time.

Tarps can be erected in a number of shelter styles, depending on weather conditions (Figure 59-3). To erect a lean-to shelter, first select a line that is long enough to stretch between two trees that are far enough apart for the tarp to be stretched tight. With the use of a timber hitch, tie off one end of the line to one of the trees at about chest height. Then, rather than passing the line itself through the grommet eyes, insert a small loop of the line through the first grommet eye, and secure the loop with a short stick that is thrust through it on the opposite side (see Figure 59-3B). Repeat this process for each grommet, stretching the tarp tight each time. After the tarp is attached to the line, tie off the other end of the line to the second tree, with the line stretched as tightly as possible. The lower edge of the tarp is then pegged to the ground or anchored with large stones or a length of log. When making pegs, select a length of wood that is 3.8 to 5 cm (1.5 to 2 inches) in diameter and that is twice as long as needed. With a saw, make one 45-degree cut at the midpoint of the stick. In this way, one cut produces two pegs, both of which are sharp enough to be driven into the ground by pounding their blunt ends with the back of an axe head or a large rock. Fill in the sides of the lean-to with vegetation.

If a fire will be built in front of the lean-to, the front opening should be parallel to the prevailing wind so that the smoke will be carried away from the shelter. If not, the back edge of the lean-to should point to the prevailing wind.

To erect a pup-tent type of shelter (see Figure 59-3C), tie a line between two trees, drape the tarp over it, and peg down the sides. Block the ends with vegetation or personal equipment.

A lean-to with an eave (see Figure 59-3D) gives more protection from rain and snow than does one without an eave. Instead of attaching the long edge of the tarp to the line between the two trees, drape the tarp over the line so that several feet are on the other side, and then tie the two corners to pegs for a down-sloping eave.

A triangular tarp shelter can be erected rapidly and provides good protection (see Figure 59-3E). It requires three pegs and an anchor point on a tree.

FIGURE 59-2 Two large plastic bags can be taped together in tandem and used with a line to form a tube tent. *(Courtesy Peter Kummerfeldt.)*

PLASTIC BAG SHELTERS

Large, heavy-grade (3 to 4 mil), orange or royal blue plastic, 208-L (55-gal) drum liners make good short-term emergency shelters. Having one to crawl into quickly will speed warming and drying as well as shelter the survivor from further wetness and chilling. However, total enclosure in a plastic bag is both uncomfortable and dangerous as a result of increased wetting from the condensation of water vapor in exhaled air and perspiration plus poor ventilation, with a lack of oxygen and buildup of carbon dioxide. To minimize these problems, cut an opening in the bottom end of the bag that is just large enough for your head, and then pass the bag over your body so that your face is at the opening (Figure 59-4). If you get too warm, you can push your head through the hole. When creating the hole, cut the plastic at 90 degrees to the fold to reduce the likelihood of the bag tearing along the seam. Start the cut about 5 inches down from one corner. The depth of this incision should be about 2 inches. The second cut should be about 1 inch deep and situated about 10 inches below the first cut. Join the two cuts and remove the excised plastic. It is better to make the hole too small to begin with and then enlarge it as needed.

WINTER AND COLD WEATHER EMERGENCY SHELTERS

Everyone who spends time in the winter wilderness should practice the construction of several types of emergency survival shelters before such shelters may be needed. The functions of a shelter are to provide an extension of the microclimate of still, warm air that is furnished by clothing; to contain the heat generated by the body, a fire, or other heat source; and to protect the individual from snow, rain, and wind. A properly designed shelter should allow easy and rapid construction with simple tools and should provide good protection from wind, rain, and snowfall. The type and size of shelter depend on the presence or absence of snow and its depth; on the natural features of the landscape, including the availability of natural building and insulating materials; and on whether firewood or a stove and fuel are available. If external heat cannot be provided, a shelter must be small and windproof to preserve body heat.

If possible, a shelter should be constructed in the timber to provide protection from the wind and access to firewood. Generally shelters partway up the side of a ridge are warmer than those in a valley, because cold air tends to collect in valleys and basins during the night. Exposed windy ridges above the timberline are cold. Areas that are exposed to flooding (e.g., drainages, dry riverbeds), rock falls, cornice falls, or avalanches or that are

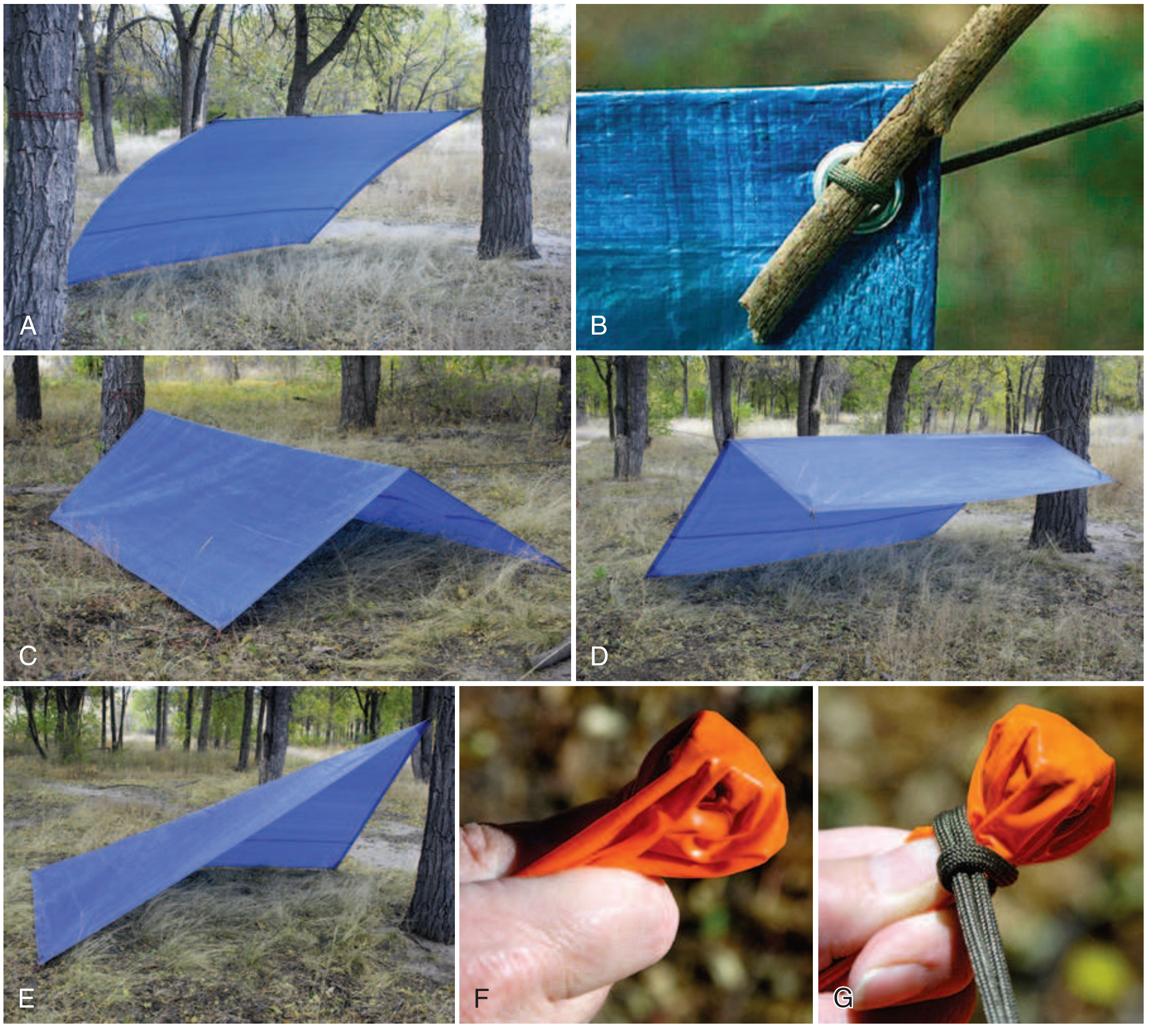

FIGURE 59-3 Four types of shelters that can be made from a tarp. **A,** A simple lean-to. **B,** An illustration of a method for attaching a line to a tarp. **C,** A pup tent type of shelter. **D,** A lean-to shelter with an eave. **E,** A triangular tarp shelter. **F,** Creating a button for attaching a line to a tarp without grommets. **G,** Attaching a line to the neck of the button with the use of a girth or a clove hitch. *(Courtesy Peter Kummerfeldt.)*

under dead trees or limbs should be avoided. If open water is available, the camp may be located nearby, although in nonsurvival conditions camps should be at least 61 m (200 feet) from bodies of water in order to minimize the risk of contaminating the water source. To avoid drifting snow, tents and shelters should be located with the entrance parallel to the prevailing wind.

FIGURE 59-4 Lean-to shelter. The sides should be closed with brush or snow and a fire built in front.

Snow is a good insulator (Table 59-2). Its heat conductivity is 1/10,000 that of copper, and its insulating ability superior to wool felt, so snow shelters may be warmer than other types of constructed shelters as long as the inhabitants remain dry. Contact with the snow or cold ground is avoided by sitting on a foam pad, dry leaves, grass, a backpack, or (in survival conditions only) a bed of evergreen boughs.

NATURAL SHELTERS

Caves and alcoves under overhangs are good shelters and can be improved by building wind walls with rocks, snow blocks, or brush. A fire should be built in such a way that heat reflects onto the occupant. The fire should be 1.5 to 1.8 m (5 to 6 feet) from the back of the shelter, with a reflector wall of logs or stones on the opposite side of the fire; the occupant should sit between the fire and the back of the shelter (Figure 59-5). Adjustments may have to be made to prevent too much smoke from reaching the occupant.

In deep snow, large fallen logs and bent-over evergreens frequently have hollows under them that can be used as small caves. Cone-shaped depressions around the trunks of evergreens (i.e., “tree wells”) can be improved by digging them out and roofing them over with evergreen branches or a tarp. A fire that

TABLE 59-2 Thermal Conductivity of Various Substances

Substance	Conductivity*	Temperature Measured (° C)
Air	0.006	0
Down	0.01	20
Polyester (hollow)	0.016	—
Polyester (solid)	0.019	—
Snow (old)	0.115	0
Cork	0.128	30
Sawdust	0.14	30
Wool felt	0.149	40
Cardboard	0.5	20
Wood	0.8	20
Dry sand	0.93	20
Water	1.4	12
Brick	1.5	20
Concrete	2.2	20
Ice	5.7	0

*Conductivity is the quantity of heat in gram calories transmitted per second through a plate of material that is 1 cm thick and 1 cm^2 in area when the temperature difference between the sides of the plate is 1° C.

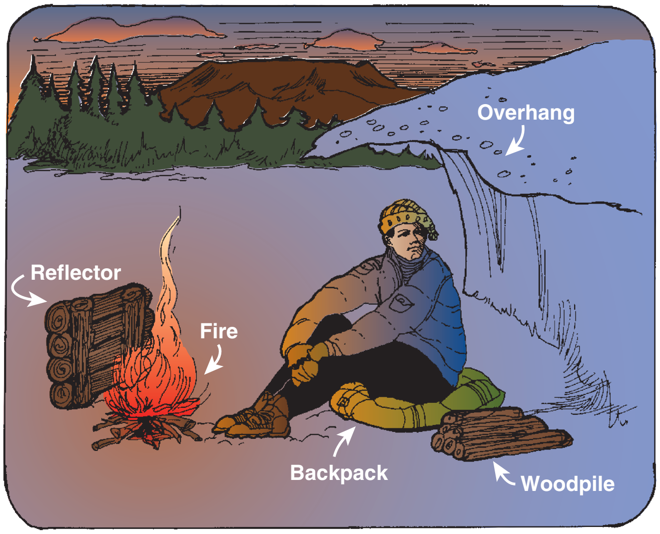

FIGURE 59-6 Natural shelter.

is built to one side of such a shelter will reflect its heat off of the snow toward the occupant. Ventilation must be adequate, and the fire should not be positioned under snow-laden branches which, when warmed, will dump snow into the fire and extinguish it.

CONSTRUCTED SHELTERS

When no snow is available, shelters can be built of small trees, branches, brush, and boughs. In cold weather with minimal or absent snow cover, the most satisfactory type is a lean-to covered by a tarp, with the two sides closed with brush or piled snow, a fire at the open front, and a wall of logs or stones on the far side of the fire to reflect heat into the interior of the lean-to (Figure 59-6). Walls or a roof of brush, branches, or broad leaves should be thatched (i.e., each layer should overlap the one below it).

SNOW SHELTERS

Snow Trenches

A snow trench is the easiest and quickest survival snow shelter and the one that is least likely to make the diggers wet. It can be dug in most areas that are flat or on slight to moderate inclines as long as the snow is 0.9 m (3 feet) or deeper or can be piled to that depth. A 1.2- × 1.8-m (4- × 6-foot) trench can be dug in 20 minutes, with one end roofed over with a tarp or boughs and a fire built at the opposite end (Figure 59-7). Again, adjustments may need to be made to avoid excessive smoke exposure, which can be prevented to some extent by setting the long axis of the trench at a right angle to the apparent wind direction.

If a large (2.4- × 3-m [8- × 10-foot]) tarp and a stove are available, a trench can be dug that is as comfortable as a snow cave; this will hold two or three people. The object is to keep the maximal amount of snow around and over the trench. The trench is dug as narrow as possible at the surface while still providing sufficient room to shovel; a suitable size for the top is 1.2 m (4 feet) wide by 2.4 m (8 feet) long. It is undercut at the back and sides so that the bottom is 1.8 to 2.1 m (6 to 7 feet) wide by 2.7

FIGURE 59-5 Example of two large plastic bags used to form a one-person survival shelter. *(Courtesy Peter Kummerfeldt.)*

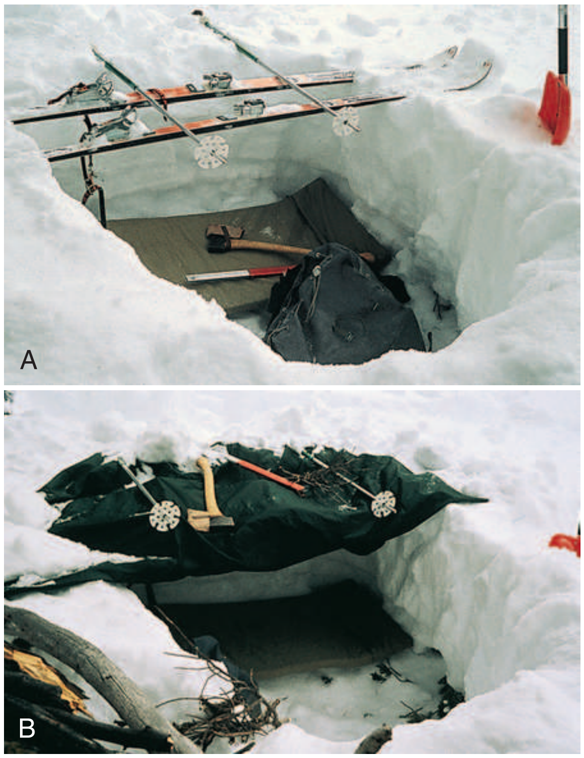

FIGURE 59-7 Emergency snow trench. **A,** A pit is dug and overlaid with skis and poles. **B,** A tarp is placed over the skis and secured with snow and heavy objects.

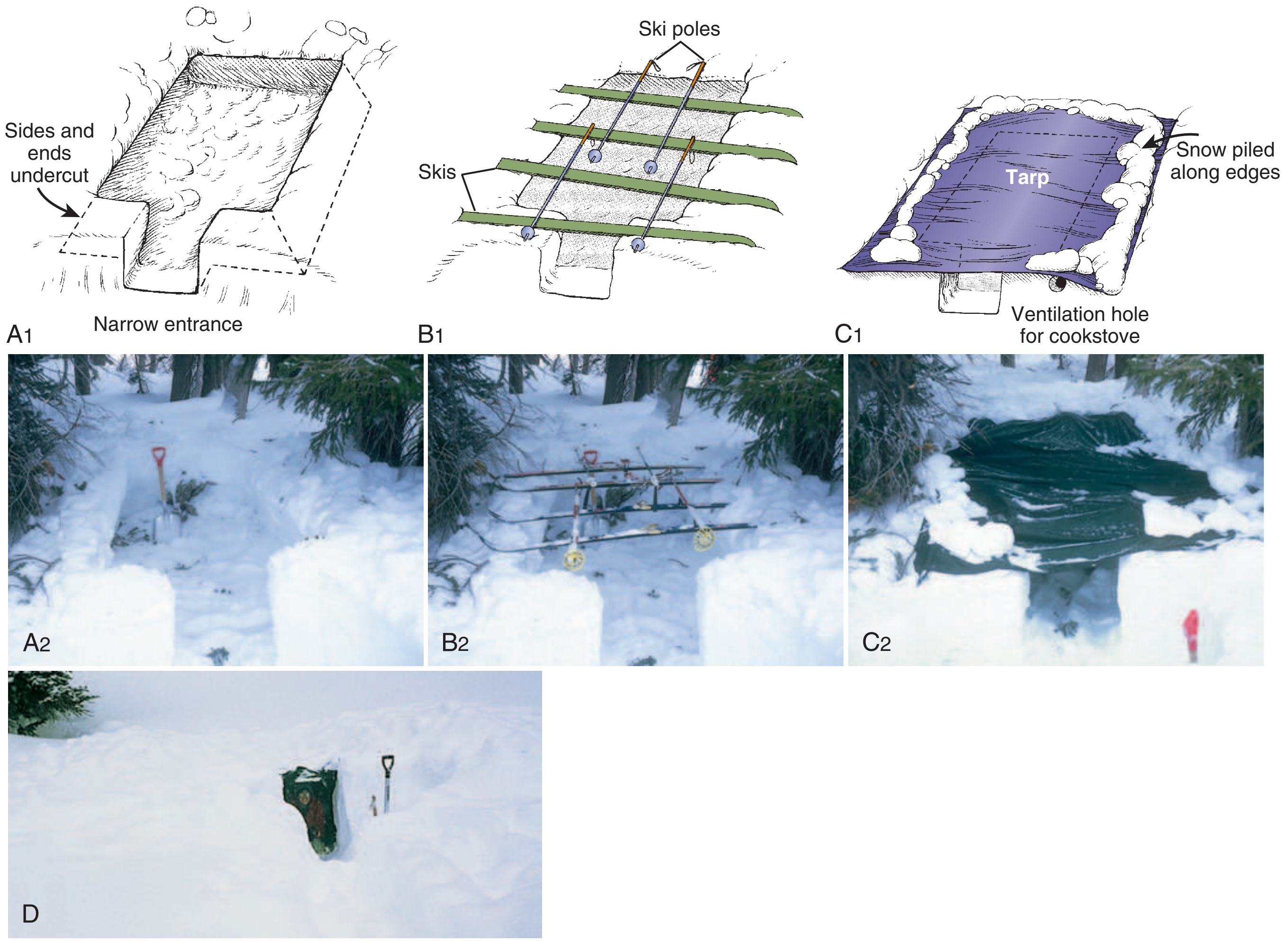

FIGURE 59-8 **A1** and **A2,** Three-person snow trench. A narrow entrance and a narrow top with undercut sides are advisable to trap as much warm air as possible. **B1** and **B2,** Skis and ski poles or stout limbs form the roof support. **C1** and **C2,** Finished trench with snow piled along the edges of the tarp to hold it down. Note the ventilation hole for the cook stove. **D,** Completed trench after a heavy snowfall.

to 3 m (9 to 10 feet) long (Figure 59-8). A narrow entrance helps to contain heat and can be closed with a small plastic sheet or a pack. Four or more skis or thick limbs are laid from side to side over the top of the trench, with ski poles or branches interwoven at right angles. A tarp is then laid on top of these and the snow piled around its edges to hold it down. In very cold weather, the entire tarp can be covered by a layer of snow; at least 20 cm (8 inches) is needed for proper insulation. When the entrance is closed, a small stove and the occupants' body heat will raise the interior temperature to −4° to −1° C (25° to 30° F). Higher temperatures should be avoided so that clothing and bedding will not become wet from melting snow.

Above the timberline in deep, wind-packed snow, a similar trench can be roofed with snow blocks that are laid horizontally, set as an A-frame, or laid on skis (Figure 59-9). Chinks between the blocks are caulked with snow.

Snow Caves

Although a small snow cave that is large enough for one person can be dug with a ski or cooking pot, it is much better to have a shovel. Two shovels are best: a medium-sized general-purpose aluminum scoop shovel and a small, straight shovel (i.e., French type) to use while excavating the interior of the cave. The best site is a large snow drift, as is found on the lee side of a small hill. Areas in avalanche zones or under cornices should be avoided. Because the diggers tend to become wet, water-resistant or waterproof jackets and pants should be worn. In the traditional snow cave, the entrance is dug so that it is just large enough to crawl through, and it is angled upward toward the sleeping chamber (Figure 59-10A); this arrangement tends to trap warm air inside. It should be large enough for a stove and two occupants who are lying side by side. After the entrance is dug with the scoop shovel, the digger crawls inside, lies supine, and uses the straight shovel to excavate the chamber until the space is large enough to allow room to use the larger scoop shovel. A long level bench about a foot higher than the floor of the cave is constructed and used for a sleeping area. A ventilation hole as large as a ski pole basket is cut in the roof over the cooking area.

Because the traditional cave takes at least 2 hours to dig and gets the diggers quite wet, the alternate "T" method has found favor. This involves excavating a much larger entrance hole, which is shaped like a "T," so that the digger can stand erect, have plenty of room to dig, and stay drier (see Figure 59-10B). The crossbar of the "T" is at the level of the sleeping bench; the digger stands in the foot of the "T." After the cave is finished, the top of the "T" is closed with snow blocks, leaving the foot of the "T" as a small access door hole.

Pine branches or other natural materials are used to cover the floor if a sleeping pad is not available.

Snow Domes

When the ground is flat or the snow cover is shallow, snow can be piled into a large dome that is 1.8 to 2.1 m (6 to 7 feet) high and left to harden for a few hours (Figure 59-11). A low entrance is dug on one side, and, from there, the interior is carved out to make a dome-shaped room that is large enough to sleep three people. A ventilation hole is cut in the roof over the stove.

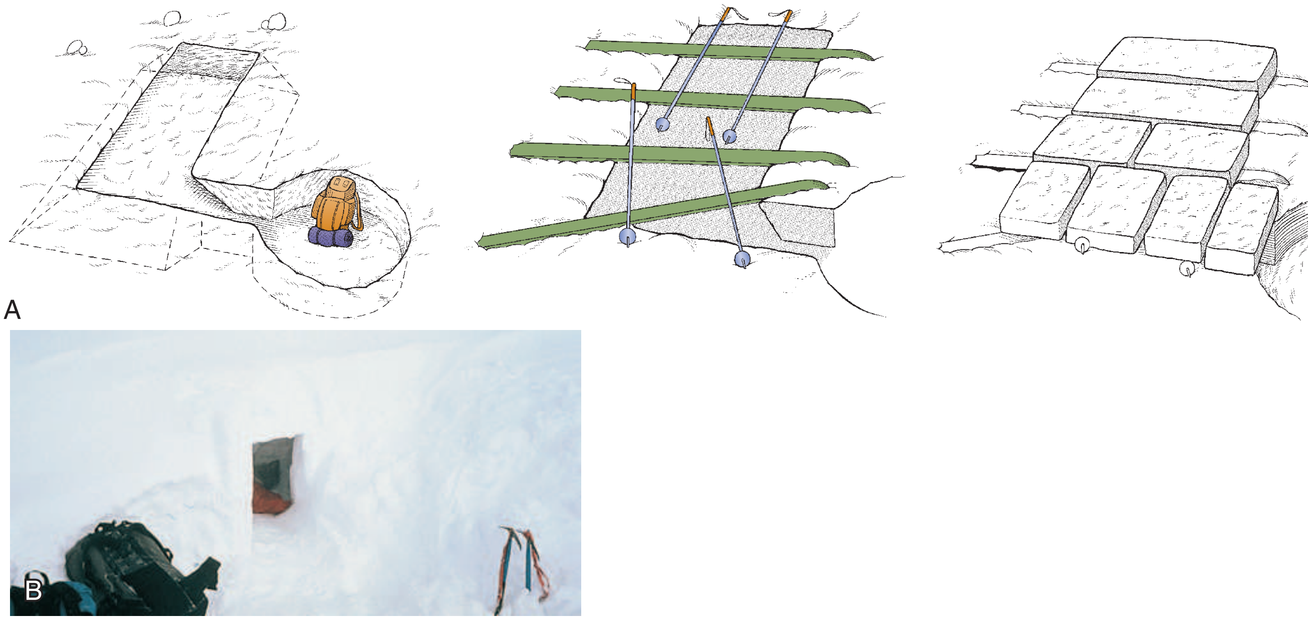

FIGURE 59-9 **A,** Above-timberline snow trench. **B,** Completed snow trench the morning after a heavy snowfall.

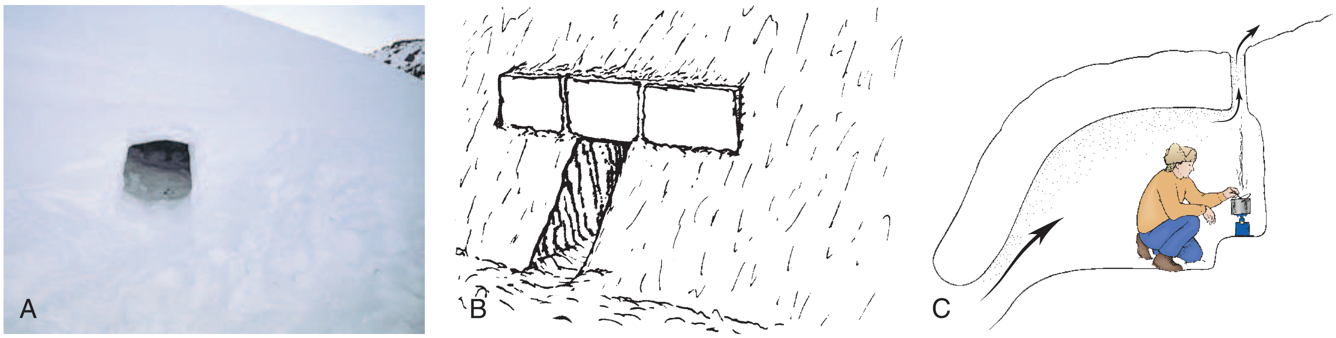

FIGURE 59-10 **A,** Snow cave entrance. **B,** Snow cave partly closed with snow blocks. **C,** Interior of snow cave.

FIGURE 59-11 **A,** Preparing a snow dome. **B,** Completed snow dome.

Another method is to make a "form" (i.e., a pile of vegetation or equipment), cover this form with snow, allow the snow to set, and then open one end and remove the form.

Note of Caution: Snow domes have been known to collapse when sufficient time is not allowed for the snow to harden sufficiently before excavating the interior. Consistency of the snow and the ambient temperature are the primary determinants of how quickly the snow hardens.

Igloos

Igloos are the most comfortable arctic shelters, but they require experience and engineering skill to build. They are not recommended for the novice, but may be worth the effort if the party will be stranded for any length of time. Igloos require one or, ideally, two snow saws and snow of the proper consistency. Wind-blown snow in a treeless area is best; otherwise, a large area of snow can be stamped well and left to harden over several hours. To mark the diameter of the igloo, an individual holds a ski pole by the handle, points it to the side, and then turns his or her body so that the pole basket makes a large circle in the snow that outlines the base of an igloo that is suitable for three people. Cutting some of the snow blocks from inside this circle will lower the floor so that fewer blocks are required for the dome.

At least two persons are needed: one to cut and carry the blocks and the other inside the igloo to lay the blocks. The blocks should be about 18 inches wide, 30 inches long, and 8 inches thick. They are laid in a circle that leans in about 20 to 30 degrees

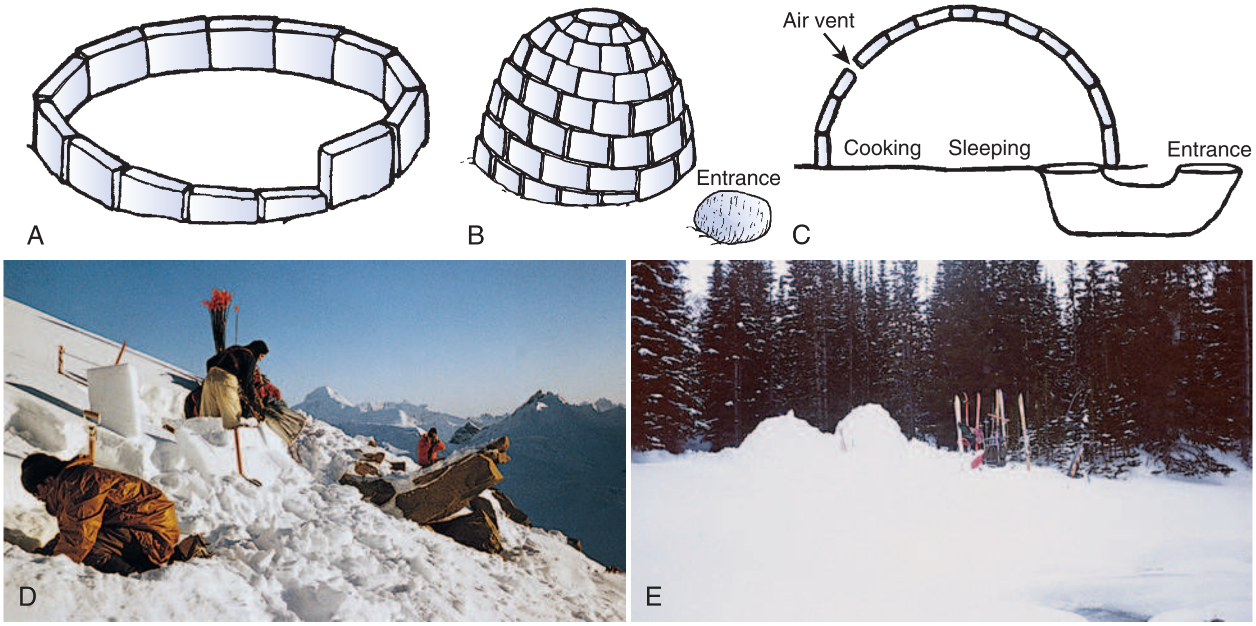

FIGURE 59-12 **A** to **C,** Stages of igloo construction. **D,** Building an igloo on the southeast ridge of Mt Foraker. **E,** Double igloo for a party of five.

toward the center of the igloo, with the sides trimmed for a snug fit. The tops of the first few blocks in the first circle are beveled so that a continuous line of blocks is laid, with the first few blocks of each succeeding circle cocked upward (Figure 59-12A and B). A common error is to not lean the blocks sufficiently inward, which results in an open tower instead of a dome. Gaps are caulked with snow. The dome should be 1.5 to 1.8 m (5 to 6 feet) high inside and can be closed with a single capstone of snow. The entrance is dug as a tunnel under rather than through the edge of the igloo to prevent warm air from escaping (see Figure 59-12C).

TENTS

Tents are generally comfortable and dry; however, in very cold weather, they are not as warm as snow shelters. They are preferable to snow shelters at mild temperatures, during damp snow conditions at temperatures above freezing, or when the snow cover is minimal. Because of their weight, they are not usually a component of emergency equipment.

BIVOUAC SACKS AND OTHER SMALL AND PORTABLE EMERGENCY SHELTERS

These types of shelters are usually made of thin waterproof or water-resistant fabric or plastic. They do not include an insulating layer, and hold one or occasionally two persons. Bivouac sacks are carried for emergencies or for sleeping purposes by climbers on long, alpine-style climbs. Their main value is to protect individuals from wind and rain. Many modern packs have extensions so that, when they are used with a cagoule or an anorak (i.e., roomy, knee-length, hooded pullover garments), they form an acceptable bivouac sack. Tube tents and plastic shelters were discussed in the previous section of this chapter.

Caution: When spending the night in a snow shelter (e.g., trench, cave, igloo), always have a shovel and flashlight inside the shelter and within easy reach.

INCREASING BODY HEAT PRODUCTION

Internal body heat production can be increased voluntarily by raising the level of muscular activity and by eating. To obtain maximal heat production from exercise, the body should be well fed and in peak physical condition. This is particularly important for persons with sedentary occupations who participate in vigorous outdoor sports and for rescue personnel who may be subject to severe, unplanned, and prolonged physical stress. A suitable physical conditioning program should develop both aerobic and motor fitness. The goal of aerobic exercise is efficient extraction of oxygen from alveolar air. This is best developed by rhythmic endurance exercises such as running, cross-country skiing, cycling, swimming, and use of exercise bicycles, treadmills, or Nordic skiing simulators. The most effective activities are those that exercise lower and upper extremities simultaneously. Exercise should be vigorous enough to produce a heart rate of 75% of the age-related maximum (i.e., 0.75 × [220 − the participant's age]) for at least 15 minutes, 4 days a week. Motor fitness, which includes strength, power, balance, agility, and flexibility, is developed by vigorous competitive sports, select calisthenics, and weight-lifting exercises.

ADDING HEAT FROM THE OUTSIDE

The ability to build a fire under adverse conditions is an essential skill that should be practiced by all people who engage in outdoor activities (Figure 59-13). Not only does a fire provide warmth that may mean the difference between life and death, but it also cheers the spirit, improves morale, serves as a signal to rescuers, and reinforces hopes of rescue and survival. Necessary equipment (which is discussed later in this chapter) includes a knife, fire starter, and dry matches at a minimum.

Most commonly, the need for a fire does not arise until a crisis is at hand (e.g., the weather has become life threatening, a person has fallen into a river and needs to be rewarmed quickly, or a hunter needs a fire to stay warm when faced with spending a night out far from camp). The need for a fire becomes critical when the survivor's clothing is inadequate and other shelter is not available. These are not the times to get one's first practice at building a fire. It is advisable to obtain that practice ahead of time in the backyard when rain or snow is falling and the wind is howling; that is the time to determine the strengths and weaknesses of fire-starting equipment and the soundness of one's fire-building skills.

HEAT SOURCES

The devices carried to produce the initial source of heat needed to start a fire must be easy to use when hands are cold and have

FIGURE 59-13 Stages of building a fire. **A,** Select a spot that is out of the wind. Start by placing tinder (i.e., small, dry evergreen twigs) in a lean-to fashion against a larger branch. **B,** Add a layer of kindling (i.e., larger dry branches and split sticks) over the tinder, and be sure that air can reach each piece. **C,** Insert a lighted match, a candle, or a cigarette lighter into the base of the lean-to. **D** and **E,** Add larger pieces of kindling and fuel (i.e., large sticks and pieces of split wood) as the fire catches well. Keep the fire small so that you can get close to it.

lost their dexterity. These devices must function every time regardless of temperature, altitude, wind, or precipitation; the amount of heat supplied must be great and long-lasting. Because survivors are often injured, the devices must function when only one hand can be used.

The heat required to ignite tinder traditionally has been provided by matches or cigarette lighters. Metal matches (i.e., ferrocerium rods) are a third, less commonly used, and underappreciated source of fire-starting heat.

Matches

Predecessors of the modern-day ignitable match date back to 577 AD and the Northern Qi court in China. Today, a match is a "consumable tool for lighting a fire in a controlled circumstance on demand." (Wikipedia)

Most matches that are currently for sale are not designed for field use but rather for lighting cigarettes or candles and other home uses.

Two general categories of matches are safety matches, which can only be ignited by striking the match against a specially prepared surface found on one or two sides of a matchbox, and strike-anywhere matches, which theoretically can be struck on any abrasive surface.

Safety Matches. For a safety match to light, the chemicals (i.e., the pyrophoric material) on the match head must be combined with the chemicals on the striking pad. The chemicals on the match head consist mainly of potassium chlorate (45% to 55%) and a filler material (20% to 40%), which are bound together with glue. The striking surfaces attached to the sides of the box are composed of powdered glass, red phosphorus, black carbon, and a binder. Safety matches can often only be ignited by striking the match head on the striking pad on the box from which they were removed; a match taken from one box may not light by striking it on the pad of another matchbox, because the combinations of the chemicals may be different (Figure 59-14).

Waterproof Matches. Commercial waterproof matches have been dipped in a lacquer that "waterproofs" the match head after it dries. To light a waterproof match, the match head must be struck against the striking pad repeatedly until the lacquer is worn away and the chemicals contained in the match head come in contact with the chemicals in the pad. For some matches, this may take only a strike or two, but with others, many strikes are required to ignite the match. With every strike, the pad becomes more contaminated with the waterproofing material, and eventually a point is reached where there are remaining matches but the pad is so contaminated that it no longer works. Some waterproof matchboxes only have a striking pad on one edge of the box, thus making a bad situation even worse (Figure 59-15).

Pouring liquid paraffin over matches to waterproof them is a common procedure that sounds good but that in practice complicates a survivor's ability to get a fire going. The paraffin must be scraped off of the match head before it can be struck. Other people recommend using nail polish and spar varnish to waterproof matches. For the reasons stated previously, this should not be done. In short, waterproof matches should *not* be included in a survival kit.

Windproof Matches. Windproof matches have longer and fatter heads than do normal matches; as much as one-half of the matchstick is covered with pyrophoric material. These matches can be difficult to light under benign conditions and almost impossible in adverse weather. Most commonly, the matchstick breaks at the junction of the match head and the stick when pressure is applied. Some windproof matches, once lit, only smolder and have little if any flame (Figure 59-16).

FIGURE 59-14 Strike-on-box safety match.

FIGURE 59-15 Waterproof safety match.

FIGURE 59-17 Strike-anywhere match.

Strike-Anywhere Matches. Strike-anywhere matches can be identified by their two-tone heads, which are usually blue and white, green and white, pink and white, or red and white. Both chemicals (phosphorus sesquisulfide and potassium chlorate) that are needed to initiate combustion are combined on the match head. The term “strike anywhere” would lead you to believe that they could literally be struck anywhere, but nothing could be further from the truth. These matches must be struck on the striking pad or on another material that is sufficiently abrasive to produce combustion yet not so abrasive that the match head is ripped off; it should come as no surprise that such a surface can be difficult to find when the ground is covered in snow. Although some people have developed the ability to ignite strike-anywhere matches by rubbing them across the seat of their pants, by flicking the match head with a thumbnail, or even by using their teeth, these techniques are not reliable in an emergency. When carrying strike-anywhere matches, always have a piece of the striking pad from the original matchbox in the kit (Figure 59-17).

Storm Matches. Storm matches are often found in civilian and military survival kits. They differ from other matches by having a “strikeable” tip with as much as one-half of the matchstick coated with a pyrophoric material that continues to burn even in wet and windy conditions. Lifeboat matches, which are a common variety of storm match, should be avoided, because they are particularly difficult to light. The striking pad, which is located on the outside of the lid, is small and wears out very quickly (Figure 59-18).

All of the matches that are currently available were tested under field conditions by the author. Two brands, REI and UCO, were found to be the best. They proved to be the most reliable for starting fires under adverse weather conditions, and were particularly effective in windy and wet conditions. As long as any match head material remains, these matches cannot be blown out, and, if they are extinguished in water, they will relight when they are removed. The REI brand consists of two boxes of matches, each of which contains 25 3-inch-long matches. They are packaged together in a vinyl pouch. The pouch also contains additional pieces of the striker material sealed in a separate waterproof packet (Figure 59-19). UCO matches are identical to REI matches, except for the packaging; 25 matches are contained in an orange, hard-plastic match case (Figure 59-20).

Match Containers

The ability to light a match is tied directly to the condition of the matchbox, which is made from cardboard or thin wood and has a striking pad along each side. Neither of these materials is particularly durable, and both tend to disintegrate quickly when wet. For this reason, matches should be protected in a container that is waterproof, easy to open with one hand, and easy to find if dropped. Do not take it for granted that a match case is as waterproof as claimed; be sure to test it.

FIGURE 59-16 Windproof and waterproof safety match.

FIGURE 59-18 Storm matches.

FIGURE 59-19 REI stormproof matches.

FIGURE 59-20 UCO matches

Boy Scout–Style Match Containers. A Boy Scout–style match container, can be very difficult to open when hands are cold and stiff or have lost both dexterity and strength. Grit or other debris that gets into the threads tends to jam the device in the closed position. Boy Scout–style match cases are almost impossible to open with one hand, especially with a nondominant hand. The "waterproofness" of these containers is questionable, and this style of match container is not recommended (Figure 59-21).

Olive Drab Military-Style Match Containers. Except for the olive-drab color, the military-style match case meets all of the criteria for a good match container. It is tough, waterproof, and easy to open with one hand. However, these cases can be difficult to find if they are dropped in the grass. Embedded in the base of the case is a small piece of metal match. Many people erroneously believe that a match can be struck on this material and ignited; rather, if this material is scraped with a sharp edge, sparks can be produced with which to ignite tinder (Figures 59-22 and 59-23).

FIGURE 59-21 Boy Scout–style match case.

FIGURE 59-22 Military-style match case.

FIGURE 59-23 Scrape the metal match material on the base of the match case to produce sparks.

Orange Military-Style Match Cases. Orange military-style match cases (Figure 59-24) are available in most sporting goods stores, where they are usually sold under the Coghlan brand name. These versions of the military-style match case are not quite as sturdy as the military versions, but they are much easier to find if dropped. This match case comes in two lengths, with the longer variety just long enough to accommodate the REI/UCO matches. If the shorter version is used, the REI/UCO

FIGURE 59-24 Orange military-style match case.

FIGURE 59-25 Multipurpose match container.

matches must be shortened before they are placed in the case. When filling a match case with REI/UCO matches, place half of the match heads toward the bottom and half of the match heads toward the top; this allows more matches to be carried in the container.

Caution: A piece of the striking pad must also be inserted in the case; be sure that when you do so, the striking surface is placed toward the plastic wall and away from the match heads.

Multipurpose Match Case. The popular multipurpose match case should be avoided. The device, which includes a whistle, mirror, small piece of metal match, compass, and match case, combines all of these survival tools into one. On the surface, this sounds like a good idea. However, should the match case become lost or damaged, one loses the ability to build a fire, signal, and navigate successfully. It is better to buy individual pieces of equipment and not to put all of one's eggs in one basket (Figure 59-25).

Regardless of the container used, the matches must be tightly packed in the match case. Loosely packed, the match heads quickly disintegrate. If space allows, a piece of a household cotton ball placed in the cap also helps to prolong the life of the matches. It is also wise to replace the matches at least annually to ensure that matches needed in an emergency are fresh and will ignite.

Other Methods of Igniting Tinder

Cigarette lighters are frequently carried by inexperienced outdoorsmen, who are generally unaware of the shortcomings of lighters with regard to starting a fire.

Consider the following: BIC-style lighters are pressure sensitive (i.e., the higher the altitude, the less the fuel will vaporize); temperature sensitive (i.e., the colder the temperature, the less the fuel will vaporize); explode if they are accidentally dropped into a fire, thus sending shrapnel in all directions; and require good hand dexterity to operate, which is not a problem when it is warm, but quickly becomes a problem in cold conditions (Figure 59-26).

Zippo lighters have a significant advantage over BIC-style lighters in that they will continue to burn until the cover is closed to extinguish the flame; BIC-style lighters continue to burn only as long as the fuel release remains depressed. This difference is put to good effect when, needing a fire, the survivor lights the Zippo, places it on the ground (stabilizing it with dirt), and then places twigs over the flame. One disadvantage of these lighters is that the fuel tends to evaporate rather quickly (Figure 59-27).

Piezo ignition-style lighters use an electronic spark to ignite the fuel, which is similar to the spark produced by an outdoor gas grill lighter to ignite the fuel. This system is much easier to use than the BIC style, and requires far less finger and hand dexterity. If you are going to carry a cigarette lighter, select one with a piezo ignition mechanism and a clear fuel reservoir to see how much fuel remains. In cold conditions, carry the lighter in an inner pocket, where it will stay warm (Figure 59-28).

Colibri Quantum lighters are more expensive devices that are alleged to be waterproof, shockproof, and windproof. It is claimed that they will ignite at higher altitudes. However, field testing of these lighters does not show this to always be the case (Figure 59-29).

FIGURE 59-26 BIC cigarette lighter.

Metal matches are manufactured from a man-made metallic material that, when scraped with a sharp edge, produces a shower of very hot sparks that can be used to ignite tinder. Metal matches have been erroneously called "magnesium matches." Although there is a small percentage of magnesium in the alloy (4%), the bulk of the mixture is made up of iron (19%), cerium (38%), and lanthanum (22%), with the remaining balance composed of other rare metals.

The metal match material, which is also called *ferrocerium* or *mischmetal,* comes in rods of different lengths and thicknesses, and is usually mounted in a plastic, antler, or wooden handle (Figure 59-30). Select a metal match with a wooden handle. Should one find oneself without tinder to light, the wooden handle can be scraped to produce shavings that can be ignited by metal match sparks; the same cannot be said of plastic or

FIGURE 59-27 Zippo lighter.

FIGURE 59-28 Piezo-style lighter.

FIGURE 59-29 Colibri Quantum lighter.

antler. Choose a metal match that has a handle that is large enough to hold firmly when the hands are cold.

Some metal matches are embedded in a block or cylinder of magnesium (Figure 59-31). When a fire is needed, the magnesium block is scraped with a knife blade or another sharp edge

FIGURE 59-31 Metal match embedded in magnesium.

to produce shavings that can be ignited by the sparks that are created from the metal match. However, several problems will be encountered. First, it takes both hands to produce the shavings. Second, it can be difficult to confine the shavings to one place when trying to start a fire in a windy location, so they may blow away. Third, magnesium shavings burn at a very high temperature (about 2760° C [5000° F]), but the burn time is very brief, which does not allow the survivor much time to capitalize on the heat. The shavings must be scraped into another flammable material that will ignite from the burning magnesium.

Metal matches come in two styles, one that requires the use of both hands to operate (Figure 59-32) and one that requires only one hand to operate (Figure 59-33). When use of both hands is possible, the user holds the metal match in one hand and a sharp edge in the other. This "sharp edge" could be a knife blade or any other piece of metal that, when scraped down the length of the metal match, produces a shower of hot sparks. Usually, the scraper is held between the thumb and index finger of the dominant hand. For a situation in which one only has a single functioning arm, it is possible to stabilize the metal match by stepping on it and then using the noninjured hand to produce the sparks. Metal matches that have been specifically designed for one-handed operation are easy to use. With these, the metal match is spring-loaded in a plastic housing that also contains the scraper. The tip of the metal match is placed on a hard surface, and, by pushing against the tip while simultaneously pressing on the scraper, a shower of sparks is created. When planning for a worst-case scenario, having a metal match that can be lit with

FIGURE 59-30 Metal match handles. From left to right: plastic, synthetic antler, and wood.

FIGURE 59-32 Metal match with a hacksaw blade scraper.

FIGURE 59-33 Ultimate Survival BlastMatch and Sparkie Fire starters.

one hand could mean the difference between having a fire or not having a fire.

When faced with choosing the best fire-starting device and comparing the fire-starting potential of a metal match with a box of matches or cigarette lighter, the metal match wins hands down. A typical box of matches contains 25 to 32 matches. For most people, who lack good fire-building skills, more than one match–sometimes many more–will be needed to start a fire. A single metal match has the capacity to start more than 500 fires (Figure 59-34). Each time a metal match is scraped, some of the material is removed, so eventually the match will have to be replaced.

BUILDING FIRES

Throughout this description of fires and fire craft, the term *build a fire* has been used instead of the more commonly used phrase *start a fire*. This choice is deliberate. *Building a fire* implies that there is a process involved that, if followed, will result in success. *Starting a fire* involves only the first step in the fire-building process: applying heat to the tinder and then hoping that it catches on fire and ignites other fuel. Many inexperienced people only think through the process as far as the starting the fire step, and forget that there is a lot more to the procedure than that. Consequently, their fire-building efforts are often unsuccessful.

When the need for a fire is critical, the tinder must light easily, and the steps used to build the fire must quickly result in a self-sustaining fire, regardless of weather conditions.

For a fire to burn, three elements are required. (1) A heat source must be sufficient to ignite the tinder; (2) oxygen must be available; and (3) good-quality fuel must be on hand. Because it is the flammable gases contained within wood that ignite, the amount of heat provided by the initial heat source must be sufficient to drive off the gases that are contained within the tinder. The heat provided by the burning tinder must, in turn, drive off the flammable gases that are contained within the larger pieces of fuel. One of the most common mistakes made by inexperienced fire builders is trying to light pieces of fuel that are far too large for the amount of heat available to light them; the heat is then insufficient to produce the gases needed for combustion.

FIGURE 59-34 Well-used metal match.

FIGURE 59-35 Breaking off dead, dry branches from a spruce tree.

Step number one in fire building is fuel collecting. Too often, people simply pick up sticks from the ground. Although this might work during the heat of summer, this fuel seldom burns well at other times of the year, when rain and snow saturate wood that is lying on the ground. It is better to collect fuel, especially that which will be used in the early stages of the fire, by breaking off dead branches found on standing trees. The moisture content of this wood is far lower than that of wood that would be collected from the ground. If the wood bends rather than snaps, it is probably green and should not be used. If there are green leaves or needles attached to the branch, discard it, because it will not burn. The small, dry, dead branches found under the overhanging branches of evergreen trees, especially fir and spruce, are particularly good for the early stages of a fire (Figure 59-35).

In some parts of the country (e.g., the Pacific Northwest), even this fuel can be wet, and it is often draped with moss. However, it is only wet and moss-covered on the outside (Figure 59-36); the interior is dry. Scrape off the moss and wet bark with a knife blade. If twigs and smaller sticks are not available, they must be fashioned by splitting large sticks into smaller pieces using a knife and mallet (Figure 59-37). Splitting wood in this manner exposes the dry inner surfaces of the wood, which can be used as fuel when other dry fuel is not available.

Gather far more fuel than you expect to need, and then go out and gather more; one can never have too much. Having accumulated a substantial pile of fuel, separate the wood into three piles by size. The first pile should be matchstick size or

FIGURE 59-36 Wet moss and soggy bark can be scraped off to reveal the dry wood underneath.

FIGURE 59-37 A saw and a knife can take the place of an axe.

FIGURE 59-39 Construct a stick platform to keep your tinder dry.

thinner; the second pile should be sticks up to the thickness of a thumb; and the rest of the pile is the remainder. When collecting fuel, gather it in long lengths. It is easier to carry or drag into the campsite, and the fire will burn the long lengths into shorter pieces, thereby saving the effort of needing to use a saw. It also saves energy if one can break the wood into pieces rather than having to saw it into pieces (Figure 59-38).

When the ground is wet, it is advisable to assemble a platform of sticks that is approximately 0.3 m^2 (1 $foot^2$) to protect the tinder (Figure 59-39). If tinder is placed directly on wet ground, it tends to absorb moisture from soil that may make it more difficult to light. There is no practical way for a survivor to build a fire on top of snow. Lacking a chainsaw with which to cut large logs to build a platform on the snow, the heat from the fire quickly melts the snow beneath a platform that is made from smaller sticks, so the fire is quickly extinguished. Try to locate an area where the snow is shallow enough to scrape it away down to ground level.

Wind has a dramatic effect on fire-building efforts. To provide the best chance of having tinder ignite and continue to burn, place a log that is about 25 to 30 cm (10 to 12 inches) long and 10 cm (4 inches) in diameter along the windward side of the platform. Place the tinder in the lee of the log, where it is protected from the wind. When trying to build a fire in rainy conditions or when snow is falling, find a sheltered area that is protected from precipitation, or erect a temporary roof over the fire site to shelter the tinder until the larger pieces of fuel are burning.

Before lighting the tinder, everything must be ready. The second most common mistake made by inexperienced outdoorsmen and women is igniting tinder and then having to scramble to find kindling to add to the rapidly burning tinder before it burns out.

With everything ready to build the fire, place the tinder on the platform in the lee of the windbreak, and ignite it (Figure 59-40). As soon as the tinder is burning, place a handful of the smallest fuel directly over the flames, with one end of the twig bundle resting on the log brace (Figure 59-41); this will only work well if you have resisted the urge to break the twigs into overly short pieces. The fuel should be broken into lengths that are 25 to 30 cm (10 to 12 inches) long. Resting one end of the twigs on the brace ensures that good airflow is maintained and that the tinder is not smothered when additional fuel is added. If it appears that more oxygen is needed, lift up on one end of the brace to allow more oxygen to flow to the core of the fire.

As the twigs begin to burn and flames appear through the first layer of fuel, lay a second handful of twigs at a 90-degree angle over the first layer (Figure 59-42). As the flames appear above this layer, place another handful of slightly larger twigs on the fire, again at a 90-degree angle to the previous layer (Figure 59-43). This process continues until the larger pieces of

FIGURE 59-38 Wedge one end of a long branch between two trees to break off pieces.

FIGURE 59-40 Cotton ball saturated with petroleum jelly being lit with a metal match.

FIGURE 59-41 Placing the first handful of twigs over a burning cotton ball.

FIGURE 59-42 Placing a second handful of twigs over a burning cotton ball.

fuel have been added and until the fire will sustain itself without the immediate attention of the person building it. Your fire-building success with the use of this method is contingent on using tinder that produces a lot of heat, that is well ventilated, and that graduates step by step from the smallest twigs to the largest sizes of fuel (Figure 59-44).

TOOLS THAT MAKE FIRE BUILDING EASIER

Hand and full-size axes have been the traditional tools carried by outdoorsmen to facilitate cutting and splitting large pieces of fuel wood (Figure 59-45). However, in the hands an inexperienced person, an axe is an accident looking for a place to happen. Lacking the years of "chopping" practice that men and women a century ago accumulated during the course of their

FIGURE 59-43 Adding another layer to a fire.

FIGURE 59-44 Self-sustaining fire.

daily lives, men and women today put themselves at risk when using an axe. As compared with saws, axes are inefficient and dangerous tools that can cause wicked injuries. Do not carry an axe unless you are highly skilled in its use.

Saws

Wire Survival Saws. Wire survival saws can generally be considered a waste of time. However, because they are compact and lightweight, they are commonly found in commercial prepacked survival kits. They require two hands for cutting. With one exception (i.e., a wire saw that comes from Sweden), the cutting teeth are not very aggressive. Consequently, when pressure is applied, the saw binds up and eventually breaks (Figure 59-46).

Linked-Style Survival Saws. The Ultimate Survival Technologies SaberCut saw makes use of a flexible linked saw blade that resembles the blade that is found on real chainsaws. Unlike a chainsaw, the blade cuts in both directions, and, as with all saws of this type, it requires the use of two hands for proper function. Although it is not designed to be used in this manner, two people could use it, with one pulling on each end. The SaberCut saw works well but requires significantly more effort to use than does the pocket chainsaw, which is described next (Figure 59-47).

Pocket chainsaws have a 56- to 69-cm (22- to 27-inch) flexible blade that looks very similar to the teeth on a conventional carpenter's saw. This type of saw cuts in both directions. Depending on the model, there are nylon lanyards or metal rings through which a short length of stick can be inserted to serve as handles that are attached to each end of the saw. This is a useful tool that should be considered for a larger survival kit. Although two people could use it, the saw is best used by one person, assuming that the individual has the use of both hands.

Folding saws are popular with outdoorsmen and can be effective cutting tools. They are usually lightweight and short enough to be carried in a fanny pack or daypack. To maximize energy expenditure, select a folding saw that cuts in both directions (i.e., some only cut when you pull). Select one that can be locked in

FIGURE 59-45 Selection of hand axes.

FIGURE 59-46 Commercial wire saw.

FIGURE 59-47 Ultimate Survival linked saw, bottom detail.

the open position to preclude the blade folding back onto the user's hand. When it comes to cutting wood, the diameter of the wood should be shorter than the length of the blade (Figure 59-48).

Bow Saws. There are many varieties of bow saws; some are ridged, and others are collapsible. To be practical, these saws must be collapsible and then assembled before they are used. However, assembly requires both hands. Bow saws are made up of multiple parts; if any part is lost, the saw becomes nonfunctional.

FIGURE 59-48 Pick a saw that cuts in both directions and has aggressive teeth.

FIGURE 59-49 Dandy saw.

The size of wood that can be cut is in large part determined by the distance between the blade and the arch of the bow. This space is often quite shallow, which requires the user to have to continuously reposition the wood as it is cut. In addition, bow saw blades are notoriously brittle in cold weather (Figure 59-49).

Pruning Saws. The pruning saw is the most advantageous for persons who need to quickly cut large quantities of wood. Because no assembly is required, this style of saw is particularly useful for a survivor who has an injured arm or hand. The blade length should not be shorter than 46 cm (18 inches). This blade length allows for a full extension of one's arm when sawing, which is efficient and conserves energy. In addition, a blade of this length is ideal for cutting snow blocks for snow-block shelters. Select a saw with a sturdy handle and one that cuts in both directions (Figure 59-50).

Gardener's shears are very useful when gathering smaller-diameter wood, such as that found above or beyond the tree line. At high altitudes or high latitudes, the only remaining fuel wood available can be obtained from low shrubby bushes. With shears, one can snip out the dead wood quickly and efficiently (Figure 59-51).

Fire-Starting Aids

Commercial Fire-Starting Aids. Many commercial products available in sporting goods stores and other retail outlets cater to persons who recreate or work in the outdoors. Select products carefully, and test them before they must be used in a survival situation (Figure 59-52).

Petroleum, oil, and lubricant (POL) products are often available from the fuel tanks of vehicles. These are frequently overlooked fire-building expedients. Many people are reluctant to use gasoline to assist with fire starting out of fear that they will be burned in the process. This fear is not without foundation, because many people are injured each year when gasoline is poured on a pile of sticks, a match is lit and thrown into the sticks, and an explosion results. Great care must be exercised when using POL products, because some—red and white gases in particular—vaporize quickly and explode when a spark or another open flame is applied. Red gas and white gas should never be poured over a pile of sticks and then ignited. Other POL products (e.g., aviation gasoline, depending on its octane)

FIGURE 59-50 Examples of pruning saws.

FIGURE 59-51 Florian gardener's shears.

are difficult if not impossible to light with a flame or spark and may require using a wick to burn. Diesel fuel cannot be ignited with an open flame and requires using a wick (Figure 59-53).

To use gasoline safely, pour about 2.5 to 5 cm (1 to 2 inches) of gasoline into a container (the bottom 2 inches of a soda can works well), and then place the container on the ground (Figure 59-54). The fuel vapor on the surface can be lit with a match, the sparks from a metal match, or another open flame source without an explosion, and the fuel vapors will burn in a controlled manner (Figure 59-55). When the fuel is burning, small sticks can be placed over the flames, and then gradually larger and larger pieces of fuel can be added (Figure 59-56). This process works particularly well when the available natural fuels are wet.

FIGURE 59-52 Commercial fire starter.

FIGURE 59-53 Coleman camp stove fuel.

Caution: Care must be taken not to upset the fuel container during the process of adding wood, because a violent explosion may occur. When larger containers are used with increased quantities of POL, place sand or other soil in the bottom of the container to add to its stability, and then light the fumes that seep to the surface. If you do not have a container, pour fuel directly into a small depression in the ground, and then light the vapor at the surface. In anticipation of having to siphon fuel from a vehicle, it is wise to carry a 1.2-m (4-foot) length of aquarium hose that can be snaked down into the fuel tank.

FIGURE 59-54 Pouring white gasoline into a container.

FIGURE 59-55 Burning automobile gasoline.

FIGURE 59-57 A mixture of cotton balls and petroleum jelly makes very good tinder.

Of all of the expedient heat sources available to a survivor, the best are household cotton balls saturated with petroleum jelly. This mixture is easy to make and ignite, is windproof and waterproof, burns for a long time, and is inexpensive (Figure 59-57).

Tease out a cotton ball (without tearing it into pieces) until you have a large, thin disk of cotton fibers (Figure 59-58). Use cotton balls that are actually made from cotton as opposed to "puffs," which are made from synthetic fibers and do not burn well. Smear large quantities of petroleum into the fibers, working the cotton between the fingers until there is no dry cotton (Figure 59-59). Store the material in an airtight and watertight container until needed; a waterproof screw-top match case works well for this. When stored in this manner, the cotton ball and petroleum jelly mixture will last indefinitely.

When needed, remove one or more cotton balls from the container. Take the cotton between the thumbs and forefingers of each hand, and pull the cotton into two pieces (Figure 59-60). Being careful to retain the fluffy "fingers" that are produced, stick the butts together and place the recombined cotton ball on a

FIGURE 59-56 Placing sticks over burning gasoline.

FIGURE 59-58 Creating a cotton ball disk.

FIGURE 59-59 Smearing petroleum jelly into a cotton ball disk.

FIGURE 59-60 Tearing a cotton ball into two pieces and retaining the feathery edges.

piece of aluminum foil, a bottle cap, the bottom half inch of a soda can, or another metallic surface (Figure 59-61). In a pinch, a small flat rock with a depression in it will work. If you do not have any of these materials, place the cotton ball on a bed of small sticks or, if necessary, directly on the ground. When the cotton ball is placed on a metallic surface, the oil that is created as the petroleum jelly liquefies from the heat is collected and contributes to burn time. Placing the cotton ball directly on the ground reduces the burn time by one-third. A spark from a metal match or from any other heat source will easily ignite the cotton fibers, which in turn causes the petroleum jelly to burn (Figure 59-62). The value of the cotton ball and petroleum jelly mixture is in its windproofness, waterproofness, and burning duration. It will continue to burn in very windy conditions and in wet conditions, and it will burn for 12 to 15 minutes if it is sufficiently large.

Before building any fire, careful consideration should be given to ensuring that the fire does not escape. Select a site that is free from materials that could inadvertently ignite and carry flames to other flammable materials. Scrape away any ground cover that might catch fire. Be careful when building a fire under overhanging vegetation that could ignite. During winter months, fires built under snow-covered branches will usually result in a cascade of snow into the fire; either shake the snow from the branches before building a fire, or select another site. Building a fire during windy conditions, when sparks could escape the immediate fire site, should be avoided if possible. If it is still necessary to build the fire, select a protected site that is out of the wind. Placing a log on either side of the fire helps to keep a fire from spreading. When it is no longer required, a fire should be completely extinguished. Dousing the fire with large quantities of water is usually the best way to do this, but when water is not immediately at hand, mixing the coals with dirt until no hot embers remain is the next best method.

FIGURE 59-61 Placing the cotton ball on a sheet of aluminum.

FIGURE 59-62 Burning a cotton ball.

Survival literature and other media sources are quick to recommend the use of aboriginal fire-making techniques (e.g., bow and drill, hand drill, fire plough) by a survivor who is in trouble (Figure 59-63). What is forgotten are the years of practice that must have taken place to develop the proficiency to reliably use these techniques. To believe that a modern person could do the same—simply with the use of a diagram and some text in a survival manual—is ludicrous.

FOOD

Although most persons who are faced with a survival emergency worry more about food than anything else, food is less important than shelter or water, because a person can survive for weeks without food, even in cold weather. However, water must be available, and energy expenditure kept to a minimum. Most wilderness parties carry adequate supplies of food; however, problems arise if food is exhausted, lost, or contaminated. Bare ridges, high mountains above the timberline, and dense evergreen forests are difficult places to find wild food, especially during winter. Success is more likely on river and stream banks, on lake shores, in the margins of forests, and in natural clearings. Because in most cases the amount of wild food found by an untrained individual will not provide enough calories to replenish the energy expended by searching for it, it is important to always carry extra food for emergencies; this is true even for a short afternoon hike.

Readers who are interested in the details of obtaining wild food should consult Chapter 90.

FIGURE 59-63 Bow and drill method of starting a fire.

WATER

Water constitutes about 60% of the body weight of an average young adult male; the value for a female is slightly lower. The percentage of water tends to decrease with age. In a sedentary adult, normal daily water losses include about 1400 mL through the urine, 800 mL through the skin and lungs, and 100 mL through the stool, for a total of 2300 mL daily. Because about 800 mL of water per day is contained in food and 300 mL is produced by metabolism, a minimum additional daily intake of 1200 mL is necessary in a temperate climate at sea level to avoid dehydration. In a hot and dry climate, at high altitude, or with exertion, insensible losses and sweating increase considerably, so fluid intake should be increased proportionally. Monitoring urine output determines whether intake is adequate; 1 to 1.5 L of light-colored urine should be excreted per day. Adding fruit flavors and making hot drinks improve the palatability of water. Electrolyte drinks and salt tablets are generally unnecessary in cold or temperate weather, because the electrolytes lost in sweat are easily replaced by a normal diet. When water supplies are limited, avoid overexertion, and try to "ration" your sweat. Almost all surface water should be considered contaminated by animal or human waste, with the possible exception of small streams that descend from untracked snowfields or springs in high and uninhabited areas. At altitudes of less than 5488 m (18,000 feet), simply bringing water to a boil will kill *Giardia* cysts and most harmful bacteria and viruses. Water can also be disinfected by filtration or by the addition of chemicals (see Chapter 88).

At subfreezing temperatures and in locations that are above the snow line, where liquid water is difficult to find, snow or ice must be melted to obtain water. This requires a metal pot (which should be included in every survival kit), fire-starting equipment, and fuel. The time and effort required to obtain water and the decrease in the thirst response in cold weather favor development of dehydration in cold weather travelers.

In the winter, whenever open water is encountered, individuals should drink their fill of disinfected water, and then top off all canteens (recommended volume 1 L). Each evening, enough snow should be melted to provide water for supper plus a full canteen, which is placed in the bottom of the sleeping bag to keep it from freezing and which is then ready for use during the night or for making breakfast in the morning. Before leaving camp in the morning, enough snow should be melted to provide everyone with at least one full canteen for the day. Melting ice or hard snow is more efficient than melting light and powdery snow. To avoid scorching the pot, the snow is melted slowly, or water is heated in the bottom of the pot before snow is added. On warmer, sunny days, snow can be spread on a dark plastic sheet for melting.

SURVIVAL IN SPECIAL INSTANCES, INCLUDING NATURAL CATASTROPHES

The general principles of survival in all catastrophes are the same, particularly the need for forethought, planning, and keeping emergency equipment, water, and food on hand. Nevertheless, different types of catastrophes require different approaches, particularly at first. Some common types are discussed in the following sections.

STALLED OR WRECKED AUTOMOBILES

Anyone who drives faces the possibility of spending an unplanned night out in a vehicle. Causes include bad weather, breakdown, running out of fuel, and getting stuck. Winter driving is especially hazardous because of the dangers of driving on snow or ice and the threats of frostbite and hypothermia. Accepting the possibility of trouble, carrying communications equipment (e.g., cell phone, satellite phone, or radio) and a vehicle survival kit, and giving some thought to survival strategies will help to prevent a night out in a car from deteriorating into a life-threatening experience.

Most travelers dress to arrive at a destination and not to survive a night out. A vehicle survival kit (see Appendix C) should include extra clothing, blankets or sleeping bags, food, water, signaling equipment, a quart-sized plastic screw-top bottle to use as a urinal, and communication equipment (e.g., cell phone, satellite phone, personal emergency beacon [SPOT or inReach] citizen's band radio in remote areas without cell service). It is also generally better to stay with the vehicle, which provides significant protection and is more visible to rescuers than is a person on foot.

In cold weather and especially for long-distance travel, drivers should keep their vehicles in the best possible mechanical condition by using winter-grade oil, the proper amount of radiator antifreeze, deicer fluid for the fuel tank, and antifreeze in the windshield-cleaning fluid. Windshield wiper blades that are becoming worn should be replaced. A snow brush and ice scraper should be carried. A can of deicer is useful for frozen door locks and wiper blades. Snow tires (preferably studded, although these are illegal in some states) are desirable, but chains should be carried as well. All-wheel or four-wheel drive is optimal, and front-wheel drive is superior to rear-wheel drive. The battery should be kept charged, the exhaust system free of leaks, and the gas tank full (i.e., "drive on the upper half of your tank"). The marooned driver should tie a brightly colored piece of cloth (e.g., a length of surveyor's tape) to the antenna and at night should leave the inside dome light on to be seen by snowplow drivers and rescuers; headlights use too much current. If it is necessary for heat, the standard recommendation is that the motor and heater be run for 2 minutes per hour (after checking to see if the exhaust pipe is free from snow). However, it has been stated that because it takes more gasoline to start a cold engine than a warm one, one should initially turn the heat up all the way and then run the engine until the inside is comfortable. At this point, shut off the engine and wait until it becomes uncomfortably cold, which could be 10 to 30 minutes, depending on the outside temperature. The engine will still be warm. Start the engine again, run the heater until the occupants feel warm, and then keep repeating this.

Carbon monoxide poisoning is a real threat, so do not go to sleep with the engine running. Keep a downwind window cracked 2.5 to 5 cm (1 to 2 inches). A reusable carbon monoxide detector is a wise addition to the survival kit. One or two large candles (i.e., "fat Christmas candle" size) should be carried to provide heat and light if the gasoline supply runs out; two lit candles can raise the interior temperature well above freezing. However, resources should be used sparingly, because you are never sure how long you will be marooned. Anticipating a possible cold weather survival situation by including heavy clothing and blankets or sleeping bags in the cold weather vehicle survival kit is better than relying excessively on external heat generation. Do not smoke or drink alcohol. If you have to get out of the vehicle, put on additional windproof clothing and snow goggles, and tie a lifeline to yourself and the door handle before moving away from the vehicle. In a blizzard, visibility can be as little as 30 cm (12 inches).

AIRCRAFT ACCIDENTS

Aircraft passengers routinely receive short lectures regarding the locations of exits and procedures for emergencies. When a crash is imminent, tighten your seatbelt as low on your hips as possible, place your feet further back than your knees, and bend forward as far as possible, placing your head against the seatback in front of you. To reduce flailing and protect your head, place one hand over the top of the other on top of your head with elbows tucked in against each side of your head. After the aircraft finally stops moving, leave it as instructed by the crew or, in the absence of crew instructions, leave the aircraft quickly. Assist injured companions to leave, and then get everyone away from the immediate area to avoid the fire hazard. Do not stop to gather personal belongings or luggage. In a remote area crash, after the fire risk is over, revisit the wreckage to salvage food, clothing, water, and other useful items.

Remember that aircraft fuselages are poorly insulated. Unless a stove is available, survivors may be better off constructing a shelter that can be heated with a fire (as described previously) outside of but near the craft. Batteries can be used as fire starters. Oil and gasoline can be used as fuel if they are poured into a container that is full of dirt or sand. Despite the fact that air travel is quite safe (probably safer than ground travel per mile traveled), an argument can be made for wearing comfortable shoes and carrying a coat, cap, and cell phone. It is illegal to carry survival equipment such as matches and a Swiss Army knife.

Unless there is no chance that a search will be mounted to find the aircraft, you should remain close to it rather than trying to go for help; it is much easier for searchers to spot a crash site than to find survivors who are on foot in the wilderness.

FLOODS

Flooding in wilderness areas may be caused by thunderstorms, unusual storms such as hurricanes, and rapid melting of ice and snow during heat waves. Flash floods in canyons can occur both during and after rain, and can be caused by rain many miles upstream. Submarine earthquakes can cause huge tidal waves (tsunamis) that may drown hundreds of thousands of shore dwellers. Whenever traveling or camping near bodies of water in the wilderness, one should keep in mind what might happen if the water should overflow or rise. When traveling or camping in box canyons, below dams, close to banks of water channels, and on low ground such as valley bottoms, one should have a well-thought-out exit strategy in case flooding occurs. If you are along the shore and receive a radio report of an impending tsunami, or if you see that the sea has receded and exposed a large expanse of sea bed, flee immediately and seek high ground as far from the shore as possible.

Persons who are caught in moving water have no recourse other than attempting to swim to the side or reach floating debris while trying to hang onto emergency supplies. Never attempt to cross an area of moving water unless you are sure that it is no more than knee deep. Even then, be very cautious.

STORMS

Thunderstorms

Dangers from thunderstorms include flooding (as discussed previously), lightning strike (see Chapter 5), and exposure, including wetting and hypothermia. Severe thunderstorms may produce hailstones of varying sizes, including stones that are large enough to harm a struck individual. During a thunderstorm, it is wise to seek shelter; this requires getting into raingear and avoiding heavy rain and hailstones by getting into a metal vehicle or a dense grove of trees. If you are on the water, head for shore as soon as threatening weather approaches. If you are in an area in which you are the highest object around, leave immediately, or crouch down on your haunches to minimize your chances of being struck by lightning. Avoid small buildings, electrical wires, metal objects, and rocky overhangs where you may be hit by side flashes from ground currents, solitary trees, and trees that are taller than surrounding trees.

Tornados

Tornados are funnel-shaped clouds that typically form on a hot spring or summer afternoon, often in the midwestern United States. They are usually preceded by large cumulonimbus clouds from the bottoms of which a careful observer can occasionally see the formation of the tornado as a dimple that elongates into a typical conical funnel cloud. Persons who witness these phenomena should leave immediately by vehicle in a direction opposite to the tornado's likely path or seek shelter on the spot. In a house, the best areas for shelter are small interior rooms with non–weight-bearing walls, preferably in the basement (but on the ground floor if no basement exists). Ditches and small buildings are not safe. Caves and outdoor root cellars are fairly safe, but vehicles are not.

Hurricanes

Hurricanes are severe tropical storms that demonstrate extreme cases of the vortices of wind and rain that frequently form over tropical seas. By definition, they contain winds of 119 kph (74 mph) or stronger. They require ocean temperatures of 25.5° C (78° F) and a spawning area that is at least 10 degrees of latitude from the equator so that the earth's rotation is strong enough to start them in motion.

Deaths that are the result of hurricanes are usually caused by high winds, flooding from heavy rain, or coastal flooding as a result of storm surges. With modern technology, formation of a tropical cyclone (i.e., tropical low) and its change into a tropical storm and then a hurricane is predictable and reported in detail by the National Oceanic and Atmospheric Administration. Persons at risk should listen to the radio or watch television so that they will be aware when there is a need for evacuation. Most casualties involve persons who remain in the affected area against advice or who are caught by winds and flooding before they get far enough inland. Persons who live in hurricane-prone areas should have emergency caches of water and nonperishable food, clothing, bedding, a first-aid kit with supplies of any medications that are taken regularly; emergency lights (e.g., candles, matches, flashlights, spare batteries); and a cell phone with a battery or a crank-operated radio. They should also keep the gas tank full in their cars, and should be ready to head inland with these supplies as soon as they are advised to do so. Before they leave, they should board or shutter all of their windows, take inside any yard objects that might be blown away, and shut off electric power and gas.

NAVIGATION IN THE WILDERNESS

Even if they are in familiar territory, backcountry travelers should always carry a compass, map, and GPS receiver (see also Chapter 106). Although availability of small handheld GPS units has revolutionized wilderness navigation, these devices have not replaced the need for good map and compass skills.

Prior training and experience with map reading and compass use are necessary. An excellent type of compass for the layperson is the Swedish Silva compass, which was designed to be used during the sport of orienteering. The compass reading is always to be believed, even if it is at odds with one's gut feelings about direction and location. Topographic maps are available at most outdoor stores in both the 7.5- and 15-minute series, and they can also be ordered from the U.S. Geological Survey (1-888-ASK-USGS or USGS.gov).

Travelers without a compass should still be able to find rough directions. At night, north can be found by identifying the Big Dipper (in the Northern Hemisphere only) and following the "pointers" (i.e., the farthest stars on the "bowl" of the dipper) to the North Star (Polaris); this is the most distal star in the handle of the Little Dipper, which is located about halfway between the Big Dipper and the W-shaped constellation Cassiopeia. On a sunny day, to establish the cardinal directions (north, east, south, west), select a sunny spot and then drive a thin stick, pointed on both ends, into the ground so that one end of the stick points directly at the sun. Manipulate the stick until the stick produces no shadow. Allow 20 to 30 minutes to elapse and note the shadow that has been created. Regardless of where you are in the world or the time of day, the shadow always points toward the east. Once east has been established, the other cardinal directions can be determined (Figure 59-64).

BACKCOUNTRY WEATHER FORECASTING

See Chapter 107 for information on backcountry weather forecasting.

SANITATION

Adherence to proper habits of cleanliness and sanitation is as important in the wilderness as at home. Hands should be washed with biodegradable soap after urinating or defecating, before cooking and eating, and before dressing open wounds. If soap is unavailable, snow or the cleanest available plain water is used. Dishes and pots are washed with hot water and biodegradable

FIGURE 59-64 Improvised navigation.

soap and rinsed well to remove all soap. Waste water is scattered over a wide area of ground and never dumped into a body of water. Bathing and washing clothes should be done at least 60 m (200 feet) from bodies of water with the use of water in a container. Gloves (preferably rubber or vinyl and impermeable) are worn when handling moist animal or human tissues, but be aware of possible latex allergy.

The most practical way to dispose of human waste is to dig a "cat hole" 6 to 8 inches deep in humus and 200 feet from water or snow that is to be melted for water, trails, and campsites. Cover feces completely with dirt. No camp should be within 60 m (200 feet) of a lake or stream, which represents 70 to 80 steps for most adults.

Travelers should urinate on rocks or dirt rather than on green plants. To avoid having to go outside, especially at night, when sleeping in a tent or snow shelter, males can use a 500-mL widemouth polyethylene bottle as a urinal. Funnels designed for use with the bottle are available for women.

PSYCHOLOGICAL AND ORGANIZATIONAL ASPECTS OF SURVIVAL

Dealing with the psychological aspects of survival is as important as confronting physical and environmental factors. As mentioned previously, the dangerous mindset that keeps a person continuing on a hazardous course—such as completing a climb or reaching a distant campsite despite conditions that would make a more prudent person bivouac or turn back—is a recurring scenario. In a survival emergency, a person with survival training, adequate oxygen, stable body temperature, shelter, water, and food may still die if he or she is unable to withstand the psychological stress. Conversely, persons have survived amazing hardships with little more than a strong determination to live. However, individual reactions cannot be predicted in advance. Groups that are faced with emergencies testify that courage and leadership appear in unexpected places. Still, if persons possess the necessary skills, have at least a minimum of survival equipment (see the appendices to this chapter), and have given some forethought to techniques of wilderness survival, the odds of surviving are strongly in their favor. Medical personnel have the advantage of being trained to suppress panic. Fear and surrender are normal reactions that must be opposed by whatever psychological tools are available. In some cases, religious faith or the desire to rejoin loved ones has been credited with survival.

Anxieties that paralyze action include fear (of the unknown, being alone, wild animals, darkness, weakness, personal failure, discomfort, suffering, and death) and panic. Panic, which is the uncontrolled urge to run away, interferes with good judgment and results in inappropriate actions, such as abandoning weaker companions, dividing the party, and discarding vital survival equipment. Useless flight saps available energy, leads to exhaustion, and hastens death.

Other psychological reactions include apathy and the normal desires to be comfortable and avoid pain. Apathy involves "giving up"; it is a state of indifference, mental numbness, surrender, and unwillingness to perform necessary tasks. The victim shows resignation, quietness, lack of communication, loss of appetite, fatigue, drowsiness, and withdrawal. Apathy in one's self is overcome by faith in one's abilities and equipment and a belief in survival and the possibility of rescue. Apathy in others is combated by communicating plans and positive feelings about resources and outcomes to them and by including all group members in planning and survival activities.

Comfort is not essential to survival. Marked discomfort as a result of injuries, illnesses, thirst, hunger, excessive heat or cold, sleep deprivation, and exhaustion is inevitable in a survival situation and must be tolerated so that one may continue to live. There are many accounts of adventurers who have survived many days with severe injuries (e.g., open fractures) because of the will to live, or who, despite multiple injuries, have dragged themselves for miles to find help.

Providing an ill or injured party member with psychological support is important. This includes appearing calm, unhurried, and deliberate while trying to encourage optimism, patience, and cooperation. A person with a minor injury or illness should be encouraged to self-evacuate and be accompanied by at least one healthy party member. When a person with a severe injury or illness needs to be evacuated, the party must decide whether to use resources at hand or to send for help. The decision will depend on the weather, size of the party, training, available equipment, distance, type of terrain involved, type of injury or illness, victim's condition, and availability of local search and rescue groups, helicopters, and other assistance. Unless the weather is excellent, the party strong and well equipped, the route short and easy, and the victim comfortable and stable, the best course of action generally is to make a comfortable camp and send the strongest party members for help. A written note should include each victim's name, gender, age, type of injury or illness, current condition, and emergency care given; the party's resources and location (preferably map or GPS coordinates); and the names, addresses, and telephone numbers of relatives. The victim who must be left alone (e.g., because of a small party size) should have an adequate supply of food, fuel, and water.

As soon as you realize that you are lost, stop, sit down in a sheltered place, calmly go over the situation, and make an inventory of survival equipment and other resources. If it is cold or becoming dark, start a fire, and eat if you have food. Take out your map or draw a sketch of your route and location that is based on natural features. Then, unless you know your location and can absolutely reach safety before dark, immediately begin to prepare a shelter for the night. Do not allow yourself to be influenced by a desire to keep others from worrying or the need to be at work or keep an appointment; one's life is more important than someone else's peace of mind.

If you are alone and unquestionably lost and especially if you are injured, you must decide whether to wait for rescue or attempt to walk out under your own power. If rescue is possible, it is almost always better to use the time to prepare a snug shelter (before dark) and to conserve strength. If you decide to leave, mark the site with a cairn or with bright-colored material such as surveyor's tape; leave a note at the site with information about your condition, equipment, and direction of travel; and then mark your trail.

These actions will help rescuers and enable you to return to the site if necessary. Travel should never be attempted in severe weather, desert daytime heat, or deep snow without snowshoes (Figure 59-65) or skis. If no chance of rescue exists, prepare as best as possible, wait for good weather, and then travel in the most logical direction.

The best way for a lost or stranded person to help potential rescuers is to do everything possible to draw attention to his or her location. Most modern rescues make use of ground parties, helicopters, and fixed-wing aircraft. When the latter locate victims from the air, they can drop supplies and vector helicopters or ground parties to the site. In addition to radios, cell phones,

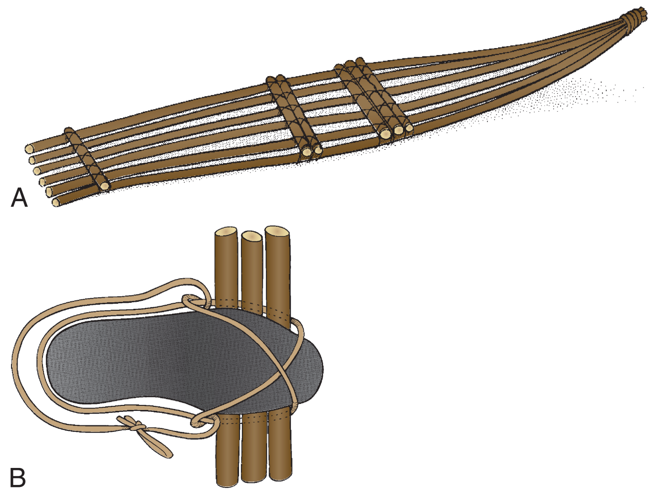

FIGURE 59-65 **A,** Emergency snowshoe. **B,** Detail of snowshoe binding.

emergency beacons and other electronic equipment, and signaling devices can be either auditory or visual. Three of anything is a universal distress signal (e.g., three whistle blasts, three gunshots, three fires). The most effective auditory device is a whistle. Blowing a whistle is less tiring than shouting, and the distinctive sound can be heard from farther away than a human voice. An effective visual ground-to-air signal is a glass signal mirror with a sighting device, which can be seen up to 16 km (10 miles) away but requires sunlight. Special rescue beacons are available and can be carried as emergency equipment; these include strobe lights, laser signal lights, special beacons with both signaling and GPS capability, and personal locator beacons.

Smoke is easily seen by day, and a fire or flashlight is seen well by night. On a cloudy day, black smoke is more visible than white; the reverse is true on a sunny day. White smoke stands out well against a green forest background but not against snow. Black smoke can be produced by burning parts of a vehicle, such as rubber or oil. When burning a tire, first deflate it by removing the valve stem or puncturing the tire. Failing to do so can cause the tire to explode, injuring bystanders. White smoke can be made by adding green vegetation to a fire. The lost person who anticipates an air search should keep a fire going with large supplies of dry, burnable material (e.g., wood, brush) and have a large pile of cut green vegetation close by. When an aircraft is heard, the dry materials are placed on the fire and allowed to flare, and then armloads of the green vegetation are piled on top; this produces lots of smoke and a hot thermal upward draft to carry it aloft.

Ground signals (e.g., “SOS,” “HELP”) should be as large as possible (e.g., at least 0.9 m [3 feet] high and 5.5 m [18 feet] long) and should contain straight lines and square corners that are not found in nature. These types of signals can be tramped out in dirt or on grass, or they can be made from brush or logs. In snow, the depressions can be filled with vegetation to increase contrast. The International Convention on Civil Aviation has adopted five ground-to air symbols for use by survivors. Although in the age of helicopters these are not as important as they once were, they are worth remembering:

V: I require assistance.
X: I require medical assistance.
N: No
Y: Yes
↑: Proceeding in this direction

Air-to-ground signals include the following:

Message received and understood: rock plane from side to side

Message received but not understood: make a complete right-hand circle

When using cell phones, radios, and other electronic devices, persons should move out of valleys and gullies to higher elevations if possible. Operational payphones in campgrounds that are closed for the season or other facilities can be used to call for help. Most will allow 911 or another emergency number to be dialed without payment, but carrying sufficient coins and memorizing your telephone credit card number are recommended.

PROTECTION FROM WILD ANIMALS

Although persons in a survival situation often worry about wild animal attacks, these are rare. Many wild animals flee when they are confronted by shouting, moving humans. Exceptions include polar bears, grizzly bears, moose, bison, cougars, jaguars, wild pigs, elephants, lions, tigers, water buffalo, leopards, wolverines, females with young (particularly bears, moose, elk, and deer), rabid mammals, and feral dogs and cats (see Chapter 30). Polar bears, some grizzly and black bears, the great cats, and crocodiles may actively hunt humans as food. Venomous snakes, insects, arachnids (i.e., spiders, scorpions, and ticks) and marine animals are also of concern (see Chapters 32, 33, 35, 36, 43, and 73-75).

The only effective weapon against large mammals is a high-powered firearm, although pepper spray may discourage attacking bears and ungulates. Improvised weapons (e.g., a spear tipped with a hunting knife) are useless.

Food should not be kept in a shelter or backpack during the night; all food should be placed in a nylon bag and hung between two trees on a high line. Above the timberline, small rodents such as mice may gnaw holes in expensive tents to reach food that is inside; therefore, all food should be removed, bagged, and hung on a line between two high boulders.

In warm weather, insect repellent should be carried and used liberally.

SUMMARY OF PREPARATIONS FOR A POSSIBLE SURVIVAL SITUATION

Keep in good physical condition by employing frequent exercise and healthful habits. Avoid tobacco and recreational drugs, and keep alcohol use to a minimum. Maintain current immunizations.

Develop the ability to swim well.

Learn how to use a map and compass, and know how to find directions without a compass.

Be able to build a fire under adverse conditions.

Have a working knowledge of local weather patterns, and be able to use an altimeter or barometer, thermometer, wind directions, and knowledge of cloud forms to predict storms. Avoid exposure to dangerous meteorologic conditions, such as blizzards and lightning strikes.

Be familiar with the special medical problems related to the type of wilderness that is involved. For example, in cold weather and at high altitude, be familiar with prevention, diagnosis, and treatment of hypothermia, frostbite, and altitude illnesses. Safe travel in the desert and tropics requires familiarity with poisonous and edible plants, tropical diseases, snakebite treatment, dangerous animals, tropical skin diseases, impact of dehydration, and heat illnesses. Understand basic principles of prehospital emergency care and improvisation of splints, bandages, and stretchers.

Carry a survival kit that contains equipment appropriate for the topography, climate, and season (see the appendices to this chapter). At a minimum, the kit should include such things as fire-starting, shelter-building, and signaling and navigating equipment plus emergency food, water, spare clothing, and a first-aid kit.

Be able to construct appropriate types of survival shelters.

Acquire a working knowledge of the characteristics of natural hazards and how to avoid them. These include forest fires, lightning strikes, avalanches, rock falls, cornice falls, flash floods, whitewater, deadfalls, storms of various kinds, and hazardous animals and plants of the area of travel.

Read and analyze accounts of survival experiences (see the Suggested Readings list online at expertconsult.inkling.com). Remember that more people are killed on simple day hikes than on long wilderness expeditions.

Be aware of the psychological aspects of a survival situation and of errors in judgment that can lead to a survival emergency.

Know the edible plants and animals of the area of projected travel, as well as the poisonous or venomous species. Know how to obtain water. Basic hunting, trapping, and fishing skills are also valuable.

Be intimately familiar with the contents of your survival kit and how to use them. Practice and perfect survival activities (e.g., fire building, shelter building, and signaling) before you need them.

Never travel alone. However, if you do, carry a personal emergency beacon. Group members who may separate should have a means of communicating with each other, such as small radios with an 8-km (5-mile) range. Products are available that combine a GPS locator with a small radio.

Leave a trip plan. Always let at least two responsible persons know your destination, the number of persons in the party, their names, the types of vehicles used and their license plate numbers, and the expected time of return. Add several hours to the latter for "normal" mishaps and miscalculations. To avoid unnecessary rescue attempts, do not fail to notify these persons of your return. Failure to follow these guidelines has led to many unsuccessful searches.

APPENDIX A Suggested Basic Contents of a Survival Kit for Temperate to Cold Weather

The kit is divided loosely into fire-building, shelter-building, signaling and navigating, and miscellaneous items, all of which will fit into a small-frame backpack with a capacity of 52.4 to 65.5 L (3200 to 4000 inches^3). The small items can be carried together in a small net bag for convenience and easy identification. Frequently used items (e.g., knife, map, dark glasses, compass) should be stored in a pocket or a belt pouch (Table 59-3).

Always remember to replace consumed items—especially first-aid items, repair-kit items, and emergency food—as soon as you return from a trip. Replace stored matches at least every year and first-aid kit medications before they expire.

TABLE 59-3 Suggested Basic Contents of a Survival Kit for Temperate to Cold Weather

Item	Approximate Weight in Grams (Ounces)
Fire-Building Equipment	
Two waterproof screw-top match containers filled with REI or UCO stormproof matches	57 (2)
Candle	43 (1.5)
Fire starter (e.g., cotton impregnated with petroleum jelly) in a waterproof container, such as an additional match container	28 (1)
Metal match	14 (0.5)
Knife: Swiss Army knife (consider a camping model with a saw, file, scissors, and so on; made by Victorinox)	142 (5)
Alternative: Leatherman tool with wire-cutting pliers, file, one serrated and two regular blades, saw, and scissors	227 (8)
Shelter-Building Equipment	
⅛ inch braided nylon cord or parachute cord, 30.48 m (100 feet)	113 (4)
Rip-stop waterproof nylon tarp, approximately 2.4 × 3 m (8 × 10 feet) with grommets around the edges	55.3 (19.5)
Alternatives:	
Tarp (blue and crinkly; laminated polyethylene weave)	737 (26)
or	
One or two large, heavy-duty (3- to 4-mil), orange or royal blue plastic bags, 0.9 × 1.7 m (3 × 5.5 feet)	255-5100 (9-18)
Folding saw or small rigid saw (e.g., 18-inch Dandy saw)	340 (12)
Signaling and Navigating Equipment	
Headlamp or flashlight with spare bulb and batteries (a good choice is a headlamp with both light-emitting diode and bulb options; the light-emitting diode light uses up much less electricity but is more diffuse and does not cast a long beam; the bulb is brighter and casts a longer beam, but uses much more electricity)	212 (7.5)

Continued

TABLE 59-3 Suggested Basic Contents of a Survival Kit for Temperate to Cold Weather—cont'd

Item	Approximate Weight in Grams (Ounces)
Plastic pea-less whistle on a lanyard	14 (0.5)
Small notebook and pencil	43 (1.5)
Small roll of orange surveyor's tape	57 (2)
Glass signaling mirror with sighting device	57 (2)
Miscellaneous	
Metal pot with bale that contains emergency food of choice (e.g., tea, soup mix, power bars, small can of mixed nuts, trail mix)	964 (334)
Metal cup with handle (for heating liquid by putting the cup at the edge of a fire)	85 (3)
Plastic or Lexan spoon	14 (0.5)
Toilet paper	43 (1.5)
Sunscreen with sun protection factor of 30 or more	113 (4)
Lip balm with sun protection factor of 30 or more	14 (0.5)
Insect repellent (e.g., N,N-diethyl-meta-toluamide)	113 (4)
First-aid kit, one per party (see Appendix D for contents)	701 (25)
Canteen (1 to 1.5 L [34 to 50 fl oz] when full; stainless steel or plastic)	1091-1446 (38.5-51.0)
Sunglasses, preferably polarized, with side shields	57 (2)
Light raingear (e.g., laminated [Gore-Tex] pants and jacket with hood)	879 (31)
Repair kit that is adapted to the type of travel (e.g., ski, snowshoe, kayak) and that includes the following:	
Small needle-nosed pliers with wire-cutting feature (if Leatherman tool not carried)	85 (3)
Small crescent wrench	57 (2)
Small screwdriver with multiple tips	156 (5.5)
Picture wire	28 (1)
Fiberglass tape, standard roll	85 (3)
Duct tape, small roll	28 (1)
Steel wool for shimming (e.g., ski binding repair)	28 (1)
Assorted nuts, bolts, and screws	43 (1.5)
Total weight of repair kit	510 (18)
Total weight of basic survival equipment (not including shovel, snow saw, backpack, or cold weather fourth layer of clothing; see Appendix B)	Approximately 6520 to 7087 g (230 to 250 oz) or 6.5 to 7 kg (14 to 16 lb)
Other Useful Equipment for Consideration	
Nondigital watch	
Altimeter	
Magnifying glass	
Two sets of correct coins for pay phone; calling card	
Light pair of leather gloves (hand protection)	
Water disinfection equipment: chemicals (e.g., Potable Aqua) or filter	
Thermometer (plastic alcohol type clipped to the outside of the pack)	
Spare eyeglasses	
Electronic communication and navigation equipment:	
Cell phone (if service is available in the area)	
Global positioning system unit	
Personal locator beacon (i.e., person emergency locator transmitter)	
Pepper spray (to repel bears, moose, and so on)	
Usual day-trip items to be added:	
Small insulated drink canister of hot or cold drink	
Lunch	
Binoculars	
Camera	

APPENDIX B Suggested Additions for a Winter Survival Kit (When Cold Weather or Snow Is Present or Expected)

Basic survival items from Appendix A
Spare clothing for severe weather to provide at least four layers total, including spare mittens
Small snow shovel (e.g., a small, collapsible, grain-scoop type with a Kevlar blade and detachable handle, with a 680-g [24-oz] capacity)
Snow saw (consider this for above-timberline travel and potential igloo building; should have a 227-g [8-oz] capacity)

OPTIONAL ITEMS

Three-quarter–length piece of open or closed cell-foam mattress or Therm-a-Rest mattress
Sleeping bag
Bivouac sac
Small stove and fuel
Small piece of closed-cell foam (0.6 × 0.6 m [2 × 2 feet]) for sitting on snow

MANDATORY FOR AVALANCHE COUNTRY

Avalanche probe (folding) or ski poles that join together to form a probe for each party member
Avalanche transceiver for each party member
Shovels (preferably one for each party member)
Inclinometer for measuring slope angles (this is included in some compasses)

APPENDIX C Vehicle Cold Weather Survival Kit

Sleeping bag or two blankets for each occupant
Emergency food
Metal cup
Waterproof matches
Long-burning candles, at least two
First-aid kit (see Appendix D)
Extra doses of personal medications, if any
Swiss Army knife or Leatherman Multi-Tool
Three 1.4-kg (3-lb) empty coffee cans with lids for melting snow or collecting urine
Toilet paper
Citizen's band radio, cell phone, personal emergency beacon, or other similar communication device, with charger
Portable radio receiver, with extra batteries
Battery booster cables
Extra quart of oil (place some in a hubcap and burn it for an emergency smoke signal)
Tire chains
Jack and spare tire
Road flares
Snow shovel
Windshield scraper and brush
Tow strap or chain
Small sack of sand or cat litter
Two plastic gallon water jugs, full
Tool kit
Gas-line deicer
Flagging (e.g., surveyors' tape, which can be tied to the top of a radio antenna for use as a signal)
Duct tape
Notebook and pencil
Reading material
Long rope (e.g., clothesline) to act as a safety rope if you leave the car in a blizzard
Carbon monoxide detector
Axe
Saw
Full tank of gas
Data from the Montana State Department of Transportation: *Montana disaster & emergency survival guide*. Available at mdt.mt.gov/publications/docs/brochures/winter_maint/winter_survival.pdf.

APPENDIX D

Minimal Equipment for a Survival First-Aid Kit

Because the most common significant medical problems in wilderness emergencies will be injuries, each item is selected on the basis of the likelihood of need, possibility of multiple uses, urgency of need, weight-to-usefulness ratio (i.e., the "biggest bang for the buck"), and whether it can be improvised from natural materials. As with the survival kit, small items can be carried together in a mesh bag for more rapid retrieval.

BASIC ITEMS

SMALL-BAG ITEMS

Cardiopulmonary resuscitation mouth shield
Surgical gloves, preferably nonlatex
20-mL syringe with needle, catheter, or splash shield for wound irrigation
Steel sewing needle (this can be part of a small sewing kit)
Clinical thermometer (consider a low-reading thermometer for a cold environment)
Small pill boxes that contain the following:
- Nonprescription analgesic of choice (e.g., acetaminophen, ibuprofen; consider ibuprofen if there is a frostbite risk)
- Prescription analgesic of choice (e.g., acetaminophen with codeine)
- Diphenhydramine, 25- or 50-mg caps

Small tube of biodegradable soap
Splinter forceps
Seam ripper
Small needle holder (this is useful for retrieving small things out of tight quarters)
Small magnifying glass
Four large safety pins

OTHER ITEMS

One or two cravats
Roll of 3-inch Ace or self-adhering roller bandage
Roll of 2-inch adhesive tape (waterproof preferred)
Small roll of 0.5-inch 3M Transpore tape
Small prepackaged bandage strips, 1 inch wide (these can be cut in half lengthwise for smaller sizes)
Nonadhering sterile gauze pads (Telfa or equivalent), 3 × 14 inches
Sterile compresses, 4 × 4 inch
Alcohol pads for skin cleansing
Duct tape or fiberglass strapping tape for improvising litters and splints (this can be carried in a repair kit)

ADDITIONAL ITEMS FOR CONSIDERATION

Acetazolamide if there is a risk of acute mountain sickness (i.e., 125 to 250 mg twice daily to speed acclimatization)
Plastic oral airways, three sizes
Pocket mask instead of mouth shield (this device is easier to use, works better than a mouth shield, and protects the user from the victim's saliva)
Povidone-iodine swabs for skin preparation
14-gauge intravenous catheter-over-needle for emergency chest decompression (a flutter valve can be improvised by using the finger cut from a rubber glove with its base tied around the base of the catheter and a hole cut in its tip)
Small bandage scissors or paramedic shears (a scissors, Swiss Army knife, or Leatherman tool can be substituted)
SAM Splint
Persons who are taking regular medications should carry emergency supplies; anyone who has had an anaphylactic reaction should carry an emergency epinephrine kit (e.g., EpiPen)

SUGGESTED READINGS

Suggested readings for this chapter can be found online at expertconsult.inkling.com.

CHAPTER 60

Jungle Travel and Survival

JOHN B. WALDEN

TROPICAL ENVIRONMENT

In these forests lies a virtually limitless supply of excitement, joy, and wonder to be encountered in new illuminations on the constructs and workings of life on Earth.[39]

Tropical rain forests, located between the Tropic of Cancer (23 degrees 27 minutes N latitude) and the Tropic of Capricorn (23 degrees 27 minutes S latitude), are regions with at least 4 inches of precipitation per month and a mean annual monthly temperature exceeding 24° C (75.2° F) without any occurrence of frost. Contrasted with temperate regions, the hours of day and night are approximately equal throughout the year. Seasons are characterized as "wet" or "dry." These seasonal designations refer to historical trends and should not be taken as gospel: in some

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years, the dry season extends for months beyond the usual range; in other years, the rains may persist for months as a daily drizzle, making it difficult to trek over the spongy terrain. In the Pacific coastal region of the Colombian Chocó and the Cayapas River basin of Ecuador, where annual rainfall can exceed 400 inches, the seasons are said to be "wet" and "wetter."

As the most biologically diverse community of living things on Earth, the tropical rain forest is a realm of superlatives: a single acre of tropical forest may contain more than one-half as many species of trees as occur in all the land mass of temperate North America; 1 square mile of Amazonian forest may be home to double the variety of butterflies that exist in all of the United States and Canada; a single tree in Peru yields as many species of ants as in all of the British Isles. Facts and figures fail to capture the essence of tropical rain forests and their extraordinary biologic diversity. Seen from the air, the forest stretches from horizon to horizon in a vast green carpet. In season, the crowns of trees in full blossom dot the landscape with vivid splashes of red, orange, and yellow. Sizable streams may be hidden beneath the emerald canopy. Rivers, usually muddy yellow or black, snake through the forest; early-morning or late-afternoon sun transforms these braided rivers into glistening, mirror-like strands of liquid silver.

Observed from the forest floor, the jungle is entrancing. In virgin, deep forest, all is muted and shadowy, save for random shafts of light that spotlight labyrinths of oddly shaped branches and spectacularly colored flowers. Shrubs and herbaceous plants are scarce in forests away from the flood plain, so it is relatively easy to walk undisturbed. The dimness is occasionally disrupted by areas bathed in bright light from larger holes in the canopy caused by a recently fallen tree, sandy beach, or cutting and burning by humans. It is in these sunlit, *light-gap areas* that the traveler encounters the lush and nearly impenetrable wall of foliage portrayed in adventure films. The tidy textbook division of vegetation into distinct tiers is somewhat arbitrary and not easily confirmed, even by experts.[45]

Drier, nonflooding, upland forests, known throughout Amazonia as *terra firme* (solid ground), are generally nutrient poor and support a crop yield cycle of only 2 to 3 years by traditional slash-and-burn farming methods. Plots of rich, black soil are encountered throughout many drier forest regions of Amazonia. This soil, commonly referred to as *terra preta* (dark Earth), is thought by many soil scientists and archeologists to be the result of intentional soil enhancement and management techniques developed by ancient farmers in the pre-Colombian era. In contrast to *terra firme, terra preta* is capable of sustaining crop production over many years. Lowland forests, or *várzeas,* which remain submerged for several months each year, although making up only a small percentage of forested land, are more fertile than their nonflooding, unimproved, and nutrient-poor counterparts.

TRIP PREPARATION

Despite environmental differences within the jungle, the basics of travel remain the same.

READING

Back issues of *National Geographic* magazine and the writings of Wilson provide an excellent introduction to people, places, and biodiversity issues.[5,61,62] The *Smithsonian Atlas of the Amazon,*[23] the definitive illustrated (150 color maps and 289 photographs) atlas of the region, is highly recommended, as is the *Conservation Atlas of Tropical Forests* series (Asia and the Pacific,[10] Africa,[47] and the Americas[27]). The references for this chapter (available online at expertconsult.com) offer insights into the complex inner workings of the moist tropical forest.[2,44,45] The books by Kritcher[32,33] and Forsyth and colleagues[21] are especially helpful.

Trips into the rain forest should be scheduled for the dry season because trails are more serviceable for trekking during that time. Information on weather patterns can be obtained from agencies of national governments, anthropologists, and missionaries. Weather Underground (wunderground.com) provides current, as well as seasonal, weather averages for many cities and towns in tropical regions.

ATTITUDE

In selecting participants, experienced expedition leaders look for a sense of humor. The ability to see the bright side in difficult times may be an asset more valuable than physical conditioning. Houston[29] and others have discussed the role of humor as a predictor of success. Erb[14,15] noted that successful or failed participation in wilderness ventures also is a significant predictor.

RELATIONSHIP CONSIDERATIONS

Couples routinely report benefits from the shared experience of wilderness adventure travel, ecotourism, and academic field research. However, in the setting of high-risk expeditions where safety and prompt rescue cannot be assured, a number of group leaders privately note that two individuals who have a sexual or other deeply emotional relationship may form a team within a team, to the detriment of the expedition as a whole.[58]

CONDITIONING

Indigenous peoples in jungle regions are almost always slender. After trekking with large numbers of nonindigenous men and women in equatorial regions, I have observed that overweight or powerfully built individuals, particularly men, seem to fare the worst, especially with heat-related illness. Achieving an ideal body weight and becoming aerobically fit by walking or jogging for extended periods of time are beneficial before jungle trekking.

Although being in good shape is sensible, a person need not be an elite athlete to trek through the jungle and enjoy the experience. Good leg strength, acquired by training 20 to 30 minutes on alternate days with stair-climbing exercise machines, offers appropriate preparation.

To keep up with native porters and guides, the prospective expedition member should practice hiking at a fast pace. Once in the jungle, travelers should imitate the energy-saving, fluid rhythm of local inhabitants.

Because trekkers frequently encounter single-log bridges, a well-developed sense of balance is desirable (Figure 60-1). Walking on the rails of untrafficked train tracks or on roadway curbs may help in preparation. To adapt to specific situations, trekkers should go to the woodlands and practice walking on logs. Head stability is important. Equilibrium can be enhanced by avoiding brisk head movements (train by consciously "locking" the nuchal muscles in a fixed position when practicing walking on logs) and by employing the "gaze-anchoring" technique of tightrope walkers—the person fixes the gaze on a spot near the end of the log and does not stare down at the spot just ahead of the feet.[4,9]

Special cleats (e.g., STABILicers Lite Duty Serious Traction Cleats or Covell Ice Walker Quick Clip Cleats) (Figure 60-2) should be considered for crossing log bridges that are high off the ground, long, and slippery. These lightweight cleats can be snapped on quickly before crossing a log bridge and promptly snapped off at the other end. Stability on logs also may be enhanced by turning the feet approximately 20 to 25 degrees to the right or left (whichever seems more natural), rather than walking with the feet in a straight line on the log.

IMMUNIZATIONS

Travelers to rain forest regions should protect against the following diseases by vaccination or with prophylactic medications (see Chapter 79):

- Diphtheria, tetanus
- Hepatitis A, hepatitis B
- Influenza (see later)
- Measles, mumps, rubella
- Polio (where appropriate)

FIGURE 60-1 A well-developed sense of balance is desirable. *(Courtesy John Walden.)*

- Rabies (see Chapter 31)
- Typhoid
- Yellow fever (in certain regions of tropical Africa and South America)
- Malaria (see Chapter 40)

Malaria is prevalent throughout the tropics. Before travel to malarious areas, appropriate prophylaxis is needed. Updated information on the risk for malaria in various regions may be obtained through the Centers for Disease Control and Prevention (cdc.gov/travel). The *Medical Letter on Drugs and Therapeutics* (medicalletter.com) and Up-to-Date (uptodate.com) are excellent sources for current recommendations on preventing and treating malaria.

Persons traveling into remote regions of Amazonia, where Indian groups live in isolation, should receive yearly influenza vaccinations to reduce the likelihood of inadvertently transmitting disease to these high-risk native inhabitants. Protection against meningococcal disease should be considered where circumstances warrant.

MEDICAL KIT

The Wilderness Medical Society points out that it is inappropriate to pack medications and equipment when no team member has the knowledge or experience to use them safely.[30] The following items for a basic medical kit (Box 60-1) are adequate for personal use in the rain forest setting:

- Bismuth subsalicylate (Pepto-Bismol tablets) is an effective over-the-counter preparation for preventing and treating common traveler's diarrhea. It also is useful for heartburn and indigestion. Pepto-Bismol tends to turn the tongue and stools black.
- Diphenhydramine hydrochloride (Benadryl, 50-mg capsules) is safe and effective as an antihistamine, for motion sickness, and as a nighttime sleep aid.
- Ciprofloxacin hydrochloride (Cipro, 500-mg tablets) is highly active against the important bacterial causes of enteritis, including diarrheogenic *Escherichia coli, Vibrio cholerae, Salmonella* species, *Shigella* species, *Campylobacter jejuni, Aeromonas* species, and *Yersinia enterocolitica*. (See Chapter 82 for further advice on treating traveler's diarrhea.)
- Clotrimazole and betamethasone dipropionate (Lotrisone) cream combines an antifungal with a steroid to treat rashes.
- Epinephrine autoinjector (e.g., EpiPen/EpiPen Jr.) provides for emergency treatment of severe allergic reactions to insect stings, foods, or drugs.
- Ibuprofen (200-mg tablets) is a good choice for mild to moderate pain from such problems as menstrual cramps, rheumatoid arthritis, and osteoarthritis. It also lowers elevated body temperature caused by common infectious diseases.
- Ketorolac (Toradol, 60 mg for injection) provides short-term relief for moderate to severe pain at the opioid level. It is preferred over narcotics only because it is less likely to cause problems with customs officers and police.
- Lidocaine hydrochloride may be required as a local anesthetic agent for relief of the excruciating pain resulting from stingray envenomation or conga ant and caterpillar stings. It should be infiltrated into and around the wound area using a dental syringe and 25-gauge needle. Lidocaine carpules (used by dentists) are easy to carry and use in the rain forest.[24]
- Mupirocin (Bactroban) ointment 2% should be immediately applied to burns, abrasions, lacerations, and ruptured blisters, which can rapidly become infected in the tropics.
- Permethrin 5% cream and 1% shampoo should be applied to treat scabies and head lice before returning home by travelers who have been in close contact with heavily infested tribal peoples. Many natives, especially in the tropics of Central and South American, are infested with these ectoparasites. Oral ivermectin (200 mcg/kg) can also effectively treat scabies.[20] Malathion 0.5% is another good choice for head lice. Marmosets and tamarins are often kept by indigenous peoples of the Americas as pets to aid in grooming for head lice (Figure 60-3).

BOX 60-1 Medical Kit for Jungle Travel

Bismuth subsalicylate tablets (30)
Ciprofloxacin hydrochloride 500-mg tablets (12)
Clotrimazole and betamethasone dipropionate cream (60 g)
Diphenhydramine hydrochloride, 25- or 50-mg capsules (15)
Epinephrine autoinjector (2 adult, 2 child)
Ibuprofen, 200-mg tablets (24)
Ketorolac, 60-mg single-dose syringe (2)
Lidocaine hydrochloride carpules (3)
Mupirocin ointment 2% (30 g)
Permethrin, 5% cream (60 g)
Permethrin, 1% shampoo (2 oz)
SAM Splint (1)
Sulfacetamide sodium ophthalmic solution 10% (15 mL)
Sunscreen (4 oz) (2)
Tinidazole 500-mg tablets (12)
Tramadol hydrochloride, 50-mg tablets (10)

FIGURE 60-2 Covell Ice Walker Quick Clip cleat. *(Courtesy Jon Willis.)*

FIGURE 60-3 Tamarins and marmosets are kept as pets to aid in grooming for head lice. *(Courtesy John Walden.)*

- The SAM Splint is lightweight, waterproof, reusable, and not affected by temperature extremes.
- Sulfacetamide sodium (Sodium Sulamyd/Bleph-10) ophthalmic solution 10% is excellent for treating conjunctivitis, corneal ulcers, or other superficial ocular infections.
- Sunscreen is essential in open areas such as rivers or jungle clearings. Sunscreens designated "waterproof" retain their full sun protection factor (SPF) rating for longer periods during sweating or water immersion than do products designated "water resistant." Opaque formulations are excellent for the nose, lips, and ears. Visitors to the tropics should wear lightweight, long-sleeved shirts and wide-brimmed hats when exposed to the sun for prolonged periods.
- Tinidazole is excellent for treating giardiasis (2 g PO once), acute amebic dysentery (2 g once PO daily for 3 days) followed by either iodoquinol (650 mg PO 3 times daily for 20 days) or paromomycin (25 to 35 mg/kg/day orally in 3 divided doses with meals for 5 to 10 days), *Trichomonas* species vaginitis (2 g PO once), and bacterial vaginosis (2 g PO once daily for 2 days). Metronidazole (250-mg tablets) also is appropriate for treating giardiasis, acute amebic dysentery, and *Trichomonas* species vaginitis.
- Tramadol hydrochloride (Ultram, 50-mg tablets) is used for moderate to severe pain.

Common sense dictates supplementary items. Women on long trips might add miconazole vaginal suppositories or fluconazole (Diflucan, 150 mg as a single oral dose) to treat yeast infections; older men might take a 16-Fr catheter and sterile lubricating jelly for dealing with urinary retention from prostatic hypertrophy. The fingers may swell rapidly during vigorous activity in the rain forest. To eliminate the possible need for emergency removal, all rings (including toe rings) should be removed before jungle trekking. Body piercings should be removed to eliminate the risk for infection.

GEAR

The goal is to travel as "light" as possible. The more gear that is packed, the greater is the likelihood of breakdowns, complications, and misery. The items mentioned in Box 60-2 have withstood the test of time over years of experience with long-distance tropical trekking. Gear must hold up under difficult jungle travel conditions that include heat, wetness, and mud. No line of advertised gear is ideally suited for travelers in the tropics.

Footwear

Because feet absorb more punishment than any other part of the body, suitable footwear is the most important item of gear. This is one area in which a person absolutely must not carry inferior equipment. If the feet cannot go, nothing can go.

Traditional military "Vietnam-style" jungle boots with leather uppers, steel insole plates, and speed lacing are unsuitable for serious, long-distance trekking. After an hour of hard walking through streams and muddy trails, blisters can form on every surface of the foot, and the skin will peel off in sheets, bringing a jungle trip to a premature end. Furthermore, safely crossing log bridges and mossy, slime-covered river rocks is almost impossible in these boots. The U.S. Army is currently testing redesigned jungle boots more suitable for field conditions; it is anticipated that a noncamouflage version of these boots will be available soon for the civilian market.

BOX 60-2 Gear for Jungle Travel

Trail shoes (1 pair)
Camp boots (1 pair)
Covell cleats
Socks, lightweight cotton or thin nylon (3 pairs)
Hat (1)
Pullover garment, polyester (1)
Shirts, cotton
  Long sleeved (2)
  Short sleeved (2)
Nylon or Taslan pants, lined with mesh underwear
Poncho, nylon (1)
Flannel sheet
Hammock or Therm-a-Rest
Mosquito net
Backpack for porter
Personal backpack
Antifogging solution for eyeglasses
Batteries
Binoculars
Camera equipment and film
Campsuds
Candles, dripless
Cup (lexan polycarbonate)/plate (Melamine)
Dry bags
Duct tape, 1 small roll
Ear plugs
Fishing supplies
Garbage bags, 13-gal size (2)
Headlamp
Inflatable cushion
Insect repellent
Laminated maps
Machete (Collins style)
Waterproof matches or butane piezo ignition lighter
Pen
Toilet paper
Leatherman pocket survival tool
Razor/battery-operated shaver
Spoon
Sport sponge
Sunglasses
Umbrella
Whistle, plastic
Wide-mouth 1-L water bottles (2)

Two pairs of shoes are needed: one suitable for the wet, slippery conditions imposed by the trail and another that meets the need for dryness and comfort in camp.

Trail Shoes. The following features are desirable in trail shoes:

- Uppers that hit just above or just below the ankles. Some people choose a high-cut design, reasoning that the extra height gives some added snake protection.
- Extra protection over the big toe. Rubber or leather toecaps prevent the big toe from being severely battered and bruised.
- Moderately deep-tread outsoles. Traction on rugged and muddy terrain is important. Running shoes with hard, "high-impact" soles should not be worn because they become slippery on wet logs or river rocks.
- Quick drying time. Uppers of Cordura nylon and split leather, in addition to resisting abrasion and being aerated, dry rapidly in the sun. Even though hiking shoes usually become soaked within minutes on the trail, it is a psychological boost to start each day with semidry shoes. Because jungle travelers can be in waist-high water while on the trail, waterproof shoes with Gore-Tex liners are not essential.
- Snag-proof design. Shoes or boots with "quick-lace" steel hooks should be avoided; vines and weeds become tangled around the metal hooks, causing the wearer to stumble and pulling the laces untied. Shoelaces should always be double knotted.
- Lightweight.
- Well broken in. Setting out on a long, strenuous trek without properly broken-in footwear is a common mistake and can result in extensive blister formation.

Camp Boots. Footwear needs are different in camp, where the trekker wants dry feet. Shoes, although excellent for the trail, are not suited for camp. A noninsulated, pull-on (laceless), open-top boot that comes to midcalf keeps mud off the feet and pants and, when worn with thin nylon socks, allows enough air to circulate to keep the feet cool and dry.

Rubber remains an excellent material for keeping water away from the feet. Rubber lug soles provide traction. When rubber-soled boots are worn at an encampment, however, extreme caution is needed when crossing bridges and walking on wet rocks. Camp boots should be lightweight because they must be carried in a pack while hiking on the trail. Discount stores usually carry lightweight, lug-soled rubber boots that meet the criteria for jungle camp boots.

Other Options. The lightweight, comfortable, mesh/neoprene fabric "water" shoes popular for beach and sailboarding activities may have a place on river trips when substantial time will be spent in dugout canoes or rubber rafts.

Thongs and open-toe sandals are fine for most towns and cities in the tropics, but in certain jungle regions, such as the Amazon basin, exposed feet invite hordes of biting insects.

The jungle traveler must never go barefoot. Plant spines and glass can puncture the feet, and larvae of ubiquitous parasites, such as *Ancylostoma duodenale* and *Necator americanus* (the hookworms) and *Strongyloides* species can enter through the skin. The burrowing jigger flea, *Tunga penetrans,* is a serious pest and can be avoided by wearing shoes.

Socks

Cotton or thin synthetic socks should be worn in the jungle to decrease the risk for blisters from wet trail shoes, to reduce insect bites, particularly from no-see-ums (Ceratopogonidae family), and to lessen the risk for lacerations from saw grass (Figure 60-4).

Clothing

In many countries, military green or camouflage-style clothing is strictly contraindicated. This is particularly true in military dictatorships or in remote border regions. To be mistaken for a guerilla or foreign infiltrator by the military, police, or security (undercover) forces can lead to harassment, detention, or worse.

FIGURE 60-4 Saw grass. *(Courtesy V. Ramey, University of Florida, Center for Aquatic and Invasive Plants.)*

Hat

For protection from radiant heat and light objects falling in the forest, the traveler should wear a lightweight, light-colored hat that has a medium or wide brim. It need not be waterproof but should be made of material that can be wadded up. A useful feature is a fastener on each side to snap the brim up for traveling on the trail. A pith helmet, widely regarded as an affectation, is fine for open savanna and river trips, but on the trail, branches upon which it will snag make it impractical.

Pullover

Drenching rain may leave a person feeling chilled and uncomfortable, particularly when traveling mainly by canoe or raft. Chilling generally is not a problem when hiking on the trail as long as the person keeps moving. A Dacron polyester fleece pullover, such as L.L. Bean's Polartec pullover, the polyester lightweight MTS long-sleeve crew from Recreational Equipment Incorporated (REI), or Patagonia's polyester pullover, will keep a person warm. Wet garments should be wrung out so that they continue to offer thermal protection. Professional white-water boatmen working in tropical regions generally pack a polyester outerwear garment.

Shirts

Two light-colored, ultralightweight, long-sleeved cotton shirts should be taken. At the end of the day, the trail shirt should be washed and rinsed so that it will be ready, although perhaps still damp, the next morning. The second shirt can be used in camp or as a spare for the trail. Expensive synthetic shirts "guaranteed to wick away moisture" are poor jungle trail shirts and make the person sweaty and sticky.

In camp, if no-see-ums and mosquitoes are few, a lightweight, short-sleeved cotton shirt is practical. Two should be packed. A four-pocket style called the guayabera, favored by men throughout Latin America and the Caribbean, is ideal. La Casa de Las Guayaberas (Naroca Plaza, 5840 SW 8th St, Miami, FL 33144; 305-266-9683) has an exceptional selection of short- and long-sleeved guayaberas; be sure to specify 100% cotton.

Pants

Two pairs of ultralightweight, light-colored pants are needed. Although synthetic shirts are unsuitable for trekking in the hot, humid tropics, nylon Supplex or Taslan pants with a built-in mesh brief are ideal. To reiterate—cotton is preferable above the waist; Supplex or Taslan is preferable below the waist. Pants made of these materials hold up well, are quick drying, and are comfortable on the trail. One pair is worn on the trail during the entire trip. The other pair is worn around camp and in towns along the way. Pants with zip-off legs to create instant shorts should be avoided; they will not hold up to strenuous trail conditions. Trail pants should be washed often. Jeans become waterlogged as soon as they become wet and are totally unsuitable for tropical trekking.

Undergarments

Underpants and sport bras should be made of cotton or polyester mesh.

Poncho

An ultrathin waterproof poncho is useful on rafting or canoe trips and in villages, but is worthless for use on the trail because it will become snagged on twigs and tree spines.

BEDDING

Flannel Sheet

Tropical rain forests become uncomfortably cold between midnight and sunrise. A cotton sheet does not provide enough warmth, a blanket is too heavy, and a summer-weight sleeping bag retains too much body heat. A flannel sheet sewn together like a mummy bag (40 × 90 inches), but without a taper, provides suitable warmth placed either in a hammock or on a pad.

Many inhabitants of the tropical forests sleep with their feet near a fire that is tended throughout the night. They have learned that the chill of damp, cool jungle nights can be lessened as long as the feet stay warm. Disposable "warm packs" (Heat Treat Toe Warmers) can be attached by the adhesive backing to the outside of socks, under the toes.

Hammock

Soft cloth hammocks are too bulky and heavy for trips and begin to have a bad odor after a few days. Fishnet cotton hammocks tend to fall apart within hours or days. So-called camping tent-hammocks or military tent-hammocks are impossible to sling properly, extremely uncomfortable, hot, unstable, and never able to keep the rain out during a heavy tropical downpour.

The EZ Sales EZ-199 Marina Double Hammock is available online from multiple sources and has proved nearly ideal for jungle travel. It is compact, lightweight, durable, and reasonably comfortable. It cannot rot or absorb odors. For easier handling, the ski rope tie-end lines that are sold with the Double Hammock should be replaced with 1-cm (0.4-inch) nylon double-braided rope available from home improvement retailers or a boating supply source such as West Marine (westmarine.com).

Therm-a-Rest

The Therm-a-Rest foam pad is the choice of expedition organizers in temperate and cold climates throughout the world. It combines the insulating qualities of foam and the cushioning of an air mattress, rolls up to a compact size, and inflates on its own when the valve is opened.

The traveler who will be sleeping on a pad should pack a 1.4 × 2.3 m (1.5 × 2.5 yard) plastic groundsheet. The sheet should not be placed directly on the jungle floor, where stinging insects and snakes abound. It should be used only in a hut or on an elevated platform. The groundsheet may also be beneficial for temporary rain protection and for keeping bow spray off a person or gear during water travel in boats powered by outboard motors. For jungle travel, a hammock may be preferred over a foam pad.

Mosquito Netting

A mosquito net designed for use with a hammock is basically a rectangular box that is open at the bottom with sleeves at each end panel for the passage of the ropes by which the hammock is slung. Properly designed, durable mosquito nets for hammocks are difficult to find outside the tropics. Fortunately, a serviceable mosquito net can easily be made from "no-see-um netting." (No-See-Um mosquito netting is available from U.S. Netting, sales@usnetting.com; 800-331-2973) See later in this chapter for the details of mosquito net construction.

BACKPACKS

A sturdy, well-designed backpack should be used to carry gear. Reflective material should be sewn onto the back of each backpack. Iron Horse Safety Specialties (800-323-5889; fabric.ironhorsesafety.com) sells red-orange reflective material for daytime visibility and reflective silver material for nighttime reflectivity.

FIGURE 60-5 Indigenous peoples are accustomed to hauling loads using a tumpline. *(Courtesy John Walden.)*

On serious jungle treks, porters are often present. This frees expedition members to carry much lighter loads.

Backpack for Porter

An internal-frame backpack with a capacity of 49.2 to 65.6 L (3000 to 4000 inches) is a good size. It should have external pockets for quick access to liter-sized water bottles.

Indigenous peoples are accustomed to carrying packs and hauling loads with a strap, known as a *tumpline,* slung over the forehead or chest. Many natives, including Amazonian Indians, dislike using the shoulder straps that come as standard equipment on backpacks. Given enough straps, almost any native porter can quickly rig a satisfactory tumpline on a backpack. If you do not have extra straps, tribesmen reared in the tropical forest will strip bark from saplings and fashion an adequate tumpline in minutes (Figure 60-5).

Personal Pack

A daypack with a capacity of 19.7 to 32.8 L (1200 to 2000 inches) is useful for carrying a camera, snack food, and other gear that must be kept handy. A waterproof liner will keep perspiration from wicking into the bag and wetting everything inside. The pack should have two outside pockets for quick access to liter-sized water bottles.

Pack for River Trips

A durable, waterproof "dry" bag, used by river runners, is worth considering, especially if the trip will involve spending days or weeks at a time in dugout canoes or rubber rafts. Most of these packs, however, cannot stand up to the demands of long-distance overland trekking. The straps tend to be uncomfortable and frequently rip out on the trail.

OTHER USEFUL ITEMS

Antifogging Solution for Eyeglasses

Antifog solution, available from dive shops, reduces humidity-induced fogging of glasses.

Batteries

Alkaline batteries should be brought from home. Batteries purchased in Third World nations do not last long and often leak.

Binoculars

The traveler who is an avid bird-watcher or enjoys watching butterflies or seeking out orchids high on distant limbs will want to pack a pair of binoculars that are lightweight, compact, shockproof, and waterproof or water resistant.

Camera Equipment

Waterproof, shock-resistant, wide-aperture (f/2 lens) point-and-shoot digital cameras are available, as are rugged, high-performance, water-resistant professional digital single-lens reflex cameras.

Camera Case or Bag

Hard-bodied Pelican cases are waterproof and virtually indestructible. The silver-gray color cuts down on heat absorption and is preferred in hot climates. The cases are ideal for rafting or canoe trips but bulky for trekking. On the trail, waterproof "dry" bags protect equipment.

Camp Soap

A biodegradable soap should be used. Campsuds soap, carried in a leak-proof Nalgene bottle, works in hot, cold, fresh, or salt water and cleans dishes, clothing, hair, and skin.

Candles

Electricity tends to fail at unpredictable times in small towns and even in larger cities in Third World countries. Travelers should carry dripless candles. Spring-loaded candle lanterns should be avoided because they give off an anemic light, gum up, get crushed or broken, and basically waste space in the pack. Solar-powered lanterns take up too much space unless carried by a large group expedition using mules or canoes.

Cup and Plate

A large Lexan polycarbonate cup is unbreakable, does not retain taste or odor, and serves the role of cup, bowl, and plate. Travelers who want an actual plate should buy one made of indestructible Melamine.

Duct Tape

High-quality duct tape, such as Gorilla Tape or Duck brand, are excellent for protecting existing blisters and for preventing blisters from developing on areas prone to blister formation when applied before trekking. Although a number of products are marketed to prevent blister formation and protect skin once blisters have formed, in my experience nothing beats duct tape. Also, duct tape is useful for removing the urticating hairs of caterpillar envenoming (see Venomous Moths, Butterflies, and Caterpillars, later).

Ear Plugs

Travel in the tropics often involves flying in incredibly loud helicopters, cargo planes, or short takeoff and landing (STOL) aircraft. Sponge ear plugs that roll up and fit in the ear canal offer inexpensive, effective protection against hearing damage. Buy ear plugs in sealed packets of two per packet, such as the uncorded Howard Leight MAX-1, and not in bulk. Once a bulk-packet is opened, all the ear plugs quickly absorb moisture in the humid tropics, making them difficult to insert into the ear canal if exposed to ambient humidity for more than a few hours.

Fishing Supplies

For additional "food insurance" when traveling in extremely isolated regions, the jungle traveler should carry 22.9 m (75 feet) of 20-lb-test fishing line, at least two 30.5-cm (12-inch) steel leaders with swivels, and a few size No. 4 hooks. Travel rods that disassemble for compact carrying and spin-cast reels should be considered for sport fishing or adding fresh meat to the daily provisions. Throughout the tropics, most species of fish find Rat-L-Trap lures, particularly the chrome and blue combination, irresistible. The hooks that come standard with Rat-L-Trap lures are not sturdy enough to withstand the hard mouth and powerful bite of tropical freshwater fish. Replace these hooks with 3× or 4× strong, size No. 4 treble hooks.

Garbage Bags

Two heavy-duty 49.2-L (13-gal) capacity plastic garbage bags (or dry bags) can keep dirty boots isolated from clean items in the backpack.

Dry Bags

Compression dry bags are excellent for storing items that must stay dry, such as bedding and clothes for camp use. Outdoor Research and SealLine dry sacks are high-quality products available from REI. See-through organizer bags help reduce clutter and minimize the risk for misplacing small items.

Headlamp

Battery-operated headlamps offer hands-free convenience at night for reading or going to the latrine. The Petzl Tikka LED Headlamp weighs only 76.5 g (2.7 oz) (with batteries) and has a battery life of 24 hours at 21°C (70°F).

Inflatable Cushion or Pillow

A small, self-inflating cushion made with a low-slip polyester fabric top and durable nylon bottom is recommended for sitting for extended periods in a dugout canoe or aluminum boat.

Insect Repellent

Insect repellent containing 15% to 30% *N,N*-diethyl-3-methylbenzamide (DEET) repels mosquitoes, flies, ticks, chiggers, fleas, and gnats, but not no-see-ums. Formulations (often called "jungle juice") should not contain higher than 30% DEET, because they may pose health hazards (see Chapter 45). Picaridin in the 20% formulation is marketed to repel mosquitoes, flies, ticks, chiggers, fleas, and offers some protection against annoying no-see-ums. Picaridin does not damage plastics or synthetic materials, does not have the "wet/sticky" feel of products containing DEET, and can be purchased in an odorless formulation. On recent expeditions into the Amazon Basin, the author found picaridin to be inferior when compared with DEET in preventing mosquito bites.[1]

Technique is critical when applying insect repellent. Before dressing, the person should spray the ankles, lower legs, and waist. If clothing has not been pretreated with permethrin (see later), then after the socks are put on, a band of repellent should be sprayed around the top; a band should also be sprayed around both pant legs to midcalf. A light spray to the shirt, front and back, may also help. The hands should be sprayed, rubbed vigorously, and run through the hair. Some repellent should be dabbed on the face, neck, and ears, carefully avoiding the eyes; contact lens wearers should be especially vigilant when applying insect repellent.

No-see-ums, which are tiny gnats that abound throughout the tropics of the Americas, are the most common source of insect annoyance in many regions. They are active at sunset and attack humans emerging from jungle streams. No-see-ums cannot bite through even the thinnest cloth and are usually inhibited by Skin So Soft (SSS), which appears to have a slight chemical repellent effect, but more likely works by drowning the tiny gnats in oil. SSS is not effective against ticks, fleas, flies, and chiggers and offers little protection against mosquitoes. SSS should be applied liberally and often to the wrists, knuckles, bare ankles, face, ears, and scalp. Men with full beards seem to be especially troubled by tiny gnats and may benefit by applying small amounts of SSS to the beard area. Picaridin (see above) in the 20% formulation offers some protection against no-see-ums.

Permethrin kills or stuns insects that land on clothing that has been impregnated with this product. Permethrin is safe, highly effective, and persists even after extensive washing of garments (see Chapter 79). It is effective against insects when used on mosquito netting, even when the netting has sizable holes and tears.

Laminated Map

Accurate maps exist for most regions on Earth. From the best map available, travelers should laminate photocopied portions that are relevant to a particular itinerary (see Rescue Strategies, later).

Machete

A Collins-style machete (Figure 60-6) is the single essential tool for jungle survival and for the many tasks in camp and on the trail that require steel with a sharp edge. Do not purchase a model with a hand guard. A hand guard serves only for protection against an opponent's blade when used as a weapon in combat; it does not offer added protection when the machete is used as a cutting implement.[28] A newly purchased machete can have a pointed, sharp tip and a cutting edge that extends all the way from tip to handle. To reduce the likelihood of accidental injury, use a metal file to dull the tip of the machete and

FIGURE 60-6 Collins-style machete with sheath. *(Courtesy John Walden.)*

also to flatten the cutting edge from the handle to approximately 2 inches from the handle. It is hazardous to use a machete in the rain or when cutting wet grass, because the weapon may fly out of the hand. Also, when cutting brush, the person often encounters saw grass (see Figure 60-4). The resulting skin lacerations, which are not noticed at first because saw grass is razor sharp, may take a week or two to heal. Because of the risks involved, an experienced individual should be in charge of transporting and using the machete. For added safety, a machete should be carried in a sheath. Gloves are rarely worn for hand protection because it is best to have skin against the handle to maintain a grip in wet conditions and to conduct the "feel" of the object being cut to allow an accurate and skillful maneuver.

Matches or Cigarette Lighter

Waterproof, windproof Hurricane Matches light when damp and stay lit for several seconds, even in the strongest wind. Many jungle travelers prefer a butane cigarette lighter with a piezo ignition system.

Pen

J.L. Darling Corp (2614 Pacific Hwy E, Tacoma, WA 98424-1017; 253-922-5000; riteintherain.com) sells professional-quality outdoor writing products, including Rite in the Rain shirt-pocket field notebooks, travel journals, and all-weather pens that write upside down without pumping, under water, over grease, and in hot and cold temperature extremes.

Pocket Tool

The Leatherman Super Tool is recommended for jungle travel and survival. It features needle-nosed pliers and 12 locking implements.

Wide-Mouth Water Bottles

Essential gear includes two quart- or liter-sized wide-mouth water bottles. Bisphenol A–free products are now available. Narrow-mouth, screw-top 56.7-g (2-oz), heavy-duty bottles come in handy for carrying a salt and pepper mixture to add flavor to boiled plantains and yucca. Nalgene products are legendary; whatever you put in a Nalgene bottle will stay there and not leak into your pack.

Wide-mouth water bottles can be quickly refilled while on the move, and the water rushes in without the delay imposed by a narrow-mouth bottle. In the rainforest, a person may consume 6 to 8 L of water daily. It is easier to fill a wide-mouth bottle and gulp down from a second wide-mouth bottle (that was previously treated from the prior refill) while on the run without a long pause. Some Amerindians do not like to slow down or stop just so someone can take a break to slowly consume a liter of water. However, with a narrow-mouth bottle, water will not run down one's chin when one is drinking at leisure in camp. It comes down to personal choice.

Razor or Battery-Operated Shaver

Both men and women should carry lightweight disposable razors. Most men find that lightweight, AA battery–operated shavers give two shaves a day for up to 2 weeks before requiring a change of batteries.

Spoon

Knife-spoon-fork sets are unnecessary. A knife blade and a good tablespoon made of either Lexan polycarbonate or stainless steel are sufficient for eating.

Sport Sponge

A camp towel, made of microporous material, is lightweight, compact, and superabsorbent; it replaces the cotton towel because the body and even hair can be dried much more quickly than with a traditional towel.

Sunglasses

Sunglasses should be polarized with full ultraviolet light protection. Many travelers prefer sunglasses with red-tinted lenses. Because red is the complement of green, these lenses make the jungle foliage stand out intensely and sharply, with enhanced contrast and depth of field. Retainers hold eyeglasses securely during vigorous activity.

Toilet Paper

American toilet paper is much softer than that purchased in Third World countries. The traveler should never wipe with jungle leaves.

Umbrella

A collapsible umbrella is useful in tropical cities and in remote villages when walking from hut to hut. It also offers excellent protection from the sun on canoe or raft trips. The umbrella should be reflective silver, not heat-absorbing black.

Whistle

A high-quality plastic whistle can be used to signal in case someone strays off the path.

COPING WITH THE JUNGLE ENVIRONMENT

> *A visit to the rain forests of the New World tropics can be either a sublime experience or a hellish ordeal.*[21]

WETNESS

The superhumid lowland rain forest receives up to 1016 cm (400 inches) of rain a year. In the higher-elevation cloud forest, dense cloud cover throughout the year is accompanied by constant mist or drizzle. In such heat and high humidity, people become mentally fatigued as a result of being constantly wet. Fortunately, travelers can use basic strategies for coping with the physical and psychological burdens of wetness.

Dryness while trekking or working during the day is not required for physical or mental health. Wetness does not equate with illness, significant discomfort, or dampened spirits. People can tolerate being wet throughout much of the day if they know that they have a dry change of clothes to wear in camp and that they will be dry at night. In addition to the psychological benefits, being dry at night means that maceration is less likely to develop in intertriginous areas.

Bedding and clothing can be protected from moisture by careful wrapping in dry-bags. Despite all efforts, however, certain "dry" items eventually become damp or accidentally soaked. Wet articles should be spread out on shrubs and bushes. They will dry within 2 hours in full sun. Myiasis caused by the tumbu fly, *Cordylobia anthropophaga,* of sub-Saharan Africa can be avoided by hanging clothing to dry in bright sunlight, never on the ground. Clothing dried over a wood fire absorbs smoky odor that does not wash out.

HEALTH ISSUES

Health Risks

The subject of the tropics causes many people to think about tropical diseases, such as filariasis, and animals, such as the candirú (see later discussion). Malaria, hepatitis, and injuries from motor vehicle accidents are the three leading health problems in most tropical regions. Tropical travelers who venture "off the path" may be exposed to bodily harm and serious diseases, such as leishmaniasis, onchocerciasis, Chagas' disease (in the Americas), and sleeping sickness (in sub-Saharan Africa). Close contact with many indigenous populations of Amazonia increases the likelihood of infestation with scabies and head lice. Bouts of diarrhea or other annoyances will likely occur, regardless of the extent of precautions taken, but death is unlikely.[18,40]

Duration of Travel and Emotional Response

Cashel and colleagues[7] examined the mood pattern of participants in eight separate 9-day wilderness expeditions conducted over 4 years and noted a high level of confusion, fatigue, anger, depression, and tension on day 4.

After 2 to 3 weeks of travel in remote areas, the general health of expedition participants deteriorates as a result of insect bites, falls, and noxious plants. Inexperienced trekkers may quickly tire of unfamiliar food, and miss usual comforts. Therefore, experienced leaders prefer to limit expeditions to not more than 3 weeks.

Preventing Heat-Related Illness

The following guidelines may help prevent heat-related illness:

- Before undertaking long-distance trekking in the tropics, acclimatize by spending at least 5 days in a hot, humid environment and engaging in moderate daily exercise. This acclimatization will be lost within a week if not maintained.
- Avoid alcohol and certain drugs. Medications, such as beta-adrenergic blockers, anticholinergics, and diuretics, increase the likelihood of heat-related illness and should be avoided if possible.
- Wear ultralightweight, light-colored, and loose-fitting cotton clothing and a wide-brimmed hat. As previously noted in this chapter, shirts should always be made of cotton. Pants, however, may be made of synthetic fabrics such as nylon Supplex or Taslan.
- Whenever possible, have a native porter carry all gear.
- Maintain adequate hydration. Before setting off on the trail, drink a liter of disinfected water. One-half hour later, drink a second liter. One hour after the second liter, drink a third, and then consume about 1 L every 2 to 4 hours during strenuous trekking.

Heat cramps, often severe, tend to occur when large amounts of water are ingested without adequate salt replacement. New formulation oral rehydration salts (ORS) with reduced osmolarity, available in premeasured powder form, added to a liter of disinfected water, provide an ideal balance for replacing lost electrolytes. AGS Brands ORS (agsbrands.com) sells new-formulation ORS in bulk at significant savings. The first liter of disinfected water (noted previously) consumed before trekking should include a packet of ORS. After especially strenuous days, trekkers should drink an additional one-half packet of ORS.

Sport beverages do not contain the ideal concentration of electrolytes found in ORS and are not recommended. Sport beverages in liquid form take up space and add unnecessary weight in the backpack on the trail. Salt tablets are not recommended because they are gastric irritants.

To eliminate or reduce the chances of intensely painful leg cramps rousing you from sleep, always perform calf-stretching exercises before falling asleep.

UNEXPECTED ISOLATION

Various factors contribute to unexpected isolation in the jungle. These include inclement weather, mechanical problems, or political turmoil that shuts down public transportation. Many people respond with anger and irritability, which can be devastating to group dynamics. Travelers should accept the situation and use the additional time to appreciate the tropical forest, take photographs, or read books.

It helps to shift out of gear mentally and allow the intellectual machinery to idle. Nearly everyone has the experience of driving for hours and arriving at a destination with virtually no recollection of the trip. The same can be accomplished in the village setting, lying around on a hammock. The hours and days pass surprisingly quickly, akin to cruising in a sailboat with no engine. The person learns patience and develops an appreciation that the rhythms of nature are not governed by the ticking of a clock.

CAMP LIFE

Shelter

Natives rarely spend the night in makeshift shelters. It is usually best to use existing dwellings for a hammock or sleeping pad. Common courtesy governs placement inside the hut of a native. Travelers should ask about taboo spots before bedding down.

When huts are not available for use, a tarpaulin provides satisfactory shelter from the rain. Rip-stop polyethylene tarps (2.4 × 3 m [8 × 10 feet]) are lightweight and waterproof. Coated nylon tarps are also acceptable but must be sealed with a product such as Seam Grip.

Figure 60-7 illustrates a typical method for erecting a tarp. First, a line is run 2.1 to 2.4 m (7 to 8 feet) off the ground between two trees and cinched tight. The long axis of the tarp is centered over the rope, and a rope attached to the middle grommet on each end is tied to the tree. The corner grommets are tied to available trees, bushes, or strong clumps of grass; a tie-down in the middle on each side is also helpful. The sides of the roof should be made high enough to enter and exit conveniently, but not so high that driving rain can come in at an angle.

Once the tarp is up, the hammock ropes are run through the sleeves of the mosquito net. Then the hammock is slung. The hammock should be suspended high enough that it will not sag to the ground during the night, because it naturally sags under an adult's weight. Next, the mosquito net is suspended. The ropes running from tree to tarp, from tree to mosquito net, and from tree to hammock should be sprayed with DEET-containing insect repellent (or permethrin insecticide) to keep ants and other pests from using the ropes as trails. Finally, a few broad leaves (banana leaves or heliconia) folded at the spine are draped over the bare rope extending from the tarp to the tree and shingled in such a way as to keep rain from running down the hammock ropes onto the hammock itself (see Figure 60-7).

Knowledge of two knots is needed for slinging a hammock. These knots always hold and always come undone quickly without jamming. The half hitch is used to tie the hammock to a horizontal beam, as follows (Figure 60-8):

1. Pass the working end of the rope around the object to which it is to be secured.
2. Pass the working end of the rope around again without crossing over itself.
3. Bring the end over and around the standing part and through the loop that has just been created. You have completed a half hitch.
4. Make a second half hitch below the first half hitch.
5. Pull tight.

The camel hitch is used to tie the hammock to a vertical post, as follows (Figure 60-9):

1. Make three turns around the vertical pole.
2. Bring the working end up and over the turns.
3. Make a turn at the top and pass the end back under itself.
4. Make a second turn at the top and pass the end back under itself.

Weather conditions can change in minutes, and travelers must be prepared with adequate shelter. The use of a tent as shelter in the tropical rain forest is not recommended. Clearing a tent space is time consuming, and the stumps remaining from cutting saplings and bushes invariably perforate the floor. Air does not circulate; after a restless night sweltering in the tent, the traveler emerges tired and irritable.

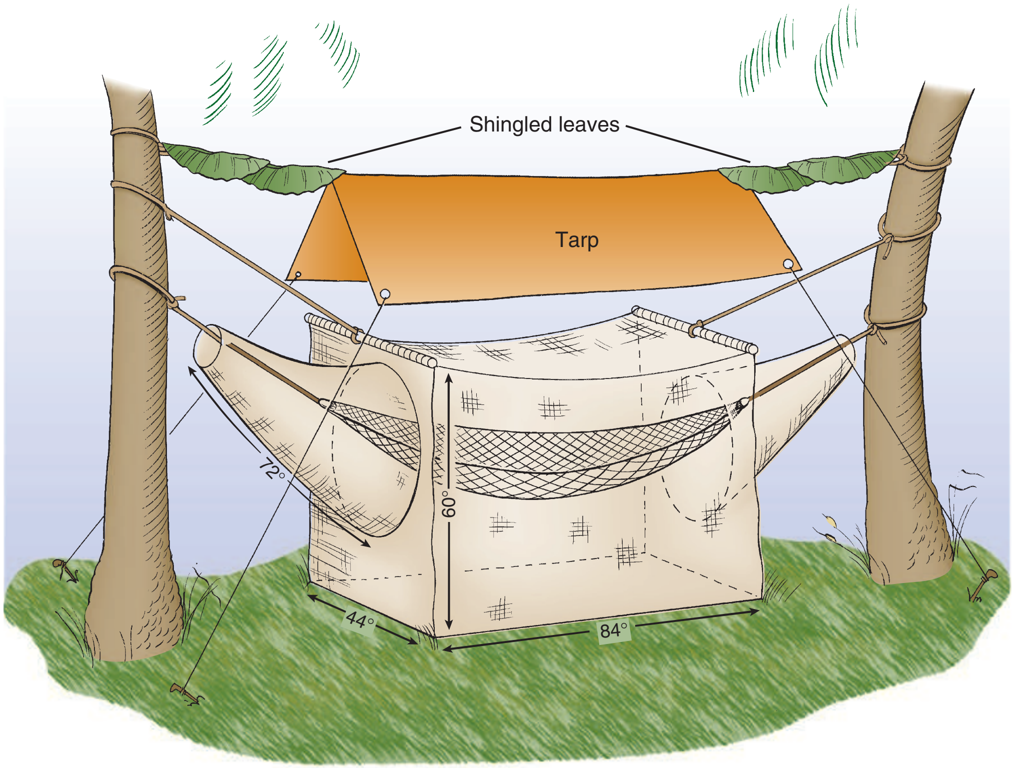

FIGURE 60-7 Construction of mosquito netting for use with a hammock: Sleeve hole is 2.2 m (88 inches) in circumference; small hole is 0.5 m (18 inches) in circumference; smallest holes (for supporting sticks) are 10.2 cm (4 inches) in circumference.

Food

Solitary travelers or small groups usually do not need to pack large amounts of food. Edibles are always available in areas inhabited by friendly natives. As a general rule, food is safe to eat if it is peeled, cooked, or boiled.

Travelers in the tropics must be open to eating local food. Most creatures are edible. These include boiled caiman (alligator), cooked capybara (a 50-kg [110.2-lb] rodent), and roasted palm grubs (larvae of *Rhynchophorus*). Raw palm grubs, up to 12.7 cm (5 inches) long, are tasty and a favorite of Amazonian Indians (Figure 60-10). They are eaten by slashing open the thin integument with the thumbnail, extracting and discarding the

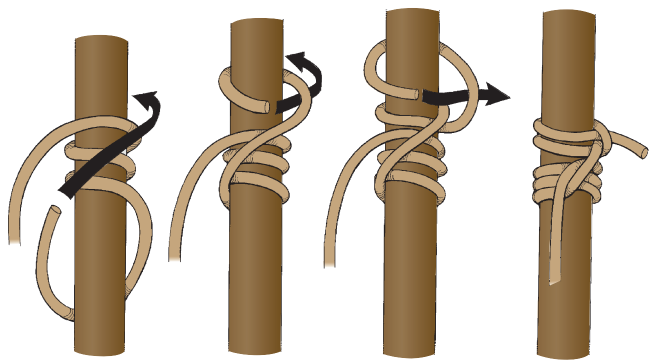

FIGURE 60-9 Camel hitch.

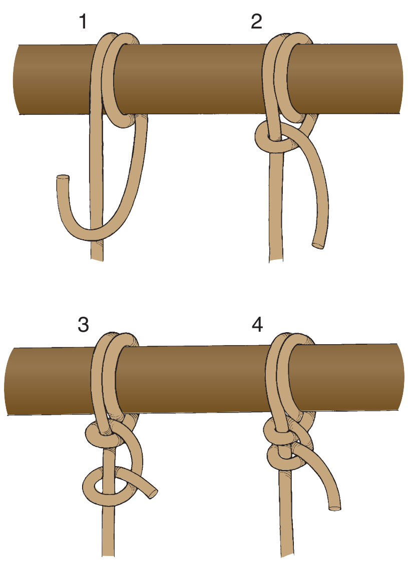

FIGURE 60-8 Half hitch.

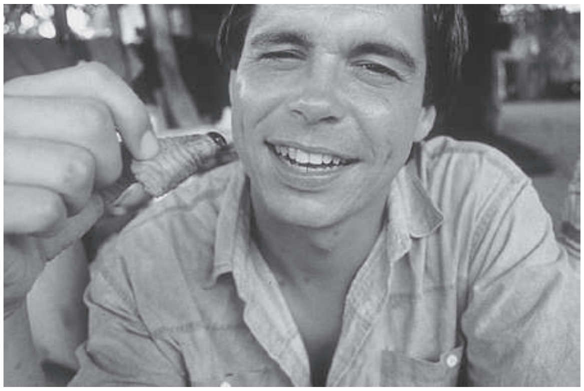

FIGURE 60-10 The palm grub is a favorite delicacy. *(Courtesy John Walden.)*

intestinal tract, placing the opened skin to the mouth, and sucking out the turgid contents.

In addition to palm grubs, more than 20 species of edible insects, including ants and termites, are collected year-round by the people of Amazonia.[13] Large hairy spiders, *Theraphosa blondi,* 25.4 cm (10 inches) in diameter, are often roasted on an open fire. After the barbed hairs are singed off, the spiders are placed in the embers. They have a shrimp-like taste.

Indians of the Americas have perfected the art of smoking fish and meat so that they remain safe to eat for long periods. It is common to see huge hunks of tapir meat or slabs of 100-lb catfish resting on racks, coal black from the smoking process.

Table 60-1 illustrates the diversity of wild game from 867 day hunts by members of the Waorani tribe of Ecuador.[64] The Aguaruna and Huambisa of Peru conceptually recognize and classify as food nearly 500 species of animals.[3]

The tropics have an abundance of flora as food. The yard-long heart of palm is cool and delicious when eaten in its raw state or may be included in a soup spiced with tropical herbs. Familiar tropical fruits include papaya, mango, pineapple, and passion fruit (genus *Passiflora*). Many New World fruits often have no familiar name in English and generally have not found their way into the world market. These include chirimoya, guanabana, pitahaya, naranjilla, uchuva, tamarillo, zapote, sapodilla, and badea.[38,43,60] The boiled fruit of the peach palm, *Bactris gasipaes,* is nutritious and flavorful.

The banana and its cousin, the plantain, provide a large percentage of the total caloric intake of natives in the American and African tropics. Curiously, in many native villages, it is difficult to find the sweet, finger-length bananas and the common yellow bananas exported from tropical countries. The green plantain features prominently in the daily fare of inhabitants of the tropics. The plantain has little taste and is exceptionally dry.

Yucca (manioc or cassava), *Manihot esculenta,* is a staple source of carbohydrate nutrition throughout the Americas and much of tropical Africa. The two kinds of yucca, "sweet" and "bitter," are the same species but differ in their distribution and amount of a poisonous constituent, a cyanogenic glycoside, in the root.[51] Sweet and bitter yucca cannot be easily distinguished; one must know which variety was planted. Sweet yucca, common in the eastern lowlands of the Andean countries of Colombia, Ecuador, and Peru, is eaten after the bark containing the toxic substance is peeled off and the root boiled. With bitter yucca, the poison is more concentrated and distributed throughout the root, so it must be extracted before consumption. Amerindians use an apparatus called the tipití (Figure 60-11) to express the poisonous juice from the peeled and grated flour of manioc roots.

Travelers in a large group should carry dried, packaged foods because the host village might not be able to provide sufficient foodstuffs or travelers might pass through isolated and uninhabited regions. Packaged foods should also be carried by travelers in regions where natives are unfriendly.

TABLE 60-1 Rank Order of Species by Total Weight

Rank	Common Name	Species Name	Total Weight (kg [lb])*	Percentage of Gross Weight
1	White-lipped peccary	*Tayassu pecari*	4940.1 (10,891.1)	26
2	Woolly monkey	*Lagothrix lagotricha*	3873.5 (8,539.6)	21
3	Collared peccary	*Tayassu tajacu*	2740.6 (6,042)	15
4	Howler monkey	*Alouatta seniculus*	2197.4 (4,844.4)	12
5	Tapir	*Tapirus terrestris*	1314.4 (2,897.8)	7
6	Salvin's curassow	*Mitu salvini*	610.9 (1,346.8)	3
7	Cuvier's toucan	*Ramphastos cuvieri*	414.4 (913.6)	2
8	Capuchin monkey	*Cehus albifrons*	400.8 (883.6)	2
9	Spix's guan	*Penelope jacquacu*	301.7 (665.1)	2
10	Blue-throated piping guan	*Pipile pipile*	261.8 (577.2)	1
11	Brocket deer	*Mazama americana*	253.4 (558.7)	1
12	Capybara	*Hydrochoerus hydrochaeris*	226.5 (499.3)	1
13	Paca	*Agouti paca*	194.8 (429.5)	1
14	Coati	*Nasua nasua*	130.6 (287.9)	1
15	Great tinamou	*Tinamus major*	116.5 (256.8)	
16	Spider monkey	*Ateles belzebuth*	110.1 (242.7)	
17	Saki	*Pithecia monachus*	100.0 (220.5)	
18	Ivory-billed aracari	*Pteroglossus flavirostris*	86.1 (189.8)	
19	Red squirrel	*Sciurus igniventris*	82.9 (182.8)	
20	Gray-winged trumpeter	*Psophia crepitans*	66.5 (146.6)	
21	Agouti	*Dasyprocta fuliginosa*	47.5 (104.7)	
22	Golden-collared toucanet	*Selenidera reinwardtii*	30.4 (67)	
23	Tayra	*Tayra barbara*	27.3 (60.2)	
24	Squirrel monkey	*Saimiri sciureus*	23.7 (52.2)	
25	Speckled chachalaca	*Ortalis guttata*	21.6 (47.6)	
26	Nocturnal curassow	*Nothocrax urumutum*	20.4 (45) 5	
27	Cayman	*Caiman sclerops*	20.0 (44.1)	5
28	Mealy parrot	*Amazona farinosa*	19.6 (43.2)	
29	Red-mantled tamarin	*Saguinus fuscicollis*	18.7 (41.2)	
30	Scarlet macaw	*Ara macao*	18.2 (40.1)	
31	Douracouli	*Aotus trivirgatus*	17.6 (38.8)	
32	Titi	*Callicebus moloch*	17.2 (37.9)	
33	Squirrel	*Sciurus cocalis*	15.4 (34)	
34	Acushi	*Myoprocta pratti*	11.1 (24.5)	
35	Yellow-ridged toucan	*Ramphastos culminatus*	11.0 (24.3)	
36	Miscellaneous small birds (numerous species)		29.3 (64.6)	
Gross weight			18,772.1 (41,385.2)	100

*Includes only those species whose total weight was more than 10 kg (22 lb).

FIGURE 60-11 The tipití expresses poisonous juice. *(Courtesy William H. Crocker, Department of Anthropology, Smithsonian Institution.)*

Dried instant food needs only water to make a meal. A few selections should be tried before a large supply for field use is ordered. It is not necessary to add hot water to all packaged foods; adding disinfected, ambient-temperature water produces acceptable results for most foods. Drawbacks to prepackaged foods include expense, space, and disposing of the empty foil packages.

The following supplemental food items are recommended for 2- to 3-week treks into remote but inhabited jungle regions: one 56.7-g (2-oz) heavy-duty "poly bottle" filled with salt and pepper mixed half and half, a few pounds of rice, a small bottle of cooking oil, a few tins of tuna or sardines packed in tropical hot sauce, and several PowerGel energy packets for trail snacks.

Potable Water

Potable Aqua (tetraglycine hydroperiodide 16.7%) iodine tablets are recommended for disinfecting water because they are easy to use and have proved effective in killing bacteria and many parasite cysts in approximately 30 minutes (see Chapter 88). Potable Aqua iodine tablets are ineffective against *Cryptosporidium*. Fortunately, diarrheal illness due to *Cryptosporidium* species usually resolves without therapy in 10 to 14 days in immunologically healthy people. Potable Aqua chlorine dioxide tablets are effective against viruses, bacteria, *Giardia,* and *Cryptosporidium*. However, they require a 4-hour treatment time to kill contaminants. Water filters are not recommended for purifying jungle water; they clog with silt and must be cleaned frequently. If a water filter is used, it should be fitted with a good prefilter to capture the excess silt.

JUNGLE HAZARDS

The following hazards are common or believed to be common in the wilderness jungle setting. Other chapters provide additional insights and viewpoints, particularly with respect to treatment.

Arthropods

Ants. The conga ant (also called the bullet ant), *Paraponera clavata,* 2.5 to 3.8 cm (1 to 1.5 inches) long, is the terror of the American tropics. The bite of these large black ants can produce intense pain and fever for up to 24 hours, which accounts for the Spanish name, *veinticuatro* (twenty-four). Fortunately, they are conspicuous because their large, shiny black bodies tend to stand out against foliage. Special caution is needed when ducking under or climbing over trees, where ants are often found. A conga bite requires strong pain medication and perhaps the injection of lidocaine at the bite site.

Travelers should avoid touching trees and bushes. Many plants in the tropics provide a home and food for ants, which provide aggressive defense of the plants.

Fire ants are common throughout the tropics and subtropics. Their bite causes discomfort but not excruciating pain. Characteristic sterile pustular lesions in crops often result from fire ant stings.

Chiggers. Chiggers, a form of mite, are a problem throughout equatorial regions. Whereas temperate-climate chiggers may cause mild discomfort for a few days, the tropical chigger sets up an inflammatory and allergic reaction that often persists for weeks.

In the South American tropics, chiggers are found in grassy fields, such as jungle airstrips and yards around mission compounds. Walking through chigger-infested areas without protection could leave a person covered with chigger bites. After a few days, the victim begins to itch mildly. As the days pass, the itching intensifies and seems to come in waves.

Prevention is the best treatment. Areas known to be infested with chiggers should be avoided when possible. Spraying shoes or boots and lower pant legs with repellent containing DEET or picaridin is highly effective. Pretreatment of clothing with permethrin is recommended. Travelers in the American tropics should never walk through grassy areas in shorts.

Jigger Flea. *Tunga penetrans,* the jigger flea or chigoe, originally found in South and Central America, has now spread to East and West Africa and India. The fertilized female flea enters the feet through cracks in the soles, between the toes, and around the toenails. The female swells to the size of a pea and may be readily identified as a white papule with a central pit, through which the female extrudes excrement and eggs. When eggs are ripe for release, intense itching causes scratching that helps release large numbers of flea eggs. Incomplete removal of the jigger frequently results in complications caused by secondary infection. A simple extraction technique virtually eliminates complications. Open the skin over the nest of eggs with a surgical blade. Fold back the flaps, remove the easily identified egg sac, and with tweezers, remove the head of the female flea, which can be seen once the egg sac has been removed. Wash the area with hydrogen peroxide.[24]

Myiasis. Myiasis (skin infestation by fly larvae) is common in many regions of sub-Saharan Africa (the tumbu fly, *Cordylobia anthropophaga*) and Central and South America (the human botfly, *Dermatobia hominis*). The victim finds an itchy swelling that slowly enlarges into a lesion with a single breathing pore from which bubbles emerge or from which drains slightly bloody fluid. Later, movement is felt under the skin as the developing larva wriggles around.

Removing the larvae before they emerge on their own is generally advised. Surgical excision, however, should be undertaken with caution because accidental rupture of the larval tegument can lead to secondary infections. Various methods to close off the breathing pore so the larva will emerge on its own include application of bacon fat, meat, chewing gum, or petroleum jelly. Extrusion of the larvae may be hastened by applying the Extractor device.

Scorpions and Spiders. Stinging scorpions and venomous spiders are common throughout the tropics and provide another reason to exercise caution before sitting down or placing a hand on logs, bushes, or the ground. The large, aggressive banana spider, *Phoneutria nigriventer,*[58] causes excruciating pain, which may require local anesthetic infiltration of the bite site for relief.

Venomous Moths, Butterflies, and Caterpillars. The larvae and adults of a number of moths (genus *Hylesia*) and butterflies bear venomous hairs that may cause skin eruptions. A rash may result from direct contact with the adults or larvae or by windblown hairs. Direct contact with certain Amazonian caterpillars can cause disabling pain.

In the Amazon tropics, noxious smoke from burning garbage (e.g., plastic wrappers) may cause large tree-dwelling caterpillars to loosen their hold on overhead branches and rain down on unwary campers.

Treatment of Lepidoptera envenomation may require injection of lidocaine at the site of intense pain and administration of analgesics, antihistamines, and corticosteroids. Moth hairs may be removed from clothing or skin with adhesive duct tape or sticky lint removers.

Wasp and Bee Stings. Sudden, intense pain from the sting of certain species of tropical wasps and bees can be so severe that it knocks the victim to the ground as though hit with an electric shock. Perfumes and brightly colored or flower-patterned clothing should be avoided. Bird-watchers should not venture too close to the hanging nests of yellow-rumped caciques and oropendolas, because wasps are invariably associated with these nests.

Fish

Stingray. The stingray, a flattened, cartilaginous cousin of the shark, may be encountered buried just beneath the surface of the bottom ooze in tropical rivers and streams throughout the Amazon basin, Africa, and Indochina. Rays inflict injury by lashing upward with the caudal appendage, driving one or more retroserrated venomous spines deep into the victim's foot, ankle, or lower leg. This produces agonizing pain, often accompanied by headache, vomiting, and shortness of breath. After the initial phase of envenomation, tissue necrosis may develop. Wearing shoes or boots when wading in water does not always prevent a stingray from jabbing its barb into the foot or leg. Prevention lies in shuffling the feet along the bottom so that the ray will have enough warning to glide away safely.

Electric Eel. The so-called electric eel (actually an eel-shaped fish) is encountered from Guatemala in Central America to the La Plata River in South America and is especially common in the Amazon region. A person can drown after being stunned by a jolt from this fish.

Electric eels are said to prefer deep water. Inhabitants of regions heavily infested with eels report a slight tingling sensation when one is close. No practical way exists to prevent these shocks.

Candirú. The candirú is a toothpick-sized parasitic catfish that inhabits Amazonian waters and has been purported to invade the urethra of urinating humans. Orifice penetration by the wily candirú can be prevented by wearing a tight bathing suit and not urinating underwater. Supposed native methods of dislodging these fish from the urethra include drinking a tea made from the green fruit of the jagua tree, *Genipa americana*.[6] Surgery is the recommended treatment. In his exhaustively referenced book entitled *Candiru: Life and Legend of the Bloodsucking Catfishes,* author Stephen Spotte downplays much of the lore regarding this little fish.[53]

Piranha. Although no human deaths have been documented, piranha have nipped off the fingertips of canoeists dangling their hands in the water. Attacks on humans by the speckled or dark-banded piranha, *Serrasalmus maculatus,* in dammed waters in Brazil have been linked to the fish's behavior of defending its brood from perceived predators.[25]

Mammals

Bats. Vampire bats are found throughout Mexico, Central America, and South America, especially in areas that have large cattle ranches. Sleeping humans are unaware of the presence of a feeding bat; the phlebotomy is painless. Both vampire and fruit bats carry rabies. Sleeping under mosquito netting helps prevent bat bites. The risk for rabies can be reduced by prophylactic human diploid cell rabies vaccine.

Rabies transmitted to humans by vampire bats in the Americas may present as "dumb" (paralytic) rabies, often characterized by an ascending paralysis similar to that of Guillain-Barré syndrome, without the initial symptoms of hydrophobia, agitation, and hypersalivation characteristic of "furious" rabies.[22]

Dogs. Most native groups keep dogs for hunting. Populations with a history of recent tribal warfare often keep packs of dogs close by as an early warning system. These semiwild dogs should be treated with caution; threatening them may cause immediate attack because they are not easily intimidated. When approaching huts or villages, the traveler should allow porters to deal with the dogs.

Dogs intent on biting often adopt particular behavior patterns. A dog protecting its territory crouches low, straightens its back and tail, emits a deep guttural growl, and stares fixedly at a specific part of the person's anatomy. Such behavior indicates imminent attack, and a sharp blow to the nose may be necessary. Freezing in place may prevent an attack, and direct eye contact should be avoided.

Jaguars. Although documented noncaptive jaguar attacks are extremely rare,[41,52] jaguar tracks are often encountered along muddy trails throughout the animal's range in Central and South America. On spying a fresh track, native guides often comment in a dismissive way, "This animal has been watching us—it is just curious." Recommendations are based on advice for avoiding a cougar attack. Increase your apparent size by raising your arms above the head and waving an object, such as a backpack or stick, or opening a jacket. Yell, shout, whistle, or speak loudly and forcefully in a low, deep tone of voice. Back away slowly; do not turn your back and run.[12]

Reptiles

Snakes. Snakebites are rare; 450,000 hours of fieldwork at sites in Costa Rican rain forests were documented without a single snakebite[11] (see Chapters 35 and 36).

Most poisonous snakes tend to blend into their surroundings, and nonnatives rarely see them. The most effective protection is putting a jungle-reared guide in front on the trail. Natives almost always spot a poisonous snake and can quickly dispatch it.

Snakes are often encountered along the shorelines of rivers and small streams. Particular caution is needed when hiking in such areas or when disembarking from a canoe or rubber raft. In the forest, the hiker should always step onto a log and then step away from it. The log should not be straddled; snakes often are encountered where the log makes contact with the jungle floor. Because many venomous snakes in the tropics are heat-seeking and hunt at night, caution is needed.

Anacondas (water boas) feature in the folklore of all native cultures in the regions of Amazonia where these enormous snakes (up to 9 m [29.6 feet] long) live. These nonpoisonous snakes kill by looping coils around prey and then tightening the coils, suffocating the victim. Anecdotal reports of anacondas attacking and swallowing humans, particularly children and women bathing at the edge of jungle streams, are unconfirmed.

Alligators and Crocodiles. Although they appear torpid lying in the sun, alligators and especially crocodiles can move amazingly fast. Humans cannot outswim or outrun a charging crocodile. Bites should be treated with thorough cleaning of the wound, surgical debridement if necessary, tetanus prophylaxis, and an appropriate antibiotic. A study of the oral flora of 10 alligators captured in Louisiana revealed various aerobic and anaerobic organisms susceptible to trimethoprim-sulfamethoxazole.[19] A fluoroquinolone or third- or fourth-generation cephalosporin should be considered as an alternative.[34]

Plants

Armed or Spine-Bearing Plants. Spine-bearing trees abound in forested areas of the tropics. The peach palm *(Bactris gasipaes),* a tall, slender palm with heart and fruit mesocarp prized by natives, is found from Nicaragua to Bolivia. The trunk of this tree is ringed with needle-sharp spines (Figure 60-12). Peach palms often grow alongside trails. Contact with this palm can result in penetration of spines deep into the flesh. Spines that enter a joint space may require surgical extraction. Secondary infection and inflammation may occur.

Chicha. Throughout much of Latin America, particularly in the Andean countries, a beer-like beverage known as chicha is consumed. Fermentation is initiated by masticating maize, cassava, plantain, or the fruit of the peach palm. Salivary enzymes

FIGURE 60-12 Needle-sharp spines ring the peach palm. *(Courtesy John Walden.)*

hydrolyze the starch to sugar, resulting in a beer of 2% to 4% alcohol content. Some traditional populations consume copious amounts of chicha; the average daily intake among men of the Shuar and Achuar tribes of Ecuador and Peru is 7.6 to 11.4 L (2 to 3 gal); and for women 3.8 to 7.6 L (1 to 2 gal).

From a health and safety standpoint, and in the social context, there are several aspects to chicha consumption that give pause. In addition to aesthetic considerations arising from its origin by way of human saliva, the starchy substrate used for preparing chicha is often kneaded by unwashed hands—a ready source of pathogens transmitted by the fecal-oral route. Although natives accustomed to daily chicha consumption seem to be unaffected with alcohol-related instability on the trail, the nonnative jungle traveler will almost certainly experience problems maintaining balance, particularly when crossing single-log bridges, if excess chicha is consumed before or during trekking.

Because chicha consumption is such a significant element in the social fabric of many tribes, to refuse to partake of the beverage can be a social gaffe. I have found it acceptable to inform my hosts, in a joking manner, that I cannot trek and drink chicha throughout the day because "I stagger and fall off logs," but that I will join in the evening rounds of ritual drinking. Among the Shuar and Achuar, eye contact with a woman who is serving chicha is a cultural signal to initiate a sexual encounter. To avoid misunderstanding, hold the chicha bowl in the outstretched hand with the head turned to face *slightly* to one side or downward; it is not necessary to avert eye contact in a dramatic fashion.

Saw Grass. In many regions of the tropics, saw grass is an ever-present nuisance. The scalpel-like blades of this grass can slice into exposed skin. Even when treated with antibiotic ointment, the lacerations often take 1 to 2 weeks to heal. Hikers should avoid saw grass; special care is needed when working with a machete.

Hallucinogenic Plants

> ***Hallucinogens permeate nearly every aspect of life in primitive societies. They play roles in health and sickness, peace and war, home life and travel, hunting and agriculture; they affect relations among individuals, villages, and tribes. They are believed to influence life before birth and after death.***[48]

To ignore the ubiquitous use of psychoactive drugs among jungle-dwelling tribesmen throughout Central and South America is to deny a key element in understanding the rich and complex weave of Amerindian life. Powerful drugs, such as ayahuasca *(Banisteriopsis)*, brugmansia, the *Virola* snuffs, and yopo *(Anadenanthera peregrina),* are used by shamans and individuals seeking the truth through visions and a supernatural experience.

Ayahuasca. Also known as caapi, natema, pinde, and yajé, this woody vine *(Banisteriopsis caapi)* is found throughout western Amazonia in Colombia, Ecuador, Peru, Bolivia, and Brazil. The term *ayahuasca* derives from the Quechua language and has been translated as "vine of the soul." The hallucinogenic activity derives primarily from harmine, the major β-carboline alkaloid in the plant. Indigenous peoples use additives (leaves of the shrub *Psychotria* and a forest liana *Diplopterys cabrerana*) to prolong and strengthen the intoxication. In addition to experiencing vivid visual hallucinations, users often report a distinct sense of clairvoyance. Adverse effects of ayahuasca ingestion include nausea, dizziness, and vomiting. For some users, the visual hallucinations are intense and disturbing.

Brugmansia. Commonly known as borrachero, floripondio, huacacachu, or toá, the lovely, large bell-shaped flowers of brugmansia are encountered throughout the Andean foothills of western Amazonia. Despite their beauty, these are among the most powerful and dangerous plant hallucinogens. The leaves and seeds of these bushy plants contain tropane alkaloids, including scopolamine, hyoscyamine, atropine, and secondary alkaloids.[49] The effects on the user tend to be highly unpleasant to the degree that those who partake of brugmansia often must be physically restrained.

Virolas. Known as epena, nyakwana, and yakee among indigenous populations of northwestern Amazonia, these hallucinogenic snuffs are made from the blood-red resin of the inner bark of trees (*Virola* species). The narcotic effect is due to tryptamine alkaloids. The drug acts rapidly. The excitement phase is followed by lack of coordination, copious nasal discharge, and vomiting. A curious effect of ingesting *Virola* snuff is macropsia, in which objects, including hallucinatory spirits (known as hekulas among the Yanomami Indians of Venezuela and Brazil), appear greatly enlarged.

Yopo. Seeds of *Anadenanthera peregrina,* a South American tree of the bean family Leguminosae, are used to prepare this tryptamine-containing hallucinogenic snuff. Employed by Indians in the Orinoco basin region of Amazonas State, Venezuela, and adjacent regions of northernmost Brazil, yopo is inhaled to communicate with spirits during the phase of intoxication. In preparation, seeds are removed from the distinctive dangling pods and, after being moistened, rolled into a paste that is roasted over a fire and hardened for later use. The dried paste is pulverized and the resulting powder mixed with lime from snail shells or ashes from certain plants. The narcotic is blasted into the nostril through a long tube with the help of an assistant (Figure 60-13). The user experiences immediate effects, including muscular twitching, nausea, profuse nasal secretions, and visual hallucinations.[42] As in the case of *Virola* snuffs, an abnormal exaggeration of the size of objects is common.[48]

Detailed discussions of additional New World hallucinogens, as well as African and Asian hallucinogens used by jungle-dwelling tribesmen, are found in the references listed online at expertconsult.com.[48-51]

Should travelers partake of hallucinogens used by tribesmen? Some argue, with a certain validity, that outsiders cannot possibly acquire insight into the Amerindian's sense of the cosmos without ingesting their mind-altering drugs and so make the case for limited use by anthropologists and others who plan to live and work closely with tribal populations for prolonged periods.

FIGURE 60-13 Hallucinogen is administered through a long tube. *(Courtesy John Walden.)*

FIGURE 60-14 Poison-dart frog. *(Courtesy John Walden.)*

Although none of the hallucinogens discussed in this chapter is known to be addictive, "recreational" use could, in the author's opinion, have significant adverse consequences for certain individuals, including a lingering blurred sense of reality. Therefore, these powerful intoxicants should be avoided.[58,59]

MISCELLANEOUS HAZARDS

Poison-Dart Frogs

Poison-dart frogs are tiny, brilliantly colored species of the genus *Dendrobates*. They are encountered in Central America and northern South America (Figure 60-14). *Phyllobates terribilis* secretes a toxin from its skin so powerful that a lethal dose could be absorbed if enough secretion entered an open wound. It is wise to avoid all contact with brilliantly colored frogs, caterpillars, and snakes.

Falling Trees

Tropical trees do not have deep roots and often fall in relatively modest winds. In many regions of the world, the risk for snakebite is significantly lower than the risk for injury or death from falling trees. In the forest, hammocks should be slung away from large trees. Travelers setting up camp should always look up at the branches of any trees near camp; although the base of the tree may appear sound, higher areas may be rotted.

Fording Rivers

The hiker should never attempt to cross a fast-flowing or deep river with a pack on his or her back. Regaining footing in a rapidly moving current can be difficult. Unless experienced in crossing such streams, the traveler should take the hand of a native guide or porter.

Canoe Travel

Most riverain peoples of the tropics are extraordinarily skilled at hewing felled trees into dugout canoes that perfectly meet their daily needs. The Chachi (Cayapa) Indians of northwest Ecuador construct canoes of astounding symmetry and visual delight. These craft are often "tippy" in the extreme and pose a problem for the inexperienced traveler not reared from infancy using these watercraft and therefore lacking the innate sense of balance of the local population. When crossing particularly hazardous stretches of jungle rivers, care must be exercised. It is usually best to sit directly on the floor of the canoe to lower the center of gravity and thus avoid a sudden reflex movement that would tip over the canoe.

Log Bridges

On frequently used trails, natives generally place a single log across creeks, ravines, and swampy areas. These log bridges may be up to 6.1 m (20 feet) high and 22.9 m (75 feet) long. Good balance is essential. Because a backpack impairs balance, a porter should carry it across. Scooting across a particularly dangerous log bridge on one's buttocks is always an option.

Mercury Contamination

Travelers to the Amazon basin should be aware of the serious, widespread contamination of waterways by mercury that gold miners (garimpeiros) use to process their ore. Travelers should exercise caution in choosing rivulets as a source of potable water in areas where mercury contamination is known or suspected. Seychelle Environmental Technologies, Inc., makes a line of filters claimed to remove an array of organic and inorganic contaminants, including mercury.

Riverain Hazards

Rising Rivers. Streams, particularly narrow ones bounded by vertical banks, can rise 6.1 m (20 feet) in a few hours as a result of intense rains. Camp should not be set up on an island or beach in a small canyon during the rainy season. A cloudburst in the headwaters can send a wall of water rushing downstream, even though it may be a clear, moonlit night at the campsite.

Safety of Swimming. River depths often drop off precipitously within 1 yard of shoreline in the swift-flowing outer loop of jungle streams. Probing ahead with a walking stick will help avoid sudden submersion (see Traveling with Children in the Tropics, below).

Leptospirosis

See Chapter 34.

Schistosomiasis

See Chapter 81.

Quicksand

Because the human body is less dense than quicksand, individuals encountering quicksand along river banks or lake shorelines or in marshlands of tropical rainforests are not at risk of being sucked beneath the surface.[31] Panic-driven flailing of the arms and legs, however, will worsen the sinking process, making extraction by the victim or a helper more difficult. Extraction from quicksand involves making slow movements and, if necessary, lying on one's back and spreading the arms and legs (to increase the surface area) to allow you to float. The best way to prevent a surprise encounter with quicksand is to follow in the steps of a local guide who knows where and where not to step.

Aquatic Plants

Free-floating aquatic plants, such as water hyacinth *(Eichhornia crassipes)*, encountered in the Americas, Africa, and Asia, may pose a risk of drowning when an individual panics and becomes entangled in the dense mat of flowers, leaves, leaf stems, and free-hanging roots. Extraction from a raft of aquatic plants can be accomplished by floating prone on the top of the mat and using the hands to slowly pull oneself to shore.

TRAVELING WITH CHILDREN IN THE TROPICS

The following guidelines should be considered when trekking with children in the tropical forest:

- Do not attempt a daylong hike. Unlike indigenous children, visitors cannot hike all day in the humid tropical forest. Preadolescents should hike only 1 to 2 hours; children age 12 to 16 years can hike 2 to 3 hours. Do not subject a child to demanding jungle trail conditions unless the child has had extensive experience hiking in hot and humid climates.
- Do not attempt difficult or dangerous trails.
- Avoid trekking during the rainy season.
- Keep the child well hydrated.
- Provide proper footwear (running or hiking sneaker-type of shoes or boots with an adequate tread). Avoid leather boots.
- Keep the child ahead of you and behind a native guide. Children should not be out of sight on the trail.
- When wading across rivers, have an adult native guide hold the child's hand.

- Always have children wear a properly sized life vest while rafting, taking canoe trips, or crossing deep, swift, or wide rivers.
- Do not allow a child to carry any equipment in a daypack other than two liter-sized bottles of drinking water.
- Ensure that routine vaccinations are up to date. Special vaccinations, such as yellow fever and typhoid, should be considered for certain jungle areas. Hepatitis A vaccine is recommended. Antimalarials are indicated.

Any child who plans to visit the tropics should be a strong swimmer. Many natives begin swimming in infancy and are accustomed to deep or rapidly flowing water that would be extremely hazardous to visiting children. Swimming holes are often located in the swift-flowing outer loop of jungle rivers, where depths may reach 1.8 m (6 feet) or more within a yard of shoreline.

SURVIVAL

Every year, inexperienced people enter the jungle and become lost. After a person ventures only a few yards into the forest, especially jungle that has been cleared and is now a tangle of secondary growth, everything begins to look the same. To avoid becoming lost, travelers should always have an experienced guide when traversing unfamiliar territory.

Tribal peoples of the world's tropical forests have an uncanny ability to find their way and arrive at the desired destination, even after days of travel. They can always find food and water and, if necessary, rapidly construct a shelter or weapon.

Occasionally, travelers are left behind on the trail by indigenous guides. Unintentional desertion occurs when trekkers hire natives who have had no experience with neophytes. Realizing that their charges cannot keep up on the trail, the guides run ahead and sit down to rest, not knowing that others cannot navigate the trail alone. Travelers who want to avoid being left behind on the trail should hire a guide who is experienced in traveling with nonnatives. Suitable guides and porters can usually be identified with the help of a village leader, local school teacher, village health worker, missionary, or anthropologist.

RESCUE STRATEGIES

For individuals in a jungle survival situation, lifesaving items include a large-scale map, Global Positioning System (GPS) unit, some form of electronic voice communication, and, especially, a machete. Topographic maps are available from international and national mapping agencies, but may be limited in availability and coverage for minimally explored tropical rainforest regions. Satellite images are available from Google Earth and Digital Globe (800-655-7929; digitalglobe.com). Imagery may be compromised by cloud cover and low resolution for many remote jungle regions throughout the Amazon Basin. In areas of hydrocarbon exploration and production, however, imagery may be of exceptional quality.

Small, lightweight GPS units display precise latitude, longitude, and altitude. Such information is extremely useful for navigation and for communicating one's location to rescue aircraft. Newer units quickly lock onto satellites and are more likely to work under the jungle canopy.

Trekkers contemplating an expedition into largely uninhabited and unexplored regions should consider buying a compact personal locator beacon, such as those made by ACR Electronics (acrelectronics.com). When deployed with a clear view to the sky, these 406-MHz units offer a reliable method of alerting various rescue services through a global satellite system. The units must be registered to the proper national authority. For U.S. citizens, the responsible agency is NOAA-Sarsat (beacon.registration@NOAA.gov). These units should be activated only in a true emergency when lives are at risk.

Handheld satellite phones are available for worldwide communication. Although currently expensive to purchase and operate, their potential to provide rescuers with a precise GPS location makes these lightweight phones worthy of serious consideration for inclusion for wilderness travel, especially on expeditions into areas of extreme isolation. I strongly recommend inclusion of satellite phones in one's gear if going off the beaten path. Portable solar panels are lightweight and allow the expeditioner to charge electronics, such as GPS units, satellite phones, and digital cameras.

Lightweight, handheld, very-high-frequency (VHF) aircraft transceivers are excellent for emergency communications. Visitors to remote areas should know the radio frequencies used by rescue aircraft. VHF transceivers are line-of-sight instruments and thus are most useful when aircraft are overhead without objects, such as trees or mountains, between the handheld unit and the aircraft. In many regions of the world, the Mission Aviation Fellowship (MAF) provides air service to remote airstrips in small villages. If assistance is needed, a handheld radio transmitter can be used to request an MAF STOL aircraft.

Bush pilots appreciate having information on the condition of seldom-used airstrips. A crude but acceptable device can be constructed to measure airstrip hardness (Figure 60-15). Cut a pole exactly 5.1 cm (2 inches) in diameter and about 1.8 m (6 feet) long. Starting exactly 15.2 cm (6 inches) from one end, taper that end to a point. Lash a cross-member on the pole, and have a person weighing about 77 kg (170 lb) stand with assistance on

FIGURE 60-15 **A,** Young man sharpening a stick to a point. **B,** Lashing a cross-member to a pole. **C,** Standing on the pole to take measurements of the depth of penetration into the airstrip. *(Courtesy John Walden.)*

the cross-member. Make a map of the strip, noting the depth to which the pointed end of the pole sinks into the ground at several dozen sites. Communicate this information to the pilot by radio. If the pole goes in only 5.1 cm (2 inches) in most areas, the strip is considered ideal; sinking in 5.1 to 10.2 cm (2 to 4 inches) is marginal; and penetration beyond 10.2 cm (4 inches) indicates that the airstrip is unsuitable for landing and takeoff.

If prompt rescue is not feasible, the goal is to get out of the jungle as quickly as possible to an area of human habitation. The traveler should continually move downstream at a fast pace. Inhabited areas usually have a trail running alongside a stream. The trail may veer away from the stream where natives have cut a path to connect two villages. Marking the trail every 9.1 m (10 yards) with a machete makes it easier to return to the starting point. To avoid confusion, the traveler should mark trees only on one side of the trail. Recall will be increased by audibly describing the surrounding topography as one hikes down the trail.

Where human paths are in frequent use, identifying a trail is fairly easy. Seldom-used trails or any trail traversed during times of optimal plant growth may be extremely difficult for the non-native to identify and follow. Even under adverse circumstances, however, there are clues to trail identification. Paradoxically, concentrating only on the actual footpath will almost certainly cause a person to lose sight of the trail. Think of the jungle trail not as a track on the ground but as the intestinal lumen of "some gigantic leafy creature,"[26] with vertical margins, often an overhead horizontal boundary, and sometimes a visible path beneath the feet. Diagonally sliced saplings or neatly severed branches indicate someone has used a machete. There is a particular reflectivity off the ground where humans have trod; this reflectivity is the best way to follow a trail at night. These trail-finding clues are often so subtle that you may sense the trail rather than see it. Game trails meander and are narrower than human trails.

In the jungle setting, navigation with a compass for a distance of more than 182.9 m (200 yards) is fraught with hazard. Travelers should not attempt to travel overland if lost, inexperienced, or on their own, unless a significant landmark is visible or sounds of humans or domesticated animals, indicating a settlement, are clearly heard.

A raft may be constructed by lashing logs together with rope or tough, pliable jungle vines. Balsa *(Ochroma pyramidale),* a tall, fast-growing tree found throughout much of tropical South America as well as Central America into southern Mexico, is ideally suited for construction of rafts due to the wood's exceptionally light weight, relative strength, and buoyancy. Balsa is often found growing alongside rivers and has the following characteristics: tall, columnar trunk with branches and leaves bunched at the top, which gives the tree a "skinny" look; beige or gray-beige trunk; bark that is smooth but tends to flake, giving it a mottled appearance; and broadly heart-shaped, more or less three-lobed leaves. Six logs approximately 3 to 4.6 m (10 to 15 feet) in length and 20.3 to 30.5 cm (8 to 12 inches) in diameter, freshly cut from young balsa trees, are lashed together using rope. Thin, supple bark stripped from local trees handily growing at the river's edge can be knotted together to form an excellent lashing; certain jungle vines (lianas), pretested for suppleness and strength, also can be knotted together for lashing (Figure 60-16).

FIGURE 60-16 Balsa raft and four-legged "tetrapod" frame to hold gear above the water.

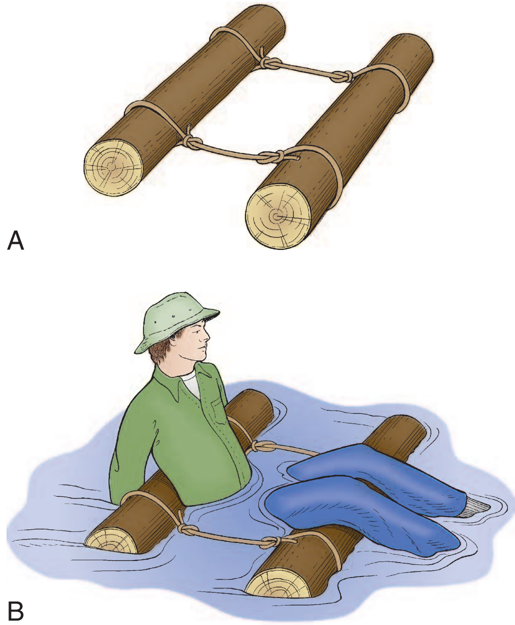

FIGURE 60-17 Log flotation device. **A,** Two lightweight logs are tied together. **B,** Device in action.

For down-river travel, a properly proportioned balsa raft can carry three to four adult men and adequate gear. Because water will usually wash over the surface of the raft, the buttocks and legs will be wet more often than not. Gear that must remain dry should be suspended from a tripod or tetrapod frame made of strong sticks, sharpened at one end and driven 5 to 7.6 cm (2 to 3 inches) into the balsa raft. Properly constructed rafts are surprisingly stable, are capable of safely running class II rapids, and will last for days with occasional relashing as the logs begin to shift over time. Subjectively, there is a sense of tranquility stemming from the "giving" motion of floating downstream on such rafts; one has the feeling of running *with* the river through fast-flowing stretches and small rapids, in contrast to fighting the current in a lurching canoe.

Bamboo can also be used to construct a first-class raft. First, cut down six stalks of bamboo approximately 3 m (10 feet) long. Next, notch out windows on opposite sides of each section of bamboo near each end. Now, run a sturdy pole through the windows that have been lined up, and lash it securely with rope or vines. A raft constructed in this manner should float for several days. Although it is possible to get away with one row of bamboo poles lashed together, better buoyancy is often obtained using two tiers. Because movement of the sections eventually breaks the bindings, it is best to coil up 18.3 m (20 yards) or so of additional vines for use when the original bindings wear out. An easier-to-build version involves a row of bamboo poles that is 3 to 6 m (10 to 20 feet) long, 6 to 10 stalks wide, with bamboo cross-bracings spaced every 0.9 m (3 feet) lashed across the top.

A log flotation device may be constructed by tying together two balsa logs or other lightweight wood placed 0.6 m (2 feet) apart (Figure 60-17).

A "brush" raft may be made by placing buoyant vegetation within clothing or a poncho. Dry leaf litter ("duff") or plants such as water hyacinth may be used.[55]

FOOD

Food is readily available in inhabited regions. Even abandoned villages yield enough fruit and vegetables on which to survive. Throughout the tropical world, bananas and the large plantain "cooking banana" are ubiquitous. Root crops, such as taro, yams, and yucca, should be sought. Yucca roots should be shredded or pounded and then boiled to release their toxic compounds.

As an extra precaution, the wet pulp should be flattened into a "pancake" and cooked on a grate to eliminate any remaining volatile hydrogen cyanide gas.

All land crabs, mammals, birds, freshwater fish, turtles, snakes, and lizards are edible, but should be cooked first to eliminate parasites. It is virtually impossible to kill game without firearms. In inexperienced hands, traps and snares are not effective. Much better results are obtained from fishing.

Edibility Test

In a jungle survival situation, the goal is to get out as quickly as possible. In the rare circumstance in which the victim cannot recognize any familiar edible plant; has been unable to capture minnows, crayfish, and insects; and, for whatever reason, is unable to walk out of the jungle or expect prompt rescue, the following abbreviated version of the Universal Edibility Test recommended by the U.S. Army[54] and the *SAS Survival Guide*[63] may be used to test an unknown plant:

Caveats

- Never eat mushrooms.
- Avoid unknown plants that have the following:
  - Milky or discolored sap
  - Beans or seeds inside pods hanging from trees
  - Bitter or soapy taste
  - Peach or "bitter almond" scent
  - Tiny barbs on the stems and leaves that could irritate the mouth and digestive tract

Choose a plant that is abundant in the area. First, inspect the new plant, and then crush a small portion; if it smells of bitter almonds or peaches, discard it. Check for skin irritation by squeezing some juice into the inner portion of the upper arm; if discomfort, rash, or swelling occurs, discard the plant. Next, proceed through the following steps, waiting 15 seconds between each to see if there is any reaction, and discard if discomfort is felt:

- Place a small portion on the lips
- Place a small portion in the corner of the mouth
- Place a small portion on the tip of the tongue
- Place a small portion under the tongue
- Chew a small portion

Swallow a small amount and wait 5 hours. Drink or eat nothing else during this period of waiting. If, after 5 hours have passed, there is no soreness of the mouth, excess belching, nausea, vomiting, or abdominal pains, the plant may be considered safe.

WATER

Water may be made safer by boiling or using chemical disinfectants. Drinkable water may be found in lianas, often called "water vines," throughout jungle regions. Vines that contain water are fairly easy to identify because they tend to resemble the "grapevines" of North American forests and have rough, scaly bark. These vines may be several inches thick and contain surprising amounts of clear water. Vines that do not contain drinkable water tend to have smoother bark and, when cut, exude sticky, milky liquid. Travelers should not drink from vines that contain milky, latex-like sap; this substance is poisonous. Maximal amounts of water are collected from water-bearing vines if the first cut is high on the vine and the second cut is lower on the vine near the ground (Figure 60-18). When the water stops flowing from the cut section, cutting about 15 cm (6 inches) from the opposite end will start the flow again.

Water may be trapped within sections of certain types of green bamboo. Bamboo that contains water makes a sloshing sound when shaken. Water also may be obtained from green bamboo stalks by bending a stalk over, tying it down, and cutting off the top. Water dripping from the severed tip can be collected in a container during the night[55] (Figure 60-19).

Large amounts of water can be found in the voluminous natural cisterns formed by the cup-like interiors of epiphytes (air plants), such as bromeliads (Figure 60-20). The water should be strained through a cloth.[55]

Water may be collected from a banana or plantain plant by cutting the plant about 0.3 m (1 foot) above the ground and scooping out the center of the stump into a bowl shape. The hollow thus formed fills immediately with water. The first two fillings have a bitter taste and should be dipped out. The third and subsequent fillings are drinkable. A banana plant can furnish water in this fashion for several days[55] (Figure 60-21).

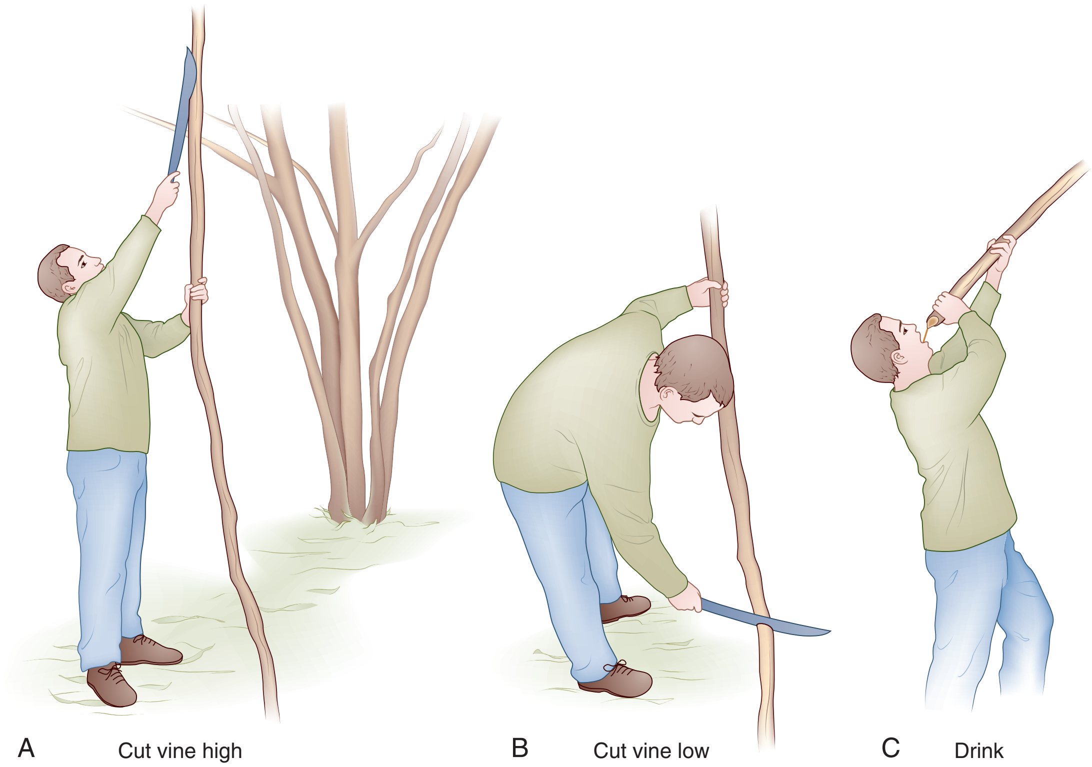

FIGURE 60-18 Water vine: First cut is high **(A)**; second cut is low **(B)**.

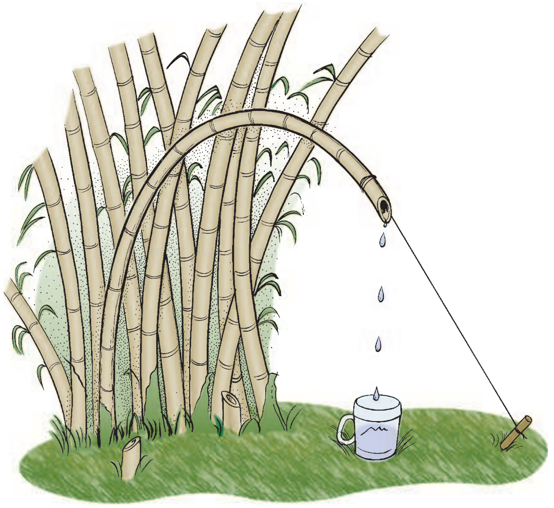

FIGURE 60-19 Bamboo can be a source of water.

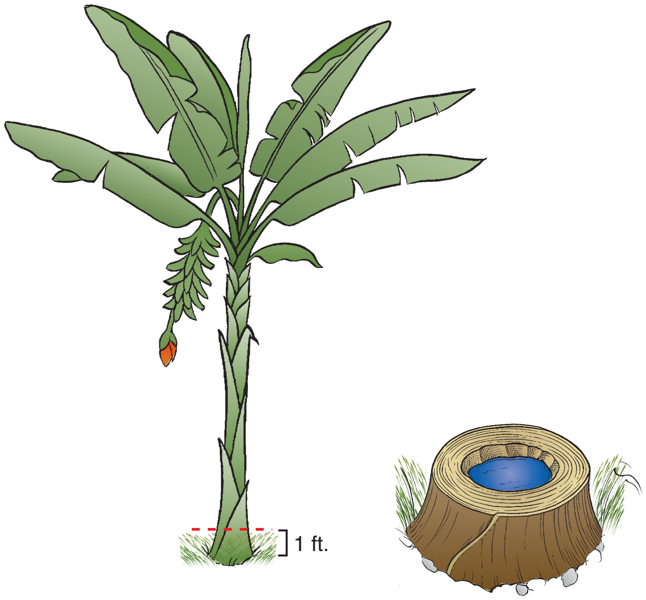

FIGURE 60-21 Water collected from a banana plant.

In coastal regions, unripe (green) coconuts provide adequate supplies of refreshing milk. The milk of mature coconuts has a laxative effect and should be avoided.

SHELTER

Abandoned, temporary shelters previously constructed by natives on hunting expeditions seem to attract particularly aggressive, large biting spiders and stinging ants. Also, venomous snakes may be attracted to rodents residing in these abandoned shelters. It is often preferable to take the extra time to set up a new camp than to risk encountering venomous insects, arachnids, and snakes.

In an emergency, a proper shelter can be constructed using only plant materials. Figure 60-22 illustrates the basics of constructing a sleeping platform and lean-to. A shingled covering can be made quickly and easily from long, broad banana or heliconia leaves. Tropical palms provide a more substantial roof, but require more time and skill in construction. After selecting a suitable ground-hugging species or chopping down a slender tall palm (palm trees with spines often provide the best fronds), each frond is separated into halves by grasping it at the distal end, separating the leaves as though parting hair down the middle, and splitting the frond in two with a quick jerk (Figure 60-23). The halves should be overlapped like shingles and secured to the roof framework.

It is much easier to construct an adequate shelter using a tarpaulin (see Camp Life, earlier).

FIGURE 60-20 Water can be found in the natural cisterns in bromeliads. *(Main photo courtesy John Walden; inset photo courtesy Erich Lehenbauer.)*

FIRE

In addition to boiling water for drinking and cooking food, fire lifts the spirits, warms the body on uncomfortably cool jungle nights, and can be used to signal rescue aircraft.

Tinder and Kindling

Small strips 0.3 × 5 × 10.2 cm (0.1 × 2 × 4 inches) of rubber tire and a butane lighter carried in a survival kit are an excellent combination for starting a fire, even in wet conditions. Tampons make a good fire-lighting aid. The silk-cotton or ceiba tree *(Ceiba*

FIGURE 60-22 Sleeping platform.

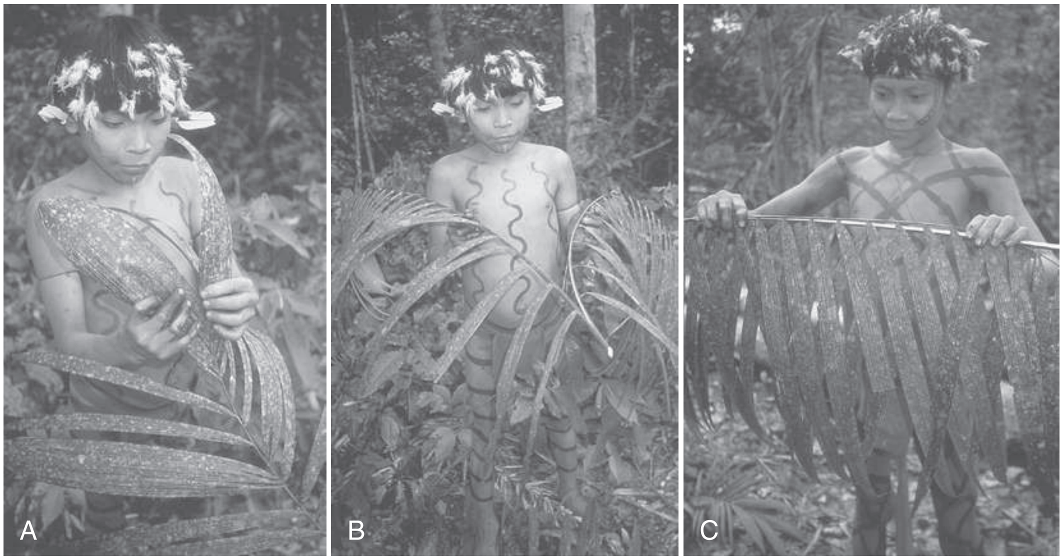

FIGURE 60-23 Indian splitting a frond to make a covering for a lean-to (see text). *(Courtesy John Walden.)*

pentandra), found throughout the American, West African, and Southeast Asian tropics, produces balls of cotton-like fibers, known as *kapok,* which immediately catch fire and make ideal tinder. The cloth-like fibrous material at the base of palm fronds makes excellent tinder.

Bamboo Fire Saw

If you do not have matches or a butane lighter handy but have access to bamboo, you can make a bamboo fire saw[55,58] (Figure 60-24).

1. With your machete, cut a section of bamboo that is 0.9 to 1.2 m (3 to 4 feet) long.
2. Split the section the long way with the machete. One of the resulting long sections will be the "base board."
3. Shorten one of the split sections to about 0.3 m (1 foot) in length. This section will be the "running board."

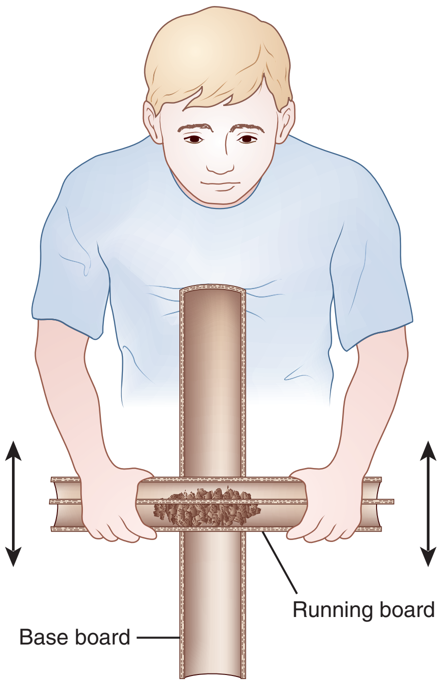

FIGURE 60-24 Bamboo fire saw. *(Redrawn from Walden JB:* Jungle travel and survival, *Guilford, Connecticut, 2001, Lyons Press, p 175.)*

4. If kapok, palm fiber, or other suitable kindling is not available, with the machete blade, prepare tinder by scraping the outer sheath of a piece of bamboo. You need one large handful of scrapings.
5. Cut a narrow notch at 90 degrees on the outer (convex) side of the running board so that it just breaks through to the inner wall. This will serve as a guide to slide the running board rapidly over the base board.
6. Fill the running board with a fluff ball of tinder.
7. Place a thin strip of wood or a strip of bamboo over the ball of tinder to hold it in place.
8. Anchor the long section of bamboo (base board) with one end in the ground or against a rock or solid log and the other end wedged firmly against your abdomen. The sharp edges of the base board should be facing upward.
9. Carefully holding on to each end of the strip of wood that is keeping the tinder trapped inside the running board, rapidly and vigorously slide the running board up and down the base board with the groove against the sharp edge of the base board.10. You will know that you are exerting sufficient effort to generate enough friction to ignite the tinder when you feel nearly exhausted, have worked up a sweat, and begin to entertain thoughts such as, "This just isn't worth it."
11. As soon as wisps of smoke begin to billow up from the tinder, gently blow upon the tinder until it bursts into flame.
12. Add small pieces of kindling, and avoid smothering the fire.

Using this or any other friction method for making fire is hard work, but it *can* be done.

Bamboo Container

Large-diameter bamboo makes a great "pot" for heating water to a sufficient degree to cook items such as crawfish and minnows. To prepare a bamboo cooking pot, take a section of bamboo cut just past each end joint. Notch out an opening by making cuts at 45 degrees near each end, and then run the machete blade between the notches and pop out the "plug." Support each end of the bamboo pot on stakes or sturdy Y-branched sticks that have been driven into the ground (Figure 60-25).

Palm Spathe Container

If bamboo is not available to construct a container, a woody spathe (the durable, canoe-shaped structure that encloses flowers and fruits of palms) can be substituted. Support the spathe at each end over a low fire, and fill the vessel with water. A palm spathe container will stay intact long enough to cook crawfish and minnows (Figure 60-26).

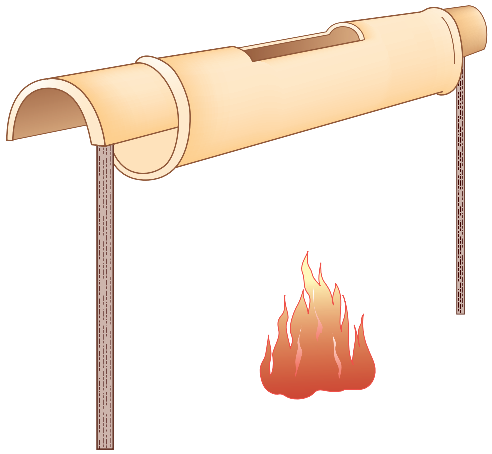

FIGURE 60-25 Bamboo container for heating water. *(Redrawn from Walden JB:* Jungle travel and survival, *Guilford, Connecticut, 2001, Lyons Press, p 178.)*

PSYCHOLOGY OF SURVIVAL

Travelers reared on movies, novels, and reality television shows depicting the horrors of the Amazon may have irrational fears of being lost or stranded in the jungle. Visible daytime threats worsen with the onset of darkness, when perception becomes distorted. Travelers incapacitated by fear may throw away survival items or may flee from rescuers.

Strategies that can increase travelers' confidence in survival include the following:

- *Previous jungle experience.* It is helpful to begin tropical excursions in the structured setting of small-group travel. Ecotours, particularly in Costa Rica, Ecuador, and Peru, offer a combination of rain forest trekking and cross-cultural experience.
- *Survival manuals.* Military experts and others provide insights from decades of experience.[55,54]
- *Information on the tropical rain forest.* Familiarity with exotic plants and animals lessens the likelihood of fear while increasing awareness of potential usefulness in a survival situation. The anthropologic literature is replete with first-person accounts by anthropologists who have lived under trying circumstances with minimally contacted tribal populations throughout the tropics.
- *Classic accounts of survival against all odds,* such as Alfred Lansing's *Endurance: Shackleton's Incredible Voyage.*[35]

FIGURE 60-26 Palm spathe container. *(Courtesy Jon Willis.)*

- *Courses in wilderness-oriented skills.* The National Outdoor Leadership School (NOLS, 307-332-5300, 800-710-6657, nols.edu) teaches wilderness-oriented skills and leadership in a core curriculum stressing safety and judgment, leadership and teamwork, outdoor skills, and environmental studies. Wilderness and outdoor safety courses (outdoorsafe.com) teach both the psychological and physiologic aspects of surviving a wilderness emergency.
- *Traveling with a Collins-style machete, the one indispensable tool.* A map, compass, GPS unit, and windproof lighter are other recommended items.
- *Taking stock.* The traveler facing a wilderness crisis assesses a situation analytically and rationally before planning the course of action. Having survival skills is important; having the will to survive is essential.[54]

CULTURAL FACTORS

Travelers who have the privilege of spending time with jungle-dwelling populations will find much to admire in the lives of indigenous peoples throughout the world. In some cultures, however, various facets of tribal life lend a discordant note and remind us that all cultures have their unpleasant aspects.[59]

Infanticide

In the few isolated tribal societies where infanticide is still practiced, the first or second of twins (depending on the customs of a particular tribe) and deformed newborns may be killed. In some tribes, when the firstborn is a female instead of the more prized male, the decision may be made to kill the child at birth.

Intertribal and Intratribal Warfare, Revenge Killings, Homicide

Although the rates may be significantly lower or slightly higher on a regional basis, the literature shows that those who observed certain indigenous populations during their first sustained contact with the outside world found a high background level of intertribal and intratribal warfare, revenge killings, and homicide. Chagnon[8] reported a warfare-associated male death rate of between 20% and 30% among the Yanomamo of Venezuela. Summarizing data for five generations among the Waorani, a linguistic isolate inhabiting the lowlands of eastern Ecuador, Larrick and associates[36] concluded that 42% of deaths were attributable to internal spearing raids and 16% were attributable to conflicts with the outside world.

Various hypotheses have been advanced by anthropologists and others to explain the high death rates due to violence among Amerindians. If you disregard the theories of squabbling academicians and ask the Indians themselves, you will find preoccupation with warfare and homicide is attributed to revenge killings (vendettas), sexual disputes, and shamanism.

Interestingly, after contact with the outside world, most groups rapidly abandon generations of warfare and violence. Influences, including Christian missions, school, and sports, in particular intervillage soccer tournaments, have been credited with transformation to more pacific lifestyles.[46]

Enigmas

You see one way awake and another while asleep, but both ways of seeing are real experiences.[16,17]

Travelers to areas inhabited by traditional societies with minimal outside contact should keep in mind that tribesmen may interpret and respond to events in ways that would not be anticipated from a Western outlook. These interpretations and responses can have implications for matters such as health care project planning and implementation and, occasionally, for personal and group safety.[59]

Perspectives on reality are driven by numerous culture-specific factors. Among several Amazonian tribes, the dream-world is considered the "real" reality in contrast to the everyday waking reality.[17,59]

The structure of language itself (linguistic relativity) is thought by some anthropologists and linguists to affect the ways its speakers conceptualize their world.[16,17]

Attribution of Causality

"....in almost all primitive societies the ideas of natural death and accident are unknown and practically unthinkable." (Aldous Huxley: Proper Studies, 1927)

Among traditional lowland tribal cultures of Amazonia, illness due to natural causes and accidents have a supernatural origin—things do not *just happen*. An invisible missile causing illness, for example, may be shot into the body by a sorcerer, or the spirit/soul may be kidnapped or has fled. Under the influence of psychoactive plants, the shaman/healer works by removing magic substances from within the body, or transforming into a jaguar to roam over long distances in the dark to retrieve the soul and put it back in the body of the victim.[58]

SURVIVAL IN HOSTAGE SITUATIONS

The following overview of survival in hostage situations is based on material developed and used by the 2nd Battalion, U.S. Army John F. Kennedy Special Warfare Center and School, and draws heavily from an outline prepared by James Liffrig, MD, U.S. Army.[37]

Some areas of otherwise pleasant tropical rain forests are in regions of risk for hostage taking by terrorists, guerillas, or criminals whose motivation may be purely mercenary. Individuals traveling to such areas should have insight into the fundamentals of survival in hostage situations.

PREVENTION

Since the late 1960s, hostage taking has been on the increase worldwide as a way of setting up a bargaining position to achieve an otherwise unattainable objective. At times, the individual taken is an innocent victim of circumstances who happened to be in the wrong place at the wrong time. Often, however, the individual has been chosen because he or she is an easy target.

The home page for the Bureau of Consular Affairs of the U.S. Department of State (travel.state.gov) provides current travel warnings worldwide and detailed country-by-country profiles on safety and security matters in Consular Information Sheets.[56] The likelihood of becoming a victim of hostage taking or kidnapping can be diminished by avoiding travel to areas of known high risk. If one must travel to an area with a history of recent terrorist attacks or kidnapping, follow common sense precautions:

- Have your affairs at home in order (current will, insurance documents, power of attorney, guardianship arrangements for minor children).
- Register with the nearest U.S. embassy or consulate through the State Department's travel registration website (travelregistration.state.gov/ibrs/).[57]
- Avoid obvious terrorist targets, such as places where Americans are known to congregate.
- Be sensitive to what you discuss with strangers, and that you may be overheard.
- Vary routines, including appointments, travel times, and routes.
- In a city, walk purposefully as if you know where you are going, even if you are lost. Indecision, hesitancy, and directionless movement attract thieves and kidnappers in the same way that thrashing surface movements attract sharks.
- As much as possible, blend in.

CATEGORIES OF HOSTAGE TAKERS

Terrorist organizations are often stratified, with educated and dedicated idealists at the top and disillusioned, young, impressionable recruits from colleges or universities lower down in the hierarchy. In some organizations, mentally ill persons and sociopaths recruited from prisons make up a nucleus of the more violent members of the group. Political and religious extremist hostage takers may represent the most danger to Americans because of the value of Americans as symbolic targets.

Paramilitary/guerilla combatants often operate out of remote jungle regions and may cross in and out of one country to another along an unguarded border. Those who trek in such areas may become "targets of opportunity" by chance encounter with these individuals. Guerilla organizations in certain parts of the world engage in drug trafficking in order to obtain money, weapons, and equipment. Such organizations have increasingly turned to hostage taking for ransom as a source of fund raising.

Although not a hostage situation in the classic sense, travelers should be aware that in isolated regions inhabited by indigenous peoples, detainment (usually temporary) of uninvited outsiders traversing tribal lands may occur. Detainment usually stems from a misunderstanding of the purpose of travel by outsiders, especially during times of heightened tension, such as periods of intratribal or intertribal feuds or when tribes have joined forces to oppose the intrusion of extractive or timbering industries and conclude that the traveler is allied with such interests. It is always best to get advice from individuals with local knowledge, such as missionaries and anthropologists, when entering remote areas, especially areas of known or suspected ethnic unrest. In some countries in South America, particularly Brazil, isolated indigenous peoples can have immunity from prosecution or receive lenient treatment in criminal proceedings, including those related to murder.

BEHAVIOR AT THE MOMENT OF CAPTURE

The initial moment of capture is dangerous because the captors are tense and may commit unintentional violence with the slightest provocation.

- Do not reach into a coat or purse to produce a document unless so instructed.
- Reassure your captors that you are not trying to escape.
- If the terrorists use blindfolds, gags, or drugs at the time of abduction, keep in mind the fact that the terrorists want you alive.
- If blindfolded, do not remove the blindfold because this could leave the terrorists no alternative but to kill you.

HOSTAGE RULES OF BEHAVIOR

Always smile: I had learned that lesson years ago in the Congo, where the penalty for dropping your grin, even for an instant, in the face of nervous soldiers or tribesmen, was slow death with both legs hacked off above the knee with pangas.[65]

Hostage taking forces the terrorist or criminal into stereotyped responses. The more knowledge and understanding a hostage can have about his or her captors, the better he or she will be able to predict the hostage taker's behavior and feel some degree of control. The conduct of the hostage can increase or decrease his or her chances for survival.

- Smile. Be polite and respectful.
- Be aware of the common "Good Guy/Bad Guy" interrogation technique.
- Determine the area of particular sensitivity, such as politics or religion, of the hostage taker, and avoid conversation in these subjects. However, if terrorists want to talk about their cause, show an interest. Explain that although you might not agree with your captors, you are interested in their point of view, emphasizing the latter point.
- Become an active listener.
- Small talk is better than no talk.
- Do not argue with captors.
- Make brief, casual eye contact during conversation; avoid prolonged eye contact.
- Do not refuse to eat unfamiliar local dishes just because they do not look or smell appetizing. It is disrespectful to refuse to eat the food that the captors may themselves be eating.
- Adapt to, but do not adopt, the hostage taker's value system (see Stockholm Syndrome, later.)

STRESS MANAGEMENT IN CAPTIVITY

Long-term captivity often leads to exhaustion, lethargy, and depression. Oppose these feelings, and try to maintain confidence.

- Exercise.
- Maintain sleep discipline, and avoid sleeping too much.

- Plan a schedule for the day, and attempt to stick to it.
- Keep a sense of humor.

ADJUSTING TO CAPTIVITY

The hostage must make every effort to adjust to captivity.
- Do not focus on mistakes made up to the point of captivity. Focus on the positive.
- A positive attitude will help sustain dignity.
- Smiles are contagious; the hostage should wear one.
- Fight boredom. Engage in creative mental and physical activities.
- Avoid setting anticipated release dates or allowing captors to establish these types of milestones.
- Remember that the longer a hostage is held in captivity, the greater are his or her chances of release or rescue.

STOCKHOLM SYNDROME

The Stockholm syndrome refers to stress-induced alteration of the hostage's behavior such that the hostage aligns with the hostage taker. This phenomenon is thought to be an automatic, unconscious emotional response to the trauma of becoming a victim. It is not uncommon for hostages to transfer anger from the hostage takers to the society or situation that created the dilemma in which they are now victims. Individuals held in the grip of the Stockholm syndrome have been known to actively participate with the captor group in terrorist activities.

ESCAPE

Escape planning should begin at the onset of detention because escape may eventually prove to be a viable option.
- Escape is considered a last resort but should be considered if conditions deteriorate to the point that the risks associated with escape seem less than the risks of remaining captive: torture, death of fellow detainees, or a credible threat of death.
- In group hostage situations, detainees should organize and make every effort to establish and sustain communications with other hostages.
- Terrorists often hold hostages in areas where the local population supports the terrorists' cause. Therefore, do not assume locals are friendly, because they may return escapees to their captors.

RESCUE

Statistically, most hostages who die are killed during rescue attempts. Hostages should therefore be mentally prepared for rescue attempts.
- The first hostage execution, if known by the rescuers, increases the likelihood of a rescue attempt.
- The hostage must be especially alert and cautious should he or she suspect that a rescue attempt is imminent or occurring.
- At the first sign of an active rescue attempt, the hostage should drop immediately to the floor and avoid any sudden movement, especially with his or her hands.
- From the rescuer's point of view, everyone on the scene is a terrorist until proved otherwise. Therefore, do not attempt to assist the rescue forces because you may be mistaken for a terrorist.
- Expect to be tied up or otherwise restrained by rescue forces until you can be positively identified. If you argue, you may be subdued.

RELEASE

Statistically the odds favor the hostage being released.
- The U.S. government will not negotiate with terrorists. The U.S. government will, however, work closely with the host government from the outset of a hostage-taking incident to encourage that government to exercise its responsibility under international law to protect all persons within its territories and bring about the safe release of hostages.
- A number of factors can come into play (including ransom demands met by private efforts) so that the hostage is released by his or her captors. If an actual release has been arranged, pay close attention to the instructions the captors are giving when the release is taking place. Do not panic or attempt to run.

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Complete references used in this text are available online at expertconsult.inkling.com.

CHAPTER 61

Desert Travel and Survival

EDWARD J. OTTEN

> *This desert landscape is the indifference to our presence, our absence, our coming, our staying, or our going. Whether we live or die is a matter of absolutely no concern to the desert. Edward Abbey, Desert Solitaire*

Many people avoid desert travel because they think that deserts are nothing but huge sand and rock wastelands with little or no beauty. Deserts, especially after a rain, can often rival an alpine meadow in the color and beauty of the flowers and plants. Deserts are common biomes for travel and can become difficult areas for survival. The key to survival is preparation, and the key to desert survival is water. We can emulate the desert flora and fauna to conserve water. The greatest hazards are dehydration and heat. Clothing, survival equipment, and training can overcome many of the obstacles. Desert travel is inherently dangerous, and special precautions are needed to decrease risk.

THE DESERT ENVIRONMENT

Deserts are land areas that receive less than 25.4 cm (10 inches) of rain, unevenly distributed, throughout the year. A number of

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climatic processes produce desert areas. The most influential are the six cells of cold air currents that descend at the poles and near the Tropic of Cancer and Tropic of Capricorn. These air currents, driven by the sun and rotation of Earth, create areas of relatively warm, dry conditions. Many of the world's deserts live in a "rain shadow," an area to the leeward side of a mountain range that prevents the small amount of moisture that is present in the air to move over the mountains. As the air rises, the moisture cools and precipitates in the higher elevations. Therefore, the area in the "shadow" of the mountain range receives little moisture. The air that does descend is quite dry and adds to the evaporative effect. The Atlas Mountains shadow the Sahara Desert, the Andes the Patagonian Desert, the Great Dividing Range the Australian Desert, and the Sierra Nevada and Cascades the Great Basin Desert. The amount of rainfall is not an absolute indicator of "dryness" because the rate of evaporation and timing of the rainfall must also be taken into consideration. The amount and type of vegetation, soil composition, altitude, average temperature, wind speed, and solar radiation all contribute to "dryness" and desert formation. Antarctica would be the world's largest desert by the definition of less than 25.4 cm (10 inches) of rainfall annually, some areas of that continent having had no recorded rain in 30 years. There is a large amount of water present in the form of ice, but it is not available for use by plants. Antarctica has its own special survival problems not associated with precipitation and, for the purposes of desert survival, will not be considered here. In contrast to Antarctica stands the northern coast of Alaska, which receives less than 10.2 cm (4 inches) of rain annually, yet is quite wet because evaporation is so low.

Deserts are one type of environment on Earth that is increasing in total area, likely because of human as well as geologic factors. Overgrazing, destruction of forests, global warming, and other aspects of increased human population contribute to desertification. Currently about 15% of the land area of Earth is desert (30% if Antarctica is included) (Figure 61-1; Table 61-1). Most of Earth's deserts can be found between 30 degrees south and 30 degrees north latitude, making them hot as well as dry. These deserts include the Sahara, Arabian, Kalahari, Australian, Atacama, Thar, Namib, and southwest United States. About 50% of Africa is desert; the Sahara by itself is almost as large as the United States. About 8% of the United States, or 776,996 square kilometers (300,000 square miles), is desert. Most of the U.S. desert areas are adjacent to national parks and forests and are frequently visited, for example, the Grand Canyon, Big Bend, Arches, Zion, Organ Pipe, Joshua Tree, Great Basin, Saguaro, and Capital Reef. Beyond 40 degrees south and north latitude and at elevations over 3048 m (10,000 feet) are the "cold" deserts, which have wide swings in temperature, for example, the Patagonian, Turkestan, Gobi, and Taklamakan. The large temperature variations in desert regions are greater at higher elevations and latitudes but are present in all deserts. Lack of vegetation, cloud cover, and ground-water surface allows 90% of solar radiation to reach the desert surface. By contrast, a forest may reflect 50% to 60% of the solar radiation, and its vegetation disperses the rest. At night, lack of cloud cover and vegetation allows almost 100% of the accumulated heat to escape, as opposed to only 50% from a humid climate. This explains why the desert temperature may reach 48.9°C (120°F) during the day and drop to 4.4°C (40°F) at night. Tropical rain forests may only reach 35°C (95°F) during the day, but at night the temperature only drops to 29.4°C (85°F).

It might seem that the extreme desert climate would only allow for sparse life, but that is not the case (Figure 61-2). Death Valley, one of the harshest environments in North America, where air temperatures have been recorded at 56.7°C (134°F), has 600 species of plants, 30 species of mammals, 25 species of reptiles, and 2 species of fishes. Oases are found in most deserts. They are isolated depressions usually fed by a constant source of water. Underground springs and wells supply moisture for plants and animals. Often one must dig to find water at the lowest point of the depression. Many named oases have supported camel caravans, allowing them to move from oasis to oasis and thus cross an otherwise impenetrable desert. Desert way stations and ancient cities have sprung up along these routes. Many ancient oases have wells hundreds of feet deep and because of overuse are gradually drying up. When the water is used up, the oasis disappears, along with its desert life.

All desert flora and fauna have one guiding principle for survival, which is to *conserve water*. The ground surface of the desert has the highest temperature because of the direct effect of solar heat and wind. Therefore, during the hottest times of the day, most animals are either below the surface, in underground burrows, or above the surface in available vegetation, cacti, trees, or shrubs. Most animals forage from dusk until dawn because temperatures are cooler. Some mammals, such as kangaroo rats, never drink but obtain necessary water through plant seeds. Plants have evolved a number of survival skills to maintain water, including stomata that are closed during the day and crassulacean acid metabolism photosynthesis. The latter allows accumulation of carbon compounds at night through the dark reaction. These compounds are converted to carbon dioxide during the day when the stomata are closed. Other adaptations include stem photosynthesis in plants without leaves, thick cuticles, water storage tissues, and widespread shallow root systems. Desert plants also have evolved a variety of defense mechanisms, such as production of toxic compounds that act as herbicides to

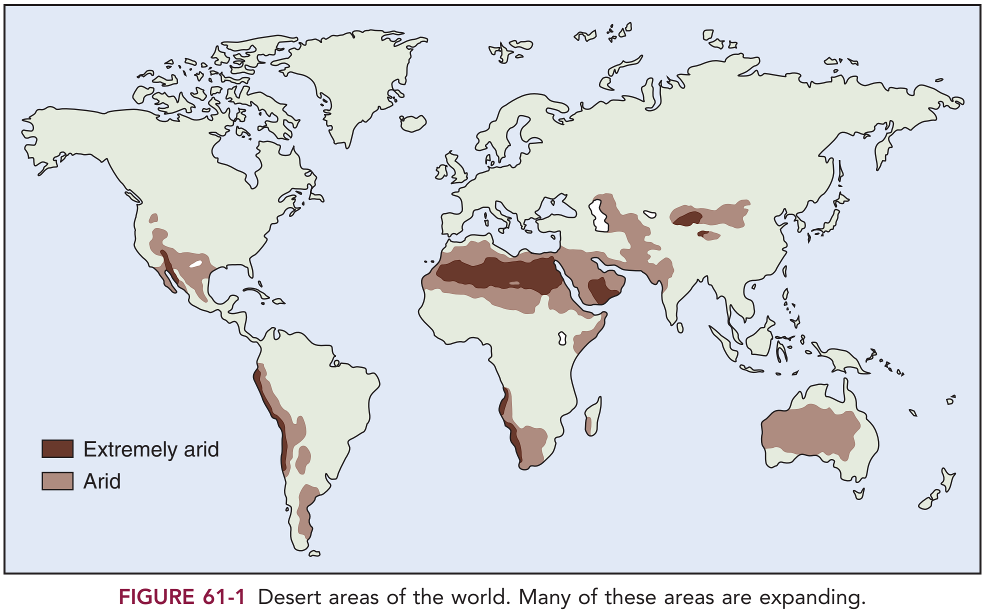

FIGURE 61-1 Desert areas of the world. Many of these areas are expanding.

PART 8 RESCUE AND SURVIVAL

TABLE 61-1 Deserts of the World

Name	Continent	Area (sq km [sq mi])	Features
Western Sahara	Africa	266,769 (103,000)	Dunes, mountains
Great Erg	Africa	392,280 (151,460)	Dunes
Tanezrouft	Africa	149,960 (57,900)	Rocky, mountains
Libyan	Africa	1,199,993 (463,320)	Rocky, dunes, oases
Fezzan	Africa	551,165 (212,806)	Rocky, mountains
Egyptian	Africa	660,001 (254,828)	Basin, plateau, oases
Sinai	Africa	60,994 (23,550)	Mountains
Niger	Africa	464,307 (179,270)	Dunes, mountains, oases
Darfur	Africa	440,298 (170,000)	Mountains
Nubian	Africa	421,650 (162,800)	Rocky, dunes
Sahel	Africa	4,999,972 (1,930,500)	Steppe
Mauritania	Africa	720,017 (278,000)	Dunes, plateaus
Somalia	Africa	587,150 (226,700)	Mountains, plateaus
Kalahari	Africa	260,009 (100,390)	Dunes, savannah
Namib	Africa	94,017 (36,300)	Dunes, plateaus
Andalusian	Europe	265,992 (102,700)	Rocky, dunes
Arabian	Asia	2,299,987 (888,030)	Dunes, mountains
Syrian	Asia	517,998 (200,000)	Rocky, plateaus
Negev	Asia	11,992 (4,630)	Plateaus, rocky
Taklamakan	Asia	323,749 (125,000)	Basin, dunes
Thar	Asia	213,997 (82,625)	Dunes, cold
Gobi	Asia	1,299,993 (501,930)	Plateaus, rocky, cold
Karakum	Asia	689,999 (266,410)	Basin, plateaus, cold
Sonoran	N. America	310,799 (120,000)	Mountains, alluvial
Death Valley	N. America	14,763 (5,700)	Basin, mountains
Gran Desierto	N. America	309,996 (119,690)	Basin, mountains
Mojave	N. America	64,998 (25,096)	Basin, mountains
Great Basin	N. America	490,000 (189,190)	Basin, mountains
Chihuahuan	N. America	517,998 (200,000)	Basin, mountains
Atacama	S. America	199,999 (77,220)	Mountains, rocky, cold
Great Sandy	Australia	360,008 (139,000)	Basin, dunes
Simpson	Australia	299,998 (115,830)	Dunes, rocky
Great Victoria	Australia	579,277 (223,660)	Dunes, alluvial

other plants, and formation of needles, spines, and thorns that dissuade browsing animals. Obviously, humans are not able to evolve these physiologic changes but must rely on behavior, technology, and other adaptations to mimic the methods used by indigenous desert dwellers.

PREPARATION

All things being equal, preparation improves the likelihood of survival. However, things are never equal, so luck is probably the most important, albeit the most uncontrollable, factor. The controllable factors are mental and physical conditioning, clothing, survival kit adequacy, and survival skills. These may allow one to survive even in the most extreme conditions.

Mental preparation is key to any survival situation. The "will to survive" has been shown to be the most important factor in the outcome of a number of situations. Knowledge of the terrain features, weather, animal and plant life, and potential hazards should all be studied before travel to a desert area. Not only does this increase one's chances for survival, but it also enhances enjoyment of the desert environment. Practical experience in finding water and food, navigation, and constructing shelters is more valuable than reading about it. Time spent in attending a course on survival in general or desert survival in particular may be invaluable if one is later in a true survival situation.

Physical conditioning and acclimatization are as important for desert travel as for mountaineering. Desert travel is difficult under most circumstances. The terrain is rough and may include sand dunes, sharp loose rock, flash floods, steep grades, and hot surfaces. Lower-body conditioning helps prevent the ankle and knee injuries that can force a survival situation in a harsh climate. Acclimatization may take 10 to 14 days and involves three well-described physiologic adaptations. These are increase in sweat volume and number of active sweat glands, decrease in concentration of electrolytes in sweat, and sweating at lower body temperature. These can be induced before arriving in a hot climate by the use of a sauna or vigorous exercise to raise body temperature (see Chapters 12 and 13).

CLOTHING

Clothing selection for desert travel is somewhat different than for most other wilderness activities. The less exposed skin, the better. Although cotton is not appropriate for most cold, wet climates, it is useful in the desert. Light-colored clothing reflects sunlight and lowers skin temperature. Ripstop cotton (cotton material with nylon threads latticed within it) is best because it resists rips that are common in the desert. It is light enough to allow heat to escape, does not have a clammy feeling in low humidity, and protects against some ultraviolet rays and blowing sand. If ripstop cotton is not available, any tight-weave cotton is

FIGURE 61-2 Desert landscape. Note the physical features and abundant flora.

adequate. Long sleeves and long pants are a "must" to protect against spines, thorns, splinters, and insects. More important, they offer some protection against solar radiation that causes sunburn and increased body temperature, and they trap more cool air next to the skin. Sweat that is trapped decreases water loss through evaporation. Trousers can be tucked into the tops of socks to protect from insects; sleeves should not be rolled up in order to minimize risk for sunburn and heat gain. Gaiters can be worn to protect lower legs and the inside of footwear from sand, rocks, and dust. In a survival situation, puttees (wraps that extend from the tops of the shoes to the knees, either over trousers or bare legs) can be made of strips of cloth, elastic bandages, or stockings to protect the lower legs. They can be incorporated into the socks and wrapped to above the knees in a fashion similar to gaiters. Because of the wide temperature swings, a pile jacket or sweater is necessary at night. Layering, just as in cold climates, is the best means of preserving body warmth. In a survival situation, any insulating material, such as seat cushions, newspapers, or dry grass, can be used to insulate whatever clothing is available. Although wind is more of a problem than is rain, a Gore-Tex jacket is also recommended, especially for "cold" deserts. A wide-brim hat or kepi (a cap with a cloth extending from the back protecting the neck) is necessary to protect the head, face, neck, and ears. In a survival situation, an expedient head covering can be made from whatever material is at hand (Figure 61-3). A cotton cravat, bandanna, or handkerchief can be used to keep the head and neck cool by soaking the material in water (if plenty of water is available; do not use precious drinking water) and then placing it on the head, followed by a hat. Alternatively, it can be wrapped around the neck and shoulders underneath a shirt. Commercially produced (Cooldanna, Climatech, StaCool) neck wraps and vests, which contain crystals that can be soaked in water and then become cool through a chemical reaction, are also available but probably do not add much in the way of total-body cooling in extreme environments. The cravat can also be used during dust storms to protect the nose and mouth, as a towel, or to absorb moisture from plants when obtaining water.

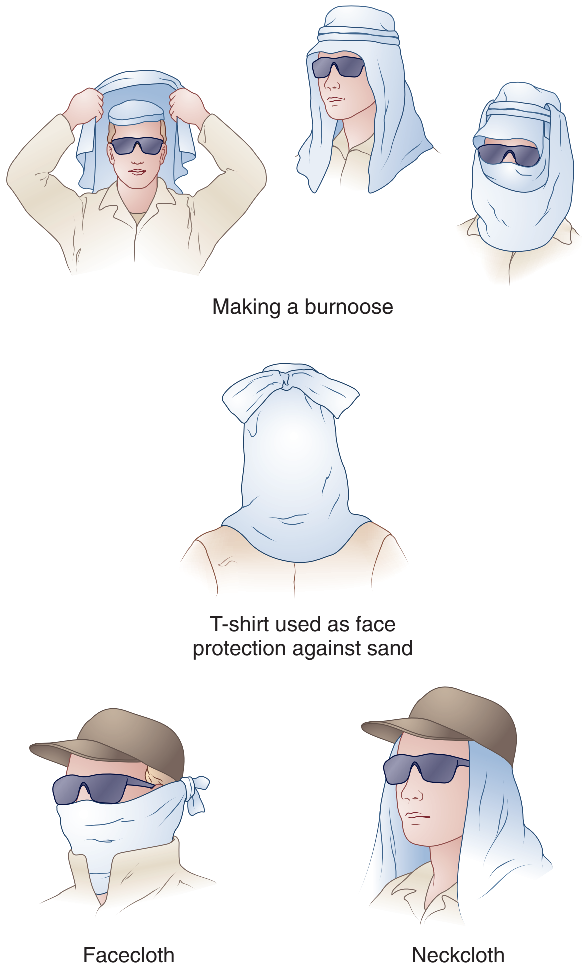

FIGURE 61-3 Expedient head coverings.

High-top (15.2 cm [6 inches]) boots composed of leather or synthetic materials are necessary to prevent sand, rocks, and burrs from entering the boots, support the ankles on rough terrain, insulate the feet from hot surfaces, and prevent the boots being pulled off in soft ground. Boots should be well broken in before hiking. Military-issue boots with metal spike protection can become extremely hot in desert conditions and should be avoided. Running shoes do not insulate the feet well and may become extremely hot. Socks should not be cotton, because of the risk for blisters and lack of wicking and insulation. Polypropylene or a combination of polypropylene and wool is best for socks because of less friction and thicker material. Foot care is extremely important, especially in a survival situation when walking is the only means of transportation. Feet should be inspected for blisters, foreign bodies, and abrasions on a regular basis while hiking. Socks should be changed frequently, at least twice a day, to allow them to dry out and to remove accumulated dust and sand. Leather gloves are desirable to protect hands from hot objects, plant spines, thorns and splinters, insects, and blisters. Abrasions and lacerations to the hands can quickly become infected in conditions where hand washing is difficult. Eye protection becomes very important in the desert, especially when traveling. Solar radiation, both direct and reflected, can cause keratitis similar to snow blindness. More commonly, blowing sand, dust, and insects may cause corneal abrasions and conjunctivitis. Contact lenses are difficult to manage in the dry, dusty environment. Tinted goggles are best, just as with mountaineering, but glacier glasses or standard sunglasses can be used. Duct tape, adhesive bandages, or other material can be used to fashion side shields for regular glasses to prevent sand and dust from entering through the sides. Insect head nets can be lifesaving, especially in African, Arabian, and Australian deserts, where insects and insect-borne diseases are particular problems.

SURVIVAL KIT

The survival kit must be carried at all times, have high-quality equipment and supplies, and be protected from the elements. Each item should have multiple uses if possible. There must be items that can be used for shelter, signaling, fire building, first aid, and other uses (Box 61-1). Many items will routinely be carried by most hikers and backpackers, but some specialized items should be added. One's clothing is the basic survival shelter and, if properly selected, will be the first step in protection from the climate. General-use items include a Swiss Army knife with as many blades as possible. The Swiss Champ includes, among many other features, a magnifying glass, which is quite useful for identifying and removing cactus spines and splinters or starting fires. Parachute cord (eight-strand) has multiple uses, including shelter construction, creation of snares, and as nets and lines for fishing. A signal mirror; whistle; matches, metal match, or lighter; first-aid supplies; compass; safety pins; water disinfection tablets; and plastic bags can be stored in a relatively small container that should be kept on one's person at all times. The first-aid kit should contain bandages, insect repellent, sunscreen, lip balm, antiseptic ointment, aspirin/ibuprofen, antihistamines, tape, and any prescription medications. The desert survival kit may include a 1.5 × 1.5 m (5 × 5 foot) piece of plastic, 1.2-m (4-foot) length of plastic tubing, and metal cup (all for making a solar still), emergency blanket (silver on one side, red on the other), extra sunglasses or eye protection, nylon canteen (minimum 4.7 L [5-qt] size), and extra sunblock.

PRIORITIES

The "rule of 3s" gives us a priority list for survival. One can live 3 minutes without oxygen, 3 hours without warmth, 3 days without water, and 3 weeks without food.

BOX 61-1 Desert Survival Kit

Swiss Army knife
Parachute cord
Compass
Topographic map
First-aid kit
Goggles
Lip balm
Leather gloves
Safety pins
Mosquito head net
Waterproof container
Rescue blanket
Plastic sheet
Plastic tube
Metal cup
Water container (4.7 L [5 qt])
Hat
Sweater or pile jacket
Gore-Tex jacket
Duct tape
Hard candy
Plastic bags
Matches
Metal match
Metal mirror
Whistle
Water filter or iodine
Peanut butter
Flashlight
Sunscreen
Insect repellent
Cravat

WATER

The key to desert survival is water. Unfortunately, water weighs 3.6 kg/3.8 L (8 lb/gal), and individual needs may be up to 7.6 L (2 gal) per day. Always carry as much water as possible. Collapsible canteens can carry several quarts of water and keep the water cooler (because the surface heat absorption to volume is less) than can hard plastic or metal (Figure 61-4). Drink at every stop. Drinking "to thirst" has been recommended to prevent dehydration and hyponatremia, both of which can be harmful. Drink while hiking if using a drinking tube with a reservoir such as a Camelbak or similar water container. Flavoring and cooling water increase palatability and thus consumption. Most hikers do not carry enough water for more than 1 day, so having a method for acquiring water is mandatory. Solar stills, vegetable stills, digging along arroyos and in dry lake beds, wiping dew from plants in the early morning, and extracting water from succulent plants are all methods for obtaining water in a desert survival environment. These alternative methods may not supply enough water for a long-term situation.

Although there are a number of methods for obtaining water in the desert, minimizing water loss might be a better strategy for a human with limited water resources. All desert plants and animals have developed adaptive mechanisms for conserving water. Humans, if they are to survive, must develop strategies for conserving their sweat, not their water. Adolph measured water intake, activity, and ambient temperature of World War II soldiers during desert operations. Soldiers who rested in the shade had significantly less water losses than did those who exerted themselves in the heat of the day, and they could extend the length of time they could survive, despite similar water intake. Although it would seem to be intuitive behavior, most desert travelers limit neither their travel to cooler times of the day nor their work activities to the shade. Employing a strategy of resting in the shade from 10:00 AM to 3:00 PM, drinking adequate water based on the appearance of the urine, and keeping as much skin covered as possible has decreased the number of heat casualties in the military during training exercises. Although thirst and the amount of sweat on clothing are poor indicators of hydration status, the color and amount of urine produced can roughly estimate it. The darker in color the urine, the more concentrated it is, indicating a greater degree of dehydration. If potable water is available, it should be consumed; it is better to conserve sweat rather than water. If there is a limited amount of water, food should not be eaten unless the food contains a large amount of water. The metabolism of food, especially protein and fat, and excretion of waste products require potentially unnecessary utilization of body water. Only potable water should be drunk because vomiting and diarrhea caused by contaminated water could quickly become fatal in the desert. Water obtained from lakes, streams, wells, or springs should be considered contaminated and must be made potable before drinking. Water holes may attract dangerous animals as well as potential food (Figure 61-5).

Desert water may be found by looking for animal signs, such as trails or spore. Some plants, such as cottonwood, sycamore, willow, and cattails, may be indicators of water. Water may sometimes be found by digging at the outside bend of a dry riverbed or stream (*arroyo* and *wadi* are terms used to indicate rain run-off channels that may contain water during the rainy season) (Figure 61-6). Rainwater, dew, and water obtained from a solar still or a vegetable still are relatively potable. Urine, seawater, alkaline pools, and brackish water should never be drunk. They contain large amounts of solutes that would require more water to excrete than they provide, thus hastening dehydration and renal failure. However, these sources can be added to a solar still to improve potability as well as increase the still's output. Liquid from radiators or windshield washer fluid is contaminated with glycols or methanol and should not be drunk or used in solar stills. Many plants, such as barrel cacti and traveler's tree, and animals, such as the desert tortoise, contain water that can be used in an emergency or added to a solar still to increase output (Figure 61-7).

A solar still (Figures 61-8 to 61-10) can be constructed by placing a 1.5 × 1.5 m (5 × 5 foot) piece of clear plastic over a

FIGURE 61-4 Collapsible 5-qt canteen.

FIGURE 61-5 Desert water hole—currently occupied.

FIGURE 61-6 Desert arroyo or wadi.

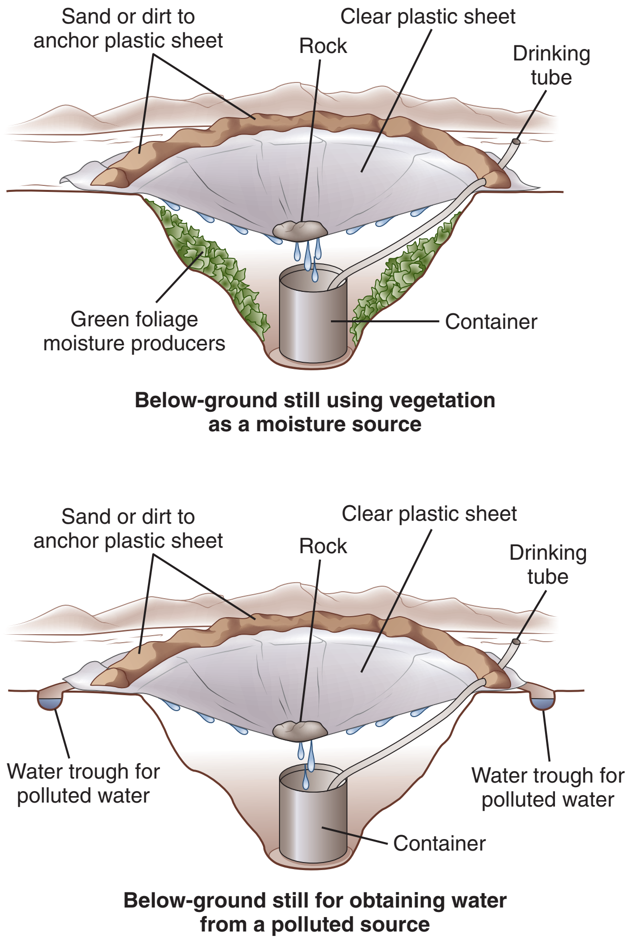

FIGURE 61-8 Diagram of solar still.

hole 0.9 to 1.2 m (3 to 4 feet) in diameter and dug 0.9 to 1.2 m (3 to 4 feet) deep in the ground into which vegetation, urine, or brackish water has been placed. Solar energy causes water to evaporate within the hole and collect on the underside of the plastic. Because it cannot escape, it will drip back into a container placed at the bottom of the hole. A tube can be attached to the inside of the container so that the water can be drunk without dismantling the still. A plug should be put in the drinking end of the tube to prevent clogging. The amount of water produced depends on the amount of moisture in the hole, the amount of sunshine directed at the still, and the size of the plastic sheet. A still dug into a dune or dry sand will not produce much water. Dew, rainwater, and edible animals may fall into the still as a bonus. Moisture can be wiped off plants during the early morning and can be squeezed from the pulp of certain plants, such as yucca or barrel cactus. A vegetable still using a plastic sheet wrapped around a bush or tree branch can trap transpired water from the plant. The plastic should be tied with a piece of cord and a small stone attached to the drinking tube placed in a dependent portion of the plastic so that water can be drunk without dismantling the still (Figure 61-11). Milky, bitter, or sour pulp should not be used, and the pulp should not be eaten. Water can be made potable by boiling, or using filters or chemicals (see Chapter 88).

SHELTER

Desert shelters are of three main types: natural, well-prepared human-made, and improvised human-made. Natural shelters are caves and rock overhangs. When using natural shelters, one must remember that there may already be other inhabitants that need eviction. Rattlesnakes, tortoises, ground squirrels, lizards, and skunks often use caves and other cool areas during the heat of the day. These animals may be sources of food but are also potentially dangerous to humans. Some reptiles are venomous, and many mammals carry rabies or plague. They can usually be removed by prodding with a long stick or dispatched with a rock. Well-prepared human-made shelters include tents, vehicles, and buildings. Most vehicles become very hot inside, which may hasten heat illness and dehydration. It is better to sit in the shade of an automobile than to be inside it during the heat of the day. Tents and buildings are best if there is adequate ventilation. Improvised shelters are typified by the desert trench shelter, shade shelter, or lean-to. Any structure that provides shade, protects from wind and blowing sand, and decreases heat gain or loss is minimally adequate. The hottest area in a desert climate is at the surface of the ground, so getting above the ground or below the ground decreases exposure to the highest temperatures. Most desert animals take advantage of this fact by their behavior. Birds perch high in trees in the shade of a branch or in some cases inside of a cactus. Most mammals and reptiles burrow into the ground, where just 0.9 m (3 feet) below the surface the temperature may be 30% cooler. Humans can imitate this behavior by constructing a desert trench shelter (Figure 61-12). This is a trench dug in the ground 0.6 to 1.2 m (2 to 4 feet) wide, 0.6 to 0.9 m (2 to 3 feet) deep, and about 1.8 m (6 feet) long. A barrier can be made of any effective material at hand, such as a blanket, sheet, poncho, tarp, or space blanket. This barrier is placed over the trench, about 45.7 cm (18 inches) above the bottom, and its edges are weighted down with rocks or sand. Another similar barrier (the first one can be doubled back on itself if it is large enough) is placed about 30.5 to 45.7 cm

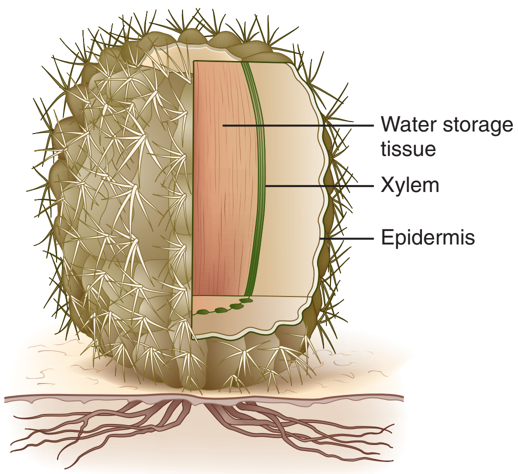

FIGURE 61-7 Barrel cactus showing pulp that can be a source of water.

FIGURE 61-9 Solar still. Note the moisture on the plastic.

FIGURE 61-10 Solar still.

FIGURE 61-11 Vegetable still. Note drinking tube and water in bottom of plastic.

(12 to 18 inches) above the first barrier and also weighted down. This construction creates an insulating barrier that traps cooler air in the bottom of the trench and reflects solar radiation from the top. Ideally, a reflective space type of blanket is used for the outer layer, which will increase the amount of heat reflected.

Removing the seat from a vehicle and sitting above the ground in the shade of the vehicle or constructing shade with a blanket or tarp and available materials can provide some shelter in the heat of the day until a more adequate shelter can be built (Figure 61-13). At night, when temperatures drop, the shade trench remains warmer because of the heat produced by the inhabitant. The top barrier, with its reflective surface, can be reversed to reflect heat back into the trench. Any insulating material can be added to the floor of the shelter to decrease heat loss to the ground. Given enough time, a shelter such as a tepee, tent, or lean-to can be constructed using tarps, blankets, parachute panels, or other materials (Figure 61-14). Construction should take place in the cooler times of the 24-hour day to conserve sweat and water. If one has a reliable source of water, such as a desert water hole or "tank" (natural collection of water in non-porous rock), then it is best to stay in that place and try to be rescued rather than attempting to travel large distances without adequate water.

FOOD

Food is not as immediate a problem as is water in the desert (see Chapter 90). Most humans have an extra 50,000 to 70,000 calories that they store in the form of fat, and can survive for weeks without eating. Food in the form of animals or plants is usually available if water is available. Cactus fruit, such as prickly pear (Figure 61-15), can be eaten when peeled. Legumes, such as acacia, mesquite, and paloverde, produce beans that can be crushed and mixed with water to form tortillas (Figure 61-16). Yucca stems, cattails, agave stems, and prickly pear pads can be cooked and eaten. Avoid plants with milky saps or white berries and other plants that cannot be positively identified as edible. Mushrooms should not be eaten. It is essential to become familiar with the common poisonous and edible plants in any area through which you will travel. Insects, birds' eggs, grubs, tortoises, and other slow movers can be captured by hand. Most small animals, such as snakes, lizards, and birds, can be killed with a rock or stick. Jackrabbits, ground squirrels, and rats may be snared or trapped. Large mammals should be avoided because the likelihood of killing one of these without a firearm is small, whereas the likelihood of becoming a casualty is high. All meat should be cooked or dried before ingestion. Animals to avoid as food or in general include caterpillars, spiders, scorpions, centipedes, millipedes, toads, and bats. Although they may be prepared as food, the risk is probably not worth the calories. Many mammals can transmit plague, Ebola virus disease, tularemia, Hantavirus infection, leptospirosis, rabies, and other zoonoses.

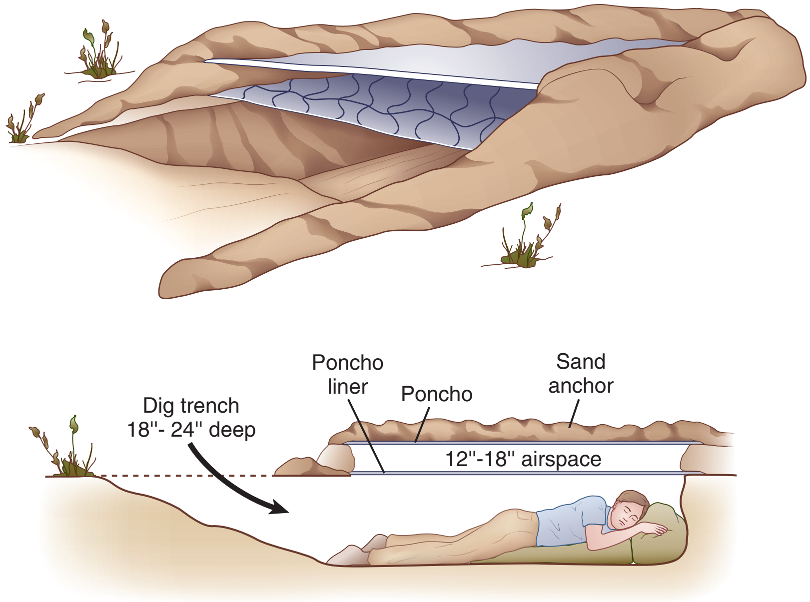

FIGURE 61-12 Desert shade shelter or trench shelter.

HAZARDS

In addition to heat and dehydration, there are other hazards that one may encounter in the desert. Blowing sand and dust created by vehicle traffic may cause eye, nose, mouth, and skin irritation. Desert winds up to 160.9 km/hr (100 mph) can blow for days, creating immense sandstorms and dust storms that can cover large areas, reducing visibility to near zero (Figure 61-17). Sand and dust storms often impregnate clothing and equipment. In addition to the sand and dust, other objects can be transported with the ferocity of a hurricane. Vehicles, tents, and buildings can be demolished and roads obliterated. Sandstorms blowing for days have caused destruction in large cities, such as Melbourne and Baghdad. Exposed skin must be protected, and shelter should be sought within a hard-sided building if possible. The possibility of an individual being buried is remote, but drifting sand can block doors and strand vehicles.

Quicksand is another hazard. There are two types of quicksand. The first is a mixture of sand and water found along the shores of lakes, seas, and estuaries of rivers. This type may look solid but is a suspension of fine sand and water that cannot compact. The second type is fine sand deposited by wind in hollow depressions. Depending on the depth of the depression, one could sink 4.6 to 6 m (15 to 20 feet). A person caught in quicksand can usually escape by flattening out and swimming to firm ground because most quicksand areas are small. Animals may panic and struggle, hastening their submersion. A rescuer can usually pull the victim to firm ground using a rope, belt, or strap. Removing one's pack and throwing it to firm ground allows for easier escape.

Animal hazards include venomous snakes and arthropods, carriers of zoonotic illnesses, and large mammals (Figure 61-18; Box 61-2).

Plant hazards include poisonous varieties that may cause dermatitis or systemic symptoms if ingested. Many types of plants produce spines, hairs, or thorns, which easily penetrate human skin and may cause infection, especially if the foreign bodies become imbedded. Removal of spines, especially small hair-like spines, can be facilitated using duct tape. Large cactus and yucca spines can penetrate joints and cause serious infections.

TRAVEL

Even in the best of circumstances, hiking in the desert can be difficult. Most modern travel is performed with high-clearance,

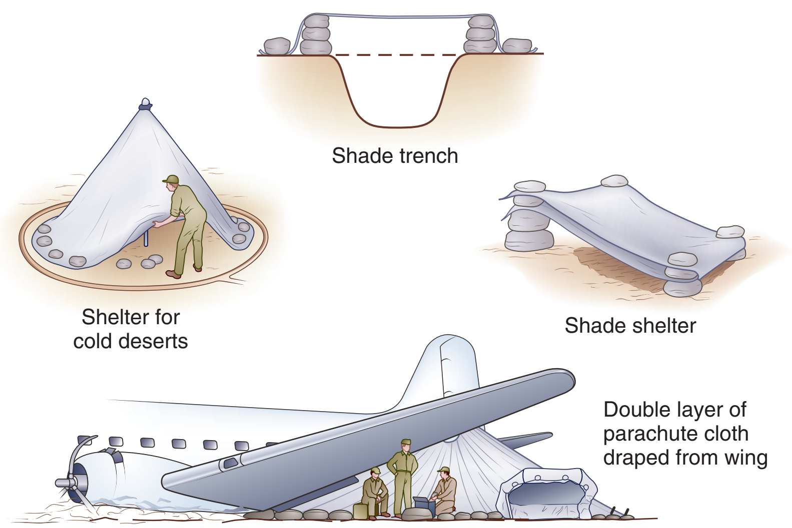

FIGURE 61-13 Expedient shelters.

FIGURE 61-14 Desert tarp shelter.

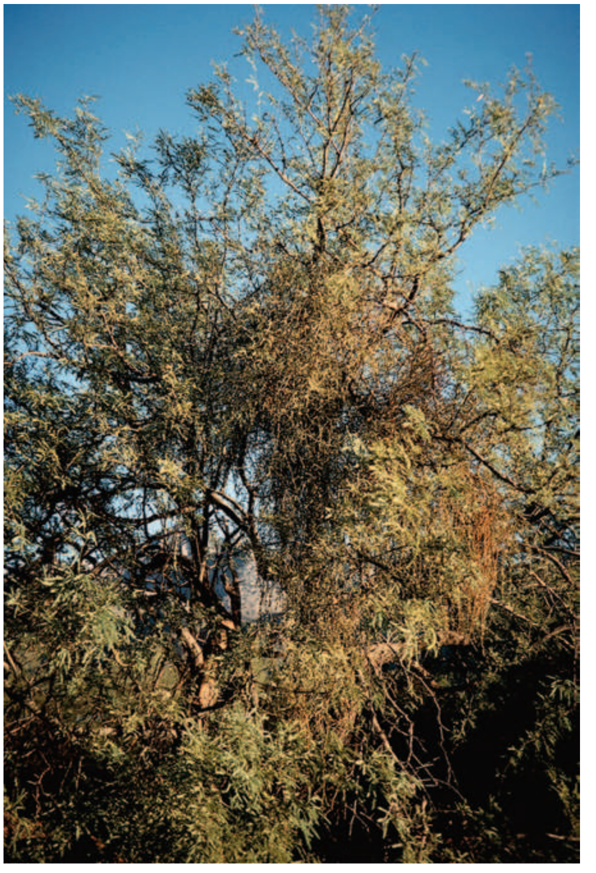

FIGURE 61-16 Mesquite seedpods.

four-wheel-drive vehicles. These vehicles should have sand mats (for added traction on soft surfaces) and a winch and cable for self-extracting the vehicle or rescuing another vehicle. Extra water, spare parts (fan belts, hoses, spark plugs, fuses, bulbs), additional fuel and oil, a shovel, two jacks, a spare battery, spare tires and tire-patching materials, a radio, and a tool kit are mandatory for desert travel. Traveling in convoys is a must, both for safety and, in some places, for security. Salt flats, mudflats, and soft sand can bog down even four-wheel-drive vehicles. Never attempt to cross arroyos or wadis when they are flooding.

Many areas offer no access to wheeled vehicles, so travel by camel, donkey, or horse is still common. Camels remain the most efficient desert transportation and can travel for long periods without food or water (Figure 61-19). They also are quite resistant to blowing sand, heat, and temperature changes. Expert assistance is needed for travel by camel. Horses and donkeys are limited to short distances and require more food and water.

FIGURE 61-17 Gigantic desert sandstorm.

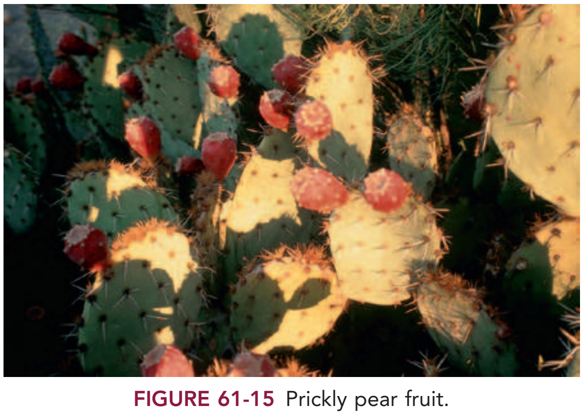

FIGURE 61-15 Prickly pear fruit.

FIGURE 61-18 Western diamondback rattlesnake.

BOX 61-2 Dangerous Desert Animals*

Arthropods

Venomous Arthropods

Spiders, scorpions, assassin bugs, ants, bees, wasps, centipedes, millipedes

Arthropods That Are Zoonotic Disease Vectors

Fleas, sand flies, ticks, mites, mosquitoes, kissing bugs, flies

Reptiles

Venomous Reptiles

Lizards, rattlesnakes, coral snakes, desert vipers, desert black snake, cobras, Australian elapids

Reptiles That Are Nonvenomous But May Attack

Crocodiles, monitor lizards

Mammals

Mammals That Are Zoonotic Disease Vectors

Dogs, rodents, rabbits, bats, squirrels, cats, primates

Mammals That May Cause Mechanical Injuries

Camels, carnivores, donkeys, antelope, deer, elephants

*See also Part 5.

FIGURE 61-19 Travelers on camel.

Current topographic maps and a good compass are essential, whether traveling by vehicle, by animal, or on foot. Local authorities should be consulted concerning water sources; these should be marked on the maps. A copy of the map should be left with someone who knows the travel plans. The route and campsites should be indicated on the map. In that way, if one becomes lost or injured, search and rescue teams will know where to initiate the search. If one becomes lost or injured, it is usually best to stay in one place and signal for help, using a mirror or other reflective object during the day and a fire at night. A cellular telephone, radio, or emergency locator transmitter may aid searchers. Flares and whistles should be used only when searchers are nearby or a search aircraft is moving in your direction. Geometric patterns drawn on the ground, such as "SOS," "HELP," or a large "X," may aid aircraft in identifying the position of a distressed person. Rocks, contrasting soil, plants, or clothing can be used to produce the patterns. It is difficult to see a single human on the ground; therefore, it is always best to stay near a vehicle if possible. An automobile can be a good source of signaling equipment. The windscreen and windows reflect light, and the mirrors can be removed and used to signal. Oil can be drained, placed in a hubcap, and mixed with sand. When set on fire, it produces dense black smoke. The hubcaps can be used to dig a desert trench shelter, the battery to start a fire, and the seat covers and floor mats for shelter and footwear. If one has adequate water, knows the direction of travel, has good footgear, and decides to try to walk to safety, it is imperative to leave a note outlining plans in a conspicuous place or to draw an arrow on the ground with rocks pointing in the direction of travel. Direction finding can be accomplished without a compass using the sun or stars (see Chapter 106). Before traveling in the desert, it is best to know the locations of key terrain features, such as rivers, highways, mountain ranges, and cities. Power lines, stream beds, and pipelines may also lead to civilization, but it may require days to arrive. It is dangerous to travel through arroyos or wadis because of the danger of flash flooding. Rainfall in mountains several miles away can wash down these formerly dry stream beds, pushing tons of mud, rocks, and water in a lethal torrent. Sand dunes should be avoided because of the amount of energy required to traverse them. Salt marshes may contain soft ground that traps the hiker. One should travel in the cool of the night to conserve water, and use the stars for direction. The dangers at night are that many desert animals are more active, and the chances of falling from a cliff, stepping into a hole, or stumbling into the spines of a cactus are greater.

SUGGESTED READINGS

Suggested readings for this chapter can be found online at www.expertconsult.inkling.com.

CHAPTER 62

Whitewater Medicine and Rescue

HENDERSON D. MCGINNIS

Whitewater is a general term describing moving water in a creek or river. Whitewater paddling activities are very popular. In addition to the standard activities of rafting, kayaking, and canoeing, which have been pursued for years, stand-up paddleboarding is gaining traction among outdoor enthusiasts.[1]

It has become quite easy to locate, rent, and buy whitewater gear. A person can have a new boat, board, and gear delivered to the doorstep with a few simple mouse clicks. Improvements in equipment design, manufacturing, and distribution of equipment allow more people to experience whitewater sports. Now that safety features have been improved, materials made stronger, and paddling skills more widely taught, more paddlers are encountering whitewater conditions that were previously considered technically difficult or impossible to run. Paddlers may have to learn to negotiate waves, rapids, and "holes" and how to avoid obstacles in the water. This chapter considers unique and

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dynamic hazards of whitewater paddling and discusses ways for paddlers to remain safe and deal with many common injuries and problems associated with whitewater activities.

HISTORICAL PERSPECTIVE

The roots of modern-day whitewater paddling can be traced back to explorers of the rivers of the western United States in the mid to late 19th century. The exploits of John Fremont and John Wesley Powell provided foundations for today's expedition-style whitewater rafting trip. The origins of the current commercial whitewater rafting industry were trips undertaken by paying customers down the Colorado River beginning in 1938, and the Snake River in the 1940s.[20,21,44,46]

Commercial whitewater rafting in the eastern United States began in the late 1960s and was centered in West Virginia and Pennsylvania.[47,48] Commercial whitewater outfitters now span the globe. There are parks with artificial whitewater where one can enjoy a raft trip or kayak, canoe, or paddleboard miles from the closest natural whitewater area.

The development of the folding kayak in 1907 by Johannes Klepper was seminal in the development of modern whitewater kayaks. Fiberglass boats debuted in the 1950s.[12,25] Most kayaks today are made from polyethylene and are either rotomolded or thermoformed (Figure 62-1). One can still find kayaks made from fiberglass or Kevlar; they are generally more specialized than the average recreational whitewater boats. Inflatable kayaks (inflatables) resemble a cross between a conventional floating raft and a kayak. They are shaped like a kayak but are constructed of tubes that hold air like a raft.

Special whitewater kayaks exist for specific tasks: Boats for descending a very steep, rocky stream may be completely different from boats designed to allow a paddler to perform tricks on a wave. All-purpose or river-running playboats are used for all types of paddling.

With early whitewater canoes, paddlers were able to launch themselves on a river but might not be able to easily get off a river before entering a rapid. The canoes were large and difficult to maneuver, so their use was limited in more advanced sections of whitewater. As canoes became more durable and maneuverable, they became more popular for whitewater exploration. Using flotation bags in open areas of a canoe to attempt to reduce the amount of water taken onboard helped the performance in whitewater. There are now also closed-deck canoes (C-boats) that hold one or two paddlers. Whitewater canoes have not been as popular as whitewater kayaks, but they continue to evolve in design and materials.[11,45]

The stand-up paddleboard has exploded in popularity for general recreational use on waters other than whitewater. With the growth of paddleboarding on oceans, lakes, and calm rivers, it was only a matter of time before someone would start paddleboarding on whitewater. In the early 1990s, Jeff Snyder stood up

FIGURE 62-1 The plastic kayak has revolutionized whitewater sports. *(Courtesy Henderson McGinnis, MD.)*

FIGURE 62-2 Class V commercial rafting. *(Courtesy Henderson McGinnis, MD.)*

and paddled an inflatable kayak down some of the extreme whitewater challenges of the day.[24] Some paddleboards are now designed for use on whitewater to allow surfing on river waves or paddling down a section of whitewater.

Whitewater rafts have evolved from wooden boats and surplus military rafts to high-performance, multichamber, self-bailing inflatables in a variety of shapes and sizes. There are still some wooden whitewater boats (dories) in use, mainly on western rivers. Rafts are powered by paddles or a set of two oars (longer and larger than paddles). Each passenger uses a paddle, and one person acts as the guide, directing the coordination of paddle strokes while steering the boat. In a raft with oars, one person uses the set of oars and is responsible for the direction and movement of the raft. There are times when an oar-powered raft is augmented with a paddle assist.

Most people who engage in whitewater rafting are commercial passengers[43] (Figure 62-2). In this scenario, a guide takes the passengers in a raft down a river. Qualifications for guides are established by each state or an oversight agency that regulates the commercial whitewater outfitters. A canoeist or a kayaker is alone in a boat but often travels downriver with other noncommercial (private) boaters. Two-person canoes and kayaks are not as popular as the standard one-person craft.

An individual can purchase a raft, kayak, canoe, or paddleboard and launch it on many rivers without a guide. On some rivers, a permit is required to launch so that the number of people on the river at any given time can be controlled. Rivers that require permits for paddlers typically are routes used mostly by large commercial whitewater outfitters who take the majority of users down the river. The Grand Canyon section of the Colorado River and the Middle Fork of the Salmon River are two such sections of rivers that require users to carry a permit.

INJURIES AND DEATHS FROM WHITEWATER BOATING

It is often difficult to determine how many injuries and deaths are associated with whitewater activities.[43] There is no central registry for whitewater accidents. Death is an infrequent occurrence in whitewater paddling; it occurs more commonly among private recreational paddlers than commercial guests.[43] It is often stated that you have a greater chance of becoming injured driving to the river than you do on the river.[22] American Whitewater, a nonprofit organization with the mission "to conserve and restore America's whitewater resources and to enhance opportunities to enjoy them safely," maintains an accident database of whitewater injuries that are voluntarily reported. American Whitewater promulgates a safety code that has guidelines for whitewater paddling participants.[23] Regulations for reporting injuries by commercial whitewater outfitters usually designate a state agency.

Because most injuries are not life threatening, they are often not reported, and there is no mandatory requirement for private parties to report. Few studies have considered injuries and deaths in whitewater sports. One study attempted to capture paddling injuries among noncommercial boaters by collecting surveys at popular rivers and through online paddling discussion forums. This study mainly evaluated injuries in kayakers and showed that injuries were most commonly of the extremities.[2,13,18,34,43] In a report on more than one million commercial rafters from 2005 to 2010 on the New River and Gauley River in West Virginia, there were 7 fatalities and 205 injured guests.[2,34] During the same time period, the American Whitewater safety database had reports of 288 deaths and 114 injuries (not including the numbers that were reported for West Virginia during that time period).[23]

The study of the New River and Gauley River demonstrated an injury rate of 20 guests per 100,000 commercial rafters and a fatality rate of 0.68 per 100,000 commercial rafters.[2]

Musculoskeletal injuries (sprains, strains, dislocations, and fractures) accounted for nearly 50% of the injuries, and soft tissue injuries (abrasions, contusions, and lacerations) accounted for nearly 45%.[2] Of the injuries, 44.3% were to the head, neck, and face; 33.9% to the lower extremities; and 21.7% to the upper extremities. Only 7.3% of injuries were to the torso.[2] These numbers are consistent with a previous study that looked at injuries in commercial whitewater activities in West Virginia.[42]

WHITEWATER PADDLING EQUIPMENT

Specific equipment for whitewater paddling has helped to increase the comfort and safety of participants. On the water, a participant must be prepared to deal with constantly changing weather and water conditions and make efforts to prevent or react to potentially life-threatening situations. The guiding principle is that in a wilderness setting, it is far easier to prevent a problem than to treat it. Whitewater raft guides always advise, "Rig to flip and dress to swim," in order for participants to be best prepared for situations likely to be encountered during a river trip.

Preparation for any whitewater activity begins with trip planning and ensuring that participants have the proper equipment and experience. All participants should wear an appropriate, properly fitted personal flotation device (PFD), commonly referred to as a life jacket. Lack of a proper PFD is one of the most common factors contributing to deaths in whitewater accidents.[16,26] There are five categories (I through V) of PFDs classified by the U.S. Coast Guard (see Chapter 70). PFDs are classified for their intended use and the amount of buoyancy that they provide. Types III and V are commonly used for whitewater activities. The average adult needs 7 to 12 lb of buoyancy to keep the head above water.

The type III PFD is usually a vest-like jacket with at least 15.5 lb of buoyancy. Type V PFDs are designed for specific uses. The type V commercial PFD is designed to float an unresponsive victim face up in the water, and the type V rescue PFD is designed for trained personnel to perform swiftwater rescues and also has a minimum of 15.5 lb of buoyancy.[26]

The PFD must be fitted to the wearer so that it stays in place and does not ride up in the water. A PFD may also provide some protection from the elements if it serves as insulation and a barrier layer. Out of the water, a PFD can be used to improvise a splint, sling, or cervical collar. It should be checked regularly for wear and replaced when there is obvious damage or signs of excessive wear or when some features, such as zippers or adjustment straps, no longer function. It is a good idea to do a float test every year while wearing the PFD in a pool or calm water to ensure that it can function if it is deployed in the field.

Many paddlers wear type V rescue vests, which are equipped with a mechanism that will quickly release a strap from a metal ring that is connected to a rope for use during technical rescue (Figure 62-3). Opening a designated buckle on the front of the PFD allows the strap to slide out of the buckle and through the metal ring, which is connected to a rope holding the rescuer in place. This allows the metal ring to fall away from the PFD and frees the rescuer from the attachment. Many type V rescue PFDs also function as harnesses, but they should not be used for climbing. Prior to using a rescue-specific PFD, one should have adequate training and experience and practice in rescue techniques. All recreational paddlers should consider completing a swiftwater rescue course (Figure 62-4).

FIGURE 62-3 **A** and **B,** Life jacket with built-in rescue harness. It is essential for swiftwater use. *(Courtesy Henderson McGinnis, MD.)*

Head injuries are a common hazard when rocks are present in moving water. Fortunately, helmet use has increased in most outdoor adventure sports as helmets have become lighter, less expensive, and more comfortable and durable. Helmets are pretty much standard equipment for kayakers, canoeists, and whitewater paddleboarders. There are also helmets designed to provide full-face protection. The helmet must be properly sized and worn as directed to be effective. Helmet use is recommended for recreational whitewater rafters and required for many commercial rafting guests.[28,41]

Evolution of technical insulation and performance clothing has increased comfort and safety of participants in many outdoor activities. Whitewater paddlers are beneficiaries of breathable insulating base layers, barrier garments (splash gear), and shoes for specific conditions; drysuits are also sometimes worn.

FIGURE 62-4 Recreational paddlers. *(Courtesy Henderson McGinnis, MD.)*

Paddlers are wise to dress in layers and adjust their clothing according to current conditions. Splash gear is pants (or bibs) and jackets that are waterproof, with adjustable closures at the wrists and ankles. The better garments are made of breathable material to allow one to stay warm and not overheat.[5,17] Drysuits, dry tops, and dry bibs are made of waterproof material (usually breathable) with latex seals at the neck, wrists, and ankles (or with incorporated waterproof socks). Dry gear is designed to keep someone nearly completely dry, but splash gear allows water to enter at the neck, wrist, ankles, and waist. If a person cools off quickly, feels cold easily, or boats in cold conditions, a drysuit is often preferred. This is a one-piece suit that has a zippered entry and has neck, wrist, and ankle gaskets (or waterproof socks) to keep the wearer dry. One wears an insulating layer under the drysuit and adjusts the base layers depending on the temperature and personal preference. Wetsuits are still used by many participants on commercial rafting day trips.

There are many types of footwear for use on the river. In the past, whitewater participants had to settle for old tennis shoes or wetsuit booties. Development of multisport shoes and sandals has created many more options. The type of footwear chosen will depend on the activities. One should wear footwear that will provide the most protection and fit into the craft being paddled; this may vary depending on the weather and the season. It is always a good idea to have protective footwear when one is scouting, portaging rapids, or hiking to or from the river. One should choose footwear with good traction and some retention device to keep them on in the water outside of the boat.

Some paddlers will wear gloves to protect the hands during cold weather or use a hand cover that attaches to a paddle. There are special gloves for paddlers and rowers to protect the hands in various temperatures. Gloves may be helpful when performing a rope rescue.

It is a good idea to carry a spare base layer and/or barrier layer. Hypothermia is nearly always a possibility with whitewater paddling. Proper nutrition and hydration are combined with proper insulation and barrier layers to prevent hypothermia. With proper preparation and equipment, it is possible to safely paddle in the winter.

RIVER HAZARDS

There are many features that make paddling on moving water enjoyable but also potentially dangerous. They include the size of the stream bed, volume of water in the stream, gradient of the stream (amount of elevation lost from section to section), and hydrologic features of the stream, such as waves, holes, or waterfalls.

The International Scale of River Difficulty grades rivers and rapids as class I to VI. An American version of this rating has been adopted by the American Whitewater Affiliation for most U.S. rivers[23] (Box 62-1). Some western rivers use the Grand Canyon system, which rates rapids on a scale from 1 to 10. No scale is a truly objective standard; individual and regional variations are common, and the margin of difficulty for a particular rapid may differ significantly for kayaks and rafts. Unfortunately, important safety parameters, such as water temperature, remoteness, and evacuation potential, are not taken into consideration.

The difficulty of a river generally increases with the volume and average gradient of flow. The volume of water in a river is usually expressed as a measure of cubic feet per second (cfs). This is the amount of water moving past a certain point during a given period of time. The volume of a river can be determined by multiplying the width by the depth by the speed of the current. For example, water in a channel 10 feet deep and 20

BOX 62-1 American Version of the International Scale of River Difficulty

Class I: Easy

Fast-moving water with riffles and small waves. Few obstructions, all obvious and easily avoided with little training. Risk to swimmers is slight; self-rescue is easy.

Class II: Novice

Straightforward rapids with wide, clear channels evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily avoided by trained paddlers. Swimmers are seldom injured, and group assistance, although helpful, is seldom needed.

Class III: Intermediate

Rapids with moderate, irregular waves that may be difficult to avoid and can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on a large-volume river. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.

Class IV: Advanced

Intense and powerful but predictable rapids requiring precise boat handling in turbulent water. The advanced river may feature large, unavoidable waves and holes or constricted passages that demand fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting is necessary the first time down. Risk for injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong Eskimo roll is highly recommended.

Class V: Expert

Extremely long, obstructed, or violent rapids that expose a paddler to above-average danger. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex, demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. Eddies may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is mandatory but often difficult. Swims are dangerous and rescue is difficult, even for experts. A very reliable Eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential for survival.

Class VI: Extreme

Class VI runs exemplify the extremes of difficulty, unpredictability, and danger. The consequences of errors are severe, and rescue may be impossible. These runs are for teams of experts only, at favorable water levels, after close inspection, and taking all precautions. This class does not represent drops believed to be unrunnable but may include rapids that are only run occasionally.

From Safety Code of the American Whitewater Affiliation: americanwhitewater.org/content/Safety/view/.

feet wide moving at a velocity of 5 feet per second (fps) equals a volume of 1000 cfs. As the water level rises, its speed and power increase exponentially, raising the difficulty of most rapids. When the speed of the current is doubled, the force of the water against an object in the current is quadrupled; that is, the force of the current increases as the square of its speed. Occasionally, a rapid with increased water volume becomes easier to negotiate because the added water submerges hazardous obstacles. The gradient is the amount of drop between two points and is expressed as feet per mile. The steeper the gradient, the faster the water moves.

HAZARDS CREATED BY THE FLOW OF WATER

Eddies

Not all water flows downstream. The most common upstream flow is an eddy, which is created when water flows around an obstacle. The water piles up higher than the river level on the upstream side of the obstacle, whereas the water on the downstream side is lower. Water flows around the obstacle and then back toward it to fill in the low spot. The line between the upstream and downstream current is the *eddy line*. Eddies are one of the most important features of the river for boat maneuvering and rescue. Exiting the main current by pulling into an eddy allows the paddler to stop a descent and safely scout the next rapid. It also provides a location for setting up a rescue for a paddler's companion upstream.

Hydraulics

Hydraulics, also known as holes, reversals, rollers, suckholes, and pourovers, are the most common hazards in rivers. A hydraulic is created when water flows over an obstacle, causing a depression that produces a relative vacuum within which the downstream water recirculates (Figure 62-5). The water below a hydraulic is typically very aerated and looks white and foamy. Rafts and kayaks can be turned upside-down by the force of a hydraulic, and if the reversal currents are strong enough, crafts and people can become trapped in the recirculating flow. When proceeding into a rapid that contains a hazardous hydraulic, one member of the group should preset a rope below the hole to facilitate rescue.

Hydraulics release water downstream from beneath the surface. This may be the only avenue of escape for a swimmer. Escape from a strong hydraulic may require a person to stay submerged and to resist the urge to return immediately to the surface. Surfacing too early can result in recirculation. Fortunately, most paddlers eventually escape from a hydraulic regardless of what action is taken by the paddler.

Novice paddlers often misjudge the force of hydraulics. It is not the height of the drop that generates the recirculating power, but rather the shape and angle of the obstruction, combined with the water volume and adjacent eddy currents. A "smiling" hydraulic has its outer edges curving downstream, so that the recirculating water feeds out into the main current and is thus easier to escape. In a "frowning" hydraulic, the outer edges curve back upstream into the center of the hydraulic, making escape much more difficult.

Low-head dams or weirs form massive hydraulics with enormous recirculating potential. Unlike natural hydraulics, the hydraulics of these human-made structures stretch all the way across the river, leaving no escape routes. In the Binghamton Dam disaster of 1975, a 4-m (13.5-foot) Boston whaler with a 20-horsepower engine was pulled into a hydraulic while attempting a rescue, resulting in the deaths of three firefighters.

Undercuts

An undercut is a rock on the side of a river that extends further upstream above the water than it does under the water. Anything that hits the rock can get pushed under the rock and may become stuck. A pile of rocks and debris may form a sieve, which can act like a colander, allowing water to flow through it but holding an unfortunate human in place. Such structures are usually found in rivers of an older geologic age. They can be difficult to recognize and pose significant risks for entrapment and drowning, even in class II rapids.

The potential for entrapment can also occur when swimmers attempt to stand up and walk in swift-moving currents. A foot can become wedged in an undercut rock or between rocks beneath the surface, causing the victim to lose his or her balance and fall face down into the river (Figure 62-6A). With the foot entrapped, the victim cannot regain an upright or even face-up position. This type of mishap has caused drowning in water less than 3 feet deep. The water is always moving faster than one thinks, and it can knock a person down and sweep the person downstream or pin a person's foot between rocks and knock her or him down.

Waterfalls

Waterfalls are as dangerous as they are lovely. Many people hike in the vicinity of a waterfall without fully realizing the potential for accidents. There are numerous reports of injuries and fatalities from slipping in moving water and falling over a waterfall, sometimes from a considerable height and onto rocks. Using common sense and practicing safe water crossings in all moving water could prevent many injuries. One should never attempt to cross directly above a waterfall or major rapid, and should avoid trying to climb up a waterfall or jump from the rocks surrounding one.

Having to Swim in Whitewater

The ideal way to experience whitewater is in a boat. If a person falls into the water and needs protection, the swimmer should always try to remain calm and safely get out of the water as soon as possible. The best way to prepare for an unexpected swim is to practice swimming in a safe area of a river. It is a very good idea to ascertain ahead of time where it is safe to swim and where one should do everything possible to leave the water as soon as possible. Other things that one can do to help survive a swim are to dress for the swim and wear proper protective

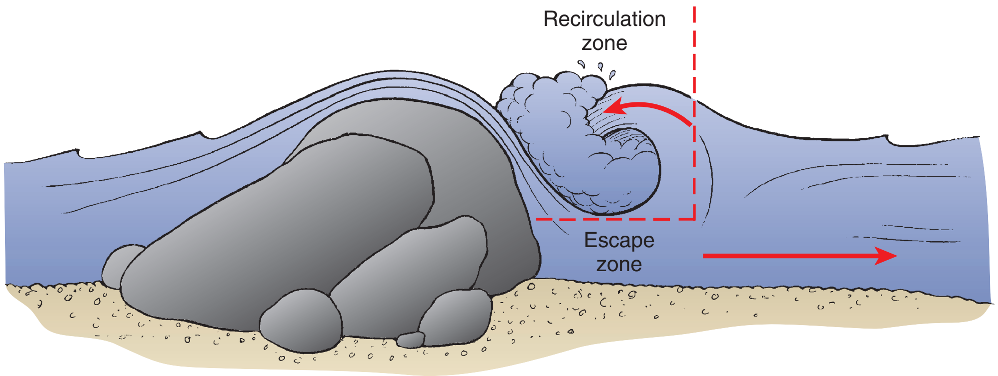

FIGURE 62-5 Recirculating currents created by a hydraulic. Water and "swimmers" are released downstream beneath the surface.

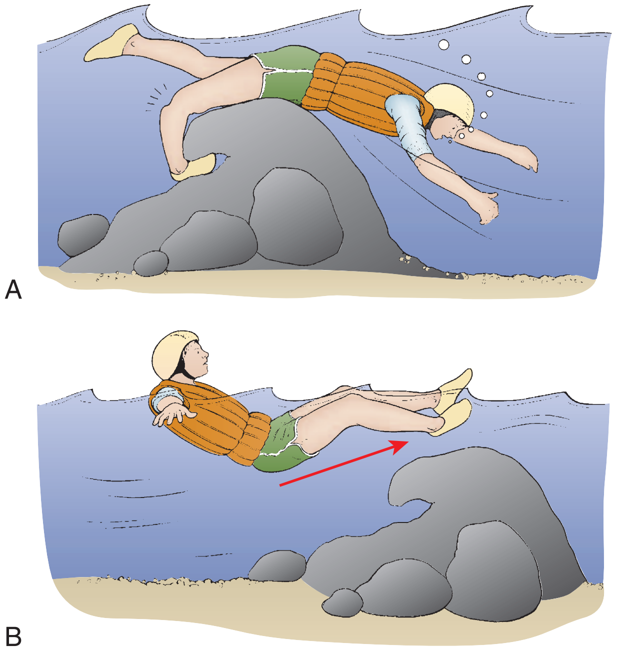

FIGURE 62-6 **A,** Attempting to stand up in shallow water can cause a foot to become entrapped in an undercut rock. **B,** Proper way to swim while in a rapid.

gear (e.g., life jacket, helmet, insulating and protective clothing layers, and proper footwear).

The basic *whitewater defensive swim position* is to float on one's back with the toes pointed downstream and use the arms to help maintain the proper position in the water. Try to keep the toes out of the water to avoid foot entrapment. These are the standard instructions given to most commercial whitewater guests when they fall out of a raft. There are many things to consider if the decision is made to swim with the boat. One must attempt to try to hold onto a paddle and the canoe, kayak, or paddleboard and avoid upcoming obstacles (e.g., waves, rocks, strainers) while attempting to leave the water.

A person who falls out of a raft into the water may surface near the boat and be able to reach it. A person in the boat may be able to extend a paddle (T-grip) toward the swimmer and pull the swimmer back into the raft. If the swimmer is out of reach of the raft, the guide or another person in the raft may throw a rope. The rope may be 25 to 75 feet long and is stored in a bag that allows it to be transported and deployed easily. If a rope is thrown, the swimmer should make sure to grab the rope and not the bag. If one grabs the bag instead of the rope, the remainder of the rope can deploy and the swimmer may be in the water longer than anticipated. There may be a person on the side of the river on in another boat that may be in a position and have the skill to toss a rope.

The defensive swim position is the standard approach for many situations. A swimmer in a rapid should assume a supine position, with the feet at the surface and pointed downstream to serve as shock absorbers. This position minimizes the potential for entrapment of the feet or for trauma to the head and neck (see Figure 62-6B). There may be occasions where someone will have to deviate from this position, as when encountering a barrier to downstream progress. There are times that a person will need to turn over and swim to try and avoid certain obstacles, such as strainers, or get to a certain place. *Strainers* are often trees, debris, fencing, or lines stuck between rocks or extending out from the shore. Strainers often stick out in the current right where a paddler or swimmer wants to be. If one cannot avoid the strainer, one should turn over onto the stomach and swim toward it. When one reaches the strainer, one should pull oneself up and over it (Figure 62-7A). This is a skill best practiced with instruction and supervision, and is often part of a swiftwater rescue instructional course.[3,23,40] Approaching a strainer feet first may lead to underwater entrapment (see Figure 62-7B).

HAZARDS CREATED BY OBSTACLES IN A RIVER

Part of the challenge and fun of whitewater paddling is moving a craft safely down the river while trying to avoid obstacles, whether they are created by nature or humans. Bridge pilings, submerged automobiles, dams, and low-hanging power lines can pose a threat to river-runners and can pin or injure them.

There will be times when one may have no choice but to hit an obstacle. If that is the case, it is best to square up and hit the obstacle head on. One should lean into the obstacle and work to get out of the boat or to free the boat from the obstacle. One should avoid leaning away from the obstacle because this will usually cause the boat to flip or the person to fall out of the boat. If that happens, one can become stuck between the boat and the obstacle. The boat may become stuck on the obstacle or another obstacle.

A *broach* is a boat in which the front and back of the boat are wrapped around or pinned to an obstacle (Figure 62-8) This poses a very serious threat to the paddler, who may become trapped if she or he is unable to get out of the kayak or canoe or becomes caught between the raft and the obstacle.

A *vertical pin* is a kayak or canoe stuck in a vertical orientation after going over a drop. One may only have a few seconds to try and free oneself from the boat before the water pressure pushing on the boat deforms the boat and prevents one from exiting (Figure 62-9).

A survey of 365 members of American Whitewater revealed that 33% of serious kayaking incidents and 41% of open canoeing mishaps involved either pinning or broaching[41] (Table 62-1). In a separate survey of 500 paddlers between 1989 and 1993, 42% of kayaking fatalities resulted from vertical pins, broaches, or entrapments in strainers.

Advances in canoe and kayak design and construction have increased durability, maneuverability, and safety of boats. This has made it easier for paddlers to exit boats through larger openings (cockpits on kayaks and C-boats). The downside of a larger opening is that there is an increased chance of the cockpit covering (spray skirt) becoming dislodged, which has resulted in paddlers losing control of their boats and even dying.[23]

Other advances in design have increased the strength of the boats. This may allow the paddler that little extra time needed

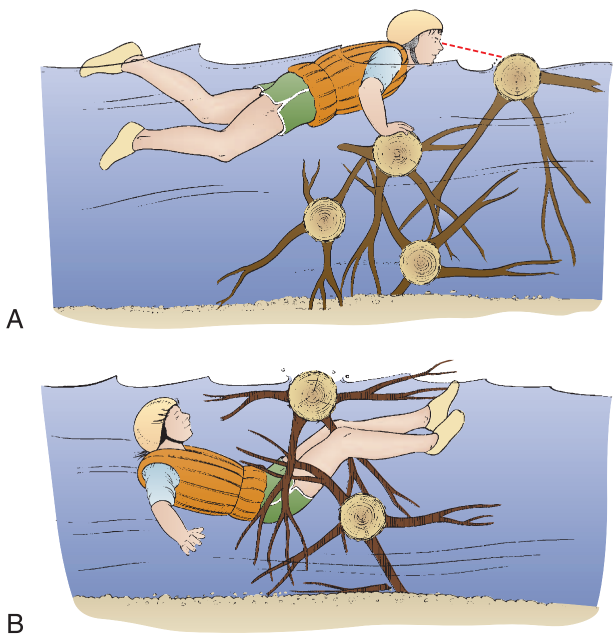

FIGURE 62-7 **A,** Proper approach to a strainer. **B,** Incorrect approach to a strainer.

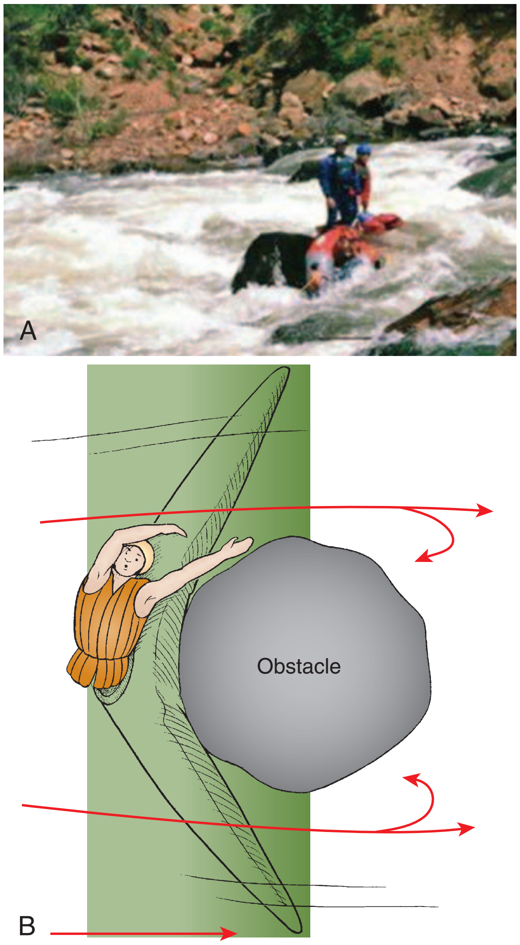

FIGURE 62-8 **A** and **B,** Broaches. (*A courtesy Henderson McGinnis, MD.)*

to get out of the boat when it is broached or pinned before the boat folds or collapses. Improved designs and padding can reduce forces transmitted to the boater when obstacles are struck. Modern plastic boats are far stronger than were their predecessors.

TABLE 62-1 Serious Whitewater Situations

Incident Type	No. of Incidents	Percentage of Accidents
Vertical pin entrapment	18	8
Broach entrapment	46	21
Rock sieve entrapment	16	7
Undercut rock entrapment	23	10
Recirculation in hydraulic	47	21
Long swim	42	19

From Wallace D: Scary numbers and statistics: results of AWA close calls and serious injuries survey, AWA J 37:27, 1992.

DROWNING

Drowning is discussed in Chapter 69.

TRAUMA

Most injuries incurred in a whitewater setting are to the extremities. These include contusions, abrasions, lacerations, sprains, strains, dislocations, and fractures.[2,14,23,42] The primary treatment is to stop bleeding; preserve circulation, sensation, and function; and prevent infection. This is often easier said than done in a resource-limited environment. (For more information on dealing with trauma, see Chapters 18, 21, and 22.)

PROPER POSITIONING FOR PREVENTION OF INJURIES

Proper positioning is important to prevent injuries and stay in the raft. For positioning in a paddle raft, one should sit on the outside edge of the raft facing into the center. One then twists the torso to face the front of the raft, with one leg in front of the body and one leg behind to brace on the thwarts. This will allow proper paddling and the positioning to effectively brace inside the raft, which is necessary when traveling down bumpy rapids and to avoid being thrown during a collision. Some people like to put a foot under the thwart in front of them or in a foot cup built into the raft. Hold the T-grip of the paddle in one hand in such a way that the top of the grip is covered in order to efficiently paddle. A firm grip may also reduce injuries from a flying T-grip that can strike another person in the boat. In an oar raft, passengers who are not rowing should position themselves out of the way of the rowers to allow the oars to move freely in

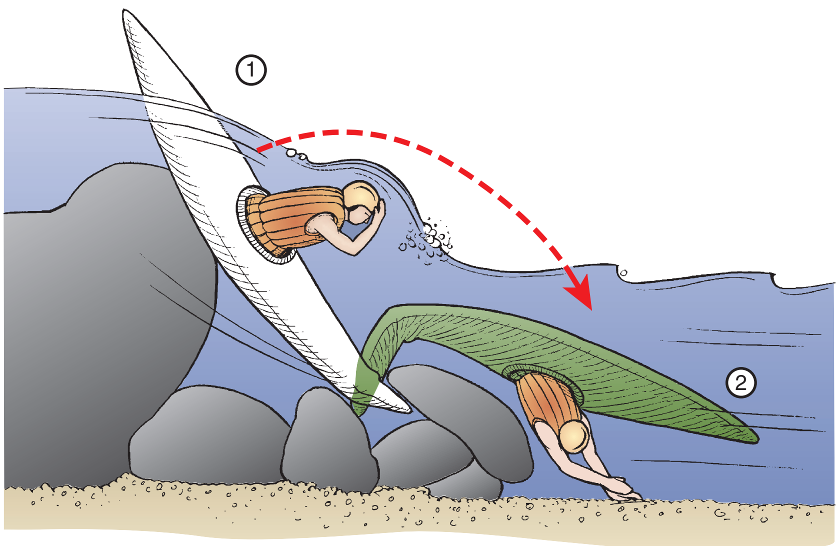

FIGURE 62-9 **1,** Vertical pin. **2,** Pitchpole pin.

and out of the water. Typically, there may be a cooler, dry box, or another flat surface upon which passengers may sit.

INJURIES MOST LIKELY TO OCCUR WITH WHITEWATER SPORTS

Overuse Injuries

Overuse injuries, such as muscle strain and tendinitis, are common. In addition to application of cold, rest, and use of antiinflammatory medications, modification of the paddling technique or using tape or braces may be helpful. Most of the treatment for these injuries takes place after the trip, unless one is on a multiday trip or part of an expedition involving multiple consecutive days of paddling.

Shoulder Dislocation

Shoulder dislocation is a classic paddling injury.[6,8,13,29] Various surveys have placed its incidence in kayakers at 10% to 16%, making it the second most common whitewater-related injury.[6,8,13,29] Anterior shoulder dislocation occurs more commonly in kayakers than in rafters because of the mechanism of injury, which is abduction and external rotation of the shoulder attributed to holding a paddle in a high brace position (Figure 62-10). The high brace is often used while supporting the kayaker in a hydraulic, surfing on a wave, or rolling the kayak upright after a flip. If the arm becomes extended behind the midline plane of the body by the force of the current, the triad of abduction, external rotation, and extension of the shoulder can stretch or rupture the glenoid labrum and capsule, resulting in anterior subluxation or dislocation.[35] The paddle acts as a lever to increase the force on the glenohumeral joint.

To minimize the risk for shoulder dislocation, the preferred method of bracing is the "low brace," in which the arm is held in internal rotation and close to the body (adduction). Although initially awkward for the novice paddler, this bracing maneuver is inherently stronger and more versatile because it allows backpaddling out of a hydraulic. Exercises that strengthen the rotator cuff and deltoids, triceps, and pectoralis muscles reinforce the glenohumeral joint.

Multiple techniques are possible for reducing a dislocated shoulder (see Chapter 22). Shoulder reduction is taught in many wilderness medicine courses. One study demonstrated the safety and efficacy of teaching whitewater paddlers with little or no medical training how to recognize and treat a dislocated shoulder.[8] The study reinforces the idea that shoulder reduction is a valuable skill for whitewater paddlers and should be part of their skill set.

One river-specific relocation technique uses the victim's life jacket to allow a single rescuer to apply both traction and countertraction.[9] This technique requires the victim to be supine, with room for the rescuer to sit adjacent to the dislocated shoulder. The rescuer slides a foot and leg through the life jacket's arm opening, under the neck, and out through the jacket's head opening. The rescuer's leg thus functions as a headrest, whereas the foot braced against the opposite shoulder strap of the life jacket provides countertraction. Holding the forearm of the

FIGURE 62-10 High brace maneuver.

FIGURE 62-11 Using a life jacket to assist in countertraction for shoulder relocation. *(From Auerbach PS. Medicine for the outdoors: the essential guide to first aid and medical emergencies, ed 6, Philadelphia, 2016, Elsevier.)*

affected side with the elbow bent at 90 degrees, the rescuer slowly leans back to apply traction while the leg exerts countertraction. The life jacket allows countertraction force to be distributed across the victim's chest (Figure 62-11). External and internal rotation can be applied to the humerus during traction to facilitate reduction.

One should always monitor the circulation and motor and sensory function to the wrist and hand before and after attempting a shoulder reduction. To prevent a recurrent dislocation, the kayaker's arm should be splinted across the chest with a sling or swath or by pinning the sleeve of the arm across the chest (Figure 62-12). If circumstances preclude exiting the river without further kayaking, the shoulder can be partially stabilized by using a functional shoulder immobilizer (shoulder spica wrap). This method allows the victim to kayak while still limiting complete abduction and external rotation of the arm (Figures 62-13 and 62-14).

Head, Facial, and Dental Injuries

Head, facial, and dental trauma are more common in kayakers and decked canoeists than in rafters because their boats may flip upside-down while they are still in them. However, one may see these injuries in rafters when the head of one rafter strikes the head of another or a paddle hits a rafter during travel through rough water. Head and facial trauma can be minimized by wearing a protective helmet and tucking forward, instead of leaning backward, while rolling a kayak, and encouraging each rafter to properly grip the paddle by the T-grip and always control the paddle.

Epistaxis (see Chapter 20) is common following facial trauma, especially in whitewater rafting, because most paddling helmets do not include face protection. Although most cases of epistaxis are minor, some present life-threatening emergencies.[49] Anterior epistaxis from one side of the nasal cavity occurs in 90% of cases.[4] If pinching the nostrils against the septum for a full 10 minutes does not control the bleeding, nasal packing may be needed. One can improvise and tape two tongue blades together to make a clothespin-like device to pinch the nostrils. Soak a piece of cotton or gauze with a vasoconstrictor, such as oxymetazoline (Afrin) nasal spray, insert it into the nose, and leave it in place for 5 to 10 minutes. Vaseline-impregnated gauze or strips of nonadherent dressing can then be packed into the nose so that both ends of the gauze remain outside the nasal cavity (Figure 62-15). This prevents the victim from inadvertently aspirating the nasal packing.

Complete packing of the nasal cavity of an adult victim requires a minimum of 1 m (3 feet) of packing to fill the cavity

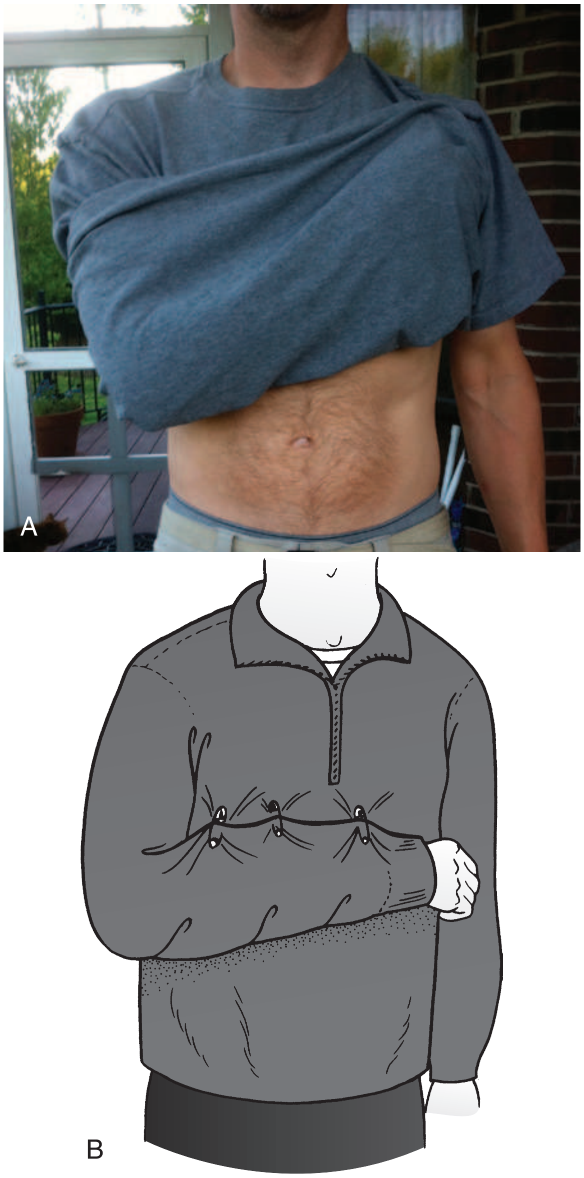

FIGURE 62-12 Techniques for pinning the arm to the shirt as an improvised sling. **A,** With a short-sleeved shirt, the bottom of the shirt is folded up over the injured arm and secured to the sleeve and upper shirt. **B,** With a long-sleeved shirt or jacket, the sleeved arm is simply pinned to the chest portion of the garment. *(**A** Courtesy Henderson McGinnis, MD; **B** from Auerbach PS. Medicine for the outdoors: the essential guide to first aid and medical emergencies, ed 6, Philadelphia, 2016, Elsevier.)*

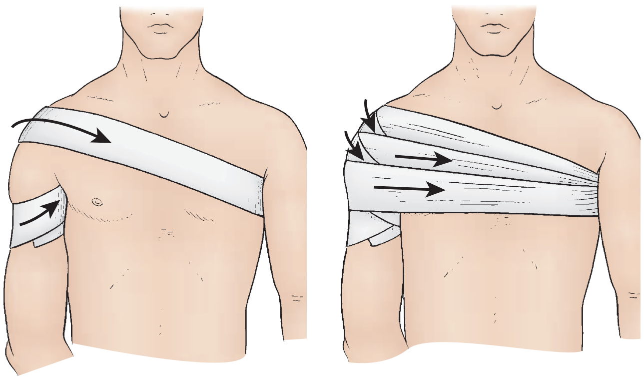

FIGURE 62-13 Shoulder harness for support after shoulder dislocation.

FIGURE 62-14 Shoulder relocation support. *(Courtesy Henderson McGinnis, MD.)*

and tamponade the bleeding site.[4] Expandable packing material, such as Weimert Epistaxis Packing or the Rhino Rocket, is available commercially. A tampon or balloon tip from a Foley catheter can also be used as improvised packing.[49]

Anterior nasal packing blocks sinus drainage and predisposes to sinusitis. In the field, prophylactic antibiotics are usually recommended until the pack is removed in 48 hours.[4]

If the bleeding site is located posteriorly, use a 14- to 16-Fr Foley catheter with a 30-mL (1-oz) balloon to tamponade the site.[7] First, lubricate the catheter with petroleum jelly or a water-based lubricant, and then insert it through the nasal cavity into the posterior pharynx. Inflate the balloon with 20 to 30 mL (0.7 to 1 oz) of water, and gently withdraw the catheter until the balloon is located in the posterior nasopharynx and resistance is met. Secure the catheter firmly to the victim's forehead with several strips of tape. Pack the anterior nose in front of the catheter balloon as described earlier (Figure 62-16).

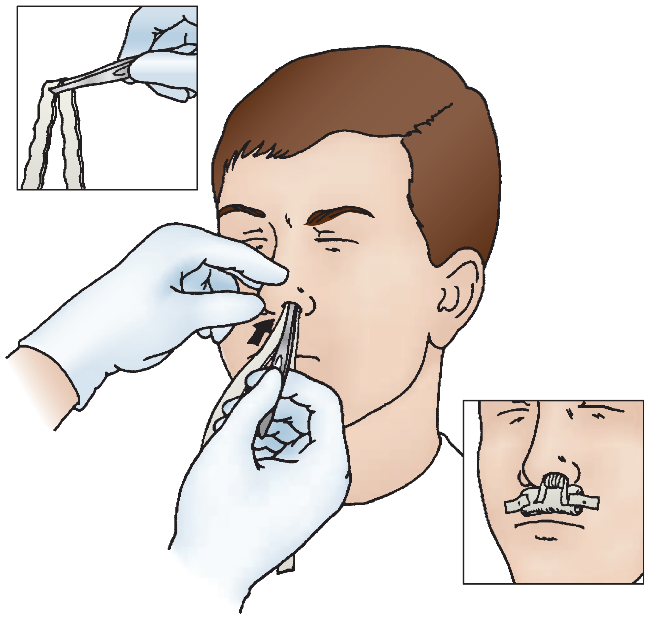

FIGURE 62-15 Anterior epistaxis from one side of the nasal cavity can be treated using nasal packing soaked in a vasoconstrictor. Petroleum jelly–impregnated gauze or strips of nonadherent dressing can be packed in the nose so that both ends of the gauze remain outside the nasal cavity.

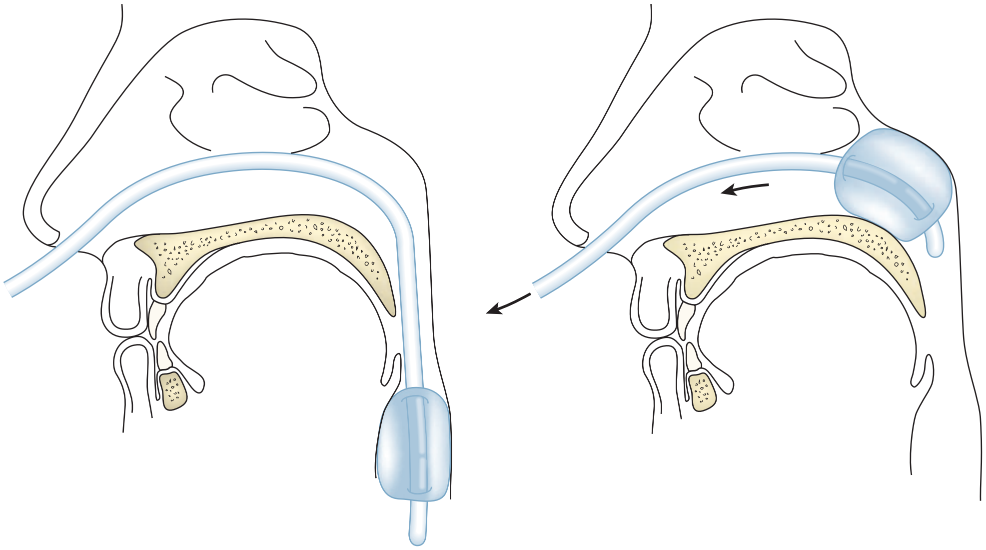

FIGURE 62-16 Packing the back of the nose. Insert a Foley catheter into the nose and gently pass it back until it enters the back of the throat. After the tip of the catheter is in the victim's throat, carefully inflate the balloon with 10 to 12 mL of air or water from a syringe. Inflation should be done slowly and should be stopped if painful. After the balloon is inflated, gently pull the catheter back out until resistance is met.

Spine Injuries

Spine fractures have been reported in whitewater paddlers.[23,36-38] Cervical spine injuries may occur in kayakers in conjunction with head trauma sustained after flipping upside-down or from an injury while swimming. Vertical compression fractures of the thoracolumbar spine occur from axial loading when a kayaker lands flat after paddling over a waterfall. One kayaker was rendered paraplegic after landing on his back on rocks while attempting to negotiate a waterfall.[39] Fortunately, his companions recognized the injury and kept him supported on Minicel foam blocks removed from their kayaks until a backboard could be obtained.

It is possible to fashion a long spine board–style litter from a kayak, canoe, paddleboard, or inflatable kayak. Depending on the situation, it may be better to stabilize and treat the patient on the scene and await professional rescue. However, there will be times when professional rescue is not available and one needs to immobilize and transport the patient. In such a case, it may be possible to use the bottom of an inverted kayak. The inside of an open canoe with the flotation bags deflated or removed, or a paddleboard, can make a great long spine backboard with little to no modification. One may also fashion a litter for transport with rope, paddles, clothing, and other items commonly found even on day paddling trips (see Chapter 23). The route chosen for extrication is important. It is important to know in advance the best way to get off of the river and reach definitive medical care. Always know the evacuation points and the nearest available medical facilities when planning any outdoor adventure.

Injuries Requiring Improvised Splinting

Practice splinting prior to the paddling season or before any big trip so that you can reinforce skills and prepare for a real injury (see also Chapter 23).

Wounds and Infections

Wound management on a river trip follows standard wound care principles.[10,32] The first step is to control the bleeding.[15,30] The next order of business is to clean the wound and treat it. It is often a challenge to keep a wound dry, so special care must be taken to keep equipment (and all other medical supplies) protected from the elements. Store them in waterproof bags or boxes designed for protection and ease of use.

Wound infections should be anticipated. In general, the larger the amount of damaged, nonvital tissue remaining in the wound, the greater the likelihood of infection.[10] The wound should be irrigated with water or a wound irrigant cleaner, preferably using optimal irrigation pressure (see Chapter 21).

It is usually impractical to suture a wound during a river trip. One may consider using adhesive surgical tape to close a wound, or even use duct tape for this purpose. Regardless of the method of closure chosen (sutures, staples, tape, tissue glue), one can usually secure and strengthen the closure by anchoring adhesive surgical tape linearly along the wound and reinforcing the closure perpendicularly across the wound.

Almost any wound is at increased risk of infection on a whitewater trip, for a number of reasons. The wound may stay moist or intermittently become wet, sometimes with contaminated water. It may become macerated. It may have friction or pressure forces applied. Gastrointestinal infections from agents such as norovirus and food-borne illnesses can debilitate an entire group and bring a trip to a halt. Proper group sanitation and personal hygiene may help reduce transmission of illness throughout the group.[27,31]

Repeated exposure to water in the external ear canal changes the pH and can damage the epithelium in the canal in such a way as to increase the risk for otitis externa. Prevention by using commercially available ear drops to change the pH and to remove water from the canal is advisable for frequent paddlers. For diagnosis and treatment, see Chapter 20.

Being in close and repeated contact with natural bodies of water increases the possibility of waterborne infections such as giardiasis and leptospirosis. Infections such as malaria may be endemic to certain regions.

Disorders Caused by Environmental Hazards

Exposure to the environment is constant when one is paddling through whitewater. The paddler is at times at risk for various environmental problems such as hypothermia or hyperthermia, contact dermatitis, bites and stings, and solar damage.

Hypothermia is a threat if a paddler is ill prepared for a swim or does not have adequate protective gear. Heat-related illness is a possibility if the paddler is wearing a nonbreathable drysuit and temperatures are warm. The treatment for hypothermia or hyperthermia is to remove the paddler from the environment that is causing the problem. The paddler may need to remove wet clothes and put on a barrier layer to warm up, or remove a nonbreathable layer to cool down.

Contact dermatitis is almost guaranteed on some whitewater trips because of the need to scout routes or carry a boat around rapids. If exposure to poison ivy, oak, or sumac has occurred (see Chapter 64), promptly wash the exposed area with soap and water.

There are many wild animals, reptiles, insects, and arthropods that can bite or sting a paddler. One should do research on the common hazards for each trip and know how to avoid an encounter and recognize and treat bites and stings. Always be prepared to treat an allergic reaction (see Chapter 67).

Solar damage (see Chapter 16) can be prevented by wearing protective clothing, liberally applying sunscreen, and using eye protection.

WHITEWATER RESCUE

RESCUE EQUIPMENT

Throw Ropes

River throw ropes are usually made of solid-braided polypropylene marine (Spectra) line with a maximum load of about 2000 kg (4500 lb). Throw lines vary in length from 15 m to more than 23 m (50 to 75 feet), with 23 m (75 feet) being optimal because that length of rope can be thrown by most rescuers. Some paddlers use shorter lengths in waist-belt systems that can be quickly deployed for victims who are only a short distance away. The ideal thickness is 9.5 mm (0.375 inch). A breaking strength of 680 kg (1500 lb) is the accepted minimum for river rescue ropes in the United States.[3,40]

The vast majority of throwing rescues are made with river rescue throw bags. Throw bags contain throw ropes. One end of a rope is secured to the bottom of the nylon sack (bag) with a disk of foam to float the bag, and the remainder of the rope is stuffed inside the bag (Figure 62-17). Throw bags typically contain 15 to 21 m (50 to 70 feet) of 9.5-mm (0.375-inch) braided polypropylene rope, with tensile strength in the range of 771 to 907 kg (1700 to 2000 lb). The bag can be clipped into a raft, kayak, or canoe with quick-release straps or a carabiner and can be rapidly deployed when needed without having to uncoil the rope. The rescuer simply pulls the free end of rope from the top of the bag and tosses the rope-filled bag to the intended victim. If the victim is moving with the current, the bag should be thrown slightly downstream of the target to account for the velocity of the current and air time.

The most common method of hurling a throw bag is underhand, in which the thrower swings the bag back and forth a few times and then releases it. The release should be at a 45-degree angle to the surface of the water. If the initial throw of the bag misses, a second throw can be executed faster by recoiling the rope into the nonthrowing hand rather than restuffing the rope into the bag. Starting with the bag end of the rope, make full arm-length coils, laying the coils into the nonthrowing hand, which also holds the bag. Once the rope is coiled, split the coils and make a second throw, allowing the rope to play out while maintaining a hold on the bag.

Commercial outfitters and large groups of rafters should carry at least one static rope of 91.4 m (300 feet) to be used for Telfar Lowers, Tyroleans, and other rescue situations in which mechanical advantages are needed.

Carabiners and Pulleys

Although originally designed for climbers, carabiners are often used by paddlers as an alternative to knots to rapidly secure and deploy throw bags and other safety equipment in river crafts.

FIGURE 62-17 Example of a throw bag.

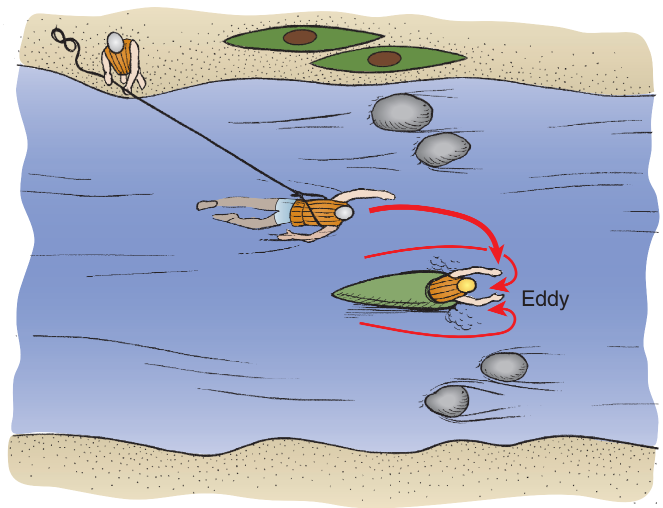

FIGURE 62-18 Strong swimmer rescue.

They can also be substituted for a pulley in a Z-drag. Locking carabiners can become jammed by sand and dirt encountered along rivers. Pulleys are often used in Z-drags and other mechanical haul systems to reduce friction and add greater pulling power to the system. As a rule of thumb, the diameter of a pulley should be at least four times that of a rope.

Prusik Loops

Prusik loops are useful for setting up mechanical advantage hauling systems, such as Z-drags, that are used to recover pinned or broached crafts. Prusik loops are usually formed from lines of 5.5 to 7 mm, with the ends tied together with a double fisherman's knot.

The Prusik hitch is tied by wrapping a Prusik loop around a rope a number of times (usually 3 to 5 times, depending on the materials) and then back through itself, forming a "barrel" around the rope with a tail hanging out the middle (Figure 62-18). When the tail is weighted, the turns tighten and make a bend in the rope. When weight is removed, the loop can be moved along the rope by placing a hand directly on the barrel and pushing.

Webbing

A loop of webbing, made by tying the ends together with a water knot, can be worn around the waist and secured by a carabiner. The webbing can be used to set up an anchor for hauling systems, as a sit harness, and as a handle or shoulder strap for carrying boats and litters.

Knives

Because of the potential for rope entanglement, knives can be lifesaving. A knife can be used to puncture the compartment or floor of a raft to free a pinned or trapped occupant in the event of a broach or flip. Some knives feature a fully serrated edge to cut through a plastic kayak to free a pinned paddler. Molded friction-release sheaths have been designed to clip to a belt or the lash tab on a PFD for rapid deployment. It is usually mounted near the shoulder on the PFD.

Whistles

Whistles should be worn on the life jacket to alert others of an incident, because it can be nearly impossible to hear someone yelling over the noise of a rapid. Choose a whistle that does not have a cork ball in it. The cork often swells when soaked in water, causing the whistle to be less effective. Fox 40 pealess whistles are louder than traditional whistles and less likely to malfunction.

RAPIDLY DEPLOYED RESCUE TECHNIQUES

Time is the most important factor in river rescue and often precludes the use of technical rope-based systems. Experience and understanding of river dynamics are essential. The abilities to move around on wet, slippery rocks and to maneuver a kayak in swift rapids are more valuable than is knowledge of technical rope-based systems.

The most common rescue scenario involves a swimmer who has exited the craft. The victim may be moving downstream at 8.05 to 16.09 km/hr (5 to 10 mph) in the middle of a large river. Because the dynamic nature of swiftwater does not often allow time for a shore-based rescue system to be established, many whitewater rescues are made from a raft, canoe, or kayak. Rafts should stay close together in rapids to render mutual aid. A throw bag can be used directly from the raft to rescue a swimmer, or a victim may often be reached with an outstretched arm and a paddle. A swimmer should be pulled back into the raft by grabbing the shoulder straps on his or her life jacket and leaning backward into the raft to pull the person in. The swimmer can assist by pulling up on the frame, D-ring, or hand line as he or she is being pulled into the boat.

Kayaks can be used to rescue swimmers in the water. The kayak is also an excellent platform for providing additional flotation for a swimmer who is trying to keep the head above the surface in rough water. The most common method of rescuing swimmers with kayaks is to have them grab the bow or stern "grab loop" of the boat and then tow them to safety. The loop is usually sized so that it is easy to grab yet will not admit an adult-sized hand. The swimmer can also grab the back of the cockpit rim and pull his or her torso onto the back deck. This gets the swimmer out of the cold water, reduces the likelihood of swimmer injury from rocks, and makes it easier for the kayaker to paddle the victim to shore.

Body boards and boogie boards, originally developed for use in ocean surf, have been modified for rescue use on rivers. River rescue boards are larger and come with two sets of handles, one for the rescuer and one for the victim. The boards add a substantial amount of flotation to a rescue swimmer and, when used with swim fins, can provide a maneuverable platform for reaching and recovering a victim in the middle of a river.

The latest craft to be adapted to swiftwater rescue is the personal watercraft, or jet ski. Introduced in 1987, the jet ski has become increasingly popular with professional rescue agencies. Because they lack an exposed propeller, personal watercraft are safe for swimmers and can negotiate shallow rivers. They can be maneuvered upstream in rapids, and can turn within a short radius. Newer versions, adapted for rescue, can tow a backboard or litter device and remain quite stable.

WADING AND STRONG SWIMMER RESCUES

Rescue from entrapment requires a higher level of skill than an open-water rescue and often presents a greater potential risk to the rescuer. The method used depends on whether the victim can maintain an adequate freeboard. If the entrapment site is accessible, direct contact with the victim is quickest and most effective. A rescuer may wade to the entrapment site or reach it by boat if there is a stable site where one can exit the craft.

The two significant risks involved in wading through swiftwater are foot entrapment leading to loss of balance and swimming through a downstream rapid. Before wading, the river downstream should be scouted for hazards, and if possible, a rope thrower should be stationed downstream in the event the rescuer loses his or her footing.

There are several techniques that help stabilize balance and facilitate walking in a swift current. One such technique involves using a paddle for support and to create three-point stability; this allows rescuers to wade into deeper water. Start by facing upstream, with the legs slightly further apart than shoulder width. Reach out, turn the paddle blade parallel to the current, and plunge it into the water. Just before the blade hits bottom, turn it sideways to the current. The force of the onrushing water will pin it to the bottom. The paddle and the rescuer's two legs form a tripod, which is more stable than the legs alone. Move slowly across the current, facing upstream, moving only one of the three points at a time. As the water deepens, one must lean more and more into the current. Although a pole, stick, or tree branch will work, a paddle blade is better because, when used correctly, it stays against the bottom more reliably. A group working together as a team can wade into water far deeper and more securely than can a single individual. Group members support one another, and by standing together, create eddies that provide them protection from the onrushing current. If there are two rescuers, they should face and grab each other by the shoulders of their life jackets and wade across the current, facing either upstream and downstream or sideways to the current. One person moves at a time; the upstream person moves first, and then the downstream person steps into the eddy created by the upstream individual. The two-person method can also be expanded for more people, with resultant increase in stability.

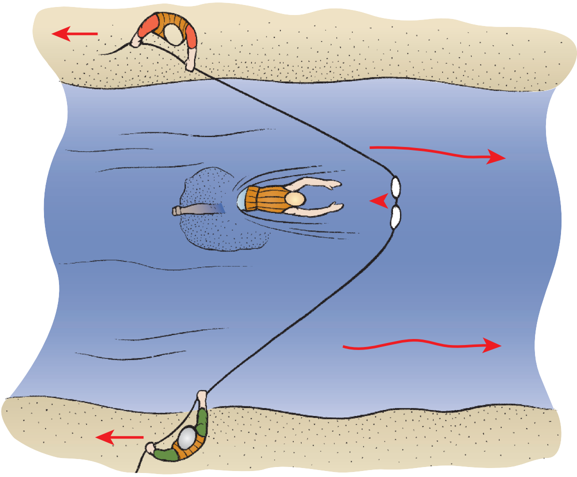

FIGURE 62-19 Tagline.

A strong swimmer rescue is the next-quickest method, but it entails significant risk to the rescuer (see Figure 62-18). The rescuer is tethered to a rope, which provides added stability against the force of the current. If a quick-release harness is not available, a loose loop of rope can be passed under the rescuer's armpits.

TAGLINE RESCUE

A tagline rescue should be considered if a victim cannot be reached directly. A tagline is a rope stretched across the river downstream that is then brought upstream to the victim (Figure 62-19). Getting the line across the river may be difficult if the river is wide; if the river is narrow, it may be possible to throw the line across. Otherwise, it can be ferried across by a boat or team of swimmers. During a ferry, as much of the rope as possible should be kept out of the water to avoid rope drag.

There are two types of taglines. A floating tagline has a life jacket, throw bag, or some other flotation device attached to the middle to keep the rope on the surface and help support the victim (Figure 62-20). A snag tag is a weighted line submerged and walked upstream to snare a foot or other body part that has been trapped under the surface. A snag tag can be made by joining together two throw bags filled with rocks (Figure 62-21).

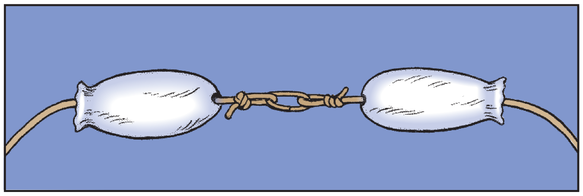

FIGURE 62-20 Two floating throw bags connected with a carabiner to make a tagline.

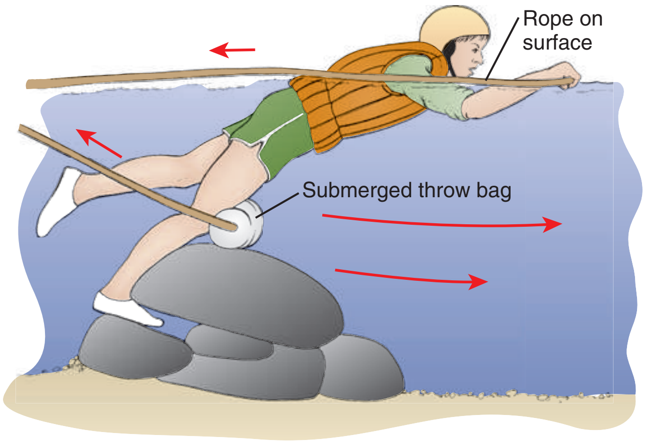

FIGURE 62-21 Submerged snag tag.

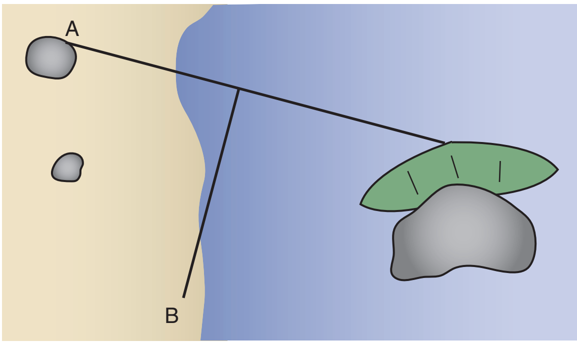

FIGURE 62-22 Vector pull.

RESCUING A PINNED BOAT

Freeing a pinned boat is a common rescue situation in whitewater paddling. In a *center pin,* which is the most common type of pin, the boat is trapped near its center at right angles to the current across an obstacle. When a raft contacts an obstacle and stops, the pillow formed by the current against the obstacle transfers to the upstream tube of the raft. If the crew fails to "high side" by transferring all weight to the downstream tube, the current will drive the upstream tube under the water. The pressure of the water against the submerged tube and the floor of the boat will either flip the raft or wrap the boat around the obstacle. When this happens, the crew will usually fall from the raft into the river and may even be trapped under the boat. If there is any possibility that someone may be trapped under the raft, the floor should be cut away carefully with a knife. A *wrap* can occur when a raft or boat is center pinned or broached on a midstream obstacle such as a rock or bridge abutment and wraps around the obstacle.

To release a center pin, determine which end of the boat is under the least pressure and pull on that end until the boat pivots free. Sometimes jumping up and down on the raft is enough to free it. It may be necessary to deflate one of the air chambers in a thwart tube to decrease the effect of the current on that point and reduce the amount of water trapped inside the raft. With a self-bailing raft with a lace-in floor, one can unlace or cut the lacings of the floor to reduce the current's effect. Avoid pushing or pulling directly against the current, and try to get as much of the pinned craft as possible out of the water by lifting it or dumping the water out of it, or both. If one can reduce the force of the current on the pinned raft at one point by pushing or pulling the pinned craft to one side, this may allow the current to push the boat around to the other side of the obstruction.[33,40]

Most pins can be released by pulling, pushing, or creating a vector pull with ropes, and do not require technical mechanical advantage systems. A vector pull can be established by first anchoring a rope between the raft and a fixed object on the shore, such as a tree or large rock. A second rope is then secured to the first rope in a manner that allows the rescuers to pull at right angles to the first rope (Figure 62-22). The vector forces generated by this method greatly amplify the force exerted between the raft and the shore anchor. At 10 degrees of deflection, 45.4 kg (100 lb) of pull translates to 227.3 kg (≈ 500 lb) on the raft.[19,33,40]

If greater force is needed to free a pinned craft, a Z-drag system that offers mechanical advantages can be employed, but this requires more equipment and expertise and is time-consuming to configure. With a 3:1 Z-drag, one person pulling on a rope exerts as much force as would three people pulling on the same line. The name comes from the fact that the arrangement of lines is roughly Z-shaped. Besides the mechanical advantage to pulling, it also uses only part of the total length of the rope for the functional part of the system. The Z-drag configuration uses two single pulleys (or carabiners) and two Prusik knots. The first Prusik knot provides the mechanical advantage. The second Prusik knot is used to hold the position of the rope and is sometimes referred to as a "progress capture device" or brake. It is also advisable to attach a soft object (such as a life vest) to the end of the line near the connection to the object being pulled, because the line is under high tension and could break free and present a dangerous flying hazard (Figure 62-23).

A *vertical pin* occurs when the bow or stern of a boat lodges in an undercut rock or obstruction or at the bottom of a steep drop. If the force of the water is significant, the boat may collapse at the fulcrum created by the obstacle that is trapping the boat, and then fold over onto itself. With a kayak, the paddler may be pinned inside the boat by the force of the current against his back. Modern kayaks made for steeper runs are shorter and have more rounded ends to mitigate the potential of boat entrapment. Larger cockpits have been created in these boats to facilitate escape should a pin occur.

If the victim can breathe, rescuers should try to stabilize the vertically pinned boat by attaching lines to it so that it cannot shift. A stabilization tagline can be set up to keep the pinned paddler's head up while other rescue methods are used to extricate him. Once the boat and paddler have been stabilized, a shore-based system, such as the Z-drag described earlier, can be set up to extricate the boat and paddler from the pin.

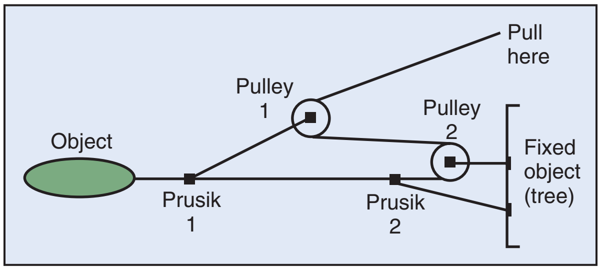

FIGURE 62-23 To set up a Z-drag, tie one end of the rope to the pinned boat. Tie an anchor around a tree and attach one of the pulleys to the anchor line (if a pulley is not available, a carabiner can be substituted, but this decreases the effectiveness of the mechanical advantage because of increased friction of the rope going through the carabiner, as compared with traveling over a pulley) and run the rope from the pinned boat through it and back toward the boat. Attach another pulley or carabiner (the "traveling" pulley) to the line with a Prusik knot and run the rope through this and back to shore. Rig a brake Prusik knot attached to the anchor.

APPENDIX A Whitewater First-Aid Kit

The whitewater first-aid kit should be configured according to the length of the trip, the area in which the trip will take place, the number of participants, any preexisting medical conditions of the participants, the amount of space available for the kit, any expected hazards, and the weather conditions that may be encountered. It is advisable to have one or more waterproof containers for transport and storage. Pack the contents in sealable plastic bags to keep them organized and close at hand so they can be retrieved quickly.

Items to consider:

Splinter forceps (tweezers)
Cotton-tipped applicators
Tongue blades
Wound closure strips
Benzoin pads
Antibiotic or antiseptic ointment
Alcohol pads
Butterfly bandages
Moleskin or transparent film for wound dressing
Examination gloves
4 × 4 sterile dressings
Tampon
Nonadherent sterile dressing
Triangular bandage
Elastic bandage of 2 or 4 inches
Gauze bandage (Kerlix) of 2 or 3 inches
Adhesive tape
Assorted adhesive bandages
Waterless hand sanitizer
SAM Splint
Small surgical stapler
2-octyl cyanoacrylate tissue glue (Dermabond)
Ibuprofen
Diphenhydramine capsules, 25 mg
EpiPen or vial of epinephrine with syringe and needle
Aspirin if paddling with patients at risk for acute coronary syndrome
Small notebook and pen or pencil
Rescue breathing barrier device
Thermometer (consider hypothermia thermometer)
EMT shears
Scalpel (No. 11 or No. 15 blade)
Irrigation syringe
Intravenous catheters: 14-gauge for needle decompression and 18-gauge for irrigation
Povidone-iodine solution
Liquid soap
Surgical scrub brush or sponge
Baby wipes
Trauma pads
Oval eye pad
Sterile dressings of additional sizes
Temporary dental filling (Cavit)

Always bring emergency preparedness (environmental) equipment, such as a headlamp, multiuse tool, waterproof matches, large heavy-duty garbage bags, plastic grocery bags, safety pins, duct tape, emergency blanket, sunscreen, lip balm, and insect repellent.

APPENDIX B Universal River Signals

Stop: Potential hazard ahead. Wait for the all-clear signal before proceeding. Form a horizontal bar with your outstretched arms. Persons seeing the signal should pass it back to others in the party (Figure 62-24).

Help/Emergency: Assist the signaler as quickly as possible. Give three long blasts on a whistle while waving a paddle over your head (Figure 62-25).

All Clear: Come ahead (in the absence of other directions, proceed down the center). Form a vertical bar with your paddle or one arm held high above your head. The paddle blade should be turned flat for maximum visibility. To signal direction or a preferred course through a rapid around an obstruction, lower the previously vertical all-clear stance by 45 degrees toward the side of the river with the preferred route. Never point toward the obstacle you wish to avoid (Figure 62-26).

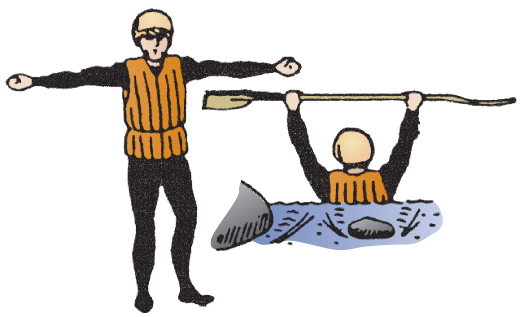

FIGURE 62-24 Stop signal.

FIGURE 62-25 Help/emergency signal.

FIGURE 62-26 All-clear signal.

APPENDIX C Organizations

American Canoe Association
7432 Alban Station Boulevard, Suite B-232
Springfield, Virginia 22150-2311
Internet: americancanoe.org
Phone: 703-451-0141
Fax: 703-451-2245
Email: aca@americancanoe.org

American Whitewater
P.O. Box 1540
Cullowhee, North Carolina 28723
Internet: americanwhitewater.org
Phone: 866-262-8429
Email: info@americanwhitewater.org

National Organization for Rivers
212 West Cheyenne Mountain Boulevard
Colorado Springs, Colorado 80906
Internet: nationalrivers.org
Phone: 719-579-8759
Fax: 719-576-6238
Email: nationalrivers@email.msn.com

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CHAPTER 63 Caving and Cave Rescue

LOUI McCURLEY AND ROGER B. MORTIMER

Caves are among the most awe-inspiring natural wilderness features remaining on Earth. Finding virgin territory within a few miles of many major cities worldwide is breathtaking. Unlike the far reaches of space or deep trenches of the oceans, uncharted caves can be explored by any reasonably fit person, without a plethora of fancy equipment.

Caves in a wide array of forms are found on every continent. The variations are endless. There are limestone caves, lava tubes, ice caves, marble caves, shelter caves, and water-filled caves. Full of beautiful formations, strikingly odd structures, and mystical allure, caves have intrigued humans since prehistoric times. From the practical use of caves as shelter to the sheer exhilaration of sport, the physical challenges of caving and rare environment found in caves set them apart.

Cavers are people who thrive on the prospect of exploring deep canyons and pits within the earth. Fascination with the unseen, the thrill of the frontier, the personal challenge of confronting the unknown, and the very darkness itself offer a distinctive aroma of adventure.

Caves can contain hostile environments. They present physical challenges, such as water obstacles, extreme temperatures, confined spaces, exposure to heights, and hazardous surfaces

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FIGURE 63-1 Litter in a tight spot. *(Courtesy Kris H. Green.)*

varying from slippery mud to jagged calcite that can catch or snag on cavers' clothing. Atmospheres can contain dangerous levels of carbon dioxide, methane, or hydrogen sulfide. Unusual pathogens, such as *Histoplasma capsulatum, Leptospira* species, and rabies virus, are more likely to be found in caves.[14] Well before engaging in underground duties, medical and rescue professionals should become thoroughly familiar with the harsh realities of the cave environment and anticipate unusual diagnoses in patients who frequent caves (Figure 63-1). Underground risks, both physical and medical, can be avoided or mitigated.

A rescue in Ellison's Cave in Georgia illustrates some of the challenges of a rescue underground. Two groups entered separate pit entrances for a crossover trip; each group left its rigging in place for the other group to ascend. Ellison's Cave has two of the deepest underground pits in the United States, at 179 m (587 feet) and 134 m (440 feet). While in the bottom of the cave, one of the explorers fell and sustained a compound fracture of the femur. His comrades stabilized it as best they could and sent for help. It took 2 hours for a fast caver who knew the route to get up the 179-m pit and out to where he could call for help.

The response involved cave rescue teams from three different states. Because it was a holiday weekend, many team members were unavailable, so cavers from the region who had been trained in rescue procedures were called in to supplement the agency response. Initial responders carried supplies to further stabilize the patient and prepare for transport. Blood was airlifted to the site and transfused at the bottom of the pit. Once packaged in a litter, the patient was moved to the base of the 179-m pit. Separate rigging teams had made a counterbalance haul system using two cavers as the counterweight. Once the rescuers had carried the patient out of the pit and the cave, the patient was flown to a hospital.

Rescuers responding to a caving accident must be fully aware of the unique challenges. Approaching a rescue situation with the idea that a cave is merely a dark version of a typical wilderness environment is at best naïve and at worst a recipe for disaster. As for any environment, potential cave rescuers should be trained, experienced, and adept in functioning on their own in the cave environment before assuming any sort of active rescue role.

The first thought that enters the minds of many newcomers to caving is "claustrophobia." In fact, claustrophobia is usually less of a problem for cavers (even new cavers) than are such issues as physical agility, route finding, endurance, and maintaining optimal performance levels in cold, wet, confined surroundings. Learning to cope, and indeed to thrive, under such circumstances is a prerequisite for the challenges of cave rescue.

Not only must cave rescuers be adept at managing the unique trials of functioning in the cave environment, they must also manage a unique set of rescue problems related to safety, equipment, logistics, access and extrication, and mission support.

A cave rescue should be initiated only with direct and intimate involvement of qualified cave rescuers. Rescuers without cave experience, or cavers without rescue experience, do not have the skills with which to launch a cave rescue. The demands of each of these two avocations are daunting enough; when caving and rescuing are combined, the physical conditioning and technical skills required are humbling.

In addition to experienced ground personnel, the incident commander must be familiar with or seek the advice of someone who is familiar with the unique challenges of the cave environment.

The time to learn about caving is not as a medic involved in a cave rescue. If there is any chance that one will encounter a cave rescue as part of his or her profession or avocation, time should be spent becoming familiar with caves and caving techniques before the need arises for a rescue.

ENVIRONMENT

Any natural opening in the earth large enough to enter is considered a cave. Caves are similar to human-made mines and tunnels only in that they share a subterranean setting. On a practical level, mines and tunnels must be approached with skills, equipment, and training that are different from those for caves. This chapter addresses only natural caves, such as may be found in a wilderness environment, and not mines, which require their own set of skills.

Caves take many forms, including sinkholes, cracks, sumps, siphons, springs, pits, and caverns. The precise geology of cave formation is a more complex and diverse topic than can be adequately addressed within the confines of this chapter. Some caves are simply topographic in nature—cracks and fissures that are a natural result of typical geologic features. Included in this category are lava tubes, which form when a volcano erupts and lava flows away from its center. Lava tube caves form as flowing lava cools hard on the outside and continues to flow on the inside, leaving a "tube" of passage. Like most caves that are formed as a result of earthen upheaval and movement, lava tubes are unpredictable and may run for long distances or be limited to short passages and isolated rooms.

More interesting is the geology of caves that form over long periods of time. An oversimplification of this formation process is that caves—particularly limestone caves, but in truth any cave found in carbonate rock—are most often formed as a result of solution reaction between water, carbon dioxide, and the rock. Known as *karst,* such topography is formed when carbon dioxide and water combine to form weak "carbonic acid," which in turn dissolves the carbonic rock. This process is most commonly found in limestone areas.

As the limestone dissolves, the acid solution follows the path of least resistance through the earth, and eventually pits are formed, then fissures, and gradually passages. When the calcium carbonate–infused water reaches a large enough opening, carbon dioxide dissipates and the calcium carbonate is deposited as *stalagmites* (icicle-like columns protruding from the ground) and *stalactites* (icicle-like columns hanging from the ceiling).

Sumps, siphons, and springs are all names that describe specific features in water-based cave formations. *Springs,* which are outflows of water from the earth, are obvious access points between an underground passage and the surface, but they can be called a cave only when they are large enough for a person to enter.

Springs differ from *siphons* in that springs outflow water, whereas siphons take in water. Air-filled cave passages that terminate in water-filled passages are known as *sumps*. Some sumps are only a few feet long before returning to air-filled sections; others can be thousands of feet long or may never resurface.

Sinkholes, cracks, pits, and *caverns* are terms that describe passages. These may be wet or dry and are differentiated by their shapes and attributes. Sinkholes, also called *sinks,* are formed when bedrock above a void collapses. Sinks may manifest as a sheer vertical opening into a cave with a well-like or open-air pit entrance, steep sloping depression with a cave entrance, or shallow depression of many acres that may not have more than a small, impassable sump to the cave below.

Cracks are narrow vertical passages formed as the carbonic acid solution finds its way through the ground. These are usually, but not always, developed along a joint in the rock. Tall canyons may form over geologic time when water flows through a passage as it rises above the ground-water level.

The term *pit* refers to a vertical cave passage. Pits can be found both inside caves and at the surface. Most open-air pits form when the roof of a sinkhole collapses. Pits can also be formed by solution reaction or erosion of a passage by flowing water.

Solution caves formed in soluble rock are the most common type found on Earth. Depending on local weather conditions and length of time, caves can take up to tens of thousands of years to form to the point where humans can enter. Caves are always changing, either getting larger, through solution and erosion, or smaller, through filling in with sand, mud, and fallen rock. These changes usually happen so slowly that they are seldom noticeable.

Most cave ceilings and walls are relatively stable. Large breakdown blocks of fallen ceiling and wall rock are often found in caves, but the chances of rock falling precipitously are slim. Breakdown usually occurs suddenly as a result of a major environmental event, such as an earthquake, or very slowly over years as the supporting rock below slowly degrades. Smaller rocks and rock slopes, often the results of ceiling and wall breakdown, are actually the greatest dangers in caves. Because they have not been stabilized by frequent travel, these slopes can shift and slide underfoot.

The continuous conduit leading through a cave is known as a *passage*. Passages can be huge, with room dimensions so large it is difficult to see distant walls (Figure 63-2) even with a light, whereas just around the next corner, the passage can change to tight impenetrable cracks or a dead end (Figure 63-3). Some cave passages wander around in a maze-like pattern that may total many miles in an area as small as a few acres of ground (Figure 63-4). Other caves may go for miles in the same direction and contain dozens of miles of passage. Many caves are only a few hundred feet long and allow only low, tight, belly-crawl passage. A passage that opens into a wide area is called a *room,* whereas a tight, narrow passage may be further described as a *squeeze* or *crawl.*

Caves are formidable, dark, and often dangerous for the unprepared. Considering that running, seeping, or standing water originally formed most caves, it is not surprising that water is a major part of many cave environments. Cavers and rescuers must be prepared to negotiate anything from crawls in water-filled tubes (Figure 63-5) to underground rivers so large that a boat is required.

Caves can be permanently or seasonally dry. Some are so dry that dust induces respiratory problems in cavers. Visitors to dusty caves should wear appropriate filter masks as a minimum level of protection from dust stirred up by the act of moving through a dry passage.

FIGURE 63-3 Typical tight crack passage. *(Courtesy Kris H. Green.)*

Temperature extremes are another common characteristic of caves. Caves tend to be at the mean ground temperature of the area. For the most part, U.S. continental caves run from cool to cold. Very warm climates, as in Puerto Rico, sport warm caves, whereas alpine mountain caves in locations such as Montana measure close to freezing temperatures and may even contain ice. Caves found in tropical and desert environments can be so hot that cavers must wear lightweight garments to explore them. Even then, these cavers are at risk for heat illness.

A more common scenario in cave rescue is the concern for hypothermia. Most caves are cool to cold, but temperature differentials can exist within a single cave, depending on exposure, orientation, and water flow. Temperature differentials or pressure

FIGURE 63-2 Typical large "room." *(Courtesy Kris H. Green.)*

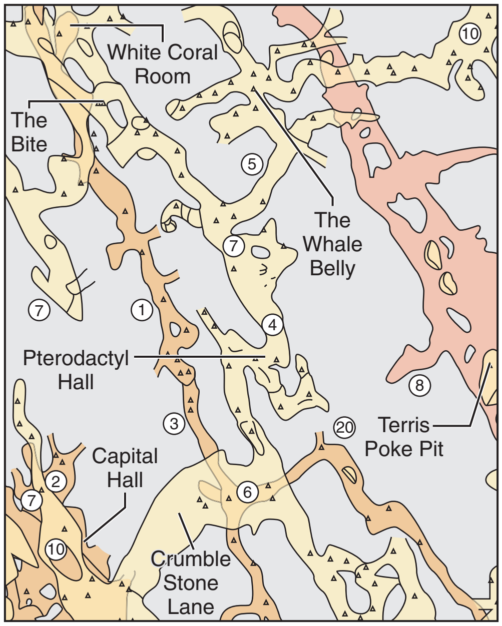

FIGURE 63-4 New complex passage in Wind Cave in South Dakota. *(Courtesy Wind Cave National Park.)*

FIGURE 63-5 Wet passages require appropriate clothing. *(Courtesy Kris H. Green.)*

FIGURE 63-7 Typical helmet-mounted light. *(Courtesy Kris H. Green.)*

differences can result in winds flowing through cave passages. It is not uncommon for a caver to be supine or prone in 4 inches (1.6 cm) of 13° C (55° F) water with his or her back pressed against cold rock, facing a stiff breeze (Figure 63-6).

If not prevented, hypothermia will complicate any cave incident. An injured, less mobile person will not generate as much heat as usual in the cold, frequently wet cave environment. Party members and rescuers must work to prevent hypothermia as soon as any injury occurs.

Rescuers must also protect themselves from hypothermia. A common scenario is for a rescuer to carry a load of heavy gear rapidly through the cave, then sit in a cold, wet passage to wait for the next assignment. The sweaty rescuer is now subject to evaporative, conductive, and convective heat loss. The well-prepared rescuer dresses in layers, travels light, and adds or removes layers of clothing as needed.

Caves can be fragile, often heavily decorated with mineral formations that have developed over thousands of years. Cavers try to protect these formations whenever possible by avoiding walking on or touching delicate areas or otherwise altering the cave. Even natural skin oils deposited by human hands can alter the growth of an active formation. The caver's motto, "leave nothing but footprints, take nothing but pictures, and kill nothing but time," extends to rescue operations. Everything brought in must be packed out at the end of the operation. An abandoned flashlight battery can leach its chemicals and poison cave-adapted life forms.

PERSONAL SAFETY

Whether entering a cave for exploration or for rescue purposes, cavers should follow personal gear requirements specifically tailored to caving. Clothing should be appropriate to the environment. Caves can be wet, dry, dusty, cold, warm, or a combination of these. The wind that can exist in passages makes chill factor a significant consideration. Undergarments should provide the necessary thermal layers and be made of a fabric that remains warm when wet. Layering undergarments provides the most versatile system of clothing.

FIGURE 63-6 Close contact. *(Courtesy Kris H. Green.)*

Many cavers wear protective suits with a rubberized, vinyl-coated, or Cordura outer layer. In very wet caves, it is not unusual to find cavers in wetsuits. Coveralls, or one-piece garments with no exterior straps or accessories, help prevent snagging in crawls or tight passages. Ventilation is an important consideration in accommodating the varying degrees of exertion required in caving.

A mountaineering type of helmet, with a nonelastic "three-point" chin strap that keeps it planted properly on the head, is a must. The helmet protects against impact with the hard and often sharp rock of cave ceilings and walls in tight or low passages and offers protection against falling rock. The helmet is also a convenient mounting platform for the required light source (Figure 63-7).

It takes only one episode of trying to navigate in complete darkness underground to understand why every person entering a cave should carry no fewer than three light sources. Rescuers who are underground without functioning lights become additional cavers in need of rescue. New LED lights have supplanted traditional carbide lights. At least two of these lights should be helmet-mountable for hands-free operation, each with sufficient "burn time" capacity or spare batteries to travel into and out of the cave.

Many cavers find gloves useful for thermal insulation and protection against sharp rocks and sticky mud. Neoprene or rubberized gloves are popular choices, and scuba or sailing gloves offer durable protection. If the cave has vertical components, leather-palmed gloves are necessary for rope work. Ideally, a rescuer should carry different pairs of gloves for rope work and for negotiating a muddy passage.

Cave mud is slippery and adheres to everything. It makes walking and scrambling through a cave dangerous. Lug-soled boots provide the best traction, and stiff leather uppers help protect feet against sharp rocks. For small passages, or "crawlways," a set of durable kneepads is a necessity, and many cavers use elbow pads as well.

Cavers, as any adventurers in a remote environment, should be self-sufficient and at least able to care for themselves for an extended period. This means being equipped with replacement batteries or carbide, potable water for drinking, food for energy, a basic first-aid kit, and extra insulation, such as thermal layers and a hat that can be worn under the helmet. In many caves, local ethics or regulations also require a "pee-bottle" and material for containing and removing solid waste. Cavers often store a folded trash bag in the suspension of their helmets to be used as an emergency shelter from wind and water, among other possibilities.

For the cave rescuer, the concept of self-reliance extends to being capable of caring for oneself, as well as a patient, for an extended period of time. Although the responsibility of patient care may be shared among several people, it takes planning to ensure that enough extra gear exists within the group so that the patient can be appropriately equipped and cared for.

Use a small, durable pack to carry extra gear. Because the gear will be alternately carried, pulled, pushed, and dragged through cave passages of different sizes, avoid excessively large packs with extra straps or external attachments, because these can impede maneuverability.

Not all caves have vertical drops, but for those that do, or when in doubt, a lightweight seat and chest harness, descent device, and rope-ascending system are essential. A rappelling device must withstand descent down a muddy or gritty rope. A brake bar rack, bobbin-type device, or sturdy figure-eight descender will do. Many devices designed for rock climbing are too lightweight to withstand these conditions repeatedly. In almost all in-cave drops, the caver will have to climb back up the rope. Thus, an ascending system is essential. One or two 6-m (20-foot) sections of 25-mm (1-inch) tubular webbing come in handy for an extra step-up or to construct a quick belay or hand line.

Vertical caving is a highly specialized sport, and vertical cave rescue is even more specialized. The National Cave Rescue Commission offers courses in cave rescue, recommended for experienced vertical cavers.

CAVE NAVIGATION

Navigating through the cave environment can be disconcerting, particularly because of the three-dimensional nature of travel. Cave passage moves upward, downward, and side to side through the layers of the earth. Passages may overlap, cross, and twist, all without the benefit of sun, stars, or GPS to provide directional clues. It is always best for several cavers (or cave rescuers) in a given party to be familiar with the cave and be responsible for navigation. If this is not possible, several options exist. The first, and best, is to use a cave map. Reading a cave map is an acquired skill that every cave rescuer should possess. In a pinch, cavers use navigational skills such as remembering landmarks, leaving temporary route markers, and using one wall of the cave as a source of consistency. Route markers are especially useful in cave rescue so that the rescuers can focus on the job at hand.

In an unfamiliar cave, keep track of prominent features so that you can find your way out. Passages often look different on the way out than they did on the way in. A small crawl that enters into a large room can be hard to find hours later when returning across that same room. One trick for finding one's way out later is to get in the habit of turning around and looking at the passage as you enter into a different room, take a significant turn, or negotiate a climb. Rock cairns, light sticks, and flagging tape can be used as reminders. Another option is to leave pieces of reflective tape to mark the way and then remove them as you leave the cave.

During operations in a particularly complex cave, it may be necessary to enlist the help of local cavers to serve as guides for rescuers unfamiliar with the cave. This may be contrary to standard protocols that forbid non–team members to participate in a search or rescue operation, but is critical to the mission to find the patient and not lose rescuers.

CAVE SEARCH

When the location of the rescue subject is unknown, a search will be required. Searching a cave is a potentially hazardous task and must be done meticulously and under good planning and management.[13] A manager of a cave search uses the same basic skills as does an above-ground rescuer. Once the decision is made to begin an in-cave search, teams of cavers will be formed into task forces. Each search task force's role is to look for, preserve, record, and recover clues that will lead to finding a missing person. The task force should consist of two or three members, one or more of whom should be familiar with basic search techniques, the cave being searched, and cave map reading. Members should be able to perform basic first aid, including patient assessment. In addition to personal caving gear discussed earlier, required equipment includes basic medical supplies, materials to mark passages, pencil and paper, food and liquid for the search subject, hypothermia protection, map, and compass. A marking system using colored flagging tape or other means should be established to mark side passages that have already been searched and to differentiate the best route in and out once a subject has been located.

Each search task force should obtain a briefing from command and then follow instructions as to where to search, how long to search, the probability of detection, how to preserve and record clues, how to report if a clue is found, and the debriefing procedures on return. If the search subject is found, the task force will assume the functions of an initial response task force. These functions are to determine whether the scene is safe, access the subject, treat the subject, consider possible courses of action (including walking the subject out if conditions allow), and then immediately notify command.

The report to the command should include a full assessment of the patient; the task force's recommendations for the course of action to be taken and for any additional medical equipment or personnel needed, type of litter needed, or rigging needed; and the task force's description of any obstacles to evacuation.

BASIC EVACUATION

On any cave rescue, each person entering the cave must have at least the minimum complement of personal gear, as described in the previous section. Beyond this, the amount of equipment used during a cave rescue is prodigious, particularly in a cave with complex terrain. Equipment and personnel are used nearly as quickly as they can be produced. Dry clothing, food, and water become valuable commodities, and extra supplies not normally used in cave exploration become necessities.

This last category, items not normally used in cave exploration, should be sourced, tested, and stored to be ready well in advance of being needed. Communications equipment, such as hard-wired field phones or cave radio systems, can be particularly difficult to find, as can experienced personnel to operate them. Other needs may include generators, warming tents, food services, and a command post.

Although most cave evacuations require litter transport, each individual situation should be evaluated carefully to determine whether a litter is really necessary. A properly stabilized "walking wounded" caver can be helped out of a cave in a short time and with little manpower. If that same individual is placed in a litter, however, the numbers of rescuers and hours to the hospital increase exponentially.

Two incidents from Lechuguilla Cave in New Mexico illustrate this. A caver 2 miles into the cave had a high tibia-fibula break from rock fall. She required a litter evacuation that took 176 rescuers 68 hours to accomplish and cost nearly a quarter of a million dollars. Two years later another caver broke his ankle a half mile further into the cave. Rather than call out a rescue, his teammates splinted him and supported him as he crawled out under his own power. Twenty-five hours later, with the help of 10 people and no real expense, he was out of the cave. The difference was not the stoutness of the cavers but the anatomic location of the injury. For one, a time-intensive litter carry was needed, but for the other, self-rescue was possible with relatively little help. A decision to litter carry a patient has significant consequences. Any measures that can support the self-rescue of a patient are a benefit to the patient, rescuers, and cave.

Not all cave rescue scenarios benefit from the fitness and ability of our Lechuguilla caver. If litter transport is deemed necessary, the next difficult decision is which litter (or litters) to use. On any given evacuation, this selection involves a fine balance of requirements. Maneuvering a bulky litter through narrow cave passages can be a challenging proposition. In larger caves, or where a vertical raise is required, basket litters are the best choice. Plastic-bottomed versions are preferable over steel and mesh versions, because plastic allows the option of dragging the litter where necessary (Figure 63-8). In tighter caves, drag-sheet types of litters, such as the wraparound SKED, provide a low profile and relative flexibility, but are less comfortable and protective for the patient.

Occasionally, a cave is so restrictive that even the length of a flexible litter is problematic, and a short board, such as a KED or OSS, is the only alternative. It is not unheard of to begin the

FIGURE 63-8 Plastic litter offers patient protection and slides easily through the passage. *(Courtesy Kris H. Green.)*

carry in a tight section of a cave using an OSS and then add a SKED once the passage opens up a bit, drop the SKED into a full basket litter for ease of carrying in a large walking passage, and remove package layers all the way back to the OSS to negotiate a tight entrance passage.

When choosing a litter and patient packaging, duration of transport and patient comfort are prime considerations. Natural positioning, pressure points, and temperature are key concerns. Although rescuers are working up a sweat, the patient lying in the litter is stationary, unable to regulate his or her own comfort, and often extremely cold. Thermal layers are a necessity and include a sleeping bag, vapor barrier, and moisture barrier to keep the patient dry. A full-body vacuum mattress works well as padding, immobilizer, and insulator. The patient should also have adequate head and face protection and, if the transport route will become vertical at any point, a harness. Waste elimination may need to be provided for.

A reasonable medical kit for a cave rescue operation should contain writing materials for recording the patient condition, basic medications, airway management tools, bandages, cervical collars, and splints. Sealing each item in plastic helps keep out cave grit, and the entire kit can be packaged in a large-mouthed bottle or other watertight, durable container. The kit should be able to fit into the rescuer's cave pack because it is much easier to carry one large pack than two smaller ones. The kit should target common injuries. More specialized supplies can be brought in as needed, but a comprehensive kit is not compatible with reasonable movement through the cave. See Box 63-1 for a minimal list of items to include in a cave rescue medical kit.

Because of extended times involved in reporting caving accidents and responding to and accessing injured cavers, most patients are either very stable or dead by the time medical help arrives. Advanced life support skills and equipment are generally not required. This is fortunate, because the effects of cave mud and water are not particularly friendly to medical electronics.

Sometimes a cave accident survivor is so badly injured that physicians or paramedics on scene choose drug intervention. At these times, electronic tools for monitoring vital signs can be extraordinarily valuable, but great care must be taken because the cave environment is ill-suited to the use of such devices. Even simple interventions such as intravenous (IV) infusions are problematic during cave rescues. In most cases, hanging a gravity-operated IV line is not an option, so positive-pressure infusion methods must be used. Furthermore, consideration must be given to methods for keeping the skin insertion point clean, and care taken not to interrupt IV fluid flow while negotiating tight passageways.

EQUIPMENT FOR A VERTICAL EVACUATION

Ropes used for high-angle underground rescue are usually of the static kernmantle variety. Low stretch, abrasion resistance, and consistent quality are key considerations. Caves can be harsh and unforgiving, so the tougher the sheath, the better the rope. The toughest-sheathed rope is usually less pliable and forgiving than those more prone to abrasion, so skilled riggers should be used for the task. Rope length varies depending on the particular cave and resources at hand. Ideally, rope lengths should be sufficient to negotiate each drop without tying knots to join ropes. Knot passes add undesired complexity to the operation.

Most cave rescues involve negotiation of difficult passages, as well as raising the patient from below ground to the surface. This may be accomplished in many ways, but pulleys and haul systems are generally basic necessities.

Techniques used in high-angle rescue in the cave environment are quite similar to those used above ground, but cave rescue may be complicated by tight spaces, darkness, environmental conditions, and lack of alternative routes. Anchors will seem less available and less obvious to rescuers who are only experienced in rigging above ground.

Brake bar racks are most often preferred for lowering operations because of their variable friction advantages. In addition to these, adequate carabiners, anchor materials, and other hardware should be available for rigging. If multiple locations must be rigged for raising, lowering, or traversing, the best possible scenario is to have enough gear to rig each site individually. Having to de-rig a system, sort the gear, carry it past the proceeding litter, and re-rig another system is time consuming and can derail the entire operation. Even a small cave might require multiple sites rigged for safe patient extrication.

Prebagged packages of gear for specific common rigging tasks are useful. These include anchor webbing, ample carabiners, pulleys, Prusiks, belay devices, lowering devices, and rope grabs, to set up one site per bag.

BOX 63-1 Contents of a Cave Medical Kit

Scissors
Adjustable cervical collar
Duct tape
Gauze bandages
SAM Splint or other flexible splint
Elastic wrap
Personal protective equipment
Stethoscope with extension
Blood pressure cuff with extension
Pencil with waterproof paper or acetate
Digital thermometer with extension (indoor/outdoor type)
Antibiotic ointment
Safety pins
Nasal and oral airways

Additions for Personnel with Higher Licensing

Oxycodone/acetaminophen pills
Injectable ceftriaxone
Injectable 1% lidocaine syringes and needles appropriate for regional nerve blocks
Povidone-iodine prep pads
Scalpel blades

LOGISTICS

Lack of easy communication, limited access, extended time, and difficulty in obtaining rest and nutrition for teams all contribute to the complexity of cave rescues.

Communication is essential to keep rescuers from becoming lost, issue instructions, and maintain the tempo of the operation. Standard radios rarely work underground. Various hard-wired field-phone systems are available for use in cave rescue, but generally only well-established teams have access to these. A relatively new development is availability of special low-frequency cave radios that can transmit the sound of a voice through dense rock and soil. Without such systems, message runners are indispensable. A group of swift, agile, safety-minded, and well-trained cavers with waterproof notepads, and a method for keeping these volunteers rested and nourished, are invaluable.

A team of rescuers sent into a known location can take hours or most of a day to reach the patient. It is logistically impractical for these rescuers to carry sleeping bags and food to allow for rest and recovery before starting their work assignment. Keeping rescuers rested, fed, hydrated, and warm as they navigate a challenging cave rescue many hours away requires an incident management team that can predict the needs of the underground workers.

Whether or not a communication system is available, establishment of a control point at or near the cave entrance is critical. Entrance control should be established as soon as rescuers arrive at the cave. A record of all personnel and equipment entering or leaving the cave should be documented in a log kept by a team member assigned to maintain entrance control. This log will become invaluable hours later in determining when teams should be replaced, verifying whether someone is still in the cave, and confirming who carried in what piece of missing vital gear.

The incident command system (see Chapter 54) or a modified version of it provides the best framework for managing cave rescue personnel by performing required functions while maintaining a reasonable span of control. Generally, the functions required during a cave rescue are similar to those required during any other rescue, although the specific means of accomplishing those functions will vary.

There should always be one person in command of an operation. This is the foundation of creating accountability and organization, which are the keys to efficiency and safety. The incident commander assesses the incident, activates resources, determines the strategy, and approves the plan for the operation. This may be particularly challenging in jurisdictions in which the cave rescue experts are not the same individuals as the emergency response experts. Preplanning and relationships developed in advance are the best solutions for preventing problems.

Other functions vital to success are planning, operations, logistics, and finance. The incident commander may have one or more assistants, or the commander may be responsible for several of these functions. Someone must plan strategies, supervise the operation, take care of the physical needs of the rescuers and required equipment, and track the resources.

CAVE ACCESS

Gaining access to the patient is a matter of overcoming an array of obstructions inherent in the cave. Merely to move a few hundred feet through a cave might require rappelling, crawling on one's belly, squeezing through cracks in the rocks, climbing over large rocks, swimming, and slithering through mud. Each of these is a more challenging experience when undertaken during a rescue while dragging a large amount of equipment.

The total darkness of a cave imposes limits on any operation and its effect can be debilitating to some individuals. This can quickly become a major obstacle, particularly if noncavers are called on to assist in medical or other aspects of the operation. Psychological inhibitions, such as fear of the dark or confined spaces, can cause panic and severe dysfunctional behavior. In no case should a would-be rescuer ever be pushed beyond his or her comfort level.

Other factors inherent to the cave rescue operation include temperature, wetness, and restrictive cave passages. Certain large or weak people or bulky and heavy equipment might be physically incapable of passing through tight spaces. These considerations exemplify why it is best for any medical or other rescue person who may eventually become involved in a cave rescue to gain knowledge and experience in advance.

If the cave rescue requires raising or lowering a patient or traversing the patient over horizontal rope lines, people skilled in cave rigging should be responsible for building the systems. Rigging in caves is an art because of anchoring difficulties, directional changes, tight squeezes, and a minimal working surface. Details on cave rigging and professional training can be acquired through the National Cave Rescue Commission, a nonprofit organization that teaches courses in cave rescue techniques and management.

Many vertical drops in caves are overhung at the top, preventing the rescuer access to a wall while descending and ascending the rope or moving the patient. In cases in which the roped drop has the rope running against a wall, it can be advantageous to place anchors at points throughout the length of the drop. This "re-belay" method allows multiple people to ascend or descend simultaneously, lessens rope wear points, and provides the added safety of having a shorter rope length for each anchor to protect. Practice at crossing re-belays is essential before attempting to enter a cave thus rigged. The caver must be able to effectively transfer from one free-hanging rope to another while hanging in midair. This is easy to do with the correct equipment setup and practice, but not so easy when the technique is tried for the first time underground on the way to a medical emergency.

Usually, single-rope techniques are used, especially where a long free-hanging drop is involved. This means that just one rope is put over the side for the rescuer to ascend or descend. Using an additional belay line not only requires additional people but also might prove more hazardous if the two lines become entangled. A moving belay line also has the potential to dislodge rocks onto the caver below.

In the United States, the most common cave-ascending systems are the frog system, Mitchell system, and various renditions of the ropewalker system. These are all efficient means of ascending and can easily be mastered with practice. The frog system requires more climbing effort, but is easier to use when ascending past re-belays in the system.[24]

It is imperative that an ascending system be fitted to the user. Some rigs work best for a person with a tall, lean frame, and others work best for heavier body types. All rescue team members entering a vertical cave should have their own personally fitted rope-climbing system and must have practiced climbing in that system in a safe practice area.

Large holes or boulder slopes inside the cave may best be negotiated by using a highline traverse. Proper setup of highlines can be a time- and equipment-intensive process, but it can shave away hours of litter movement time by passing above difficult cave terrain that otherwise would present many challenges for a litter carried by hand. Use of a highline is most practical when it is known in advance that there will be sufficient time for rigging. The decision to take the time to rig a highline traverse should be made based on three factors: the time it will take to move the patient to the obstacle you want to traverse, the time necessary to rig the highline, and the time that will be saved by using the highline to move the patient over the obstacle.

ENVIRONMENTAL HAZARDS

One often-overlooked hazard to cavers is the ambient atmosphere. Most caves in the United States breathe naturally, either from changes in barometric pressure or from the chimney effect of multiple entrances. When this airflow is interrupted, limited, or polluted, the resulting air quality can be hazardous to entrants.

The most basic type of atmospheric hazard is lack of oxygen. Some caves have small rooms with so little airflow that a few cavers can quickly consume most of the oxygen. While frightening, this type of atmospheric hazard is usually quickly recognized when open flame headlamps sputter or cavers become short of breath. Once recognized, the hazard can be mitigated by avoiding panic, controlling air consumption, and relocating to a "friendlier" part of the cave.

Another type of atmospheric hazard involves buildup of toxic gases, such as carbon monoxide, carbon dioxide, methane, and hydrogen sulfide. This can happen as a result of the natural metabolism of organic material or through external influences. Gasoline may seep into caves from underground storage tanks. If poor air quality is suspected, using an air-monitoring device is essential. It is possible to enter a cave containing high levels of unhealthy gases, but only with appropriate caution. In such cases, it is advisable to solicit participation of the local hazardous materials emergency response team.

With the assistance of a hazardous materials or confined space rescue team, "bad air" in caves can be mitigated in several ways. One way is to release compressed air into the cave, forcing good air in and bad air out. Success of this method is limited, and because of the massive amounts of air in a cave, this approach is slow at best. If this method is used, entrants should carry an air monitor because pockets of bad air may remain trapped in parts of the cave. The concept of simply releasing oxygen into the cave is a nice idea, but impractical in all but the smallest of spaces. Exhaust fans offer a reasonable method, although care must be taken to prevent generator exhaust from entering the cave.

If necessary, rescuers can be equipped for entry with surface-supplied air with bailout bottles, a self-contained breathing apparatus, or rebreathers. Each of these has advantages and disadvantages, but all are difficult to manage in the cave environment and should be avoided if possible. It is imperative to train for rescue and practice the safe use of any equipment before a rescue is needed and before entering an atmosphere that is hazardous for breathing.

Whenever there is reason to suspect atmospheric hazards, appropriate precautions should be taken prior to entering a cave. In the case of biologics such as histoplasmosis, a well-fitting HEPA-compliant mask is appropriate. In the case of gasses, a calibrated gas monitor can detect a low oxygen environment and several specific gasses. Once a problem is detected, it can be mitigated with a self-contained breathing apparatus or other equipment. Hazardous atmospheres are rare in cave rescue. It may be best to call in a qualified mine rescue team to assist in these cases.

Other environmental hazards posed by caves may be more readily recognized and should also be considered before any rescue. As discussed earlier, water and caves are usually closely associated. Created by water, caves are a natural deposit for overflow or drainage from a variety of sources. This makes caves particularly prone to flooding with little or no warning. A recreational caver (Figure 63-9) or rescuer caught in a flooding cave is in mortal danger.

Flooding is usually associated with heavy rains, which can cause diffuse seepage over a large area of the cave or a high flow into sinkholes. Occasionally, sinking streams can carry floodwater. In some parts of the world, entire rivers disappear underground, flow through caves, and resurface miles away. A flood crest from many miles upstream can pass through these caves without warning.

FIGURE 63-9 Recreational caver in wet pit. *(Courtesy Kris H. Green.)*

Flood-prone caves are generally identifiable by their makeup. Cave walls coated with thick mud can be an indication that flooding is not unusual in that section of the cave, and extra caution is warranted. Bedrock cave walls with gravel deposits at key points in the cave and debris lodged in the ceiling can also be warning signs.

Becoming trapped in a flooding cave can be survived. If possible, find a high point in a wide passage, downstream of any major constriction, and wait out the flood. It is also possible, with enough advance warning, to remove a sediment dam downstream that may otherwise cause water to back up into your "safety zone." It is seldom wise to attempt to swim, either upstream or down.

For a rescuer called to assist cavers trapped in a flooded cave, entering the torrent is not wise. If the location of the trapped persons is known, it may be possible to use (or make) another entrance from which to evacuate them. Knowledgeable local cavers can be extremely valuable in this instance.

If entry into a flooded cave through the main entrance is absolutely necessary, it is imperative that the water level be controlled before entry. Methods of accomplishing this goal vary depending on the situation. Often, it may be enough to simply wait out the flood and let the water level subside naturally. If the water level is still on the rise, however, or if the source remains constant, additional measures may be warranted. Keep in mind that water is a powerful force, and any plan should be engineered by professionals.

One of the simplest diversion methods is to broaden the flood crest so that less of it flows into the cave. Water can be diverted using sandbags, hay bales, or dirt or by digging channels. If this is not possible or feasible, one may be able to lower the water level by digging through debris downstream, thereby expediting the outflow. Pumping is an option, although the hazards inherent in this method should be evaluated closely beforehand. Pumps run on fuel or electricity. Fumes from fuel-driven pumps and generators have entered caves and poisoned the air of the cavers awaiting rescue. Electrical power in a flooded cave situation adds a high risk for electrocution. Failure of the pumps after rescuers enter a cave can trap additional people if the water rises again.

Entering a flooded cave with scuba equipment is a dangerous, last-resort method that should be attempted only by certified cave divers. A scuba entry may be justified if cavers are known to have been trapped for an extended period of time or if there is a known medical emergency. In these cases, it may be advisable for divers to enter and assess the condition of trapped people, transport survival supplies, or provide medical assistance. Even certified cave divers require additional skills and equipment to enter a recently flooded or sumped cave passage, compared with the typical sport cave dive. A flooded cave may have little to no visibility, currents, and debris blocking the passage. Only in the most dire circumstance is it justified to attempt to transport a patient through a flooded passage.

At a minimum, a scuba entry requires two to three divers, as well as a backup diver. Diving is gear intensive and requires an air compressor, extra tanks, 110-volt electricity to charge dive lights, underwater communications equipment, waterproof bags, full face masks for subjects, water rescue suits, underwater lights, transport cases, and surface personnel to assist with transporting equipment.

MEDICAL HAZARDS

The most common cave-acquired disease is histoplasmosis, which is caused by *Histoplasma capsulatum,* a dimorphic fungus present worldwide but especially prevalent in the Ohio and Mississippi River valleys of the United States.[1,14] It is associated with bird, and especially bat, guano (Figure 63-10).[12] At a national caving convention in 1994, at least 18 people contracted symptomatic histoplasmosis, with an attack rate of greater than 70% for attendees going into two local caves.[1] A follow-up skin test survey found that 60% of one group of cavers showed evidence of *Histoplasma capsulatum* exposure.[1]

FIGURE 63-10 Caver in guano. *(Courtesy Peter Febbroriello.)*

Cavers get histoplasmosis by breathing dust from affected parts of the cave. Incubation is 2 to 3 weeks. Most primary cases are not recognized because they resemble a flulike illness with fevers, headaches, and cough.[22] Persons with significant illness demonstrate patchy lung infiltrates, which may calcify, and hilar lymphadenopathy. Some cases progress to cavitation or dissemination. Detection by urinary antigen is the mainstay of diagnosis. In most cases, treatment is not necessary. If symptoms last longer than a month, treatment is indicated with itraconazole or another azole drug or, in cases of dissemination, amphotericin B. Patients may require 3 to 6 months of treatment.[9]

Leptospirosis has been reported on caving expeditions to tropical climes, but is probably also a risk in temperate regions.[6,5,18,23] Transmission occurs when water contaminated by urine from infected animals comes into contact with mucous membranes, the conjunctivae, or abraded skin.[19] Cavers often crawl through small passages in the rock to explore, sometimes greatly abrading the skin, especially in hot humid caves where protective clothing may be minimal. Immersion may increase the risk.[4] Water that has percolated through carbonate rocks in which most caves form will have a higher pH, which favors survival of leptospires.[11]

Leptospirosis manifests with fevers, chills, myalgias, and headache after a 1- to 4-week incubation time.[17] More specific findings are conjunctivitis, proteinuria, and hematuria. It is most commonly diagnosed with serum microscopic agglutination titers. The diagnosis is confirmed by a fourfold rise in the titers, but is suggested by a titer of 1:800 with appropriate exposure and symptoms. Treatment is IV penicillin or ceftriaxone for severe cases and oral doxycycline for mild cases. It can be prevented with 200 mg weekly of doxycycline.[26]

The Centers for Disease Control and Prevention recommend rabies vaccination for "spelunkers." This dates from a concern about two cases of rabies in cavers that were attributed to aerosol transmission. These two people separately visited Frio Cave in Texas, where millions of bats congregate, and developed rabies soon thereafter. Subsequent research demonstrated the presence of rabies virus in the air of Frio Cave, presumably from bat respiratory secretions.[2,27] Transmission to animals exposed only to the airborne virus has since been demonstrated in the laboratory and in Frio Cave.[7,8] In the context of massive bat maternity colonies, aerosol transmission of rabies appears possible.

However, the matter is not so simple. In both cases, there was a more probable cause for rabies than aerosol transmission.[10] In the first case, the caver was employed in a rabies laboratory and worked inoculating bats with rabies virus.[15] The second patient denied being bitten by a bat, but was noted to have a bleeding lesion on the face while exiting Frio Cave.[10,16]

So what are cavers to do? Certainly, anyone doing bat research needs to be vaccinated against rabies and to check titers routinely. Anyone working in a cave such as Frio Cave needs an appropriate mask to filter the hazardous atmosphere, of which rabies virus would be just one component. It is questionable whether sport cavers really have any business at all roaming in a bat maternity colony.[3] Decades of exposure have not resulted in further documented cases of cavers contracting rabies. Although some persons have called for vaccination of all cave explorers, the opinion is not unanimous.[3] Each caver needs to decide on the level of risk and act accordingly.

PATIENT CARE

As with many remote accidents, the time it takes to report on, respond to, and gain access to a caving accident usually means that the person, if alive, is relatively stable. Although this generalization has exceptions, the treatment issues faced by most rescuers are related to extended transportation times.

Data compiled for the journal *American Caving Accidents* indicate that the leading cause of caving injury is falls, and that lower and upper extremity fractures and head injuries top the list of complaints.[20,21,25] Hypothermia is a common complication of injuries. With significant falls, spinal injury must be contemplated, which compounds the transportation challenge. The approach to medical care should be similar to that for any other medical situation, with one notable difference: The patient has suffered an acute injury but will be confined for an extended period. Care, then, will be a combination of acute emergency responses adapted for a patient who is, for all practical purposes, bedridden.

Once the patient has been stabilized and packaged, the assessment process should continue throughout the evacuation. It is best if one medical person stays with and monitors the patient throughout the evacuation (Figure 63-11). The ideal medic is a strong caver with good single-rope technique skills and training at least to the level of paramedic. By constantly staying with the patient, the medic is best placed to observe changes. The medic will need to know the complete patient history and clinical evolution while en route in order to make decisions that affect the extrication effort, such as needs for urgency and patient orientation. Although other evacuation personnel may cycle through the rescue, the constant presence of

FIGURE 63-11 Monitoring the patient as the litter moves. *(Courtesy Kris H. Green.)*

the medic is reassuring to the patient. Because the medic may need to spend many hours with the patient, he or she should not take part in the strenuous activity of litter handling.

Hypovolemia is a common complaint in caving injuries, so establishing an IV line early in the intervention can be useful, even if it is often difficult to maintain. Take measures to ensure that rescuers will be able to maintain IV access and manage the supplies throughout the evacuation. If the patient is alert and oriented, oral fluids are very appropriate. The patient is unlikely to be at a hospital soon, so it is not necessary to automatically keep the stomach empty, as one might in an urban rescue. Adequate fluid resuscitation creates the need to urinate. A Foley catheter might be necessary, or a diaper might suffice. Selected patients may be assisted to leave the litter in order to attend to personal needs. This also allows a more thorough reassessment and relieves pain from pressure points. As much as possible, maintain communication with the patient, encouraging him or her to flex muscles to maintain good circulation. Allow the patient to assist in care when possible.

THE CAVING EXPEDITION

All of the issues that make a caving rescue difficult in developed areas become magnified during expeditions abroad. In some locations, there may be no organized rescue team, let alone one qualified to do cave rescue. Freight costs for personal gear and expedition gear make additional costs for litters and first-aid supplies seem prohibitive. When the purpose of the expedition is to chart virgin caves, there will be no map to share with rescuers, other than an improvised sketch. First-aid and other medical supplies may be limited to very general, multipurpose items. Specialized gear may be days away.

Expedition leaders must prepare for accidents. All members must have had appropriate vaccinations and be taking appropriate prophylaxis for the area, guided by recommendations available at the travel section of the Centers for Disease Control and Prevention website. Someone on the trip should have a medical background and be responsible for medical supplies. Most expeditions have enough ropes and carabiners to construct appropriate systems to extract an injured patient, although this equipment may be spread out in the caves. An extra set of gear dedicated to rescue, such as pulleys and Prusik loops, should be kept with the medical supplies. A portable, all-purpose litter, such as a SKED, should be kept in camp or staged appropriately. Medical supplies should be multipurpose and capable of being packaged to survive a trip into the cave. As an expedition begins or when new cavers arrive, the expedition leaders should orient cavers to the rescue gear, make them aware of its location and how to use it, and explain procedures for a rescue should an accident occur.

CLOSING COMMENTS

Never underestimate a cave rescue. Caves are unique environments, and entry should not be attempted without appropriate technical training and preparation.

The advantage to any rescue group of establishing a good working relationship with local cave rescue resources, as well as local recreational cavers, cannot be overemphasized. These are the people with the best knowledge of the caves; with the training, equipment, and experience to handle the obstacles and the environment; and who already feel at ease underground. They could prove to be the most valuable resource for a successful cave rescue. Many cavers have taken extensive training in cave rescue techniques and are members of organized cave and cliff rescue teams. The first step to finding cavers is to contact a local chapter, or "grotto," of the National Speleological Society, the largest cave exploration, education, and science-oriented organization in the United States.

National Speleological Society
6001 Pulaski Pike Huntsville, AL 35810-1122
nss@caves.org
caves.org/

People interested in cave rescue training should contact the National Cave Rescue Commission. The commission conducts week-long cave rescue seminars and weekend orientations across the United States. It can be reached at the address above as the National Cave Rescue Commission of the National Speleological Society, or online at caves.org/io/ncrc/.

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