PART 4

Trauma

CHAPTER 18

Wilderness Trauma and Surgical Emergencies*

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This chapter has been written primarily to provide physicians and health care workers with a logical approach to management of trauma and surgical emergencies that may be encountered in the wilderness environment. The focus is on health care professionals who will be responsible for the urgent management of such emergencies for all expedition members.

Wilderness expedition health care providers have varied experiences and capabilities. In this environment, the location, distance from medical facilities, conditions, and available resources are the most influential factors in patient outcome. It is often impractical to perform complex interventions in the field, but it remains clear that simple, basic processes, such as identifying injuries, establishing an airway, keeping the patient warm, and expediting evacuation, strongly influence the patient's chances of survival.[40,104] The key to successful management of wilderness emergencies is preparedness. Advanced Trauma Life Support (ATLS) protocols can provide a template for preparation for wilderness travel. The principles embodied in ATLS concepts are well suited to management of wilderness emergencies, especially in circumstances where scant resources are available and, thus, a prompt response is essential for the victim's survival. The American College of Surgeons has formulated the Rural Trauma Team Development Course, which emphasizes the ATLS principles in situations where a small trauma team, typically two or three rescuers, is in charge. The course is applicable to the wilderness environment.[135]

When team members are planning an expedition, the role for each member should be explained clearly. Teamwork is essential for solving problems, communicating, executing procedures, transporting a patient, and continually improving the skills of team members. The medical director (director) of an expedition takes on significant responsibility during preparation. The director must screen participants to make sure they can tolerate the expedition and must tell the expedition leader of the findings. It is important to know the medical and surgical history of each expedition member. The director must also know wilderness medical protocols. For lengthy expeditions, the director should consider carrying diagnostic modalities such as a portable ultrasound unit and point-of-care testing equipment. Communication with appropriate rescue facilities prior to starting the trip is essential. The director should also have a plan for transfer of information to the next level of care. When an emergency occurs, the director will likely be placed in a position of authority, so it is essential to clarify the command structure and role of each member. The specifics of wilderness preparation, equipment, and medical supplies are presented in Chapter 102.

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WILDERNESS TRAUMA EMERGENCIES OVERVIEW

All classic mechanisms of trauma (penetrating, blunt, and thermal) occur in the wilderness environment and are discussed in this chapter. Blast injury is also mentioned briefly because its treatment in combat situations has led to some important advances in wilderness medicine. Blunt trauma remains the most common cause of injury in an austere environment; it can often be difficult to definitively diagnose. Delays in diagnosis in the wilderness can substantially increase complications and deaths.

HISTORY OF WILDERNESS MEDICINE

The medical literature is limited regarding the incidence of injury during wilderness-related activities. It is estimated that more than 10 million Americans participate in wilderness backpacking and camping activities annually. A study by Gentile and colleagues[57] documented the injury and evacuation patterns recorded by the National Outdoor Leadership School over a 5-year period. Injuries occurred at a rate of 2.3 per 1000 person-days of exposure, with orthopedic and soft tissue injuries most frequent. Montalvo[95] analyzed case incident report files from eight California National Park Service parks and found an injury incidence of 9.2 nonfatal events per 100,000 visits, with 78 fatalities reported in a 3-year period. In a prospective surveillance study evaluating 38,940 days of wilderness exposure on the Appalachian Trail,[18] foot blisters and diarrhea were the most common reasons for premature discontinuation of hikes. Leemon and Schimelpfenig[89] showed that more than 50% of evacuated participants in the National Outdoor Leadership School were able to return and finish their courses. The Rocky Mountain Rescue Group reported on their rescue experiences from 1998 to 2011 in Boulder County, Colorado, where they had a total of 2198 rescues over that time period.[83] These studies document a low risk for injury but highlight the possible morbidity resulting from wilderness injury or illness and the need for rapid, uniform intervention.

A 2001 study from the University of Arizona[61] highlighted wilderness deaths over 13 years. Alcohol was the most common causative factor, involved in 40% of the 59 unintentional trauma deaths. In addition, 80% of these victims died immediately or before evacuation could be completed. This emphasizes the importance of sound judgment and preparedness of rescuers and expedition members in maximizing care. A recent study of emergency medical services (EMSs) in the California state parks emphasizes the difficulty of providing care to wilderness participants.[65]

ESTABLISHING PRIORITIES IN THE WILDERNESS

There are three immediate priorities in managing wilderness trauma:

1. *Control oneself*. It is normal to feel anxious when confronted with an injured victim. However, anxiety must not be transmitted to the victim or other members of the expeditionary team. One must be in control of oneself to take control of the situation.

2. *Control the situation.* The first priority in controlling the situation is ensuring the safety of uninjured members of the party. Expeditious evacuation of a victim requires that all expedition members function at maximal efficiency; even minor injuries to other members in the group can jeopardize physical strength, functional manpower, and success of the evacuation. Although the physician member of the team may not be the expedition leader, his or her position is automatically elevated during a medical crisis. However, this does not mean that the physician should dominate the evacuation process. Although the expedition leader must rely on the medical assessment provided by the physician, the leader is best prepared to plan the evacuation.
3. *Obtain an overview of the situation.* The victim's general condition should be evaluated. Is the victim in immediate distress from a condition that requires relatively straightforward management, such as airway control? Is the victim in such a precarious environmental situation that he or she needs to be moved prior to any attempt at resuscitation? Scene security may be integral to the safety of the injured person and caregiver. Is the victim properly protected from the elements, including sun, wind, cold, and water?

There are several key principles paramount to treatment of injuries in an austere environment: ensure scene and provider safety, use primary and secondary surveys, provide cervical spine immobilization, control external hemorrhage, keep the patient warm and use warm intravenous (IV) resuscitation fluid if possible, initiate early transport, and, above all, do no further harm.

After the victim has been placed in the most stable and safest environment possible, the examining physician is ready to implement the ATLS-based five steps of wilderness trauma management:[135]

1. Primary survey
2. Resuscitation
3. Secondary survey
4. Definitive plan
5. Packaging and transfer preparation

The purpose of the primary survey is to identify and begin initial management of life-threatening conditions by assessing the ABCDEs of trauma care:

*A*irway maintenance and cervical spine stabilization
*B*reathing
*C*irculation, with control of significant external hemorrhage
*D*isability: neurologic status
*E*xposure/environmental control: completely undress the victim with careful attention to prevention of hypothermia

After the primary survey has been performed, resuscitation efforts are initiated. The level of resuscitation depends on the equipment and expertise available. At a minimum, resuscitation consists of control of external hemorrhage and administration of oxygen and warm IV fluids when they are available.

The third step is the secondary survey, a head-to-toe evaluation of the trauma victim that uses inspection, percussion, and palpation techniques to evaluate each of the body's five regions: head and face, thorax, abdomen, skeleton, and skin. A history should be taken while the secondary survey is being done. The specifics of the mechanism of injury may be of vital importance (i.e., loss of consciousness, head injury, height of a fall, or species of attacking animal may influence treatment and evacuation plans and also affect the stability of the scene). After this survey, the examining physician should formulate a definitive plan. It is useful to document all observations if circumstances permit. Such data may be critically important for field evacuation or hospital personnel.

The first step in formulating a plan is to compile a list of injuries. The next step is to determine if any injury warrants evacuation. The route of evacuation, whether air, land, or water, must be chosen. Aeromedical evacuation is expensive and, depending on the environment, may pose its own risk to both victim and medical evacuation team; it should be considered only for victims with potentially life- or limb-threatening injuries where the terrain and environment allow safe access, for the purpose of evacuation, to the patient.

Packaging the victim for evacuation is the final step. The evacuation effort requires organization, coordination, and great effort on the part of the expedition team.

The most effective means of managing the injured patient in the wilderness setting is to take the approach of the old adage "the best offense is a good defense." Preparation for wilderness patient care should address the challenges associated with varying levels of personnel help, minimal medical resources, prolonged prehospital care, and difficult evacuation proceedings. With ATLS knowledge, improvisation, and an organized effort, the patient's outcome can be maximized.

UNIVERSAL (BODY FLUIDS) PRECAUTIONS IN THE WILDERNESS

A number of life-threatening viruses are transmitted through contact with bodily fluids. The Centers for Disease Control and Prevention have established a set of standard precautions to be applied in all cases of contact with human body fluids:

Goggles
Gloves
Fluid-impervious gowns
Shoe covers and fluid-impervious leggings
Mask
Head covering

Multiple types of body fluids (blood, semen, vaginal secretions, and cerebrospinal, pleural, synovial, pericardial, peritoneal, and pericardial fluids) can place a caregiver at risk. In the wilderness setting, the materials necessary for universal precautions are rarely available. Every victim in the wilderness must be assumed to carry a communicable disease, and every effort should therefore be made to approximate universal precautions, particularly protection of the hands and eyes.

PRIMARY SURVEY

Persons injured in the wilderness should be assessed and their treatment priorities established based on the mechanism of injury, vital signs, and specific injuries. The vital signs must be assessed quickly and efficiently, with restoration of life-preserving vital functions.

AIRWAY

Rapid airway assessment should include inspection for signs of obstruction, including foreign bodies, and signs of facial or tracheal fractures. A chin lift or jaw thrust may be helpful to establish an airway, can be lifesaving, and may be all that is necessary. If the victim can speak, the airway is likely not jeopardized, but this is not an absolute rule.

Specific attention should be directed toward the possibility of cervical spine injury. The victim's head or neck should never be hyperextended, hyperflexed, or rotated to establish or maintain an airway. A cervical spine injury should be assumed to exist in any person with a significant injury above the level of the clavicle. If a situation requires removal of immobilizing devices, in-line stabilization, not traction, must be maintained.

BREATHING AND VENTILATION

The victim's chest should be exposed and chest wall movement observed. Establishment of an airway during the primary survey, although critical to patient survival, does not ensure adequate oxygenation or ventilation. All trauma victims must be continuously monitored for signs and symptoms of hypoxemia and hypercarbia.

Auscultation, observation, and palpation of the chest after establishment of the airway are integral parts of the primary survey. Diminished breath sounds or asymmetric chest wall movement can occur with pneumothorax (simple or tension), hemothorax, tracheobronchial obstruction, or main-stem intubation. Observation and palpation of the chest may identify thoracic injuries such as rib fractures, fractures with flail segments, or pneumothorax (by the presence of subcutaneous emphysema).

CIRCULATION

Circulation is evaluated by assessing the cardiac output and controlling any major external hemorrhage. Manometric blood pressure measurement is not easily performed in the field, although it may provide useful data. Important information regarding perfusion and oxygenation can be obtained rapidly by determining level of consciousness, assessing peripheral and central pulses, looking at skin color, and evaluating capillary refill time.

Pulses should be assessed first. Although the following are only general estimates and carry some inaccuracy, approximations of the minimum systolic blood pressure can be used if a palpable pulse is present:

Radial artery: 80 mm Hg
Femoral artery: 70 mm Hg
Carotid artery: 60 mm Hg

If hypovolemia is suspected on the basis of absent pulses or prolonged capillary refill, the examiner should immediately assess the neck veins. Distended neck veins, although a nonspecific sign, may suggest tension pneumothorax or pericardial tamponade in the context of hypotension. Flat neck veins may suggest hypovolemia and hemorrhagic shock.

Major hemorrhage can occur in five anatomic areas:

Chest
Abdomen
Retroperitoneum
Thigh
External environment

Exsanguinating external hemorrhage should be identified and controlled during the primary survey. Control of blood loss is addressed specifically in later sections; it basically involves using direct pressure or a tourniquet. Proper stabilization of long bone (femur) fractures minimizes blood loss into soft tissues. In the wilderness, little can be done about significant intrathoracic or intraabdominal hemorrhage. Survival of patients with significant blunt injuries is likely if basic ATLS principles are followed.

DISABILITY AND NEUROLOGIC ASSESSMENT

Neurologic assessment during the primary survey should be rapid and efficient. The level of consciousness should be established, and pupillary size and reactivity should be assessed. Level of consciousness assessment uses the Glasgow Coma Scale (GCS) (Box 18-1). It is critical that the neurologic assessment be repeated hourly, particularly if evacuation is delayed. Deterioration in mental status portends a poor prognosis, although a variety of conditions other than intracranial injury can affect mental status.

BOX 18-1 Glasgow Coma Scale

The Glasgow Coma Scale evaluates the degree of coma by determining the best motor, verbal, and eye-opening responses to standardized stimuli.

Eye Opening	
Spontaneous	4
To voice	3
To pain	2
None	1
Verbal Response	
Oriented	5
Confused	4
Inappropriate words	3
Incomprehensible words	2
None	1
Motor Response	
Obeys command	6
Localizes pain	5
Withdraw (pain)	4
Flexion (pain)	3
Extension (pain)	2
None	1
Maximum Score	**15**

Hypoxia, hypovolemia, and hypothermia should be promptly corrected.

EXPOSURE AND ENVIRONMENTAL CONTROL

The victim should be fully undressed and exposed, if possible in a protected environment. Garments and gear should be removed if necessary by cutting them away, unless the garments can be dried and are essential for future protection from the environment. Wet clothing must be removed early to prevent hypothermia. It is mandatory to visualize the entire victim to document and assess injury. However, this step of the primary survey should be performed with caution. First, it is imperative to cover the victim immediately after removal of clothing. Hypothermia and its effects on mental status, cardiovascular function, and coagulation are among the most underappreciated entities in care of the trauma victim. The possibility of hypothermia should be entertained in all environments. A victim with hypothermia may not be able to use stored energy to carry on normal metabolic processes. A severely injured patient may become hypothermic in any ambient environment. Second, clothing and gear should not be removed unless complete immobilization of injuries can be achieved. Assessment of an area of injury should be performed, but clothing should be left to cover the patient to ensure that the body temperature is maintained. A patient may be wearing a variety of gear and clothing, including a helmet for biking, skiing, or climbing; the helmet should be removed, with in-line stabilization of the cervical spine.

SECONDARY SURVEY

The secondary survey is an extension of the primary survey and should not be undertaken until the primary survey is complete and the victim has been stabilized. In addition, resuscitative regimens, if available, should have been initiated. The secondary survey is a head-to-toe assessment of the victim, including history taking and a physical examination. The face, neck, chest, abdomen, pelvis, extremities, and skin should be examined in sequence. A more detailed neurologic examination should be completed, including reassessment of the GCS. The neck should be examined independently of the thoracolumbar spinal cord. Examination of the pelvis should not include the traditional “rocking” to determine stability, because if pelvic fracture has occurred, this action may exacerbate existing comminution.

The detailed secondary survey should not delay evacuation packaging. As in the nonwilderness setting, it is imperative to repeat the primary survey as the victim’s condition warrants. Specific examinations are discussed in the sections covering regional injuries.

HISTORY

The victim’s history should be assessed during the secondary survey. Knowledge of the mechanism of injury and any comorbid medical conditions or allergies may enhance understanding the victim’s physiologic state.

The ATLS “AMPLE” history is a useful and rapid mnemonic for this purpose:

*A*llergies
*M*edications currently used
*P*ast medical history/*P*regnancy
*L*ast meal
*E*vent or *E*nvironment related to the injury

ADJUNCTS TO SURVEYS

Resuscitation should be initiated as the primary survey is being done. The degree of resuscitation depends on available resources, experience of the rescuer(s), and environmental conditions. Under the best circumstances, initial management of the wilderness trauma victim provides for airway control, adequate oxygenation and ventilation, appropriate fluid resuscitation, and stabilization of cardiac function; monitoring and reassessment of vital signs should continue. A urinary catheter and nasogastric (NG) tube can be placed as adjunctive measures. This degree of resuscitation is almost never possible in the wilderness setting; resuscitation may be limited to oral administration of warm, high-calorie fluids and maintenance of victim comfort and body temperature.

An NG tube and indwelling urinary (Foley) catheter should be placed if available and appropriate. Aspiration of gastric contents can be catastrophic in terms of patient survival after trauma. Gastric decompression with an NG tube may help prevent this adverse event in patients with a depressed level of consciousness. It should be remembered that children can exhibit significant hemodynamic consequences secondary to massive gastric distention. In this setting, decompression becomes critical. If possible, NG tubes should be placed in persons who are endotracheally intubated in the field. The tube can be aspirated sequentially with a syringe or left open to gravity drainage. Any suspicion of facial fracture should deter attempts to place an NG tube, and orogastric decompression should be chosen instead.

A Foley catheter can assist in volume assessment and hemodynamic status determination in a critically injured victim. Hourly urine output typically does not decrease until the onset of class III hemorrhagic shock, with loss of 30% to 40% of blood volume. Contraindications to urinary catheter placement in the field are blood at the urethral meatus, high-riding prostate, and scrotal hematoma; personnel not experienced in placement are also a reason for caution.

ADVANCES IN WILDERNESS CARE ADAPTED FROM COMBAT MEDICINE

Wilderness medicine has been enhanced in many ways by the precepts of Tactical Combat Casualty Care.[12] During the recent conflicts in Iraq and Afghanistan, tourniquets and hemostatic agents were packaged in easily carried, compact systems so that exsanguinating hemorrhage from severe extremity injuries could be controlled more rapidly.[82] The equipment and the lessons learned have been transferred to treatment of injuries in the wilderness; when the easily mastered techniques are used early, chances of survival increase.[45,91]

Throughout recorded history, trauma care in armed conflicts has advanced the care of civilian trauma patients (see also Chapter 28). Such care is uniquely suited for wilderness trauma. Blackbourne and colleagues[12] defined recent advances in trauma care in Iraq and Afghanistan as revolutions in military medical affairs, and Sward and associates recognized the rapid implementation of battlefield lessons in civilian care.[133] The use of tourniquets, topical hemostatic agents, and freeze-dried plasma in prehospital care, as well as procedures such as hypothermia prevention, transport of patients by teams, and permissive hypotension, has improved survivability from combat wounds. Individuals wounded in Iraq and Afghanistan had higher survival rates than those in any other conflict in U.S. history.[49] The advances in prehospital care can and should be applied to trauma emergencies in remote or austere environments.[133]

VASCULAR ACCESS

Obtaining vascular access is a basic tenet of ATLS. The best procedure for initial access remains placing two large-bore peripheral catheters in the veins of the antecubital fossa. If one is unable to easily obtain peripheral IV access in the upper extremities, the lower extremities may be considered.

Recent recommendations by the Eastern Association for the Surgery of Trauma (EAST) suggest moving to intraosseous (IO) access devices if peripheral access is not obtained after two attempts.[35] The U.S. and coalition military medical personnel have used IO access extensively in Iraq and Afghanistan. There are several commercially available devices for IO access in the sternum, tibia, or humerus. The FAST1 IO device is designed to obtain access to the manubrium. The EZ-IO device (a drill-based device) and the Bone Injection Gun (a spring-loaded device) can be used to obtain IO access in the tibia and humerus. The skills for placing IO devices can be easily learned and simulated in a multitude of models. The San Antonio Fire Department recently demonstrated that with a short didactic and hands-on training session, paramedics were able to successfully place humeral IOs with the EZ-IO drill with a success rate of over 90%[139] (Figure 18-1).

The EAST guidelines also suggested that, depending on the expertise on hand, an attempt at central venous access using a Seldinger technique is acceptable after two failed attempts at peripheral venous access. The internal jugular, subclavian, and femoral veins are usually chosen. Venous cutdown can be considered as a last resort.

PREHOSPITAL HEMORRHAGE CONTROL

Tourniquets

The first area of emphasis is on prehospital hemorrhage control. Direct pressure is an excellent technique for control of hemorrhage, but this is not always feasible in the austere environment. Direct pressure is practical if there is one casualty and sufficient rescuers to control hemorrhage and facilitate transport or other care. If there are multiple casualties or the rescuer needs to perform tasks such as controlling the airway, evacuating the patient, gathering supplies, or providing security, the rescuer is going to need other tools. Tourniquets developed for combat medics can and should be used by civilian rescuers. Use of tourniquets in the civilian world has traditionally been discouraged because of concerns about harmful effects.[88] Data on U.S. casualties in Vietnam demonstrated that at least 2% of deaths resulted from hemorrhage from isolated extremity wounds.[93] Although death is more common with combat injuries, it can also result from isolated extremity injuries in civilian urban populations.[44]

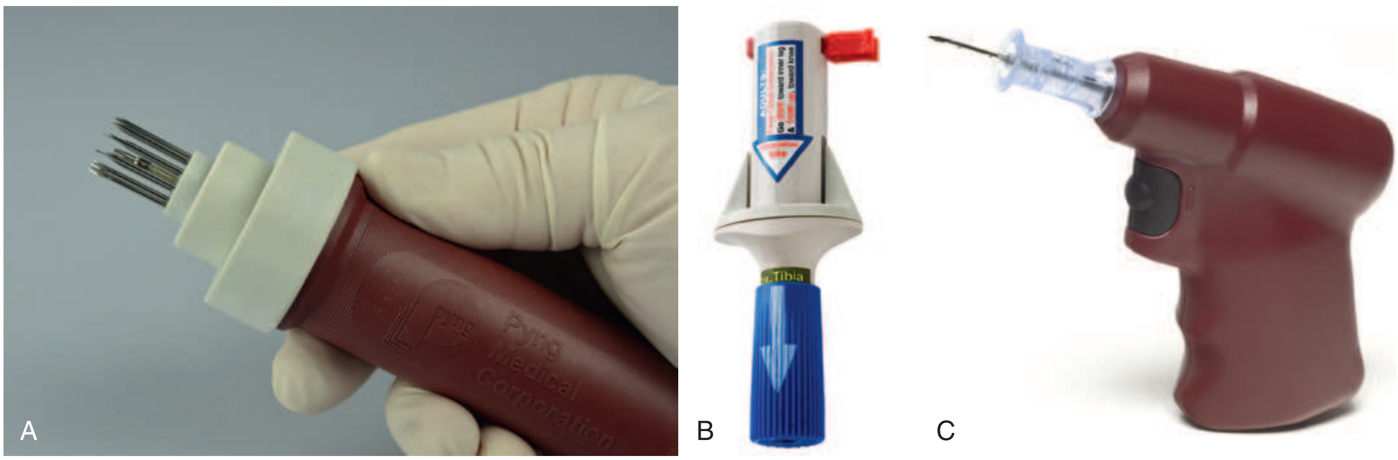

FIGURE 18-1 **A,** FAST1 intraosseous infusion system. **B,** Bone Injection Gun (BIG). **C,** EZ-IO.

The Israel Defense Forces doctrine has mandated use of prehospital tourniquets for control of extremity hemorrhage since the late 1980s. Medical personnel demonstrated that tourniquets were safe, easily applied (by medical and nonmedical personnel), and potentially lifesaving.[84] Use of tourniquets was not effectively or widely taught in the U.S. military at the beginning of Operation Enduring Freedom and Operation Iraqi Freedom. However, injury patterns from these and previous conflicts demonstrate that most injuries sustained by combatants are of the extremities.[9] Kragh and colleagues from the U.S. Army Institute of Surgical Research (USAISR) prospectively evaluated the use of tourniquets at the busiest Combat Support Hospital in Iraq in 2006. They concluded that tourniquets can be lifesaving, especially when used early in the prehospital setting prior to the onset of shock.[82] A tourniquet is defined as a limb-constricting device that is placed in an attempt to arrest extremity hemorrhage; the device can be improvised or one of the many commercially available devices. The author's experience is primarily with the Combat Application Tourniquet (CAT; Composite Resources, Rock Hill, SC). The extensive USAISR research on tourniquets in combat has led to development of recommendations for their use[81] (Figure 18-2 and Box 18-2).

BOX 18-2 Tourniquet Use Recommendations

- Apply the tourniquet early, before the onset of shock.
- Use scientifically designed, laboratory-tested, clinically validated tourniquets.
- Using an improvised tourniquet is acceptable if a commercially available tourniquet is not available.
- Continuing education on the use of tourniquets is essential for personnel who will be expected to use them.
- The goal of the tourniquet is to stop bleeding and stop the distal pulse.
- Avoid placement over Hunter's canal (≈ 5 cm above the femoral condyle).
- Side-by-side use of tourniquets is acceptable if single tourniquet application does not arrest hemorrhage.
- Effectiveness of the tourniquet will be inversely proportional to the girth of the extremity.
- Tourniquets should be applied directly on the skin.

Hemostatic Dressings

The high-tempo combat operations of Operation Iraqi Freedom and Operation Enduring Freedom accelerated development of hemostatic dressings. Both civilian and military data show that the most common cause of potentially preventable death in trauma patients is exsanguinating hemorrhage.[49,118] Almost 20% of these lethal hemorrhages will be from junctional anatomic locations, primarily the groin and axilla.[49] To facilitate use in austere locations or combat operations, the ideal hemostatic dressing would be rapidly available, simple to use, lightweight, and relatively inexpensive and have a long shelf life.[109] Several products are on the market, with the largest reported experience being with the mucoadhesive Chitosan-based HemCon (HemCon Medical Technologies, Portland, OR) and the procoagulant supplementor, kaolin-based product QuikClot Combat Gauze[62] (Z-Medica, Wallingford, CT). Case reports from combat operations and civilian EMS support the preclinical data that have shown that these products are effective in arresting hemorrhage in the prehospital environment.[24,111,140] Hemostatic dressings are easily applied, and the mechanism of action is not complicated. When the rescuer identifies bleeding that cannot be controlled with direct pressure or a tourniquet, application of a hemostatic dressing can potentially be lifesaving. Remove the product from its packaging, place it on the bleeding area, and hold it with direct pressure for at least 3 minutes. Once hemorrhage has been controlled, the dressing stays in place. The dressing works by being in direct contact with the bleeding source, so piling further hemostatic dressings on top is not productive. The hemostatic dressing must be removed eventually, but this can be done in a delayed fashion once the victim reaches definitive care (Figure 18-3).

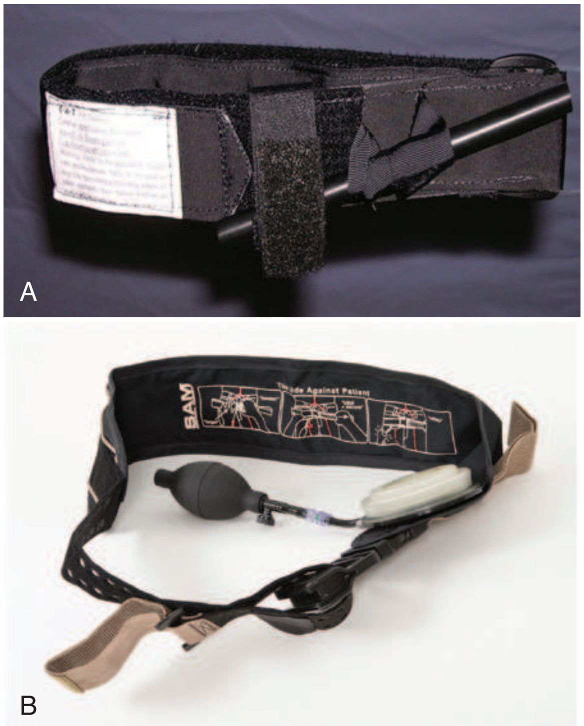

FIGURE 18-2 **A,** Combat Application Tourniquet. **B,** SAM Junctional Tourniquet (**A** *from North American Rescue, Greer, SC.* **B** *from SAM Medical Products, Wilsonville, OR.)*

Junctional Tourniquet

Another product for the control of lethal hemorrhage is the junctional tourniquet. Several types exist, with the basic premise being that the belt encircles the pelvis or torso and has pressure devices to occlude the axillary or external iliac vessels. The devices use either direct mechanical or pneumatic pressure to achieve occlusion. There are limited data to support use of these tourniquets, but laboratory investigations of the SAM Junctional Tourniquet (SAM Medical Products, Wilsonville, OR) suggest that they are effective in hemorrhage control.[74] Use of these tourniquets requires familiarity with them and, often, hands-on instruction and experience prior to application. The manufacturers all provide written and video educational tools to help users (see Figure 18-2).

Wound Closure Device

The iTClamp (Innovative Trauma Care, San Antonio, TX) wound closure device is a recent innovation that brings the edges of a wound together, causing a hematoma underneath the skin. This hematoma causes pressure on the bleeding site, thus forming a clot and stopping bleeding.[52,97] This product is small, light, and simple to use. The clamp has several pins that pinch the wound together and lock in place. The disadvantages are the small size and that one clamp will not provide adequate closure of a large or nonlinear wound (see Figure 18-3).

DAMAGE CONTROL RESUSCITATION: DIRECTLY ADDRESSING THE LETHAL TRIAD

Of patients arriving at civilian trauma centers, only about 3% require massive transfusion or damage control resuscitation (DCR).[33] Military wounds caused by high-energy blasts have a much higher rate of DCR and massive transfusion.[69] The term *damage control* has become standard for describing a variety of surgical tactics and techniques applicable across a wide range of surgical disciplines. When DCR is extended to the prehospital and early resuscitation phases, it is called *damage control zero*.[8,31,73,86] Damage control zero takes place before the patient arrives at the hospital, with the goal of preventing patient deterioration. DCR directly addresses the lethal triad that is often fatal when patients become cold, coagulopathic, and acidotic.[96] Hypothermia in the austere environment is a significant challenge. The U.S. military recognized in the combat environment that hypothermia prevention was lacking in battlefield care. Therefore, the

FIGURE 18-3 **A,** HemCon gauze-based chitosan dressing. **B,** QuikClot Combat Gauze. **C,** iTClamp. *(**A** courtesy Tricol Biomedical, Inc, Portland, OR; **B** courtesy Z-Medica, Wallingford, CT; **C** courtesy iTraumaCare, San Antonio, TX.)*

Joint Theater Trauma System developed a clinical practice guideline to address hypothermia prevention at all levels of care. In the austere environment, this should be the goal of the wilderness medical team. A team or individual will use everything available (e.g., jackets, blankets, improvised coverings) to protect the patient from the environment. Several lightweight compact adjuncts can be used to assist with prevention of hypothermia. These essential items can easily be packed as part of the team's kit. Injury in a hot environment does not prevent hypothermia in a seriously injured patient. One commercially available product is the Hypothermia Prevention and Management Kit (North American Rescue, Greer, SC), which is a self-contained, self-heating shell liner to encompass the casualty. Eastridge and colleagues were able to show a significant drop in hypothermia incidence after institution of a comprehensive clinical practice guideline.[48] Prehospital providers need to be proficient in identifying casualties who require the DCR approach. It may be difficult for a rescuer to rapidly identify this group of patients. Although there are no uniformly accepted criteria for identifying patients who will benefit from DCR, several groups have developed scoring systems (using a variety of anatomic, physiologic, and laboratory variables) for identifying patients who will likely require massive transfusion and thus be more likely to enter the vicious cycle of hypothermia, coagulopathy, and acidosis.[94,99,137,145] Each of these scoring systems is quite accurate, but two that are most applicable to EMS are the shock index and the ABC system (Boxes 18-3 and 18-4). In the austere environment, the shock index by Vandromme and colleagues is most useful due to its simplicity.[99,137]

The tenets of DCR are limited crystalloid resuscitation, permissive hypotension, hemostatic resuscitation, and proper patient selection.[8,10,35,69,99,137] Limited crystalloid resuscitation has become an accepted tenet for care of hemorrhaging patients. The EAST guidelines[35] on prehospital resuscitation state that there is a need to (1) embrace permissive hypotension in penetrating torso patients; (2) base resuscitation on mental status and presence of radial pulse; (3) give patients a bolus with smaller aliquots of IV fluids than the traditional 1 to 2 L; and (4) consider using hypertonic saline as the resuscitative fluid.[10,35,113] Although blood products may be difficult to obtain, depending on the austerity of a particular expedition, early use of blood products needs to be discussed, including a "walking blood bank" (using whole blood donated by locally available personnel). In the past 15 years there has been a paradigm shift toward use of blood products in trauma resuscitation and limiting crystalloid infusion.[69] During Operation Iraqi Freedom, Borgman and associates showed the utility of a high or nearly equivalent ratio of red blood cells to plasma to platelet resuscitation.[16] Most experts recommend delivery of these blood products in a ratio that resembles the normal composition of whole blood, with 1 unit of red blood cells:1 unit of plasma:1 unit of apheresis platelets.[100] The complexity of massive transfusion protocols may not apply to every austere situation, primarily due to lack of resources. The medical team should consider the ability to establish a walking blood bank as part of the medical kit.

BOX 18-3 Shock Index

Shock index = Heart rate/Systolic blood pressure
Shock index > 0.9 identifies patients at risk for massive transfusion

FRESH WHOLE BLOOD

Primarily a tool of the military, fresh whole blood has been used in combat theaters dating back to World War I.[103] The U.S. military has continued the use of fresh whole blood extensively in ongoing conflicts.[130] Fresh whole blood is warm, the volume is close to 500 mL, the hematocrit is 38% to 50%, there are 150,000 to 400,000 platelets per microliter, there is 100% coagulation activity, and 1500 mg of fibrinogen is included. Fresh whole blood does not possess the "storage lesion" of banked blood. Fresh whole blood has the ultimate 1 : 1 : 1 ratio. There are several downsides to using fresh whole blood: It must be type specific, and there are the potential for transmission of blood-borne disease, a limited donor pool, and potential deleterious effects on the donor (who in the austere environment may have a job to do that prevents taking the time to donate blood). Even with these known risks, we strongly encourage use of fresh whole blood in certain austere locations from which the patient cannot be easily transported or at which blood products are not readily available.[130]

Organization of Walking Blood Bank

The process of obtaining fresh whole blood requires superb planning and coordination. It is helpful to have a prescreened donor pool; questionnaires are available to help determine a safe

BOX 18-4 Assessment of Blood Consumption (ABC) Score for Massive Transfusion

The presence of two or more of the following factors identifies patients at risk for massive transfusion:
Systolic blood pressure < 90 mm Hg
Heart rate > 120 beats per minute
Penetrating mechanism
Positive FAST signs (**F**ace drooping, **A**rm weakness, **S**peech difficulty, **T**ime to call 9-1-1)

donor pool. This must be done prior to the team's expedition. Trying to do this when a casualty has arrived would cause a dangerous delay in the initiation of hemostatic resuscitation. The beginning donor pool is all of the persons on the expedition. The plan must include a predetermined method to activate and operate the walking blood bank. A responsible individual must have access to the blood donor pool and be able to manage the walking blood bank. The authors recommend using the rapid screening kits to evaluate for human immunodeficiency virus, hepatitis, and human T-lymphotropic virus.[130] These rapid immunoassays may not be as accurate as desired, but a positive result can be helpful.

Collection of Fresh Whole Blood

When the decision to use fresh whole blood has been made because blood components are unavailable or the normal blood bank has been exhausted, the preassigned individuals mobilize the donors and begin to collect the fresh whole blood. The basic procedures require proper identification of individuals in the donor pool, confirmation of an up-to-date screening questionnaire, and selection of individuals that have not recently donated. If one is able to screen for blood-borne infectious diseases, this should be done. Once a person has been deemed physically fit to provide a donation (this should be done quickly), the walking blood bank personnel should crossmatch the donor to the recipient, check the donor for significant anemia, and proceed with collection of up to 500 mL of whole blood into a commercial collection bag with anticoagulant citrate phosphate dextrose adenine. The collection area should be as calm as possible, because chaos breeds errors. A clerical error leading to transfusion of the incorrect blood type could create a devastating hemolytic reaction. The collection area may be within a few feet of the patient, but the collected blood must nonetheless be properly labeled. After labeling, the unit of blood is "walked over" to the patient and infused. This entire process can take less than 25 minutes.

INJURIES TO THE HEAD, FACE, AND NECK

The secondary survey begins with examination of the entire head and scalp for evidence of skull or facial fractures, ocular trauma, lacerations, and contusions. The scalp is thoroughly palpated for tenderness, depressions, and lacerations. The bones of the face, including the zygomatic arch, maxilla, and mandible, are palpated for fractures. Elements of the GCS are repeated.

Treatment of injuries to the eye is discussed in detail in Chapter 48, but general examination principles are simple. Significant periorbital edema may preclude examination of the globe, so assessment should be carried out early. The eye should be evaluated for visual acuity, retinal detachment, pupillary size, conjunctival hemorrhage, lens dislocation, and entrapment. Individuals with significant facial trauma have a high incidence of associated ocular or orbital injuries.[122,124] Recent studies of ocular injuries in trauma victims have emphasized underappreciation by many disciplines of ocular and periocular signs indicative of significant underlying injury.[122] A black eye alone has a nearly 70% chance of having an associated underlying facial bone fracture.[26]

HEAD INJURIES

Approximately 2 million cases of head injury occur in the United States yearly, with a significant portion of them occurring in remote locations as a result of outdoor activities such as hunting, rock climbing, and hiking.[58,106,135] Of these, approximately 16% result in hospitalization; 3% of patients die before reaching the hospital.[135] Long-term disability associated with head injury is significant, with 80,000 to 90,000 persons suffering various degrees of permanent impairment. Because of the high-risk nature of traumatic brain injury (TBI) and the impact of initial management on disability and survival, clinical management objectives must address both immediate survival and long-term outcome. Management guidelines specific for head injuries in a wilderness setting do not exist, and a wide range of clinical approaches are used in hospital settings.[58] However, the literature suggests that morbidity and mortality can be reduced by means of a protocol that includes early airway control with optimization of ventilation, prompt cardiopulmonary resuscitation, induced hypothermia, and rapid evacuation to a trauma care facility.[63,131]

Initial management of head injury in the wilderness should follow established ATLS protocols. Prompt attention must then be given to victim triage, evacuation strategies, and ongoing resuscitative needs to prevent or minimize secondary brain injury from hypoxia and hypotension. Expeditious evacuation to a trauma center in which neurosurgery can be performed is essential.

Multiple clinical and experimental studies have demonstrated the detrimental effects of hypoxia on the injured brain. A definitive airway should be established if any degree of neurologic or respiratory compromise exists, but not at the expense of risking severe hypoxia to accomplish it in an otherwise well-ventilated patient.[55] Cervical spine injuries are common in patients with TBI. Therefore, cervical spine immobilization is paramount to prevent devastating neurologic injury.

After immobilization, attention is directed to prevention of secondary brain injury. Given adequate resources, all efforts should be made to avoid oxygen saturation levels of less than 90% and to maintenance of blood pressure of more than 90 mm Hg.[55] The purpose of the wilderness head injury protocol is to allow individuals with widely varying levels of experience and expertise to identify signs of significant head injury, begin proper resuscitation in the context of prevention of secondary brain injury through airway maintenance and hemodynamic support, and evacuate appropriately.

Anatomy of the Head

The scalp has five layers of tissue that cover the calvaria: skin, connective tissue, galea aponeurotica, loose areolar tissue, and periosteum of the skull. The galea is a fibrous tissue layer with important ramifications in closure of scalp wounds, discussed later in this chapter. Loose areolar tissue beneath the galea represents the site of accumulation of blood in scalp hematomas. A rich vascular network located between the dermis and galea supplies the scalp. When lacerated, these vessels can be a significant source of hemorrhage, which may be important if evacuation is impossible or delayed. As shown in Figure 18-4, these injuries can be complex, deep, and associated with large-volume blood loss. Hemostasis of these wounds should be achieved with primary suture closure or some other mechanism.

The skull has two groups of bones that form the face and cranium. The cranial bones are the bones of the calvaria and the skull base. The calvaria is made up of frontal, ethmoid, sphenoid, parietal, and occipital bones. Within the skull, the brain is covered by three membranous layers that may be of pathophysiologic importance after injury. However, in the wilderness, these layers have little clinical relevance (except in terms of defining an open versus a closed brain injury).

Pathophysiology of Traumatic Brain Injury

Traumatic brain injury (TBI) can be divided into primary and secondary brain injuries. Primary injury consists of the physical or mechanical insult at the moment of impact, and the immediate and permanent damage to brain tissue. Little can be done in the wilderness setting relative to primary brain injury. Secondary brain injury is the biochemical and cellular response to the initial mechanical trauma and includes physiologic derangements that may exacerbate effects of the primary trauma, including hypoxia and hypotension. Compounding these pathophysiologic alterations in TBI is elevation of the intracranial pressure (ICP). Increased pressure increases cerebral ischemia and exacerbates secondary brain injury. Without swift access to advanced medical care, persons injured in the wilderness are at high risk for secondary brain injury.

Many forms of head injury result in elevated ICP, the duration of which is significantly correlated with a poorer outcome. The Monro-Kellie doctrine states that the volume of intracranial contents must remain constant because the cranium is a rigid

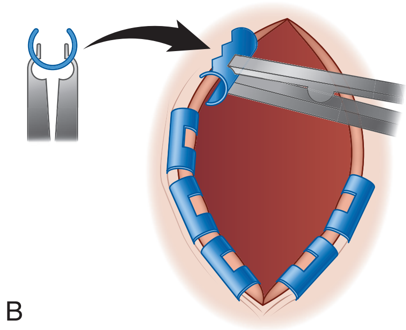

FIGURE 18-4 **A,** Deep and complex scalp laceration. **B,** Raney clips can be used to effectively achieve hemostasis in these types of wounds.

container. The normal compensatory response to increased intracranial volume is to decrease venous blood and cerebrospinal fluid (CSF) volume within the brain. If this normal response is overwhelmed, small increases in intracranial volume result in exponential increases in ICP. A rigid bony cranium cannot expand to accommodate increases in brain volume and the resultant increase in ICP. Brain parenchyma becomes compressed and eventually displaced from its anatomic location. In the most devastating circumstances, the brain parenchyma herniates toward the brainstem through the largest cranial opening (foramen magnum), and death rapidly follows. The volume-pressure curve in Figure 18-5 shows the small, but critical, time period between the development of neurologic symptoms, hemodynamic decompensation, and brainstem herniation.

Elevation in ICP directly correlates with secondary brain injury, and the field provider must attempt to minimize the ICP of head-injured patients to the greatest extent possible.

The most important priority in minimizing secondary brain injury in the field is optimizing cerebral perfusion pressure (CPP). CPP is related to ICP and mean arterial pressure (MAP) as follows:

$$CPP = MAP - ICP$$

An ICP of less than 20 mm Hg after head injury should be maintained, and the CPP should be between 50 and 70 mm Hg, based on current recommendations.[21,135] At a MAP of between 50 and 160 mm Hg, cerebral autoregulation maintains the cerebral blood flow at relatively constant levels. Not only is autoregulation disturbed in injured regions of the brain, but a precipitous fall in the MAP can further impair autoregulatory function, decreasing the cerebral blood flow and exacerbating ischemia-induced secondary injury. The field provider is able to combat a rise in ICP by simply optimizing the MAP through aggressive IV fluid resuscitation. Body temperature regulation may also play a significant role in secondary brain injury, especially on the cellular level. Some investigators have demonstrated that controlled hypothermia may reduce the level of secondary injury in severe head injuries.[117] Standard methods of controlling ICP (hyperosmolar therapy, sedation, intubation, chemical paralysis, barbiturate coma) are rarely if ever available in the wilderness. Multiple trials have shown that mild-to-moderate hypothermia may be of benefit in reducing ICP in the head-injured patient, with potential survival benefit.[117]

Diagnosis of Head Injury

The three useful descriptions of head injury that may be applied to field recognition are history, severity, and morphology. History includes the mechanism of injury, timing of the event, and related circumstances. This knowledge assists in the decision-making process with regard to initial assessment of severity of injury.[135] Mechanism of injury is identified as blunt or penetrating trauma. The anatomic demarcation between blunt and penetrating injury is traditionally defined by violation of the outer covering of the brain (dura mater). Blunt injuries in the wilderness setting most often result from falls, falling objects, or assaults. Penetrating injuries are most commonly gunshot or other projectile wounds. Severity of injury can be estimated by quantifying the GCS and pupillary response. The generally accepted definition of coma is a GCS score of 8 or less; these patients often require endotracheal intubation. Although the GCS score does not directly correlate with the need for intubation, it is essential that all head-injured patients be provided a stable, secure airway by the most appropriate means available in order to maintain adequate oxygenation and avoid secondary injury due to hypoxia. It is important to note the TBI victim's best initial motor response because this is most predictive of long-term neurologic outcome. Any victim with a GCS score of less than 15 who has sustained a head injury should be evacuated if possible. A low or declining GCS score suggests increasing ICP. Abnormal pupil size or asymmetric pupillary responses suggest increased ICP. These clinical deteriorations demand the rapid attention of rescue or evacuation personnel to optimize the MAP and CPP, minimize secondary brain injury, and prevent brainstem herniation. Injury morphology may be difficult to assess in the wilderness setting and relies on the

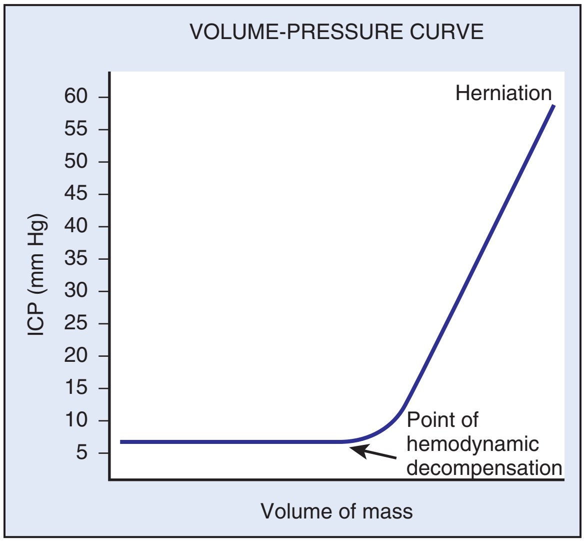

FIGURE 18-5 Pressure-volume curve for intracranial pressure (*ICP*).

level of suspicion and clinical signs and symptoms. After attention to the primary survey, including airway provision and spinal immobilization, the physical examination component of the secondary survey is imperative and can provide information about the presence of a TBI.

Head Injury Classification

Intracranial injuries have a wide range of causes, with variable severity. In order to simplify evaluation of the head-injured patient, the GCS has been used.[134] The initial GCS score of the patient assists the treatment team in developing a treatment plan. Mild injury is classified as a GCS score of 13 to 15; moderate, 9 to 12; and severe, 3 to 8. Patients with an initial GCS score of 8 or less in the field have a predictive value for a poor outcome of at least 40%, and need urgent medical attention.[7] This risk increases proportionally with a lower GCS score. These individuals should be evacuated to a trauma center as soon as possible if a favorable outcome is possible. Patients with mild TBI should be assessed for limitations that would preclude them from continuing on the expedition, mission, or activity. Patients without loss of consciousness associated with head injury only need continuous monitoring for deterioration but are otherwise safe to continue. Patients with loss of consciousness but a GCS of more than 13 do not necessarily need to be transferred to a trauma center but should be evaluated and undergo CT scanning at the earliest and safest moment.[7,71] Moderately injured patients with a GCS of 9 to 12 or 13 are the ones in whom the outcome can be affected by early, correct interventions. Avoidance of hypotension in isolated head injury is paramount. As in combat-related head trauma, use of mannitol, hypertonic saline, hyperventilation, and antibiotics is indicated for prophylaxis in penetrating head trauma.[20]

Physical Examination for Head Injury

After the primary survey and initial attempts to stabilize the victim, a more complete physical examination should be done. This examination should not delay patient evacuation. A hallmark of TBI is an altered level of consciousness. Determination of the GCS score aids in recognition of TBI and should be regularly reassessed to provide a mechanism for quantifying neurologic deterioration. Physical signs that may denote underlying brain injury include significant scalp lacerations or hematomas, contusions, facial trauma, and signs of skull fracture. Findings specific for basilar skull fracture include ecchymosis behind the ears (Battle's sign) and periorbital ecchymosis (raccoon eyes). Blood behind the tympanic membrane on otoscopic examination (hemotympanum), frank bleeding from the ears, and CSF rhinorrhea or otorrhea also suggest skull fracture and underlying TBI.

The pupillary examination may provide valuable data in assessing an underlying TBI. Herniation of the temporal lobe of the brain may be heralded by mild dilation of the ipsilateral pupil with sluggish response to light. Further dilation of the pupil followed by ptosis (drooping of the upper eyelid below its normal level), or paresis of the medial rectus or other ocular muscle, may indicate third cranial nerve compression by a mass lesion or herniation. Table 18-1 relates pupillary examinations to possible underlying brain lesions.

Most dilated pupils (mydriasis) are on the ipsilateral side to the mass lesion. With direct globe injury, traumatic mydriasis may result, making evaluation of TBI more difficult. Also, 5% to 10% of the population has congenital anisocoria (a normal difference in pupillary size between the eyes); however, the pupil will maintain a response to light. Casual inspection may overlook a prosthetic eye, which is mistaken for a fixed pupil. Neither direct trauma nor congenital anisocoria should be assumed in a head-injured victim exhibiting mental status change in the wilderness.

After quantification of the GCS score, pupillary examination, and examination of the head and face for signs of external trauma, a concise neurologic examination should be performed. The goal in the field is to identify motor or sensory focal deficits suggestive of intracranial injury. Sensory deficits follow the general dermatome patterns shown in Figure 18-6.

Unilateral hemiplegia may signify uncal herniation resulting from mass effect in the contralateral cortex because of compression of the corticospinal tract in the midbrain. Ipsilateral pupillary dilation associated with contralateral hemiplegia is a classic and ominous sign of tentorial herniation. Deep tendon reflex changes in the absence of altered mental status or lateralizing signs are not indicative of TBI. Detailed evaluation of brainstem function cannot be undertaken in the wilderness setting. Evaluations of the gag and corneal reflexes may provide some information helpful in triage and evacuation planning, but the findings would not automatically obviate the need for prompt evacuation.

TABLE 18-1 Interpretation of Pupillary Findings in Victims with Head Injury

Pupil Size	Light Response	Interpretation
Unilaterally dilated	Sluggish or fixed	Third nerve compression secondary to tentorial herniation
Bilaterally dilated	Sluggish or fixed	Inadequate brain perfusion; bilateral third nerve palsy
Unilaterally dilated or equal	Cross-reactive (Marcus Gunn pupil)	Optic nerve injury
Bilaterally constricted	Difficult to determine; pontine lesion	Opiates
Bilaterally constricted	Preserved	Injured sympathetic pathway

Resuscitation with Head Injury

Resources and circumstances permitting, resuscitation should be initiated as an adjunct to the primary survey. The main focus for the head-injured victim, as for any traumatized victim, is the airway.[135] During the primary survey and performance of the ABCDE sequence, IV access should be established. It is not advisable to administer fluids orally to the victim with head injury because of the likelihood of vomiting, airway compromise, and aspiration. In the patient with suspected head injury without confirmatory imaging, the use of hypertonic IV fluids or mannitol will effectively reduce the ICP.[56,125]

Individuals sustaining head trauma have a high incidence of concomitant injuries, and many of these individuals, especially if the injury is related to combat, have persistent postconcussive symptoms for 6 months or longer.[85,90] A victim who does not have a palpable peripheral pulse or presents with other signs of hypotension in the context of suspected head injury must not be assumed to have a neurogenic cause of shock, so other causes must be thoroughly and aggressively investigated. Recognition of additional injuries is critical in the setting of head injury for multiple reasons. Management of a head injury should be secondary to other life-threatening injuries, which, if not addressed, may lead to hemorrhagic shock and preclude survival. As previously discussed, maintenance of the MAP (and thus the CPP) and adequate oxygenation are critical in preventing secondary brain injury.

The type of resuscitative fluid administered to trauma victims continues to be controversial. Previously, recommendations warning of the dangers of overhydration in head injury led to recommendations for restricting fluids. The need for resuscitation and intravascular volume support has been well established. Possible resuscitative fluids include isotonic crystalloid, hypertonic crystalloid, or colloid solution. Osmotic agents, such as hypertonic saline, have been shown to increase hypoperfused regions of the brain after TBI.[121] Hypotonic fluids, however, are not appropriate in TBI secondary to an increase in whole-brain water content and subsequent elevation in ICP. Data from animal studies of TBI suggest that colloid solutions offer no advantage over isotonic crystalloids, such as lactated Ringer's solution, in terms of augmenting cerebral blood flow or preventing cerebral edema.[146] As previously noted, no prospective trial has clearly

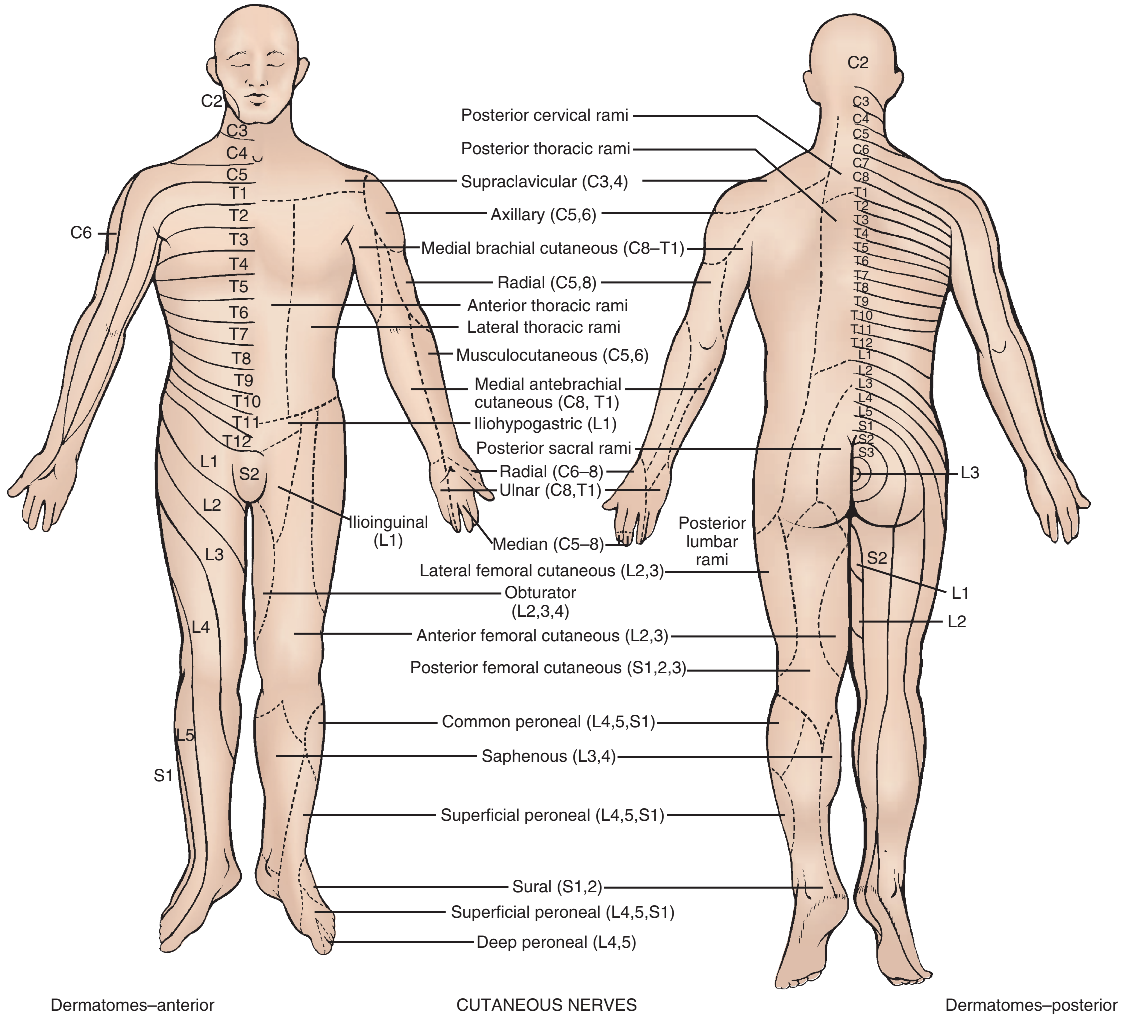

FIGURE 18-6 Dermatome distribution map.

documented an advantage of colloid over crystalloid administration in the victim with multiple systemic injuries. Evidence is accumulating that hypertonic solutions, particularly mannitol or hypertonic saline, may be beneficial in TBI.[56] However, an advantage has not been demonstrated in trauma victims overall, especially with concomitant injuries. The recommended resuscitative fluid for the head-injured victim in the wilderness setting is isotonic crystalloid in the form of lactated Ringer's solution, with a target MAP of 80 to 90 mm Hg based on cuff blood pressure determinations or extrapolation from evaluation of distal pulses.

Further Management of Head Injury

Numerous adjuncts exist for management of the head-injured victim, few of which are applicable in the wilderness setting. Once the primary and secondary surveys are complete, the airway is secured, resuscitation has been initiated, and spine immobilization has been achieved, the victim should be placed in a 30-degree head-up position. This position assists in control of ICP, and thus CPP, through augmentation of venous outflow. This maneuver should not be attempted if the spine cannot be adequately immobilized.

If endotracheal intubation is possible, ventilation should be optimized without hyperventilating the victim. Hyperventilation has been used aggressively in the past to promote hypocarbia-induced cerebral vasoconstriction and, theoretically, to decrease brain swelling. However, if the Pa_{CO_2} falls below 25 mm Hg, severe vasoconstriction ensues, effectively reducing cerebral blood flow, promoting ischemia, and possibly augmenting secondary brain injury. Studies have demonstrated worse outcomes in victims with severe head injury who were hyperventilated.[98] Inability to measure or titrate the Pa_{CO_2} in the wilderness mandates that respiration be controlled to approximate near-normal minute ventilation while maintaining oxygen saturation of more than 95%.

All bleeding from the scalp or face should be controlled with direct pressure. Scalp hematomas, regardless of size, should not be decompressed. Open wounds, particularly skull fractures, should be irrigated and covered with the most sterile dressing available. Fragments of displaced cranium overlying exposed brain tissue should not be replaced. If signs of skull fracture are present, broad-spectrum antibiotic prophylaxis and immunization against tetanus are administered. Although diuretics have been widely used in the intensive care management of intracranial hypertension, no rationale exists for their use in the field. The wilderness trauma victim may have many injuries that are impossible to evaluate fully in the field. In this setting, particularly in the presence of hemorrhagic shock, attempts to induce osmotic diuresis to decrease ICP may be life-threatening. Diuretics such as furosemide or mannitol may exacerbate hypotension, cause metabolic alkalosis, and induce renal complications in the absence of physiologic monitoring.[4] Corticosteroids have no role in head injury in the field or intensive care unit. Studies have documented no beneficial impact on ICP or survival. Attempts at brain preservation by slowing the metabolic rate and oxygen consumption have no role in the wilderness setting. Barbiturates have been used for elevated ICP refractory to other measures, but they may induce hypotension, depress myocardial function, and confound the neurologic examination.[4] Feasibility of these advanced interventions may not be advisable in the wilderness, especially if skilled providers are not available. The use of hypertonic saline empirically in the treatment of TBI has little likelihood of complication and is often deployed in combat by today's military embedded medical technician.[47]

Approximately 50% of persons with severe head injury experience posttraumatic seizures.[21] Phenytoin, valproate, or levetiracetam, if available, can be safely administered in the field. Prophylactic administration has not been shown to change long-term survival rates, but seizure prophylaxis may benefit patients with TBI by reducing additional accidental injury, psychological effects, and loss of driving privileges. Controlling seizures may reduce secondary injury due to hypertension, increased ICP, changes in oxygen delivery, and excess neurotransmitter release.[21]

Skull Fracture

Skull fracture in the wilderness mandates evacuation. Therapeutic options in the field are few, with intervention limited to identifying the injury and arranging rapid transport. Skull fractures may be open or closed, linear or stellate, and may occur in the vault or skull base. These fractures are associated with a high incidence of underlying intracranial injury. Skull fractures with depression greater than the thickness of the skull may require elevation. No attempt at elevation should be made in the field. Any exposed brain surface should quickly be covered with the most sterile covering available, preferably moistened with crystalloid solution. Loose bone or brain fragments should not be manipulated. If a broad-spectrum antibiotic is available, it should be administered. After attention to the wound and stabilization of associated injuries, the victim should be rapidly evacuated.

Penetrating Head Injuries

Most penetrating head injuries in the wilderness are gunshot wounds; knives and arrows may also penetrate the cranium. Such penetrating injuries are usually catastrophic; more than 60% of patients with gunshot wounds to the head succumb prior to reaching a medical treatment facility.[115] Some persons have survived small-caliber, low-velocity injuries and tangential wounds that need only local debridement or antimicrobial therapy without an operation.[115] As with closed-head injury, management priorities consist of maintenance of the airway, prevention of secondary brain injury, and rapid evacuation. If the cranium has been violated, the victim should receive antibiotics and tetanus immunization in the same manner as for open skull fracture. In the rare instance that the projectile is embedded in the skull, no attempt at removal should be undertaken. If the length of the projectile makes immobilization or transport cumbersome, the excess length may be removed but only if this can be done without displacement of the intracranial segment.

Evacuation of Patients with Head Injury

Survival and outcome of head injury in the wilderness correlate directly with rapidity of evacuation. Certain situations dictate immediate evacuation. Any person with evidence of an open or closed skull fracture should be evacuated. There is reasonable evidence to suggest that 30% to 90% of persons with raccoon eyes or the Battle's sign will show abnormalities on computed tomography (CT) scanning.[15,30] Similarly, any person who sustains a penetrating injury should be evacuated. Decisions concerning evacuation of victims who have sustained closed-head injuries can be simplified by dividing the victims into three groups based on probability of injury. The experience provided by the military from recent conflicts in Iraq and Afghanistan suggests that all patients with a GCS score of 9 to 13 be transported to a trauma center immediately for evaluation.[20] The low-risk group with a GCS score of 14 or greater includes persons who have suffered a blow to the head but are asymptomatic, did not lose consciousness, and complain only of mild headache or dizziness. These individuals do not necessarily require evacuation but may not return to duty or activity until disorientation resolves.[20] Finally, persons with a GCS score of 3 to 8 must be evacuated to a trauma center with neurosurgical capability.[20]

Persons who meet low-risk criteria with a GCS score of 15 and have no loss of consciousness, minimal symptoms, and an unlikely mechanism may have suffered a concussion. The Quality Standards Subcommittee of the American Academy of Neurology[60] defines concussion as a trauma-induced alteration in mental status that may or may not involve loss of consciousness. The neurologic impairment is short lived and resolves spontaneously without any structural injury to the brain. These individuals should not be allowed to return to activity until they are asymptomatic and are no longer taking any medications. The following signs indicate that more advanced medical care is necessary: (1) inability to be awakened; (2) severe or worsening headaches; (3) somnolence or confusion; (4) restlessness, unsteadiness, or seizures; (5) difficulties with vision; (6) vomiting, fever, or stiff neck; (7) urinary or bowel incontinence; and (8) weakness or numbness involving any part of the body. No prospective validated guidelines for return to activity have been established, although level III evidence recommends a graded plan for return to activity.[60] Generally, one should not return to an environment in which concussion is a risk (e.g., contact sports) until symptoms have been absent for 14 days and the individual is no longer taking medications.

The group for which the evacuation decision is most difficult is the moderate-risk group. These persons have a history of a brief loss of consciousness or change in consciousness at the time of injury, or a history of progressive headache, vomiting, or posttraumatic amnesia. If any of these signs is present in the face of concurrent systemic injury, the victim should be evacuated immediately. Studies associating clinical variables and abnormal results on CT scan have demonstrated the significance of a decreased GCS score, presence of symptoms, and loss of consciousness. If these signs are present in isolation and the evacuation can be completed in less than 12 hours, the evacuation should proceed. If the evacuation is impossible or will require longer than 12 hours, the victim should be closely observed for 4 to 6 hours. If the examination improves to normality during the observation period, it is reasonable to continue observation.

NECK INJURIES

Blunt Neck Injuries

Injuries to the neck may be classified as blunt or penetrating. Significant blunt injuries include cervical spine injuries and laryngotracheal injuries. The neck is divided into three distinct zones that help predict injury and guide management (Figure 18-7). Fracture of the larynx and disruption of the trachea usually require surgical intervention that is unavailable in the wilderness. The sooner laryngeal repair is accomplished, the better the outcome with respect to phonation.[39] Victims present with a history of a significant blow to the anterior neck. Physical examination findings include difficulty with phonation, subcutaneous emphysema that may extend as far inferiorly as the abdominal wall, stridor, odynophagia, and often acute respiratory distress. Blunt cerebrovascular injuries pose unique challenges in the wilderness because they are difficult to diagnose. Practice

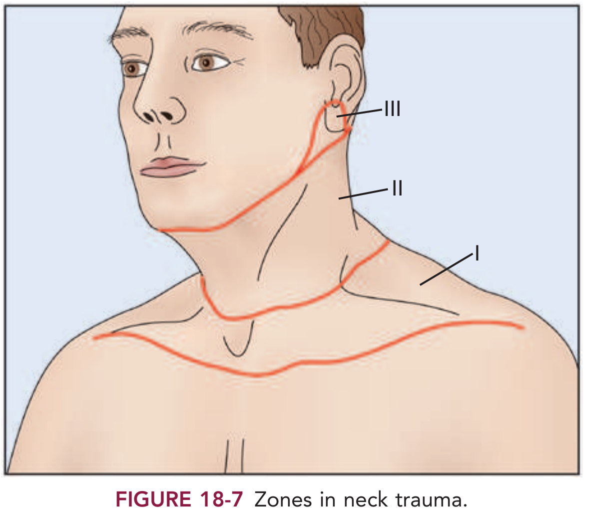

FIGURE 18-7 Zones in neck trauma.

management as well as diagnostic and surveillance guidelines have been suggested for these injuries, but they fall outside the scope of wilderness medicine.[23,25,34]

The airway is frequently in jeopardy, and treatment is focused on establishing and maintaining an airway until evacuation can occur. Because of the propensity for injuries of this type to result in significant, progressive edema, endotracheal or nasotracheal intubation is often necessary. If these options are unavailable, airway maintenance techniques, as described in the Primary Survey section, should be used. If intubation fails or is not available and hypoxic death is impending, a surgical cricothyrotomy may be needed. A recent study of prehospital cricothyrotomies demonstrated that trained personnel had success rates of more than 90% regardless of the environment in which the cricothyrotomy was performed.[67] For further descriptions of airway management, refer to Chapter 19.

Vertebral column injury, with or without neurologic deficits, must be identified in any wilderness multiple-trauma victim. Fifteen percent of victims sustaining an injury above the clavicles and 5% to 10% with a significant head injury have a cervical spine injury. In addition, 55% of spinal injuries occur in the cervical region.[135] In the wilderness setting, fractures or dislocations of the cervical spine are a result of falls from a significant height or of high-velocity skiing or vehicular accidents. Approximately 10% of persons with cervical spine fractures have discontinuous fractures elsewhere in the spine, necessitating early and complete spine immobilization.[135]

Anatomy of the Neck. The cervical spine has seven vertebrae. The anteriorly placed vertebral bodies form the weight-bearing structure of the column. The bodies are separated by intervertebral disks and held in place anteriorly and posteriorly by longitudinal ligaments. The paraspinal muscles, facet joints, and interspinous ligaments contribute as a whole to stability of the spine. The cervical spine, based on its anatomy, is more susceptible to injury than are the thoracic spine or lumbar spine. The cervical canal is wide from the foramen magnum to C2, with only 33% of the canal constituting the spinal cord itself. The clinically relevant tracts in the spinal cord include the corticospinal tract, spinothalamic tract, and posterior columns.

Classification and Recognition. Fractures of the cervical spine may result in neurologic deficit, with total loss of function below the level of injury. Spinal cord injuries should be classified according to level, severity of neurologic deficit, and spinal cord syndrome. Fractures of the C1-C2 complex generally result from axial loading (a C1 ring fracture, or Jefferson's fracture) or an acute flexion injury (a C2 posterior element fracture, or hangman's fracture). Approximately 40% of atlas (first cervical vertebra) fractures have an associated fracture of the axis (second cervical vertebra). The atlas fracture, if survived, is rarely associated with cord injury but is unstable and requires strict immobilization. A complete neurologic injury at this level is usually unsurvivable due to paralysis of respiratory muscle function. One-third of victims sustaining a severe upper cervical spine injury die at the scene. The severity of cervical spine fractures is a result of the neurologic compromise incurred. The most common mechanism of injury is flexion. The most common cervical fracture is of C5, and the most common level of injury is C5-C6 due to the relative fulcrum associated with this position.[135]

Fractures and dislocations may result in partial or complete neurologic injury distal to the fracture or in no neurologic injury at all. Partial injuries to the spinal cord result from typical patterns of injury. Because flexion injuries are the most common type of injury to the cervical spine, the anterior cord syndrome (see later) is the most commonly seen serious neurologic picture. A careful neurologic examination in the field to grade motor strength and document sensory response to light touch and pinprick yields important information that should be documented and reported to the treating physician at the definitive care facility.

When appropriate resources are available, a rectal examination should be performed. Complete lack of tone and failure of the sphincter muscles to contract when pulling on the penis or clitoris (the bulbocavernosus reflex) indicate the presence of spinal cord injury.

BOX 18-5 Sensory and Motor Deficit Assessment

Sensory
C5: Area over deltoid
C6: Thumb
C7: Middle finger
C8: Little finger
T4: Nipple
T8: Xiphisternum
T10: Umbilicus
T12: Symphysis pubis
L3: Medial aspect of thigh
L4: Medial aspect of leg
L5: First toe web space
S1: Lateral foot
S4 and S5: Perianal skin

Motor
C5: Deltoid
C6: Wrist extensors
C7: Elbow extensors
C8: Finger flexors, middle finger
T1: Small finger abductors
L2: Hip flexors
L3: Knee extensors
L4: Ankle dorsiflexors
L5: Great toe extensors
S1: Plantar flexors

When individuals with cervical spine fractures or dislocations are transported, the neck must be stabilized to prevent further injury to the spinal cord or nerve roots at the level of the fracture or dislocation. Approximately 10% of persons with cervical spine fractures have discontinuous fractures elsewhere in the spine[135]; therefore, the entire spine must be protected during transport.

A pure flexion event can result in dislocation of one or both of the posterior facets without fracture or neurologic injury. The victim may complain only of neck pain and limitation of motion. If so, the victim should be transported with the neck rigidly immobilized. With this injury, posterior instability is present (because the interspinous ligament is ruptured), and any further flexion stress could produce a spinal cord injury.

Physical Examination. A thorough neurologic examination should be performed. Initial documentation of deficits and frequent repeat examinations are critical to follow-up care. The classification of injury in the field begins with determination of the level of injury. Knowledge of sensory dermatomes (see Figure 18-6) and motor myotomes is invaluable. The sensory level is the lowest dermatome with normal sensation and may differ on each side of the body. Vertebrae C1-C4 are variable in their cutaneous distribution, so assessment should begin at C5. The examiner should not be confused by the occasional innervation of the pectoral skin by C1-C4, known as the cervical cap. Light touch and pinprick should be assessed.

Motor function should be assessed by the myotomal distribution listed in Box 18-5. Each muscle should be graded on a six-point scale:

0: Total paralysis
1: Palpable or visible contraction
2: Full range of motion without gravity
3: Full range of motion against gravity
4: Full range of motion with decreased strength
5: Normal strength

Each muscle must be tested bilaterally and its function documented. The reflexes alluded to in the classification section, as well as anal sphincter tone, must be tested.

Spinal Cord Syndromes. There are three clinically useful spinal cord syndromes:

Central cord syndrome is characterized by a disproportionate loss of motor power between the upper and lower extremities, with greater strength retained in the lower extremities. Sensory loss is variable. The mechanism of injury usually involves a forward fall with facial impact and hyperextension of the spine.

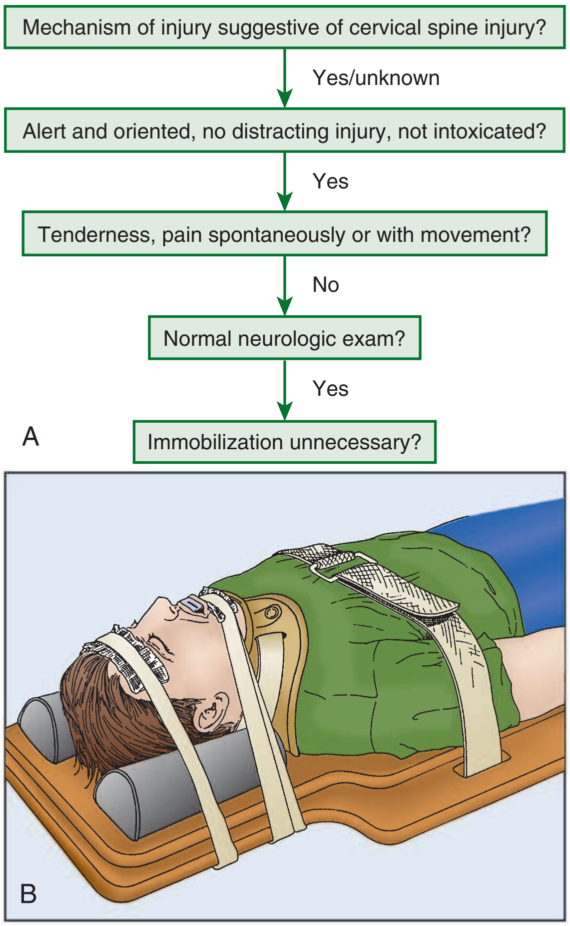

FIGURE 18-8 **A,** Clinical assessment of cervical spine stability. Failure of any criterion suggests need for immobilization. **B,** Proper spine immobilization.

Anterior cord syndrome is characterized by paraplegia and loss of pain and temperature sensation. It is the most common manifesting syndrome caused by cervical spine injury and carries a poor prognosis.

Brown-Séquard syndrome results from hemisection of the cord. It consists of ipsilateral motor loss and position sense with contralateral sensory loss two levels below the level of injury. It is usually secondary to penetrating injury.

Immobilization. After identification of injury, the caregiver faces the critical decision, with important ramifications, of whether to immobilize the patient.[110] Victims who would as a matter of course be immobilized in an urban setting might not be appropriate candidates for immobilization in the wilderness. The decision to immobilize converts an otherwise ambulatory victim who can actively participate in his or her own evacuation to one requiring more involved evacuation procedures. The subsequent evacuation can be dangerous to the victim and rescuers and demands significant expense and use of resources.

Risk criteria for cervical spine injury and the need for immobilization have been defined.[135] All criteria for the exclusion of immobilization must be satisfied. These include normal mental status without chemical influence; lack of distracting injury; normal neurologic examination; and a reliable neck examination without midline neck pain, deformity, or tenderness. Figure 18-8A presents an evidence-based algorithm for determining the need for immobilization; although such a need poses hazards for the evacuation process, if criteria are met, immobilization takes precedence over ease of evacuation. Additionally, using the trap squeeze technique for positioning and moving the patient with a suspected cervical spine injury has been shown to be safe and effective.[110] A difficult balance must be struck in the wilderness between the likelihood of true injury and the danger to the expedition members and rescuers that may ensue when the victim is immobilized. If a rigid litter is not available, the victim should be maintained on the flattest surface possible. A rigid cervical collar should be placed. All collars allow some degree of movement, particularly rotation; soft collars provide the least amount of immobilization.[51] The Philadelphia collar allows 44% of normal rotation and 66% of normal lateral bending.[92] To achieve 95% immobilization, a halo and vest are necessary. Any number of materials may be used to improvise an immobilizing device (see Chapter 46). Restriction of flexion, extension, and rotation must be achieved to the greatest degree possible. Optimal immobilization consists of a long spine board or litter, rigid collar, bolsters to the sides of the head, and tape or straps restricting movement (see Figure 18-8B).

Treatment. Because little definitive treatment for cervical spine injury can be accomplished in the field, survival and outcome depend on speed of transport and maintenance of the airway. This is particularly true when cervical spine injury is associated with head injury and major systemic trauma. Transport all victims with proven or suspected cervical spine injury to a definitive care facility.

Penetrating Neck Injuries

Like penetrating head injuries, penetrating neck injuries are usually due to gun or knife wounds. Most do not confer bony instability; however, stability should not be assumed. Neurologic deficits, if present, can progress with further movement of an unstable spine. Projectiles should not be removed if embedded in the neck. Penetrating injuries to the neck may not directly injure the spine, but neurologic sequelae may result from a blast effect. The same immobilization criteria should be implemented as when dealing with blunt injuries.

Penetrating injuries to the neck are classified according to anatomic zones of injury (see Figure 18-7). Zone I injuries extend from the clavicles to the cricoid cartilage. Zone II injuries occur between the cricoid cartilage and the angle of the mandible. Zone III injuries occur superior to the angle of the mandible.

Historically, treatment has been based on penetration of the platysma muscle. In the wilderness setting, if the examiner is confident that platysmal penetration has not occurred, the victim may be observed and the wound considered a laceration. Much debate has taken place over management of platysmal penetration within respective topographic zones, with treatment arms consisting of surgical exploration versus radiographic evaluation. In the wilderness setting, such considerations remain relevant, including the definition of what constitutes a life-threatening penetrating neck injury. Injuries that produce hard signs of bleeding (arterial bleeding, expanding hematoma, airway compression, neurologic symptoms, palpable thrill, audible bruit) should be treated with direct compression, and movement to immediate evacuation should begin.[50] These penetrating injuries violating the platysma muscle not only indicate the possibility of significant neurovascular injury but also esophageal or tracheal injuries. These victims should be evacuated promptly with close attention to the airway.

INJURIES TO THE THORAX

Thoracic trauma accounts for about 25% of all fatalities in trauma patients, yet only 10% require major surgical intervention. In most injuries, especially in the austere environment, supportive management with supplemental oxygen and pain relief are all that is required. However, on occasion chest drainage may be necessary. The key is to rapidly identify patients that require urgent intervention.[135] The most common mechanism in the wilderness is blunt trauma from falls or direct blows to the chest. Penetrating injuries can be caused by gunshot wounds, knife and arrow injuries, or impalements. The approach to thoracic injuries depends on the mechanism, severity, and location and whether the injury is through the chest wall only or through the wall plus the pleura and into the lung parenchyma.

Rapid examination of the thorax by inspection, palpation, and auscultation can assess life-threatening injuries, which are delineated in Box 18-6.

BOX 18-6 Life-Threatening Chest Injuries

Airway obstruction
Tension pneumothorax
Open pneumothorax (sucking chest wound)
Massive hemothorax
Cardiac tamponade

The typical patient will complain of chest pain and shortness of breath with point tenderness at the site of the impact. As with any injury, the physical examination first requires assessment of the airway. Intercostal or supraclavicular retraction suggests airway obstruction. The chest wall in general should rise symmetrically. The best way to visualize and inspect the chest is from the foot of the patient, looking for retraction and a possible flail segment, wherein the chest wall moves paradoxically. Dyspnea, cyanosis, and use of accessory muscles are indications of impending respiratory compromise. Hypotension, tachycardia, and ashen or cyanotic skin suggest shock. Diaphoresis is common in low-flow states such as cardiac tamponade and commonly precedes hypotension, especially in the young trauma patient with tamponade. If the patient has distended neck veins, suspect tension pneumothorax or pericardial tamponade. However, the absence of distended neck veins does not exclude these two entities, especially in a hypovolemic patient.

It is important to examine the patient's back by logrolling the patient while maintaining in-line position and immobilization. Palpation can identify significant chest wall and sternal segment movement when both hands are placed on the two hemithoraces to palpate for symmetric chest wall motion. This technique can also identify a flail segment. Crepitus is common with chest trauma and may indicate subcutaneous emphysema from an underlying pneumothorax. Subcutaneous emphysema can extend up into the neck and down into the inguinal ligaments, and is almost always associated with a significant pneumothorax. Palpation of the thoracic cavity should occur symmetrically, beginning at the distal clavicles and working medially toward the sternum, palpating and inspecting each rib individually for tenderness, contusion, or fracture. Auscultation of both chest walls can aid in diagnosis. Dullness to percussion may suggest a hemothorax; hyperresonance or tympani may indicate a large pneumothorax or tension pneumothorax.[51]

Portable ultrasound can be used in the austere environment to diagnose traumatic conditions of the chest, including pericardial fluid collections, pneumothorax, and hemithorax. Pneumothorax is identified by loss of "comet tails" or pleural sliding (Figure 18-9).[6] Numerous articles in the literature have found this to be a sensitive and specific means of diagnosing significant chest wall injuries (see Chapter 109).[13,37,77,127]

SPECIFIC THORACIC INJURIES

Blunt chest trauma in the wilderness is associated with deceleration injury, a fall from a significant height, or a direct blow. Compression of the chest wall by moving or falling debris can contribute to major intrathoracic injuries.

Rib Fractures

Rib fractures range from isolated nondisplaced, single-rib fractures that cause minor discomfort to a major flail segment with associated underlying hemothorax and/or pneumothorax with or without pulmonary contusion. Rib fractures usually cause pain, especially during inspiration. The patient will often have a rapid, shallow breathing pattern and point tenderness. The health care provider can occasionally feel displacement or crepitus overlying the rib fracture. Lower rib fractures should provoke consideration of associated liver or splenic injury. In these situations, the patient should be examined for intraabdominal tenderness and ultrasound may be useful to detect peritoneal fluid indicative of hemorrhage. Figure 18-10 demonstrates fluid in the right upper quadrant.[116]

Most rib fractures can be managed with oral analgesics. Deep breathing, incentive spirometry, pain control, and possibly supplemental oxygen usually allow the patient to be evacuated safely. Taping, splinting, or use of a rib belt is contraindicated in chest wall injury because these measures hinder movement and decrease chest wall expansion, leading to atelectasis and worsening hypoxia. Extremely painful shallow respirations can be associated with multiple rib fractures. Intercostal nerve block or subcutaneous block over the area of injury may help the patient hike out of the wilderness.[68,76] Multiple segmental rib fractures associated with a significant underlying lung injury, pneumothorax, hemothorax, or pulmonary contusion will necessitate emergent evacuation. Sternal fractures are caused by impact to the sternum by blunt force, most commonly in the upper or middle portion of the bone. The patient complains of anterior chest pain with or without ecchymosis. A palpable deformity may be evident with motion of the fracture fragments upon respiration. The primary treatment is analgesia and pulmonary toilet. Sternal fractures are seen in combination with other major chest injuries when multiple injuries are present, including rib fractures, pulmonary contusion, and blunt myocardial injury. In these cases, it may be important to rule out a myocardial injury.[46,102,143]

FIGURE 18-9 **A,** Portable ultrasound devices are easily transported for rapid assessment of physiologic and anatomic parameters. **B,** Example of pneumothorax on ultrasound.

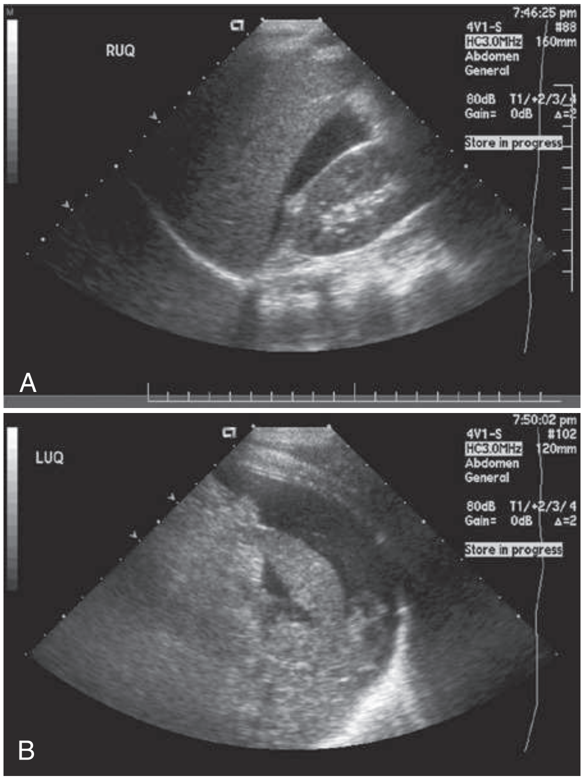

FIGURE 18-10 **A,** Ultrasound image demonstrating fluid in Morison's pouch. **B,** Fluid around the spleen.

Pneumothorax

As air enters the pleural cavity, causing the intrapleural pressure to equal the atmospheric pressure, the lung collapses (pneumothorax). The three types of pneumothorax are simple, tension, and open pneumothorax.

In *simple pneumothorax,* symptoms include tachypnea, dyspnea, and hyperresonant breath sounds in the affected hemithorax. Treatment of a simple pneumothorax, depending on its symptoms and size, is decompression of the pleural cavity.[41] In the wilderness, tube thoracostomy can be difficult to perform. A small pneumothorax can often be managed without placing a chest tube, especially if the patient can ambulate with adequate analgesia. Frequent rest breaks may be necessary. Suspicion of a pneumothorax alone on physical examination does not necessitate placement of a catheter or chest tube.[22,128] However, if the patient develops incapacitating symptoms, decompression may be necessary to avoid a life-threatening situation. Portable ultrasound can be used to make the diagnosis (see Chapter 109). The patient should be monitored with physical examination and pulse oximetry.

Tension pneumothorax develops when the intrapleural pressure increases, so that the heart and great vessels are shifted away from the pneumothorax. This commonly impedes venous return from the superior and inferior venae cavae, decreases cardiac output, and causes hypotension leading to shock. The patient may have distended neck veins and tracheal deviation away from the side of the lesion. Other physical findings are absent breath sounds, hyperresonance on percussion, respiratory distress, cyanosis, and cardiovascular collapse. This life-threatening injury demands immediate chest decompression, followed by evacuation. A temporizing treatment is to insert a needle or catheter into the pleural space, which converts the tension pneumothorax into a simple pneumothorax. This is done by inserting a 14-gauge catheter percutaneously over the second rib in the midclavicular space or laterally in the anterior axillary line in the fifth intercostal space.[72] The needle is placed over the anterosuperior surface of the rib through the intercostal muscles to avoid the inferiorly located neurovascular bundle. If successful, a rush of air is usually heard upon release of the tension pneumothorax. In muscular or obese individuals, the catheter needle must be long enough to reach the pleural cavity. The lateral approach may be easier. A plastic catheter can be advanced over the needle, the needle withdrawn, and the catheter left in place to ensure ongoing decompression. A rubber glove or a finger cot can be attached to the catheter to create a unidirectional flutter valve that allows egress but not ingress of air from the pleural cavity. A commercially available system for this purpose is the Asherman Chest Seal (Chinook Medical Gear, Durango, CO).[5] With limited resources, one might use a sharp instrument and a finger thoracostomy or placement of a hollow tube. The skin is optimally first cleansed with an antiseptic. A premade kit such as a Heimlich Chest Drain Valve kit (Chinook Medical Gear, Durango, CO) can be used for decompression. This is a valued addition to any expedition's first-aid kit.

Open pneumothorax is described in the section on Penetrating Chest Wounds, below.

Chest Tube Placement. Appropriate positioning of the patient will aid in the placement of a tube thoracostomy. The patient should be supine and the ipsilateral arm raised and placed behind the patient's head to open the space between the latissimus and pectoralis muscles and allow a better window for insertion. It is important in females to place the chest tube lateral to the breast tissue. The area should be cleaned with an antiseptic and anesthetized with 1% lidocaine if possible. All layers of the chest wall, including the intercostal muscles, rib surface, and especially pleura, should be infiltrated with anesthetic to provide adequate analgesia. Oral or IV narcotics and a mild sedative, such as midazolam, will help with pain and anxiety relief during the insertion period. A 2- to 3-cm incision is made through the skin and subcutaneous tissue down to the ribs and intercostal space. A blunt instrument, such as a clamp, is carefully inserted into the pleural space and directed close to the superior surface of the rib. Confirmation of entry into the pleural space can be made digitally to ensure that the underlying lung parenchyma is dissected away from the pleura, so that chest tube insertion will be done properly. For a simple pneumothorax, a 20 or 22 French tube is used, or a pigtail catheter if available. The catheter or chest tube should be directed posteriorly and apically, and secured with a suture or tape. If possible, the tube should be connected to suction or an underwater seal. The tube can be left open to the atmosphere to accomplish decompression and the end of the tube covered with a rubber glove, finger cot, or plastic bag modified to permit unidirectional egress flow of air. Preinsertion antibiotics, oral or parenteral, to cover gram-positive skin flora will reduce the chance of a subsequent pleural infection.[38]

Hemothorax

A hemothorax is the presence of blood in the pleural space, usually associated with an overlying major chest wall injury with multiple rib fractures. The most common cause is a direct blow to the chest that causes laceration of the lung, intercostal vessels, or pulmonary vasculature. Tenderness, inspiratory pain, and dyspnea can be associated with a hemothorax. In the wilderness, a tube thoracostomy is rarely required or feasible, but can be placed if the equipment is available and the patient is symptomatic, especially with prolonged evacuation. A 32F to 36F chest tube should be inserted if a hemothorax is suspected. If more than 1500 mL is evacuated after placement of the chest tube, this is indicative of a massive hemothorax. This mandates rapid evacuation and ongoing resuscitation in anticipation of operative intervention. The major goal in treatment is to evacuate the pleural space and allow expansion of the lung, which helps appose the lung pleura and visceral pleura and potentially decreases bleeding from the lung and other low-pressure sources.[51]

Flail Chest

When two or more ribs are fractured in two or more places, that segment of the chest wall has lost bony continuity with the rest of the bony thorax. An unstable segment will have paradoxic motion inward upon inspiration. This is often associated with an underlying pulmonary contusion, which may blossom only after 12 to 24 hours. These injuries, especially in the elderly, can be associated with significant oxygenation and ventilation compromise and may require mechanical ventilation[2]; therefore, rapid evacuation may be necessary. Intercostal nerve blocks may provide short-term management of pain and pulmonary toilet. Bilateral fractures of the costochondral cartilage can cause a central flail segment, where the entire sternum paradoxically moves with respirations.

BLUNT CARDIAC INJURIES

Pericardial tamponade or major symptomatic blunt myocardial injuries are relatively rare in the wilderness. Most blunt myocardial injuries are self-limited and improve within the first 24 hours. However, the risk of significant dysrhythmias is high within the first 24 hours. The classic presentation of a blunt myocardial injury is sinus tachycardia refractory to analgesia. Other dysrhythmias include premature ventricular contractions and bundle branch block. Any patient with symptomatic dysrhythmias or development of hemodynamic instability should be evacuated immediately. Rare major blunt cardiac injuries include chamber rupture or valvular disruption. In the wilderness, major cardiac injury is likely nonsurvivable.[14,32]

Acute pericardial tamponade can be life-threatening. Even a small amount of blood acutely contained within the pericardial cavity can cause severe restriction of cardiac function. As little as 15 to 20 mL is sufficient to produce shock. The classic clinical finding is Beck's triad (distended neck veins, hypotension, and muffled heart sounds), which is difficult to diagnose in the wilderness. Less than one-third of patients with tamponade have all three findings. The patient is often agitated, diaphoretic, and tachycardic. Another sign of cardiac tamponade is pulsus paradoxus, in which there is a decrease in systolic blood pressure of more than 10 mm Hg with inspiration. Diagnosis of cardiac tamponade in the wilderness has been made much easier with the use of portable ultrasound. Once the diagnosis of tamponade has been made, immediate evacuation of the patient is necessary, because nearly all require median sternotomy for definitive treatment. A temporizing measure that can be performed prior to definitive management is pericardiocentesis. If there is high suspicion of pericardial tamponade and shock that is unresponsive to resuscitation has developed (and death is impending), a long (16-cm) 16- to 18-gauge needle with overlying catheter can be introduced 1 to 2 cm below and to the left of the xiphoid, and advanced superiorly at a 45-degree angle with the tip aimed at the tip of the left scapula. The catheter should be aspirated as the needle is advanced until blood is obtained. Traditional teaching states that pericardial blood is nonclotting; however, with a large amount of fresh blood in the pericardium, clots may form. Once the blood is aspirated, the needle is removed and the catheter left in place and secured. Repeat aspiration may be required according to the hemodynamic status as the patient is being evacuated for definitive care. Cardiac tamponade can also result from penetrating trauma to the "box," which is an area outlined by the nipples, sternal notch, and xiphoid.

TRAUMATIC ASPHYXIA

Traumatic asphyxia can occur with burial during landslides, avalanches, or earthquakes, particularly when there is a severe crush injury of the chest wall. Craniocervical cyanosis presents with symptoms of facial edema, diffuse upper body petechiae, subconjunctival hemorrhage, and hypoxia-related neurologic symptoms. The pathophysiology is an acute increase in intrathoracic pressure, which is dissipated to the inferior and superior venae cavae. In this circumstance, venous flow reverses in the veins of the head and venous hypertension causes capillary rupture, with subsequent facial edema and petechiae.

The patient can have significant facial and laryngeal edema. Care is supportive. Death is associated with pulmonary dysfunction and associated injuries. Expeditious evacuation is essential.[75,101]

PENETRATING CHEST WOUNDS

Penetrating chest trauma above the nipples is most often associated with pneumothorax, hemothorax, or cardiac injury, and below the nipples with intraabdominal penetration.

An *open pneumothorax,* or "sucking" chest wound, is a traumatic defect of the chest wall at least two-thirds the diameter of the trachea. This injury causes decreased ventilation owing to preferential movement of air through the chest wall defect instead of the major airway. This injury requires rapid reconstruction of chest wall integrity to avoid hypercarbia and hypoxia. A hand can first be placed over the sucking chest wound, and field treatment can include placing petroleum gauze on top of the wound, covered by a patch of gauze 4 inches square taped to the skin on three sides. The untaped side serves as a flutter valve mechanism to prevent a tension pneumothorax by allowing air to move out with expiration but not back into the pleural space during relaxation or inspiration. An Asherman Chest Seal kit serves the same purpose. Additionally, a chest tube can be placed remote from the wound to decompress air and blood in the pleural cavity (Figure 18-11). Most often, these large wounds require surgical intervention for closure, and, thus, the patient should be transported urgently to definitive care.

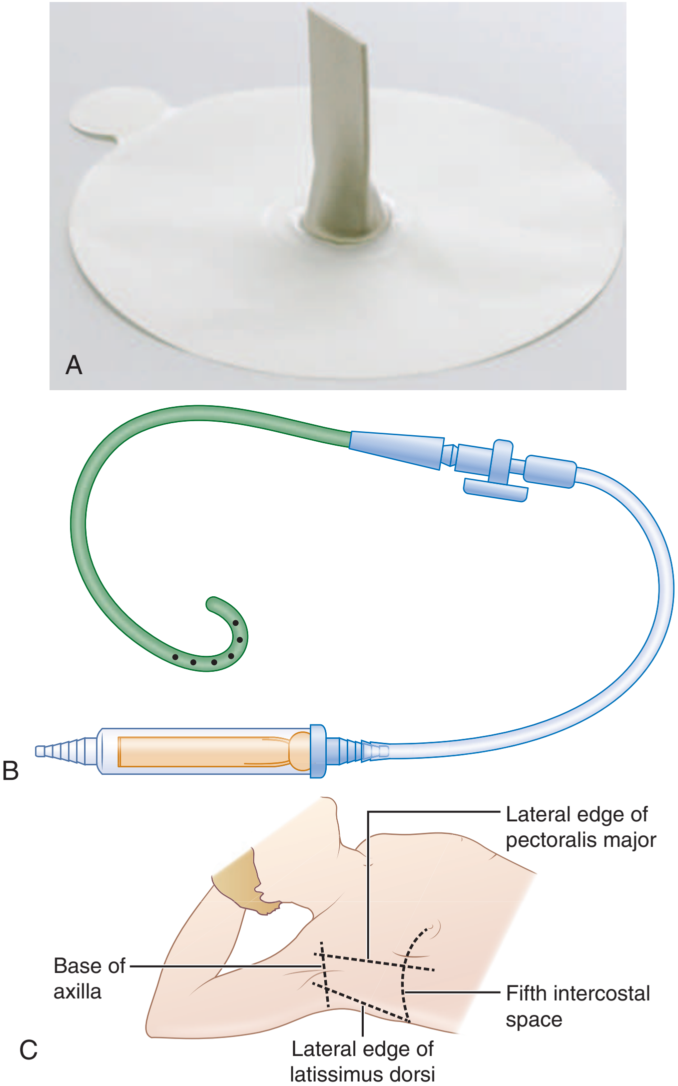

FIGURE 18-11 **A,** Asherman Chest Seal device. **B,** Heimlich valve attached to a pigtail pleural catheter. **C,** Proper position for chest tube insertion.

INJURIES TO THE ABDOMEN

Intraabdominal injuries in the wilderness setting are difficult to recognize. Once recognized, all require appropriate resuscitation and immediate evacuation. The abdomen is the most frequent site of life-threatening hemorrhagic shock; however, in the wilderness setting, few diagnostic and treatment options exist.

BLUNT ABDOMINAL TRAUMA

Blunt intraabdominal injury is commonly associated with falls. Abdominal injuries are often associated with fractures or closed-head injuries. Often the decision for evacuation is made on the basis of other injuries; however, the wilderness physician must be attuned to the potential for intraabdominal hemorrhage as an occult injury.

Anatomy of the Abdomen

For descriptive purposes, the abdomen may be divided into thoracic, true, and retroperitoneal compartments. The thoracic abdomen contains the liver, spleen, stomach, and diaphragm. The liver, spleen, and, more rarely, stomach may be injured by direct blows to the ribs or sternum. Twenty percent of persons with multiple left lower rib fractures have a ruptured spleen. A direct blow to the epigastrium may result in increased intraabdominal pressure, with subsequent rupture of the liver or diaphragm. The true abdomen contains the small bowel, large bowel, and bladder. Isolated bowel injuries are rare in the wilderness setting. Blunt bladder or rectal injury usually occurs in conjunction with severe pelvic fracture and carries a high risk of death. The retroperitoneal abdomen contains the kidneys, ureters, pancreas, and great vessels. It is notoriously difficult to evaluate by physical examination. Life-threatening hemorrhage can occur into the true abdomen or retroperitoneal space.

Diagnosis

The wilderness physician must have a high index of suspicion and perform a superlative history and physical examination. With the advance of ultrasound technology, access to a small portable unit may be helpful in determining the absence or presence of free abdominal fluid (see Figure 18-9 and Chapter 109).

Handheld ultrasound devices are as sensitive and specific as more powerful units designed for inpatient use; they are no less accurate and their positive and negative predictive values are the same.[78] In the wilderness, invasive diagnostic procedures such as peritoneal lavage are not recommended.

Physical Examination

Look for signs of early shock, with tachycardia, tachypnea, delayed capillary refill, a weak or thready pulse, and cool or clammy skin. Physical examination of the abdomen begins with visualization and inspection. Contusions and abrasions may be the only harbingers of occult visceral injury. Periumbilical ecchymosis associated with abdominal hemorrhage (Cullen's sign) is virtually never present in acute abdominal trauma. Abdominal distention due to hemorrhage is a late sign and is never present before shock and cardiovascular collapse have developed. Abdominal inspection should survey the flanks, lower chest, and back. Inspection of the back should follow palpation of the spine while the victim is supine. The victim should be carefully log-rolled if there is any suspicion of spinal injury.

Looking for muscle guarding, the examiner gently palpates the abdomen in all four quadrants. Persistent guarding or tenderness after trauma mandates rapid evacuation. Percussion tenderness is an indicator of peritoneal irritation, also mandating evacuation. The presence or absence of bowel sounds has little prognostic significance. Bowel sounds may be present in the face of significant intraabdominal hemorrhage or, conversely, absent when extraabdominal injuries induce ileus.

Referred pain to the left shoulder (Kehr's sign) strongly suggests a ruptured spleen. This pain is often exaggerated by placing the victim in the Trendelenburg position, increasing the amount of left upper quadrant blood irritating the diaphragm. Pain from the retroperitoneal abdomen associated with injuries to the kidneys or pancreas may be referred to the back. However, referred pain is usually a late finding and is not helpful in evaluation of acute trauma.

Gross hematuria that does not clear immediately or that is coupled with an associated injury, such as pelvic fracture or abdominal or back pain, requires immediate evacuation. To minimize blood loss, the victim should be kept stationary and the evacuation team brought as close to the victim as possible.

In a wilderness setting, rectal and vaginal examinations add little to the evacuation decision when evaluating for abdominal trauma. The unstable pelvic fracture associated with rectal and vaginal injuries is usually the determinant for evacuation.

PENETRATING ABDOMINAL TRAUMA

Penetrating intraabdominal injuries may result from blast, gunshot, stab, or arrow wounds. The social context in which these injuries occur (accidental, intentional, or self-inflicted) makes little difference in the wilderness setting. Recrimination, guilt, and blame only interfere with the paramount goal of immediate evacuation.

Gunshot Wounds

A low-caliber gunshot injury often manifests with a small entrance wound and no exit wound. A high-caliber, high-velocity gunshot injury may have a relatively innocuous entrance wound but a large, disfiguring exit wound and extensive internal injuries. No matter what the caliber or trajectory and no matter where the entrance and exit wounds, all gunshot wounds from the nipple line to the inguinal ligament should be presumed to have penetrated the abdominal cavity and created an intraabdominal injury. These injuries mandate immediate surgical intervention. A victim of gunshot wounds to the head, neck, chest, abdomen, or groin should undergo immediate evacuation and should receive a single-agent broad-spectrum antibiotic, such as an oral fluoroquinolone, second-generation cephalosporin, or extended beta-lactam drug. Hunting injuries are discussed in Chapter 26.

Shotgun Injuries

Shotgun injuries to the torso are managed in the same manner as gunshot wounds. Shotgun injuries have a potentially lower incidence of underlying visceral injury than do gunshot wounds, but there is often extensive soft tissue damage requiring surgical debridement. The potential exists for delayed development of peritonitis from a single penetrating pellet to the viscera. Consequently, shotgun injuries should also be treated with emergency evacuation and a broad-spectrum antibiotic, as recommended previously for gunshot wounds.

Occasionally, a close-range shotgun blast results in a soft tissue defect large enough for bowel to extrude through the wound. The bowel should not be placed back into the abdomen. Injured bowel displaced from the abdominal cavity conceptually should be treated as though it were an enterocutaneous fistula. Because evacuation is often delayed in the wilderness, it is better to have fecal contents outside, rather than inside, the peritoneal cavity. The exteriorized bowel should be kept moist and covered at all times. Uncovered bowel outside the peritoneal cavity rapidly desiccates and becomes nonviable, mandating later surgical resection. Exposed bowel should be covered with an abdominal pack or cloth moistened with sterile saline at best, or at worst with potable water. The dressing should be checked and remoistened at least every 2 hours.

Stab Wounds

The penetrating object is usually a knife but may be as varied as a piton, ski pole, or tree limb. Any deep skin laceration from the nipple line to the groin should be considered to have damaged an intraabdominal organ. Whereas the odds of an abdominal gunshot wound injuring a visceral organ exceed 85%, the odds of a stab wound injuring a visceral organ are less than 50%.

In certain urban hospitals, the high incidence of negative surgical explorations for stab wounds had led to a more selective approach toward patients with abdominal stab wounds.[11] Significant injuries from penetrating trauma have been statistically decreasing in most trauma centers. The practice of nonoperative management for penetrating abdominal trauma has its place in the right setting, including one where hemodynamics can be continuously monitored, frequent physical examinations can take place, and the patient can be taken immediately to the operating room if the condition changes or peritonitis develops. This approach uses local wound exploration and frequent physical examinations. This is not appropriate for the wilderness environment; all patients with suspected violation of the fascia from penetrating abdominal trauma should be promptly evacuated.

Although there are no data addressing the management of stab wounds in the wilderness, the following approach is practical and reasonable. If the wound extends into the subcutaneous tissue, the evacuation decision depends on local wound exploration. This procedure is simple to perform, even in the wilderness. The skin and subcutaneous tissue are infiltrated with local anesthetic, and the laceration is extended several centimeters to clearly visualize the underlying anterior fascia. It is helpful to use lidocaine 1% with epinephrine to minimize slight but annoying bleeding that can impair visualization. The wound should never be probed with any instruments, particularly if overlying the ribs.

Wound exploration is confined to the area from the costal margin to the inguinal ligament. Local exploration is contraindicated in wounds that extend above the costal margin, because it is possible for such exploration to communicate with a small pneumothorax, potentially exacerbating respiratory distress.

If thorough exploration of the wound shows no evidence of anterior fascial penetration and there is no evidence of peritoneal irritation, the wound can be closed with tape (e.g., Steri-Strips) or adhesive bandages and dressed, and the evacuation process may be delayed. Physical examination should be performed every few hours for the next 24 hours. If no peritoneal signs develop and the victim feels constitutionally strong, a remote expedition may resume with caution and an eye to evacuation should the victim become ill.

In the wilderness, it is prudent to have a low threshold for evacuation because of technical difficulties in performing wound exploration, such as insufficient light and inadequate instruments. Persons who have been impaled by long objects, such as tree limbs or ski poles, should have the object left in place and carefully shortened, if possible, to facilitate transport.

PELVIC TRAUMA

In the wilderness setting, fractures of the pelvis are generally associated with a fall from a significant height, a high-velocity ski accident, or a vehicular accident.

Pelvic fractures have a significant risk of death; if the fracture is open, the risk at least doubles.[53,144] With opening of the pelvic ring, there may be hemorrhage from the posterior pelvic venous complex and occasionally from branches of the internal iliac artery. For hemodynamically unstable victims with severe pelvic fractures, resuscitative efforts should be instituted. In addition, simple techniques to reduce increased pelvic volume using circumferential binding sheets or slings may slow bleeding.[129] Several pelvic binders provide circumferential pressure to minimize the pelvic volume with essentially equal efficacy.[79] Even the improvised use of a sheet has been shown to provide adequate compression of the pelvis in cadaver models.[108] In the field, a blanket, sheet, binder, or jacket may be used to hold compression (Figure 18-12).

The key factor in the initial management of pelvic fractures is early suspicion, identification, and proper management and transport of the victim. Posterior ring fractures or dislocations are associated with a greater incidence of significant hemorrhage, neurologic injury, and death than are other pelvic fractures. The diagnosis of pelvic fracture should be identified early in the primary/secondary survey. The examiner may see pain, swelling, and ecchymosis. The authors do not recommend repeated or aggressive stressing or compression on the pelvis during examination. A person with a pelvic ring fracture must be immediately evacuated on a backboard, with care taken to minimize leg and torso motion.[87]

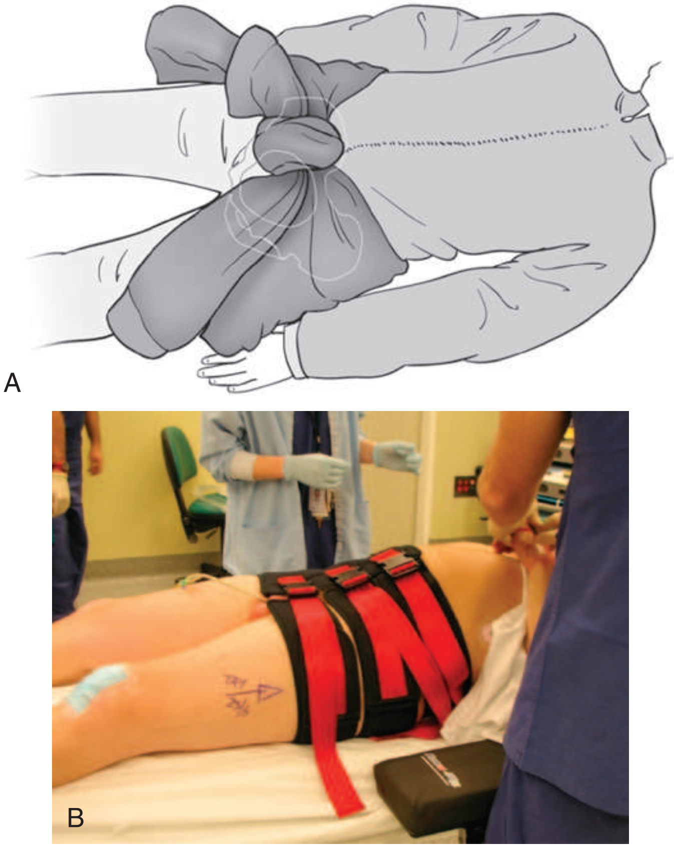

FIGURE 18-12 **A,** Pelvic sling improvised with a jacket provides compression to the pelvis to control bleeding. **B,** Pelvic binder.

The flank, scrotum, and perianal areas should be inspected for blood at the urethral meatus, swelling or bruising, or a laceration in the perineum, vagina, rectum, or buttocks suggestive of an open pelvic fracture. Rectal and vaginal examinations should be performed by an experienced provider to recognize a possible "open pelvis." The pelvis should be examined carefully once, without any aggressive rocking motion. The first indication of mechanical disruption is leg length discrepancy or rotational deformity in the absence of an obvious leg fracture or hip dislocation. For more information on pelvic fracture, see Chapter 22.

EXTREMITY TRAUMA

Most wilderness-related extremity injuries are fractures and sprains, which are discussed in Chapter 22. This section focuses on general field management of significant extremity vascular injuries, traumatic amputation, and recognition and treatment of rhabdomyolysis.

VASCULAR INJURIES

Injury to the major vessels supplying the limbs can occur with penetrating or blunt trauma. Fractures can produce injury to the vessels by direct laceration (rarely) or by stretching, which produces intimal flaps. Penetrating injuries can be devastating if transection of a vessel occurs. Significant vascular injuries, from penetrating or blunt causes, can result in subtypes of multiple vessel injuries, each of which may threaten the limb. Injury subtypes include laceration, transection, contusion with spasm, thrombosis, true or false aneurysm, external compression, and arteriovenous fistula. Accurate history taking, expeditious physical examination, and prompt evacuation are the keys to life and limb salvage.

Significant vascular injuries result in one of two clinical presentations, hemorrhage or ischemia. The main priority is stopping hemorrhage. The victim of trauma may die in short order from a major vascular injury. Ideally, control of hemorrhage can be accomplished without resultant ischemia of the distal extremity. Hemorrhage from an extremity wound can almost always be controlled with direct pressure and pressure dressings. These measures permit circulation to and from the extremity outside the area of pressure application. In some circumstances, a tourniquet may be required.

History of the Injury

A complete history of the time and mechanism of injury is invaluable in planning further management. Although no absolute ischemia time has been established, a goal of less than 6 hours to reperfusion is prudent.[135] Recent military experience demonstrates that tourniquets are an effective method of stopping hemorrhage. The optimal ischemia time is less than 2 hours; however, minimal morbidity has been achieved with longer applications.[80,81] The amount of blood present at the scene should be quantified. A history of pulsatile bleeding of bright-red blood that abates suggests arterial injury. Thirty-three percent of victims with arterial injuries have intact distal pulses.

Physical Examination

Vascular examination in the field can be difficult. Hypovolemia, hypothermia, and hostile conditions make accurate examination challenging. Skin color and extremity warmth should first be assessed. Distal pallor and asymmetric hypothermia suggest vascular injury. Pulses should be palpated. In the upper extremity, the axillary, brachial, radial, and ulnar pulses should be assessed. In the lower extremity, the femoral, popliteal, posterior tibial, and dorsalis pedis pulses should be assessed. Location and direction of the wound, amount of hemorrhage, and presence of hematomas or palpable thrill should be noted.

A neurologic examination that quantifies motor and sensory deficits is critical. Because of the high metabolic demands of peripheral nerves, disruption of oxygen delivery makes neuronal cells highly susceptible to ischemic death. Conversely, skeletal muscle is relatively resistant to ischemia. Loss of sensation or limb paralysis is an alarming sign of impending anoxic necrosis.

Treatment of Vascular Injuries

All external hemorrhages should be identified during the primary survey and controlled with direct pressure at the site of injury. Tourniquets should be applied only when direct pressure fails to control bleeding or cannot be applied (as while a casualty is being evacuated by hoist to an aircraft). Tourniquets should be released every 5 to 10 minutes to attempt to limit ischemia, unless severe hemorrhage continues when the tourniquet is loosened. In this case, it should be left tightened. Efforts to control bleeding with pressure should be undertaken. Direct pressure permits collateral flow to provide some perfusion to the distal extremity.

Hematomas should never be explored or manually expressed without surgical capability readily available. Attempts to clamp or ligate vessels are not recommended. Frequent repeat neurovascular examinations are mandatory.

Once bleeding is controlled and the wound is covered with a sterile but nonconstrictive dressing, completion of the primary survey, identification and stabilization of associated injuries, and appropriate resuscitation with normal saline should follow. After hemostasis is achieved, a nonconstrictive dressing will obviate the chance for unintended venous outflow obstruction. The extremity should be splinted to prevent movement. The need for evacuation depends directly on the results of the physical examination. Examination results can be grouped into "hard signs," indicative of ischemia or continued hemorrhage, and "soft signs," suggestive of, but not indicative of, ischemia (Boxes 18-7 and 18-8).

All victims with hard signs should be evacuated emergently. Based on current data, an isolated soft sign may warrant observation alone, depending on the remoteness of the expedition and the risks of evacuation. The data for observation of soft signs have emerged from hospital settings and must be applied with great caution in the wilderness. If soft signs are present, clinical suspicion is high, and evacuation can be accomplished safely, the victim should be transported and observed in a medical facility.

BOX 18-7 Vascular "Hard Signs"

Pulsatile bleeding
Palpable thrill
Audible bruit
Expanding hematoma
Six Ps of regional ischemia
- Pain
- Pulselessness
- Pallor
- Paralysis
- Paresthesia
- Poikilothermia

Although not feasible in the wilderness, the use of vascular shunts has been shown to be a viable option for increased limb salvage without an increasing risk of death.[28] Based on recent military conflict data, the use of battlefield temporary vascular shunts does not lead to increased limb loss rates.[17] Porcine models have demonstrated safety of temporary vascular shunt use without increased thrombosis rates within 48 to 72 hours of placement.[29] Additionally, the more proximal the shunt on the extremity, the better the patency. This is also true of shunted venous injuries.[112]

TRAUMATIC AMPUTATION

In the wilderness, amputation victims require immediate evacuation. Hemorrhage is controlled during the primary survey with direct pressure, and resuscitation is instituted. Tourniquets are rarely required. The victim should be kept warm and calm. Reassurance and analgesics should be administered. Amputations should be completed only if minimal tissue bridges exist and it is clear that the neurovascular supply has been interrupted.

Amputation of a mangled extremity, defined as an extremity with a high-grade open fracture and significant soft tissue injury, should not be carried out in the wilderness except to free a trapped victim to avoid further severe injury or even death, or in the case of uncontrollable hemorrhage threatening the life of the victim, and then only by experienced surgical personnel. All other severely injured extremities should be wrapped in available sterile materials, splinted, and kept moist.

Amputated extremities should be cooled if possible, optimally in a plastic bag in ice or ice water. Avoid placing the extremity in direct contact with ice. Without cooling, the amputated extremity remains viable for only 4 to 6 hours; with cooling, viability may extend to 18 hours. The amputated extremity should accompany the victim throughout the course of the evacuation.

CRUSH INJURIES AND RHABDOMYOLYSIS

Rhabdomyolysis is a potentially fatal syndrome that results from lysis of skeletal muscle cells. In its fulminant form, rhabdomyolysis can affect multiple organ systems. Compartment syndrome, renal failure, and cardiac arrest are the major complications.

Any condition resulting in significant acute or subacute striated muscle damage can precipitate rhabdomyolysis. Crush injuries of the extremities and pelvis, revascularization of ischemic tissue, ischemic extremities, animal bite and snakebite, frostbite, and traumatic asphyxia can all result in rhabdomyolysis in a wilderness setting. Crush injuries are frequently results of avalanches, falls from heights, or rock slides.

BOX 18-8 Vascular "Soft Signs"

Injury in proximity to major vessel
Diminished but palpable pulses
Isolated peripheral nerve deficit
History of minimal hemorrhage

The pathophysiology of rhabdomyolysis remains controversial. The exact mechanism of muscle injury appears not to be simple direct force or isolated ischemia and is probably multifactorial. The common cellular derangement is interference of the normal function of muscle cell membrane sodium-potassium adenosine triphosphatase with intracellular calcium influx and cell death through activation of proteases and phospholipases.[147] After cell death, multiple intracellular constituents, including myoglobin, creatine kinase, potassium, calcium, and phosphate, are released into the systemic circulation.

The metabolic derangements of rhabdomyolysis depend directly on release of intracellular muscle constituents. Myoglobinemia, hypercalcemia, hyperphosphatemia, hyperkalemia, hyperuricemia, metabolic acidosis, coagulation defects, and contracted intravascular volume result.

The clinical presentation of rhabdomyolysis may include muscle weakness, malaise, fever, tachycardia, abdominal pain, nausea and vomiting, or encephalopathy. The danger of the syndrome lies in the cardiovascular effects of electrolyte disturbances and renal failure secondary to changes in renal perfusion and direct toxicity of myoglobin to tubular cells.

Successful treatment relies on prompt diagnosis based on clinical signs and urinalysis, aggressive hydration, and forced diuresis. Myoglobin turns urine the color of tea; this is an important indicator of significant muscle death and the need for aggressive treatment.

Crystalloid solution should be administered intravenously at 1 to 2 L/hr to achieve a urine output of 100 to 300 mL/hr. Signs of fluid overload should be monitored. Victims who are trapped in rubble should have resuscitation initiated before extrication if possible. The addition of agents to alkalinize the urine and promote diuresis has been shown to improve clearance of myoglobin but not to alter survival rates. In addition, diuretics may be detrimental in multisystem trauma victims who are hypovolemic. All victims demonstrating myoglobinuria should be evacuated.

WILDERNESS SURGICAL EMERGENCIES

In the wilderness it is important to distinguish between a surgical and a nonsurgical emergency for evacuation purposes. Table 18-2 reviews the differential diagnosis of abdominal pain. Certain differential diagnoses can be difficult, such as a black widow spider bite or mushroom ingestion, both of which can simulate an acute surgical abdomen. The key is to identify surgical problems related to peritoneal inflation and conditions that will need evacuation and urgent operative intervention. Common genitourinary problems that can cause abdominal pain in males include appendicitis, renal colic, urinary retention, and testicular torsion. Common genitourinary problems causing abdominal pain in females include pelvic inflammatory disease, urinary tract infections, dysmenorrhea, ruptured ovarian cysts, and ectopic pregnancy. Pain is the hallmark of the surgical abdomen, and therefore it is important to obtain an accurate history and physical examination to determine the nature and onset of pain, and its severity, location, and precipitating factors. The onset of pain can be explosive, rapid, or gradual. Explosive agonizing pain is most common with rupture of a hollow viscus into the peritoneal cavity. Renal or biliary colic may also cause acute severe pain, but it is not as excruciating as that with a perforated viscus. Pain that is of rapid onset and progressively worsens is most often indicative of acute pancreatitis, mesenteric thrombosis, or small bowel strangulation. Gradual onset of pain is usually from progressive peritoneal inflammation, as commonly occurs with appendicitis or diverticulitis. Unrelenting and excruciating pain that is unresponsive to narcotics should alert the clinician to an acute vascular insult, such as a ruptured abdominal aortic aneurysm or intestinal infarction. Vague or poorly localized pain usually means an inflammatory process of the parietal peritoneum, as is initially present with appendicitis. Colicky pain with cramps and rushes is indicative of gastroenteritis. Small bowel obstruction can also cause colicky pain, but it is more rhythmic in nature, with pain-free intervals.

Patients who are unable to lie still often have renal or biliary colic, but those lying perfectly still may have peritoneal inflammation. Auscultation can reveal rushes and tinkles of a small bowel obstruction or the completely silent abdomen related to ongoing peritoneal inflammation. Any patient with severe pain upon shaking or percussing the abdomen, along with nausea, fever, or vomiting, most likely needs to be evacuated, because many require surgical intervention.

Volume depletion from both surgical and nonsurgical disease processes is common in the wilderness. Severe dehydration and electrolyte depletion can result from vomiting and/or diarrhea, especially in the later stages of disease and if evacuation has been delayed. Crystalloid resuscitation in the field should be

TABLE 18-2 Features Considered in the Differential Diagnostic of Abdominal Pain

Disease	Location of Pain and Prior Attacks	Mode of Onset and Type of Pain	Associated Gastrointestinal Problems	Physical Examination
Acute appendicitis	Periumbilical region or localized generally to right lower abdominal quadrant	Insidious to acute and persistent	Anorexia common; nausea and vomiting in some	Low-grade fever; epigastric tenderness initially; later, right lower quadrant pain
Intestinal obstruction	Diffuse	Sudden; crampy	Vomiting common	Abdominal distention; high-pitched rushes
Perforated duodenal ulcer	Epigastric; history of ulcer in many	Abrupt; steady	Anorexia; nausea and vomiting	Epigastric tenderness; involuntary guarding
Diverticulitis	Left lower quadrant; history of previous attacks	Gradual; steady or crampy	Diarrhea common	Fever common; mass and tenderness in left lower quadrant
Acute cholecystitis	Epigastric or right upper quadrant; may be referred to right shoulder	Insidious to acute	Anorexia; nausea and vomiting	Right upper quadrant pain
Renal colic	Costovertebral or along course of ureter	Sudden; severe and sharp	Frequently nausea and vomiting	Flank tenderness
Acute pancreatitis	Epigastric penetrating to back	Acute; persistent, dull, severe	Anorexia; nausea and vomiting common	Epigastric tenderness
Acute salpingitis	Bilateral adnexal; later, may be generalized	Gradually becomes worse	Nausea and vomiting may be present	Cervical motion elicits tenderness; mass if tuboovarian abscess is present
Ectopic pregnancy	Unilateral early; may have shoulder pain after rupture	Sudden or intermittently vague to sharp	Frequently none	Adnexal mass; tenderness

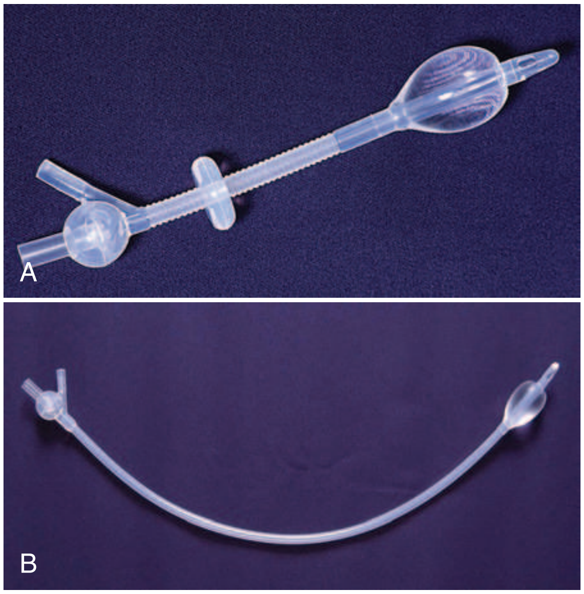

FIGURE 18-13 **A,** OPTION-*vf* (female) catheter. **B,** OPTION-*vm* (male) catheter. *(Courtesy Practica Medical Manufacturing, Inc, Dublin, Ohio.)*

initiated to counteract potential sepsis and hypovolemic shock. Decompressing the stomach with a NG tube may alleviate severe nausea and vomiting if antiemetics are ineffective, which is often the case with a small bowel obstruction. Confirmation of proper placement of a NG tube is made by aspirating gastric contents or oscillating gastric air when one insufflates the stomach through the tube. Monitoring the urine output is a good estimate of intravascular volume status. Therefore, placing an indwelling urinary catheter in circumstances of major volume depletion may be helpful to determine the adequacy of the resuscitation (Figure 18-13). Portable ultrasound can also be used to diagnose certain intraabdominal conditions and is valuable in determining the size of the vena cava as an estimate of intravascular volume.

ACUTE APPENDICITIS

About 7% of people have a chance of developing acute appendicitis during their lifetime.[1] In normal circumstances, early diagnosis and definitive surgical treatment result in a low complication rate. In the wilderness, however, delayed diagnosis or late presentation can cause severe illness and sepsis. It is important to carefully assess and evacuate the patient early if acute appendicitis is suspected. The most common differential diagnosis with acute appendicitis is mesenteric adenitis, which is often preceded by an upper respiratory tract infection and associated with vague abdominal pain beginning in the right lower quadrant. Pelvic inflammatory disease in young women usually occurs within a week of menses. With gastroenteritis, vomiting often precedes abdominal pain and is often associated with diarrhea.

Clinical presentation of acute appendicitis revolves around the associated abdominal pain. Classically, the pain is initially achy in nature and located in the periumbilical area. As the disease progresses, the pain becomes sharper and localized in the right lower quadrant. It is associated with fever, anorexia, and malaise. In later stages, the patient often remains still, occasionally with the right hip flexed, complaining of pain on passive hip extension (psoas sign). The patient may have indirect tenderness in the right lower quadrant upon palpation of the left lower quadrant. As mentioned, if acute appendicitis is suspected, evacuation is required to avoid perforation. Once the appendix is ruptured, the patient develops generalized peritonitis and abdominal rigidity. Initial field treatment of appendicitis includes IV hydration and initiation of broad-spectrum antibiotics covering anaerobic and gram-negative bacteria (e.g., cefoxitin 2 g, or piperacillin-tazobactam 3.375 g). If only oral antibiotics are available, a fluoroquinolone, such as oral ciprofloxacin 750 mg twice a day, is recommended.

ACUTE CHOLECYSTITIS AND BILIARY COLIC

About 15% of the population develops gallstones, but only about 25% develops biliary colic. An even smaller percentage of these patients develop acute cholecystitis or gallstone pancreatitis. Biliary colic occurs when a gallstone obstructs the neck of the gallbladder. The pain is usually constant and aching, and the patient often states that similar episodes have occurred in the past. The pain is mostly localized in the right upper quadrant or epigastric region, and radiates to the right scapula and back. This type of pain often follows a spicy or fatty meal, usually lasts up to an hour, and then abates. It is occasionally associated with nausea and vomiting but usually not with fever. In this circumstance, evacuation may not be necessary unless the condition advances to acute cholecystitis, which occurs when the stone obstructs the duct and the gallbladder becomes inflamed. In this circumstance, the pain often persists for more than an hour and is accompanied by fever, tachycardia, and worsening right upper quadrant pain. Acute cholecystitis requires evacuation and often hospitalization, because it can progress to gangrenous changes and perforation, or cholangitis and gallstone pancreatitis. Initial management is IV hydration and broad-spectrum antibiotics (e.g., IV piperacillin-tazobactam 3.375 g every 6 hours, or oral ciprofloxacin 750 mg twice a day) to cover gram-negative enteric bacteria and *Streptococcus* species.[27]

PEPTIC ULCER DISEASE

Peptic ulcer disease is on the decline in the United States, especially with the advent of acid-reducing agents and the treatment of *Helicobacter pylori* infection. Duodenal ulcer perforation is a serious complication and should be in the differential diagnosis of upper abdominal pain in the wilderness. Patients often have a history of peptic ulcer disease, which is much more common in males than females. The use of nonsteroidal antiinflammatory drugs and smoking are the most common risk factors. These patients have an acute onset of constant epigastric pain that radiates to the midback. There is tenderness and tympany of the upper abdomen. Signs of peritonitis mandate evacuation. Temporizing measures may include insertion of a NG tube and administration of broad-spectrum antibiotics and a proton pump inhibitor. If the perforation is anterior, the patient more often develops peritonitis; posterior perforation causes upper gastrointestinal bleeding. The differential diagnosis may include pancreatitis, acute cholecystitis, myocardial infarction, or a perforated viscus.

DIVERTICULITIS

Most patients with diverticulitis remain asymptomatic. Patients that present with uncomplicated diverticulitis usually have nonspecific symptoms, including vague, colicky, left lower quadrant abdominal pain. Diverticulitis can involve the entire lower abdomen and is occasionally associated with diarrhea and fever. Classically, the patient is in moderate discomfort with left lower quadrant pain with or without localized guarding. Perforation and abscess formation can present with minimal symptoms if the perforation is contained in the retroperitoneum. However, if the perforation extends into the peritoneal cavity, it can present with generalized peritonitis. Treatment in the wilderness for diverticulitis includes hydration, bowel rest, and broad-spectrum antibiotics; if evacuation is delayed, IV antibiotics covering gram-negative enterics and anaerobes are given. Oral antibiotic coverage with ciprofloxacin and metronidazole may be adequate for mild cases of diverticulitis. Because of the unpredictable response to antibiotics and potential for progression, evacuation is most often indicated when patients develop diverticulitis.

MECHANICAL SMALL BOWEL OBSTRUCTION

Small bowel obstruction is a common surgical condition; in the wilderness, it is a true emergency. The most common cause is postoperative adhesions, followed closely by an incarcerated abdominal wall incisional hernia. The clinical presentation varies between patients according to the level of obstruction, the time course, and the presence of or potential for strangulation. Initially there may be hyperperistalsis as the bowel attempts to overcome the obstruction with proximal dilation. This leads to acute diffuse crampy abdominal pain, which can be associated with vomiting and obstipation. Late physical findings include a very distended tympanitic abdomen; many liters of fluid may be sequestered in the abdominal cavity and within the bowel wall, causing significant dehydration. If the process progresses to strangulation of the bowel, the result may be fever, tachycardia, and subsequent peritonitis from a perforation. Therefore, it is important to identify impending or actual strangulation, because the patient requires immediate evacuation and emergent operative intervention. In the interim, NG decompression and IV hydration should be initiated. Serial examinations of the abdomen are important to note any changes in symptoms. The colicky pain can become localized and constant, or signs of peritonitis may develop.

INCARCERATED ABDOMINAL WALL DEFECT

Most incarcerated hernias developing in the wilderness will be in the inguinal region, followed by incisional and umbilical hernias. Many patients had previously been aware of the asymptomatic bulging hernia. New or known hernias that cannot be reduced are concerning. Constant point tenderness, especially when associated with vomiting, fever, and tachycardia, is indicative of incarceration and potential strangulation. Physical examination shows a palpable tender groin or scrotal mass for inguinal hernias. The differential diagnosis for a tender groin mass includes lymphadenopathy, testicular torsion, and epididymitis. A painful mass below the inguinal ring is highly suspicious of a femoral hernia. Other areas of potential incarceration or strangulation include a painful mass at the site of an abdominal wall incision or at the umbilicus. The bowel that becomes incarcerated within the hernia sac can progress to necrosis within 3 to 5 hours; the decision to evacuate the patient depends greatly on whether the hernia can be reduced. Any patient with an incarcerated hernia and signs of toxicity must be evacuated immediately. A newly incarcerated hernia without contraindication can be reduced by personnel who are experienced in this technique. This includes gentle pressure that is exerted on the hernia mass. If the incarceration is in the inguinal region, the patient should be lying flat with hips elevated. This technique can also be attempted with incarcerated umbilical or incisional hernias in the early stages of obstruction. Analgesia and sedation are helpful adjuncts in assisting with attempts at reduction.[64] An absolute contraindication to attempts at reduction includes the presence of a femoral hernia or any signs of intestinal ischemia or necrosis where the mass is exquisitely tender and the overlying skin may be erythematous and warm to the touch. These patients require emergent evacuation and early operative intervention.[3]

ANAL FISSURE AND HEMORRHOIDS

An anal fissure is a superficial, linear tear in the anoderm distal to the dentate line. It is often associated with constipation and passage of hard stools or anal trauma (Figure 18-14). Patients complain of severe pain during a bowel movement that continues for several minutes to hours and recurs after each bowel movement. About 70% present with bright-red blood on the toilet paper. Most occur in the posterior midline. First-line treatment includes relief of constipation with stool softeners and fiber supplements, along with hydration. Mineral oil (15 mL twice a day), along with warm sitz baths after bowel movements, helps lubricate the stool and reduce pain. Second-line treatment includes topical analgesics such as 1% to 3% lidocaine jelly and, if available, topical nitrates (0.4% nitroglycerin ointment) or calcium channel blockers (e.g., 2% diltiazem ointment) directly applied to the internal sphincter to relieve the pain associated with sphincter spasm.

A hemorrhoid is an abnormal dilated venous plexus that can protrude from the anus. Most patients are aware of the problem before the excursion. The condition can be first recognized or exacerbated by constipation. Symptoms include severe itching and discomfort. Hemorrhoids can be very painful if prolapsed or

FIGURE 18-14 Anal fissure.

thrombosed. Blood may be noted on the toilet paper after a hard bowel movement. If a hemorrhoid becomes bothersome in the field, begin measures to soften and lubricate the stool with hydration, stool softeners, and mineral oil. Avoid bearing down during a bowel movement, take a sitz bath several times a day, and use hemorrhoidal suppositories or creams.

These lesions often present as dark, firm, tender purple nodules protruding from the anal opening, or they can be palpated within the anal canal. Small thrombosed hemorrhoids often resolve spontaneously. Those greater than 2.5 cm in diameter may require incision and evacuation of the clot to relieve pain. Wash the anal area with soap and water and provide local or topical analgesia if available. Pressing ice against the nodule can provide effective analgesia. Incision on the top of and into the thrombosed hemorrhoid and evacuation of the clot often causes dramatic relief of pain. The incision should be left open and abdominal pads placed to absorb drainage. Warm sitz baths for the next several days will improve symptoms.[66]

UROLOGIC EMERGENCIES

RENAL COLIC

Renal colic is a symptom complex resulting from acute obstruction of the urinary tract secondary to calculus formation. The goal of the wilderness physician is to recognize the symptom complex and institute treatment. After obstruction of the urinary tract, the pain crescendo of renal colic begins in the flank. The pain progresses anteriorly over the abdomen and radiates to the groin and testes in men and labia in women. Because the autonomic nervous system transmits visceral pain, many abdominal complaints may manifest. Nausea and vomiting are common. With severe colic, the victim writhes in pain and is unable to find a comfortable position. Diagnosis in the wilderness is assisted by the presence of gross hematuria.

Management of ureteral colic is pain control. Although almost universally deployed, forced diuresis may reduce ureteral peristalsis. Thus, forced oral fluids or aggressive IV hydration is of questionable benefit.[142] Most calculi pass spontaneously in 4 to 6 hours. The goal of management is to control pain until passage of the stone has occurred. A number of pharmacologic approaches may be used. Nonsteroidal antiinflammatory drugs such as ibuprofen and ketorolac have been effective for management of renal colic. For symptoms uncontrolled by antiinflammatory agents, narcotics may be added. Narcotic analgesics are most effective if given parenterally; however, agents such as meperidine, codeine, and hydromorphone may be given orally. Antiinflammatory agents and analgesics can be combined. An antiemetic may be added to relieve nausea. When administering pain medication in the field, particular attention should be given to airway maintenance, induced nausea, and vomiting.[138] Any person whose symptom complex cannot be controlled must be evacuated. Additional indications for evacuation include calculus anuria, evidence of obstruction-induced infection, and signs of systemic infection.

URINARY RETENTION

Urinary retention is a painful experience in which the patient is unable to voluntarily urinate. This condition requires immediate medical, and sometimes surgical, intervention.[123,141] Causes of urinary retention can be categorized as obstructive, infectious, inflammatory, pharmacologic, or neurologic.[123] Twenty-three percent of men reaching 80 years of age will experience acute retention at some time.[19] Acute urinary retention can lead to incapacitating symptoms in the wilderness; prompt recognition and intervention are necessary and can be addressed with limited resources.[136]

Principal symptoms are bladder distention and pain that may mimic acute abdomen, overflow incontinence, dribbling, and hesitancy. Physical examination findings include prostatic enlargement in men and lower midline abdominal tenderness and distention. If painful distention of the bladder is present, decompression should be undertaken.

Medical therapy may be considered before complete obstruction to urinary flow. Third-generation α-adrenergic blockers may provide some relief. The α-adrenergic blockers such as terazosin promote bladder neck and prostatic urethral relaxation.[59]

Bladder decompression should be initially attempted with a standard Foley catheter. In men with prostatic hypertrophy, passage of the catheter may be challenging, and a large catheter or coudé catheter should be used if a standard Foley catheter cannot be passed.[123] Instrumentation of the urethra with hemostats or dilators is dangerous and should not be attempted in the field.

There are several valved urinary catheters that eliminate the need for the urine drainage bags and connecting tubes normally required with Foley catheters. These catheters incorporate a manually activated valve at the end of the catheter that allows the patient to store urine in the bladder and to mimic normal voiding behavior.[141] The catheters may be used with a continuous drainage adapter when appropriate, so that a bag may be placed and the urination rate and volume assessed.

If multiple attempts are unsuccessful and symptoms are severe, needle decompression is indicated. The skin of the suprapubic region should be anesthetized, if possible. The distended bladder is palpated to guide aspiration. If ultrasound is available, it can be used to guide the decompression. A 22-gauge needle attached to a syringe is introduced through the skin of the lower abdomen two fingerbreadths above the pubic symphysis and directed at the anus. The needle is advanced with simultaneous aspiration of the syringe until free-flowing urine is visualized. Palpation of the bladder in combination with adherence to this technique should lead to successful decompression.

Complications related to decompression can occur. Drainage of more than 300 mL/hr can induce mucosal hemorrhage. A small number of victims develop obstructive diuresis that may lead to dehydration, in which case aggressive oral hydration or crystalloid repletion should be undertaken.[105] Finally, surgical decompression is temporizing, and retention will recur. Treatment may need to be continued or repeated. Drainage of the bladder acutely relieves symptoms and may allow ambulatory evacuation, but the underlying cause must be addressed once the patient is undergoing definitive care.

ACUTE SCROTUM

Acute onset of scrotal pain and swelling requires immediate attention. Causes are multiple, but the three that should be considered as soon as possible are incarcerated hernia, testicular torsion, and necrotizing infection. Although any one aspect of the history and physical examination may not be diagnostic, when all aspects are taken as a whole, they frequently suggest the cause of the scrotal pathology.[36]

Testicular torsion can occur at any age, but it is more likely near puberty. The likelihood of testicular salvage is inversely proportional to the elapsed time from torsion; this is a true surgical emergency. Acute onset of severe testicular pain is the hallmark. Mild to moderate pain is more suggestive of torsion of a testicular appendage or epididymitis. It has been stated that victims who can ambulate with minimal pain are less likely to have testicular torsion. In addition, nausea and vomiting may accompany torsion, whereas fever, dysuria, and frequency are associated with epididymitis.

Physical examination reveals a patient in extreme discomfort with a swollen scrotum and a tender testicle; the affected testicle may be higher than normal and have a horizontal lie.[36] Scrotal skin may be edematous and discolored. Unilateral scrotal swelling without skin changes is more indicative of a hernia or hydrocele. In testicular torsion, the affected testis is often larger than the unaffected testis. Prehn's sign (relief of pain accomplished by elevation of the testicle) may be helpful to some degree in differentiating testicular torsion from acute epididymitis.[119] With torsion, which twists the spermatic cord and elevates the testicle, pain is not relieved by elevation (negative Prehn's sign); with epididymitis, pain is relieved by elevation (positive Prehn's sign). This maneuver has low sensitivity in distinguishing the two conditions, but may be helpful in conjunction with other findings.[119]

Treatment consists of surgical detorsion, which should be accomplished within 12 hours of torsion.[36] Manual detorsion is not the treatment of choice; however, remoteness of the wilderness environment may mandate manual attempts. Studies of manual detorsion are scant and the cohorts small.[36]

If manual detorsion is necessary, the victim should be placed supine. The procedure can be assisted with IV sedation with or without local anesthetic. Classic teaching has suggested that testicular torsion typically occurs in the medial direction. Therefore, detorsion is initially attempted with outward rotation of the testis (toward the ipsilateral thigh). Simultaneous rotation in the caudal to cranial direction may be necessary to release the cremasteric muscle.[114]

The surgical treatment of testicular torsion includes pexing the testes to prevent recurrent torsion. Thus, although detorsion may be a temporary treatment for an acute situation in the field, all victims must be evacuated for definitive treatment.

PROSTATITIS

A number of forms of prostatitis have been defined, including viral, bacterial, nonbacterial, and chronic forms. The acute bacterial form may potentially lead to severe infection.

Bacterial prostatitis is an infection of the prostate caused primarily by gram-negative bacteria, with 80% attributable to *Escherichia coli*. It is an acute, febrile illness characterized by perineal pain radiating to the low back, chills, malaise, and voiding symptoms, such as urgency, frequency, and dysuria. Urinary retention is common, and cystitis frequently accompanies the infection. On rectal examination, the prostate gland is usually boggy, warm, and tender, and enlargement is variable.

In an ideal situation, treatment is individualized to the cause, which may be difficult to discern in the wilderness. The infection may respond to an oral antibiotic such as ciprofloxacin (750 mg orally twice a day), ampicillin (500 mg orally 4 times a day), or trimethoprim (160 mg) with sulfamethoxazole (800 mg) orally twice a day. Penetration of prostatic secretions has been shown to be best achieved by trimethoprim/sulfamethoxazole. The chosen antibiotic should be administered for 30 days. If retention is present, catheterization or suprapubic aspiration should be undertaken.

Acute bacterial prostatitis can escalate in severity to systemic toxicity. Persons with evidence of systemic toxicity unresponsive to a trial of oral or parenteral antibiotic therapy should be evacuated.

URINARY TRACT INFECTION

Urinary tract infections (UTIs) are extremely common and include episodes of acute cystitis and pyelonephritis occurring in otherwise healthy individuals. These infections predominate in women; approximately 25% to 35% of women 20 to 40 years of age report having had a UTI. Conversely, men between the ages of 15 and 50 years rarely develop UTI.

Despite the striking difference in prevalence, symptoms are similar in men and women. The symptoms may represent urethritis, cystitis, or an upper UTI; the distinction is often difficult. Common symptoms include frequency, urgency, dysuria, suprapubic pain, flank pain, and hematuria. Flank pain with tenderness to percussion suggests pyelonephritis. On urinalysis, pyuria is nearly invariably present, and hematuria may assist in the diagnosis. The definitive diagnosis is based on significant bacteriuria. The leukocyte esterase test has a screening sensitivity of 75% to 96% and a specificity of 94% to 98% in detecting more than 10 leukocytes per high-power field.[70]

Treatment in the wilderness setting for both men and women should be directed at the most common causative agents, although 50% to 70% of cases resolve spontaneously if untreated. Causative bacteria include *E. coli* (70% to 95%); *Staphylococcus* species (5% to 20%); and, less frequently, *Klebsiella, Proteus,* or *Enterococcus*. Fortunately, oral antibiotics are highly effective. Although resistant *E. coli* strains are being reported, trimethoprim/sulfamethoxazole is an excellent first-line drug. Alternative regimens include nitrofurantoin, a fluoroquinolone, or a third-generation cephalosporin. A 3-day course of therapy has been shown to be more effective than single-dose therapy.[70] For pyelonephritis, a similar antibiotic in a 10-day course is an acceptable initial treatment. Evacuation should be reserved for systemic toxicity unresponsive to oral antibiotics.

SKIN AND SOFT TISSUE INFECTIONS

A variety of conditions ranging from minor skin infections to localized abscesses to necrotizing soft tissue infections can occur in any austere environment. The nomenclature has recently been changed to acute bacterial skin and skin structure infections (ABSSSIs).[107] The vast majority of these superficial skin infections are self-limited. However, some can progress to a systemic condition and in a few cases be life-threatening, requiring emergency surgical treatments. Coagulase-positive *Staphylococcus aureus* is the predominant organism present in skin and soft tissue infections. Coagulase-negative organisms, such as *Staphylococcus epidermidis,* have lower virulence and are a less common cause of infection in healthy people. Of the *Streptococcus* species, it is the beta-hemolytic group that is primarily responsible for severe infections and sepsis. Other clinically important organisms are anaerobic gram-negative rods, such as *Clostridium perfringens*, and gram-negative bacilli, such as *Pseudomonas aeruginosa*.

CELLULITIS

Cellulitis is acute infection of the dermis and subcutaneous tissue that causes erythema, pain, and swelling of the affected area. There are often well-demarcated borders that advance as the infection worsens. The most common cause of cellulitis in the wilderness is trauma. It is important to mark the boundaries of the erythema and monitor its progress. Rapid advancement despite treating with antibiotic therapy could be related to an underlying soft tissue infection that may need surgical intervention. In most circumstances, treatment for cellulitis is wound hygiene and skin flora coverage with antibiotic therapy directed at the most common pathogen, which is group A *S. aureus*. Methicillin-resistant *S. aureus* (MRSA) is an increasingly common infection in the field; it is discussed in further detail later in this chapter. It is important to regularly examine the affected area and determine if there is fluctuance or swelling that would indicate an underlying subcutaneous abscess requiring surgical drainage.

LYMPHANGITIS

Lymphangitis is infection of the subcutaneous lymphatic system and often follows a puncture wound, commonly in the hand from an animal bite. This entity causes linear erythematous streaks along the lymphatic drainage basin of the wound. The treatment is antibiotics, moist soaks, immobilization, and elevation of the affected limb. Broad-spectrum antibiotics covering gram-positive bacteria are important; often a combination of a fluoroquinolone to cover *Staphylococcus* and penicillin to cover *Streptococcus* is necessary to treat this entity.

CUTANEOUS ABSCESS

If left untreated, many of the superficial infections described previously can convert to an abscess, which is a localized collection of exudate contained within a membrane. These abscesses tend to "point" to the nearest epithelial surface, which is predominately the skin. Physical examination shows a raised fluctuant mass with overlying warmth and erythema. The mainstay of treatment for subcutaneous abscess is incision and drainage. Local anesthesia administered as a field block before the incision may aid with pain relief. The mass should be incised in the line of the tissue planes over the area of maximum fluctuance. The incision should be large enough to adequately drain the cavity. All of the purulent material should be evacuated and the cavity copiously irrigated with saline or water. Also, finger fracturing of internal cavities is important to ensure adequate drainage. If packing is performed, it is important to not pack too tightly to avoid surrounding ischemia and pain. Not all abscesses require packing, but they should be frequently irrigated and the dressings changed. The wound should be covered with a sterile dressing. Another option that might work is to use an incision/counterincision technique where two incisions are made to enter the abscess cavity so that an irrigation path is created. Irrigation of sterile solution can be flushed through both incisions until the purulent material is evacuated. A Penrose or other rubber drain can be inserted that traverses both incisions, and the ends tied together to create a moveable loop (Figure 18-15).

COMMUNITY-ACQUIRED METHICILLIN-RESISTANT *STAPHYLOCOCCUS AUREUS* INFECTIONS

Staphylococcus aureus is the most common cause of skin and soft tissue infections. About a third of healthy people are colonized with *Staphylococcus* bacteria, which live in the nose and

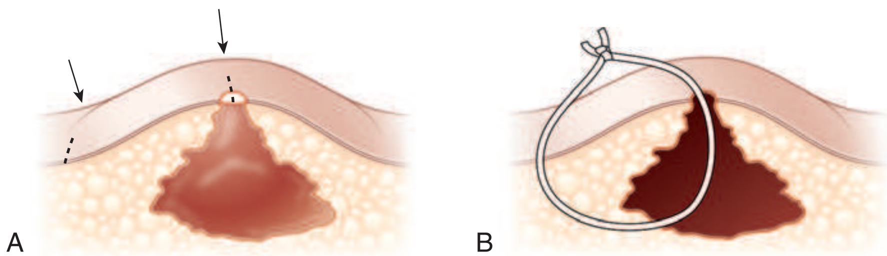

FIGURE 18-15 **A,** Two incisions are placed approximately 1 inch apart to allow the loop technique for abscess drainage. **B,** The rubber is tied off to create a loose loop. *(From Auerbach PS. Medicine for the outdoors: the essential guide to first aid and medical emergencies, ed 6, Philadelphia, 2016, Elsevier.)*

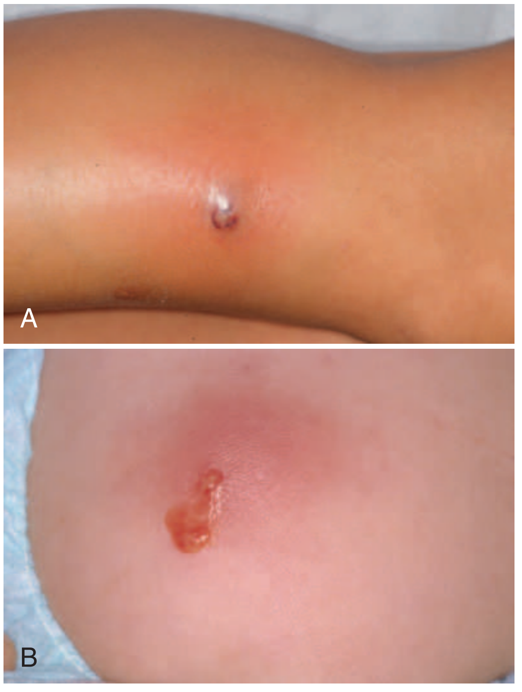

FIGURE 18-16 Cutaneous MRSA infection.

on the skin of humans. About 2% of the population is colonized with community-acquired *S. aureus* (CA-MRSA), which is resistant to beta-lactam antibiotics. CA-MRSA can spread by contact with an infected person or by exposure to a contaminated object or surface. Sharing personal items, such as towels or razors, is a common mode of spread.

About 80% of MRSA infections involve the skin and soft tissue (Figure 18-16). MRSA infection can also involve bones and joints, leading to severe sepsis. Outbreaks have been reported during wilderness excursions. Areas of skin violation that are most vulnerable include lacerations, burns, blisters, abrasions, and insect bites. Areas of increased body hair, such as the buttocks, axillae, back of the neck, and beard, are more likely to be infected. The most frequent presenting sign is a red, swollen, painful lesion resembling an infected spider bite. Subsequent yellow or white central pustules or boils may drain spontaneously. The spectrum of CA-MRSA infections includes cellulitis, furuncles, carbuncles, and cutaneous abscesses.

CA-MRSA has been found in 75% of cutaneous abscesses in the community. The mainstay of treatment is adequate drainage. Oral antibiotics that have been effective include clindamycin and trimethoprim/sulfamethoxazole. These infections can occasionally disseminate and become life-threatening, with associated bacteremia, septic arthritis, or endocarditis. Avoidance of dissemination is best accomplished with preventive measures, which include washing the hands on a regular basis, using a hand sanitizer with 60% alcohol, wearing long pants and protecting the skin from injury, and not sharing personal items such as towels and clothing. If skin injuries occur, keep them covered and clean and report all suspected skin infections promptly.[42,132]

These life-threatening conditions are caused by virulent toxins produced by bacteria, the most common being group A beta-hemolytic *Streptococcus,* with or without *Staphylococcus* present. Frequently these infections are caused by multiple mixed flora of both anaerobic and facultative aerobes, especially *C. perfringens* and *Bacteroides*. The depth of tissue involvement may include subcutaneous tissue, fascia, or even muscle. These infections most commonly occur in the extremities, abdominal wall, or perineum and occur within a week of the inciting event. Necrotizing infections occur with increased frequency in immunosuppressed patients, including those with diabetes, peripheral vascular disease, and chronic renal failure; drug abusers; and persons of advanced age. The area of cellulitis spreads progressively, which causes pain and fever with spreading erythema, induration, blue-black discoloration, and blister formation. The extent of infection often exceeds what is evident from the skin. Treatment in the wilderness is limited. An experienced provider may want to consider debriding as much visible necrotic tissue as possible while plans for immediate evacuation are initiated. Administration of IV broad-spectrum antibiotics is necessary, and evacuation must be done expeditiously because time is of the essence and the mortality rate is extremely high.[120]

WOUND MYIASIS (MAGGOT INFESTATION)

Myiasis is infestation of the skin by developing larvae (maggots) of a variety of species of the arthropod order Diptera. The two main clinical types are furuncular (follicular) myiasis and wound myiasis. Fly larvae may infest open wounds in a living host. Myiasis is usually self-limited with minimal morbidity in most cases but can be complicated by wound cellulitis. The diagnosis is typically made by identifying the larvae in an open wound. Severe cases may be associated with fever, chills, bleeding from the infested site, and secondary infection. Treatment requires removal of the maggots, which is accomplished by irrigation and debridement of dead host tissue. Local anesthesia may be required and the wound should be packed with a broad-spectrum topical antimicrobial in a wet-to-dry dressing, using agents such as mafenide acetate, Dakin's solution (diluted sodium hypochlorite), or 0.25% acetic acid.[54,126]

STERILITY IN THE AUSTERE ENVIRONMENT

One of the major disadvantages of operative procedures in the austere environment is inability to sterilize instruments and establish a sterile field. The goal is to decrease the risk for bacterial contamination as much as possible.

Antiseptics are agents used to decontaminate skin. Chlorhexidine is an antiseptic with excellent antimicrobial activity and prolonged length of activity. In many health care facilities, chlorhexidine has replaced iodophors as the antiseptic of choice. Isopropyl alcohol may be used if no other antiseptic is available. It is particularly ineffective on dirty skin and has little persistent activity. If nothing is available, soap and water may be of benefit. Soap removes unattached bacteria from the surface of skin, but does not remove adherent bacteria.

If sterile fluid is not available for wound irrigation, potable water may be used. Boiling water before irrigation does not rid the water of spores. If water is to be boiled, the boiling should be "rolling" for 20 minutes to be effective. Any fluids used should be removed from the wound as best as possible. Wounds should be managed to ensure that no devitalized tissue or foreign bodies remain in them.

If preparations are made for the possibility of surgical procedures during an expedition, instruments taken into the field should be packed sterile in durable containers. Paper wrappers can become perforated, permitting contamination. A *disinfectant* is an agent that will decontaminate inanimate objects. If surgical instruments are not sterile, disinfectants can be used to decrease the bacterial count on the surface. Of course, all instruments should be clean of debris. Unfortunately, many of the disinfectants used in health care facilities are not practical for the austere environment. Ortho-phthaladehyde, peracetic, and glutaraldehyde are effective disinfectants, but hazardous for personnel and the environment and impractical in the field environment.[43] The antiseptic chosen, such as chlorhexidine, for skin preparation may be applied to the instruments.

Placing instruments into boiling water decreases the bacterial count but will not completely eliminate bacterial spores. Applying flame to instruments may kill bacteria but leave products of combustion on the instruments that are then left in the wound as foreign material.

The U.S. Army has developed a field sterilization system that is lightweight and does not require an external energy source. The system is the size of a suitcase and has the capacity to accommodate a surgical tray. A mixture of water and dry reagents controllably generates chlorine dioxide. The chlorine dioxide kills all vegetative cells and bacterial spores within 30 minutes.[43] Although the specific system used by the army may not be available to the public, there are a number of commercially available products that can be easily found on the Internet for the purpose of field sterilization.

ANESTHESIA IN THE WILDERNESS

Local and regional anesthesia will be the techniques of choice to provide comfort during minor operative procedures. General anesthesia should not be considered without a full complement of trained personnel and equipment. Procedural sedation and analgesia may be used with the availability of adequate monitoring, and the capability of establishing a definitive airway should be immediately available. Common agents used to supplement local or regional anesthesia are opioids and benzodiazepines. Should these agents be used, reversal agents of naloxone and flumazenil should be available. Ketamine is an excellent agent for providing dissociative sedation and pain reduction.

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CHAPTER 19

Emergency Airway Management

ANDREW J. EYRE AND CALVIN A. BROWN III

Emergency airway management skills are crucial in the care of critically ill or injured patients. Airway management consists of a structured patient assessment, methodical approach, and effective oxygenation and ventilation, typically by inserting a cuffed endotracheal tube. Effective airway management takes precedence over all other clinical considerations.

In resource-limited, austere environments, airway management is by definition challenging. Many resources that are readily accessible in a hospital or emergency department setting are not available in remote settings. Improvisation may prove invaluable.

AIRWAY ANATOMY

The airway consists of the mouth, nasal and oral cavities, pharynx, nasopharynx, hypopharynx, glottis, and tracheobronchial tree (Figure 19-1). It begins at the oral and nasal apertures. The nasal cavity extends from the nostrils to the posterior nares (i.e., choanae). Due to anatomic features (e.g., turbinates), resistance to nasal airflow is approximately twice that of oral airflow. The nasopharynx extends from the posterior nasal cavity to the level of the soft palate. Primary impediments to airflow through the nasopharynx are the tonsils. The oral cavity is bounded by the teeth anteriorly, the hard and soft palates above, and the tongue and floor of the mouth below. The oropharynx communicates with the oral cavity and nasopharynx and extends from the soft palate to the tip of the epiglottis.

The oropharynx continues into the hypopharynx, which extends from the epiglottis to the upper border of the cricoid cartilage (level of the C6 vertebral body). The larynx connects the laryngopharynx and trachea, and serves as the organ of phonation. The larynx and epiglottis serve to protect the lower airway from aspiration. The larynx is made up of muscles, ligaments, and cartilages (i.e., thyroid, cricoid, arytenoids, corniculates, and epiglottis).

The epiglottis is flexible. It originates from the hyoid bone and base of the tongue and covers the glottis during swallowing. During laryngoscopy, the epiglottis is an important landmark because it serves as a guidepost for the glottic inlet and laryngoscopic blade placement. The vallecula is the space at the base of the tongue that is bounded posteriorly by the epiglottis and anteriorly by the anterior pharyngeal wall. The base of the vallecula contains the hyoepiglottic ligament. This structure is key to successful visualization during direct laryngoscopy with a curved blade. Engaging the hyoepiglottic ligament with the bulbous end of a MacIntosh laryngoscope blade elevates the epiglottis and reveals the glottic aperture. Failure to fully engage the hyoepiglottic ligament can result in a poor glottic view and intubation failure. The laryngeal inlet is the opening to the larynx that is bounded by the epiglottis, aryepiglottic folds, and arytenoid cartilages. The glottis is the vocal apparatus. The glottis consists of the true and false vocal cords and glottic opening (i.e., the triangular fissure between the vocal cords and the narrowest segment of the adult larynx).

Externally identifiable landmarks are important for airway assessment and management (Figure 19-2). The mentum is the anterior aspect of the mandible that forms the tip of the chin. The hyoid bone forms the base of the floor of the mouth. The thyroid cartilage forms the laryngeal prominence (Adam's apple) and thyroid notch. The cricoid cartilage, which lies inferior to the thyroid cartilage, forms a complete ring that provides structural support to the lower airway. The cricothyroid membrane lies between the thyroid and cricoid cartilages and serves as an access point during surgical airway management.

Knowledge of anatomic differences between adults and infants is integral to effective pediatric airway management. These important differences are summarized in Table 19-1 and Figure 19-3.

THE DECISION TO INTUBATE

A decision to intubate is based on three criteria: (1) failure to maintain or protect the airway, (2) failure of ventilation or oxygenation, and (3) the patient's anticipated clinical course and likelihood of deterioration.[23]

FAILURE OF AIRWAY PROTECTION

A patent airway is essential for ventilation and oxygenation. If a patient is unable to maintain an unobstructed airway, the provider should establish patency by repositioning, performing a chin lift and/or jaw thrust, or inserting an oral or nasopharyngeal

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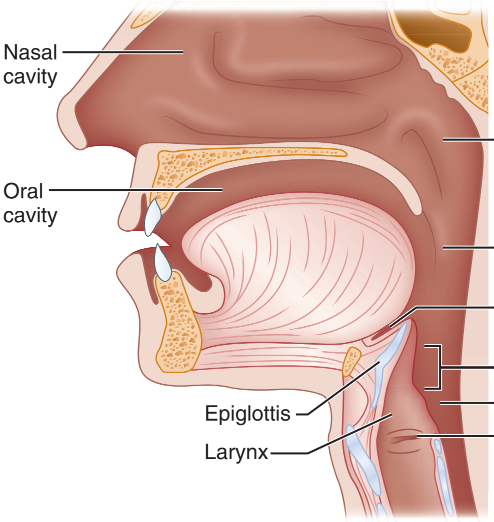

FIGURE 19-1 Lateral airway anatomy.

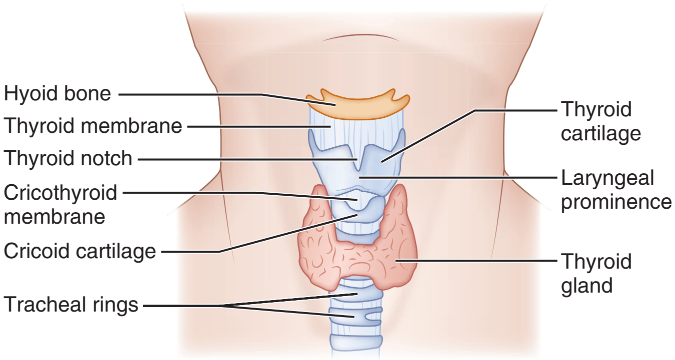

FIGURE 19-2 External airway anatomy.

airway. The patient must be able to protect against aspiration of gastric contents. The presence of a gag reflex is neither sensitive nor specific for predicting the need for intubation. A patient's ability to swallow or handle secretions is a more reliable indicator. The recommended approach is to evaluate the patient's mental status, phonation, response to verbal commands, and ability to manage secretions. If a patient has pooling secretions, has difficulty phonating, is comatose, or cannot respond to simple verbal cues, the patient likely cannot adequately protect against aspiration. Intubation is required. In most patients, if a maneuver for establishing an airway is needed, definitive airway management is also required.

FAILURE OF VENTILATION OR OXYGENATION

Oxygen is required for vital organ function. Removal of carbon dioxide (i.e., ventilation) is equally as important. Cardinal indications for intubation include hypoxemia despite maximal oxygen supplementation and ventilatory failure that is not immediately reversible (e.g., opioid overdose). Assessment of the patient's clinical status and peripheral oxygen saturations, augmented by capnography (if available), provides critical data. In the absence of objective data (i.e., pulse oximetry), central cyanosis and poor respiratory effort are key physical examination findings that can indicate the need for airway management.

ANTICIPATED CLINICAL COURSE

Patients with a moderate to high likelihood of airway deterioration often require endotracheal intubation despite airway patency, adequate oxygenation, and normal vital signs. For instance, a patient with significant blunt trauma from a climbing accident may require intubation due to pain severity and likelihood of deterioration. Assess the structural integrity of the central face and mandible. Injuries to these structures may lead to airway distortion and compromise. Inspect the anterior neck and chest for penetrating wounds, asymmetry, or swelling that may herald impending airway compromise. Anticipating deterioration or progression of disease that may confound subsequent intubation attempts is crucial.

In children, visual signs of airway compromise and respiratory distress include tachypnea, cyanosis, drooling, nasal flaring, and intercostal retractions. A child with severe upper airway obstruction may sit upright with the head tilted back (sniffing position) to straighten the airway and reduce occlusion. A child with severe lower airway obstruction may sit up and lean forward on outstretched arms in the tripod position to augment accessory muscle function.

TABLE 19-1 Anatomy of the Airway in Infants Compared with Adults

Infant Anatomy	Clinical Significance
Large intraoral tongue that occupies a relatively large portion of oral cavity	High anterior airway position of glottic opening compared with that of adult
High tracheal opening: C1 in infancy; C3 or C4 at age 7 years; C4 or C5 in adulthood	Straight blade preferred over curved blade to push distensible anatomy out of the way to visualize larynx
Large occiput may cause flexion of airway; large tongue easily collapses against posterior pharynx	Sniffing position is preferred; large occiput elevates head into sniffing position in most infants and children a towel may be required under shoulders to elevate torso relative to head in small infants
Cricoid ring is the narrowest portion of the trachea as compared with vocal cords in adults	Uncuffed tubes provide an adequate seal because they fit snugly at the level of the cricoid ring; correct tube size is essential because variable expansion cuffed tubes are not used
Airway anatomy varies consistently by patient age; there are fewer abnormal variations related to body habitus, arthritis, or chronic disease	Age less than 2 years, high anterior airway Age 2 to 8 years, transitional airway Age older than 8 years to small adult; "normal" adult positioning of airway
Large tonsils and adenoids may bleed; more acute angle between epiglottis and laryngeal opening results in nasotracheal intubation attempt failures	Blind nasotracheal intubation not indicated for children; nasotracheal intubation failure
Small cricothyroid membrane	Needle cricothyroidotomy difficult and surgical cricothyroidotomy impossible in infants and small children

Modified from Walls RM, Murphy MF, Luten RC, et al, editors: *Manual of emergency airway management,* 2nd ed, Philadelphia, 2004, Lippincott Williams & Wilkins.

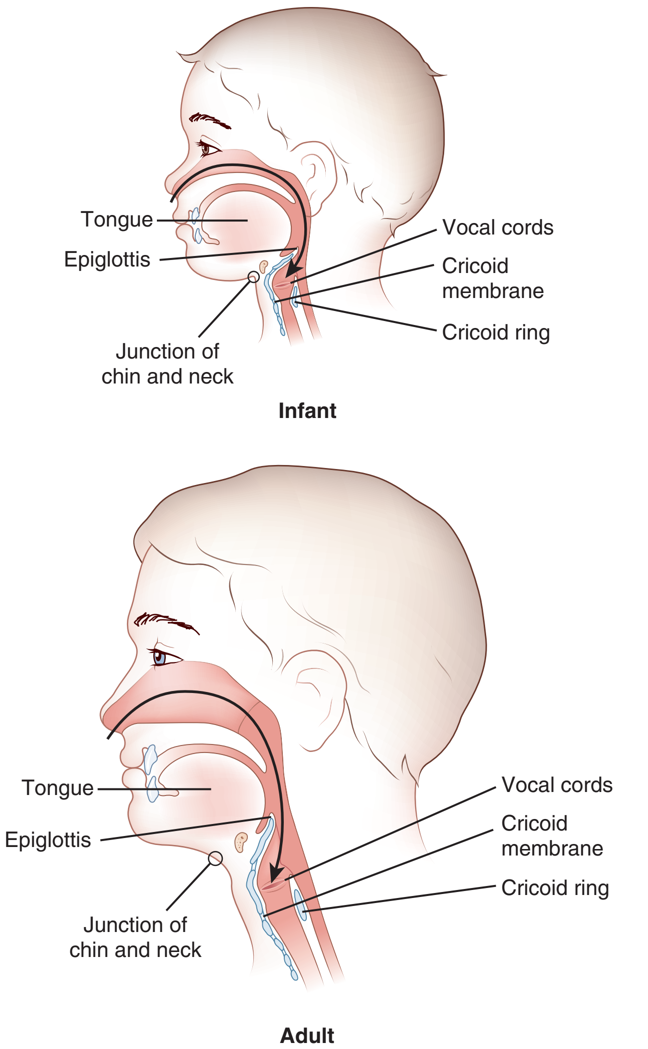

FIGURE 19-3 Anatomic airway differences between infants and adults. Anatomic differences particular to infants include (1) a higher and more anterior position for the glottic opening (note relationship of the vocal cords to the chin-neck junction); (2) a relatively larger tongue that lies between the mouth and glottic opening; (3) a relatively larger and floppier epiglottis; (4) a cricoid ring that is the narrowest portion of the pediatric airway (in adults, the narrowest portion is the vocal cords); (5) the position and size of the cricothyroid membrane; (6) a sharper and more difficult angle for blind nasotracheal intubation; and (7) a larger relative size of the occiput. *(Redrawn from Walls RM, Murphy MF, Luten RC, et al, editors:* Manual of emergency airway management, *2nd ed, Philadelphia, 2004, Lippincott Williams & Wilkins.)*

BASIC AIRWAY MANAGEMENT

Opening the airway and ensuring airway patency are essential for adequate oxygenation and ventilation. In an outdoor environment, these priorities are critical because definitive airway management may be delayed due to the distance to a medical facility, weather conditions, or a lack of equipment. Conscious patients maintain airway patency and protect against aspiration (e.g., of foreign substances, gastric contents, or secretions) using protective reflexes of the innervating musculature of the upper airway. In severely ill or injured patients, these protective airway mechanisms may be impaired or absent. In obtunded patients, upper airway obstruction most commonly results from posterior displacement of the tongue against the posterior pharynx. The presence of foreign bodies, blood, or secretions, as well as airway edema, commonly leads to partial or complete airway obstruction. Head positioning, manual airway techniques, and mechanical airway adjuncts may be employed to alleviate upper airway obstruction.

HEAD POSITIONING

Head positioning can play a critical role in airway management. If there is concern for cervical spine injury, the head and neck should be stabilized in a neutral position and care should be taken to avoid all unnecessary head and neck movements. In the field, certain actions (e.g., evacuation from a dangerous setting) may take priority over strict cervical spine immobilization.

Recovery Position

Unconscious, spontaneously breathing patients that are judged not at risk of cervical spine injury should be placed in the recovery position (Figure 19-4). This encourages airway patency while reducing the risk of aspiration. In the recovery position, the tongue is less likely to occlude the airway and vomitus is less likely to be inhaled.

MANUAL AIRWAY TECHNIQUES

Manual airway techniques employ specialized positioning of the head and facial structures to elevate the tongue and soft tissues of the pharynx to open the airway. These techniques are often effective but require continuous involvement of a single provider in order to maintain airway patency. Typically, manual airway techniques are used as temporizing treatments until an airway adjunct or definitive airway is placed.

Head Tilt and Chin Lift

The head tilt/chin lift is a simple and effective technique for opening the airway in patients assessed as unlikely to have cervical spine injury (Figure 19-5). Place one palm on the patient's forehead. Apply firm downward and backward pressure to extend the neck and tilt the head posteriorly. Fingers of the other hand are placed under the chin's bony anterior and lifted forward. These fingers support the jaw and maintain the head-tilt position.

Jaw Thrust

If a cervical spine injury is suspected or if the head tilt/chin lift is not effective, a jaw thrust should be performed to maintain airway patency. A jaw-thrust airway positioning maneuver lifts the mandible forward, thereby lifting the tongue away from the posterior pharyngeal wall. To perform this maneuver, take a position behind the supine patient's head. Place both hands alongside the patient's jaw. Rest thumbs and thenar eminences along the maxilla and zygoma. Place the rescuer's remaining fingers along the mandibular margin and angle of the mandible. Pull up (i.e., anteriorly) to displace the jaw while using the thumbs for support (Figure 19-6). This maneuver is tiring, yet

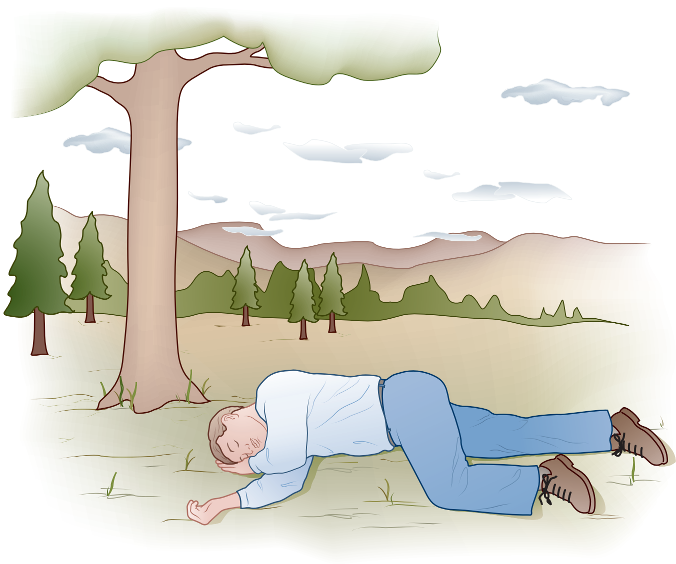

FIGURE 19-4 Recovery position.

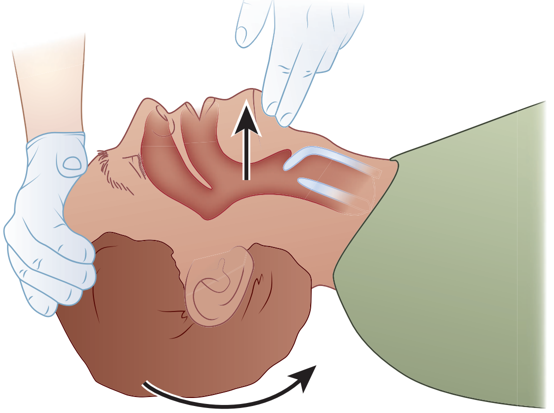

FIGURE 19-5 Head tilt with chin lift.

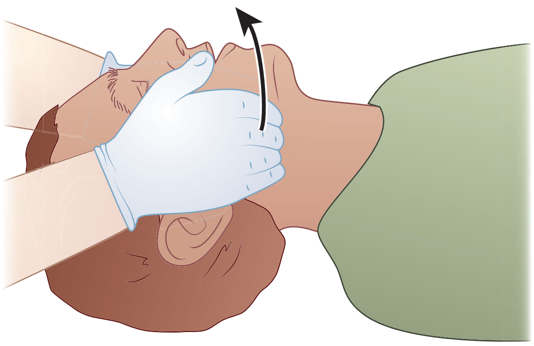

FIGURE 19-6 Jaw thrust without head tilt.

quite effective. If cervical spine injuries are not suspected, it can be used in combination with a head tilt/chin lift.

MECHANICAL AIRWAY ADJUNCTS

After a patent airway has been established, it is critical that the airway remain open. This requires continual reassessment of airway patency. An oropharyngeal airway (OPA) or nasopharyngeal airway (NPA) device can be placed to create a patent conduit for spontaneous or assisted ventilation. Each device has specific indications and contraindications and must be properly selected to avoid causing harm. Although OPAs and NPAs help to maintain airway patency, they do not protect against aspiration. They serve as temporizing measures until a definitive airway can be established or the patient's condition improves.

Oropharyngeal Airway

The OPA is a curved, rigid device designed to hold the tongue away from the posterior pharyngeal wall (Figure 19-7). When properly placed, an OPA prevents the tongue from obstructing the hypopharynx and creates a conduit for ventilation. Certain types of OPAs allow for airway suctioning. These devices should only be used in minimally arousable or unconscious patients. Using an OPA in an alert patient with a gag reflex or cough is generally contraindicated because the OPA will likely stimulate retching, vomiting, or laryngospasm. OPAs are typically made of disposable plastic and come in varying styles and sizes to accommodate patients of all ages. The size is based on the distance in millimeters from the OPA flange to its distal tip. The proper OPA size is estimated by placing the OPA's flange at the corner of the mouth so that the bite-block segment is parallel with the victim's hard palate. The distal tip of the airway should reach the angle of the jaw.

To place an OPA, select an appropriate size and manually open the mouth. The pharynx should be cleared of any debris (e.g., foreign bodies, secretions, or emesis). Insert the OPA into the mouth horizontally or in an upside-down orientation, with the distal tip facing superiorly. Gently advance the OPA tip until it reaches the junction between the hard and soft palates (approximately at the level of the uvula), and slowly rotate it 90 or 180 degrees. After rotation, continue inserting the OPA's curved aspect along the base of the tongue until the OPA flange reaches the lips or teeth. Alternatively, use a tongue blade to push down on the tongue while inserting the OPA with its inner curve along the tongue. After placement, ensure that the OPA has created a patent airway by lifting the tongue (and not displacing it into the pharynx) and that it has not stimulated the patient's gag reflex.

Nasopharyngeal Airway

The NPA is a soft, uncuffed, rubber cylinder that provides a conduit for airflow between the nares and the hypopharynx (Figure 19-8). The NPA is inserted through the nose. The NPA has a distal flange to prevent insertion beyond the nostril. The device is less likely to stimulate a patient's gag reflex and so is better tolerated than an OPA. An NPA is most commonly used in a semiconscious patient (e.g., under the influence of sedative drugs or alcohol). It is effective when trauma, trismus, or other obstacles preclude OPA placement. NPAs are contraindicated in victims with suspected basilar skull or significant midface fractures because inadvertent intracranial placement may occur.

NPAs are made of pliable rubber or plastic and come in varying designs and sizes to accommodate patients of all sizes. The sizes (as indicated by the internal diameter) range from 12 to 36 French. The proper NPA length is determined by measuring the distance from the tip of the patient's nose to the tragus of the ipsilateral ear.

After selecting the appropriate size, the NPA is lubricated with a water-soluble lubricant. Insert it gently into the nostril with its beveled end pointed toward the nasal septum. Continuing to act gently, advance the NPA along the floor of the nasal passage and into the nasopharynx. If resistance is met, gently rotate the NPA, select a smaller size, or attempt to insert it through the other nostril. In position, the flange should rest against the patient's nostril. The distal end should rest behind the tongue in the posterior pharynx. Ensure that the NPA has created a patent airway. If necessary, an NPA can be placed in each nostril.

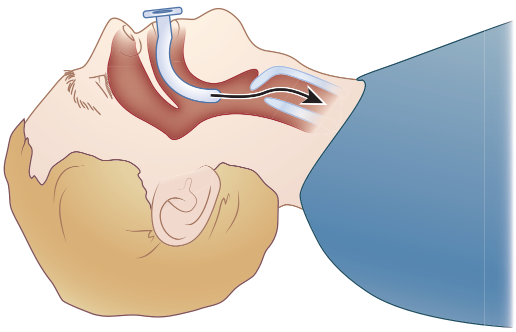

FIGURE 19-7 Oropharyngeal airway.

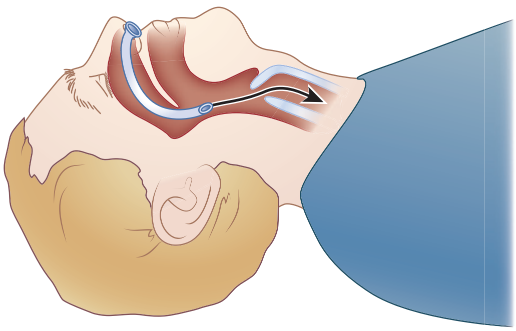

FIGURE 19-8 Nasopharyngeal airway.

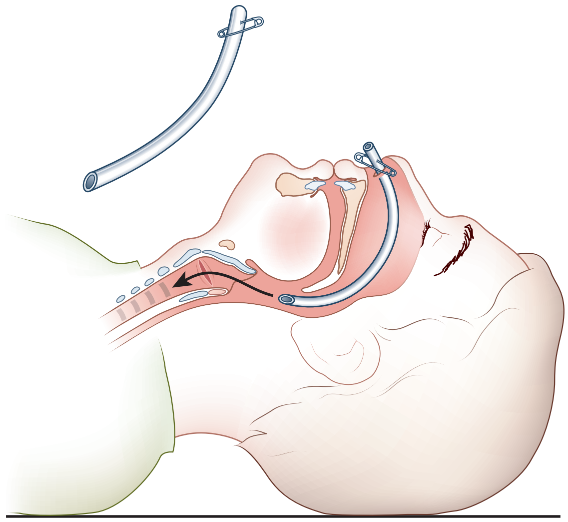

FIGURE 19-9 Improvised nasal trumpet.

Improvised Nasopharyngeal Airway

Any flexible tube of appropriate diameter and length can be used as a temporary NPA substitute. Various types of tubing that may be present in camping or wilderness situations include a solar shower hose, siphon tubing, an inflation hose from a kayak flotation bag, and a Foley catheter. Round and bevel one end of the substitute nasal airway to minimize its potential for injuring the nasal mucosa. An endotracheal tube (ETT) can be shortened and softened in warm water to substitute for a commercial nasal trumpet. Improvise a flange by placing a safety pin through the nostril end of the tube (Figure 19-9).

AIRWAY OBSTRUCTION FROM A FOREIGN BODY

Foreign bodies (e.g., food, dislodged teeth) may cause airway obstruction. A patient with partial airway obstruction can usually phonate or produce a forceful cough in an attempt to expel the foreign body. In a patient with a partially obstructed airway, if air exchange is adequate, encourage forceful coughing and closely monitor the patient's condition. If obstruction persists or if air exchange becomes inadequate, manage the situation as a complete airway obstruction. Ominous signs that indicate the need for immediate aggressive airway management include a weak or ineffective cough, increased respiratory difficulty, decreased air movement, and cyanosis.

A patient with a complete airway obstruction cannot speak (aphonia), exchange air, or cough. The person will often grasp the neck in the universal distress signal for choking and open the mouth widely. An unconscious patient with a complete airway obstruction will not demonstrate chest movement or other signs of adequate air exchange. Failure to relieve a complete airway obstruction leads to hypoxia-induced cardiac arrest. If a patient collapses with suspected complete airway obstruction, attempt immediate laryngoscopy to remove obvious foreign debris. If the patient remains unresponsive and apneic despite the removal of foreign material (or if no foreign body is identified), the patient should be endotracheally intubated. If a midtracheal foreign body is suspected, advance the ETT (with stylet in place) to move the foreign body into the right mainstem bronchus. The ETT can then be retracted above the carina and the left lung ventilated, taking care not to cause barotrauma.

SUCTION

Sick or injured patients are at risk for airway obstruction and pulmonary aspiration of secretions, vomitus, or blood. Many lifesaving interventions, such as manual ventilation, increase this risk. If foreign material cannot be cleared manually, suction becomes essential to create and maintain a patent airway and to prevent aspiration.

Portable suction devices for austere environments may be manually or externally powered, by oxygen, air, or electricity. Hand-operated units are lightweight, compact, reliable, and inexpensive. All units should have large-bore, nonkinking suction tubing; an unbreakable collection container; and a sterile disposable suction catheter, and should provide sufficient negative pressure for adequate pharyngeal suctioning.

Flexible (French) suction catheters are used to suction the nose, mouth, and oropharynx. Rigid suction catheters are used to suction the mouth and oropharynx. Suction catheters should not be inserted beyond the base of the tongue, and suction should occur as the catheter is withdrawn from the pharynx. To prevent oxygen deprivation, do not suction adults for more than 10 to 15 seconds. Infants and children should be not be suctioned for more than 5 seconds at a time. In children, take care when using rigid suction catheters, because oropharyngeal stimulation may result in cardiac muscarinic stimulation that leads to bradycardia. Infants up to 4 months old are obligate nose breathers. Use a bulb syringe to suction their noses and mouths.

A "mucus trap" suction device can be improvised from a jar with two holes poked in its lid and two tubes taped into the holes (Figure 19-10). One tube goes to the source of the suction (i.e., a suction device or rescuer's mouth) and the other goes toward the patient's airway. The jar serves as a trap to capture secretions and decrease the likelihood of a rescuer being directly exposed to suctioned bodily fluids or foreign substances, such as mud.

SUPPLEMENTAL OXYGEN

Supplemental oxygen therapy should be provided to all sick or injured persons with cardiac disease, respiratory distress, shock, or trauma, even if measured arterial oxygen tension is normal. Oxygenation in preparation for intubation should be provided using the oxygen delivery system that can provide the highest inspired amount of oxygen. This typically is a face mask with an oxygen reservoir that delivers a fraction of inspired oxygen of approximately 70%. Leave this in place as the patient breaths tidally for 3 minutes. Supplemental oxygen applied as part of an overall resuscitation strategy should start with a high oxygen concentration and then be titrated downward to maintain the desired oxygenation.

Various oxygen delivery techniques may be employed, depending on the desired oxygen concentration and clinical circumstances (see Chapter 103).

VENTILATION

Even if the airway is patent and supplemental oxygen is being received, a patient is not necessarily being ventilated. Adequate ventilation requires sufficient air exchange between ambient conditions and the lungs to deliver oxygen to the alveoli and

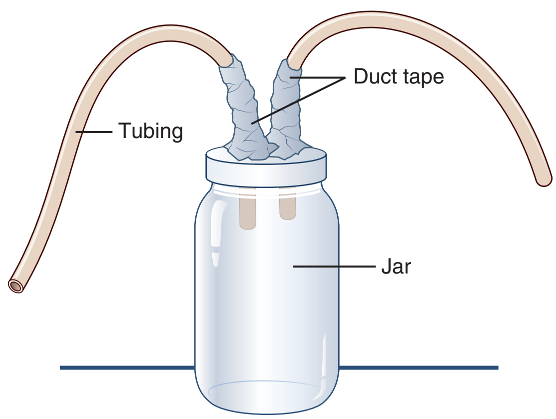

FIGURE 19-10 Improvised mucus trap suction device.

facilitate carbon dioxide removal. To establish adequate ventilation, open the airway and assist with ventilation or provide manual ventilation using positive pressure. When providing manual ventilation, employ barrier protection (e.g., a mask with a one-way valve) to avoid contact with patient secretions, blood, or infectious agents. Persistent hypoventilation without an obvious reversible component is one of the cardinal indications for intubation.

MOUTH-TO-MOUTH VENTILATION

Mouth-to-mouth ventilation is an efficient way of providing manual ventilation. Failure to use a barrier device during mouth-to-mouth ventilation places a rescuer at risk for exposure to infectious bodily fluids. To provide mouth-to-mouth ventilation, open the airway and clear any foreign bodies, secretions, or debris. If there is no concern for cervical spine injury, open the airway using the head tilt/chin lift maneuver. Once the airway is open, pinch the patient's nostrils tightly shut and use the other hand to keep the patient's mouth slightly open. After establishing a tight mouth-to-mouth seal, deliver full, slow breaths. Deliver enough breath volume to create a visible chest rise. Between breaths, break the mouth seal to allow for passive exhalation. When the rescuer is the sole provider for a patient with cardiac arrest, rescue breaths should occur at 2 breaths per 30 chest compressions.

MOUTH-TO-NOSE VENTILATION

In a patient with mouth injuries or abnormal anatomy that precludes effective mouth-to-mouth ventilation, mouth-to-nose ventilation should be considered. The mouth-to-nose technique is similar to that for mouth-to-mouth ventilation. Open the airway in a similar fashion, and then close the mouth using the thumb and forefinger to seal the lips. The patient's nostrils are left open, and the rescuer's mouth is sealed around the patient's nose. Breaths are delivered until chest rise is observed.

FIGURE 19-11 Rescuer using mouth-to-mask ventilation. The rescuer is providing rescue breathing with a face mask and supplemental oxygen during cardiopulmonary resuscitation. The rescuer is using the cephalic technique (i.e., the rescuer is positioned at the top of the patient's head). Both of the rescuer's hands are used to hold the mask securely in position while keeping the patient's airway open. The rescuer's thumbs and forefingers hold the mask in place while the third, fourth, and fifth fingers lift the jaw (i.e., jaw thrust) and maintain an open airway with the head tilted. Alternatively, the thumbs and a portion of the rescuer's palms can anchor the mask, and the index and remaining fingers can lift the jaw and hold it against the mask. *(Redrawn from American Heart Association: Guidelines 2000 for cardiopulmonary resuscitation and emergency cardiovascular care.* Circulation *102:I95, 2000.)*

MOUTH-TO-MASK VENTILATION

Mouth-to-mask ventilation is the safest and most effective technique for rescue breathing (Figure 19-11). A pocket face mask or a similar barrier device allows the rescuer to provide ventilation without making direct contact with the patient's mouth and nose. The mask has a one-way valve in the stem to prevent exhaled gases and bodily fluids from reaching the health care provider. A disposable filter may be added to trap infectious air droplets and secretions.

The pocket face mask is made of pliable plastic material and can be easily carried. Some masks have an oxygen inlet so that supplemental oxygen can be administered. Devices are available in a number of sizes. If an infant mask is not available, an adult mask can be turned upside-down for a better fit. To use a pocket mask, first open the airway and clear any obvious obstruction using the head tilt/chin lift or jaw thrust. Take a position behind the patient's head. In an unresponsive patient, insert an OPA or NPA to help maintain a patent airway. Stretch the mask and apply it to the patient's face. Apply pressure to both sides of the mask with the thumbs and base of the palm to create an air-tight seal. As with a jaw thrust, place the remaining fingers underneath the patient's jaw and apply upward pressure. Provide breaths directly to the mask, ensure adequate chest rise, and allow for passive exhalation between breaths.

BAG-VALVE-MASK VENTILATION

A self-inflating ventilation bag with face mask (i.e., bag-valve-mask [BVM] device) allows for emergency ventilation with a high concentration of oxygen. Devices are equipped with several one-way valves to allow coordinated airflow into and out of the patient without creating dead space ventilation (Figure 19-12, *A* and *B*). Used correctly and attached to a high-flow oxygen source (15 L/min), BVM devices can supply approximately 100% oxygen. Patient characteristics associated with difficult rescue mask ventilation include traits that prevent an adequate mask seal (e.g., beard, facial trauma) or limit flow to gas-exchanging portions of the lungs (e.g., chronic obstructive pulmonary disease, airway obstruction, morbid obesity).[12,13] The MOANS mnemonic outlines predictors of difficult bag-and-mask ventilation (see Box 19-2). Face mask fittings are interchangeable with distal ETT adapters. The same bag can be used after intubation.

Competence with a BVM device is a vital emergency skill and a prerequisite for the use of paralytic agents for endotracheal intubation. Whenever possible, use a two-handed and two-person technique. Holding the mask with a thenar grip results in more effective ventilation, even by novice airway managers. With thumbs pointed toward the patient's chest, place the thenar eminences against the lateral walls of the mask. Wrap the other fingers around the mandibles and pull the jaw up into the mask. Ensure an even mask seal.[9] If a single-handed mask hold is required, the operator must remain vigilant to prevent mask leakage and ineffective ventilation. When rescue ventilating a supine, apneic, and unresponsive patient, an oral airway is imperative because the tongue falls against the posterior pharynx and occludes the airway. During prolonged mask ventilation, apply cricoid pressure to limit gastric insufflation. For infants and children, use smaller BVM devices to prevent overinflation and barotrauma. In the absence of a BVM device that precisely regulates the volume of air transferred, the amount of air transferred by a BVM is a clinical estimate based on the patient's weight, approximately 5 to 7 mL/kg, or enough to create visible chest rise.

ADVANCED AIRWAY MANAGEMENT

A definitive airway requires patency and protection provided by a stabilized, inflated cuffed structure in the trachea attached to

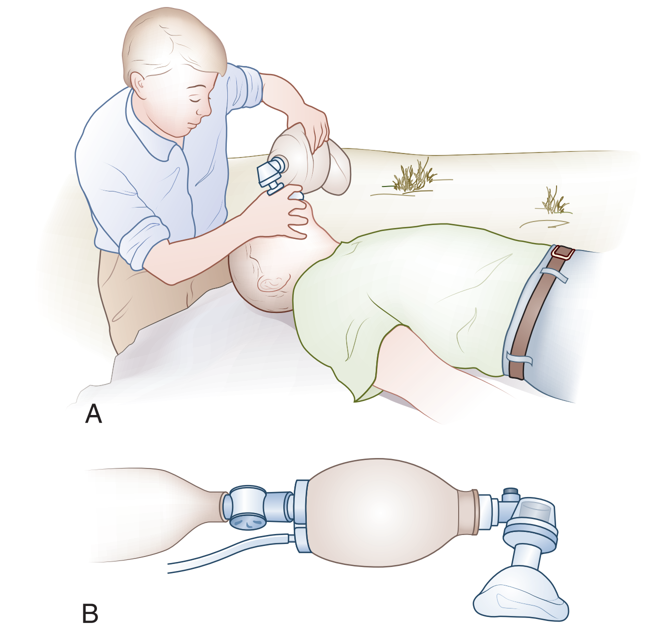

FIGURE 19-12 View of a bag-mask ventilation device. **A,** Rescuer provides ventilation with a bag and mask attached to an oxygen supply. Rescuer uses E-C technique to hold the mask to the face by creating a "C" with thumb and forefinger while lifting the jaw along the bony portion of the mandible with the last three fingers of the same hand; these fingers make the "E." The second hand squeezes the bag while the rescuer watches the patient's chest to ensure that it rises with each ventilation. **B,** Common elements of a standard bag-mask ventilation system with supplemental oxygen. A system consists of a self-refilling bag with an oxygen inlet, valve, and standard fittings (in this case, the bag is joined with a standard fitting to a mask). *(Redrawn from American Heart Association: Guidelines 2000 for cardiopulmonary resuscitation and emergency cardiovascular care.* Circulation *102:I95, 2000.)*

an oxygen source. Failure to secure a definitive airway in a timely manner can lead to disastrous consequences. Once it has been determined that a patient requires intubation, use an algorithmic approach to airway management. Successful algorithms depend on the caregiver's knowledge of airway anatomy, pharmacology, difficult airway recognition, and rescue techniques. The most common approach to emergency airway management is orotracheal intubation facilitated by rapid sequence intubation (RSI).[3] Other methods may be used if a difficult airway is predicted or when the need for airway management is immediate (e.g., a patient with rapidly progressing lingual edema due to anaphylaxis or one who is deteriorating to an agonal ventilatory effort and critical hypoxia). Approaches to definitive airway management include immediate oral endotracheal intubation, awake oral intubation, rapid sequence oral intubation, nasotracheal intubation, and surgical airway (e.g.,cricothyrotomy).

PREDICTORS OF AIRWAY DIFFICULTY

For most patients, intubation is accomplished without complications.[3,14] Modern observational registries of emergency departments report cricothyrotomy rates of less than 0.5%.[3] Difficult BVM ventilation occurs in approximately 2% of operative patients. In emergency patients, the percentage of difficult BVM ventilations is higher because preoperative assessment and patient selection cannot occur.

To assess for RSI, evaluate for (1) difficult intubation, (2) difficult rescue mask ventilation, (3) difficult placement or use of an extraglottic device (EGD), and (4) difficult cricothyrotomy. Although specialist backup, difficult airway devices, and rescue techniques may be limited in wilderness settings, knowledge of the four aspects of assessment is crucial to successful planning. Preintubation discovery of difficult airway characteristics is highly predictive of a challenging intubation. Providers should *always* be ready for a difficult-to-manage airway because unseen complications may not be discovered by bedside assessment.[14]

Aspects of a difficult airway are recalled by the mnemonics LEMON, MOANS, RODS, and SMART.[24] Some patients have an isolated anatomic or pathophysiologic feature responsible for airway challenges, and others may have multiple features. Patients with evidence predicting a difficult airway may still be candidates for neuromuscular blockade. Patients with multiple markers of a difficult airway may be best managed using an "awake" technique without paralysis because neuromuscular blockade may place the patient at high risk for a failed intubation situation. In a patient with a concerning bedside assessment, neuromuscular blockade may be used in conjunction with a double setup (i.e., prepared for cricothyrotomy) as part of a planned approach.

Predicting Difficult Direct Laryngoscopy with the LEMON Mnemonic

Successful intubation is strongly associated with the ability to see the glottis (whether using conventional direct laryngoscopy or video-assisted laryngoscopy). Video laryngoscopy typically provides better glottic views than does direct laryngoscopy.[2,18,21]

To predict difficult direct laryngoscopy, use the LEMON mnemonic (Box 19-1):

L—Look externally. Use the operator's clinical impression and initial gestalt. If judged difficult simply by bedside inspection (e.g., patient with a distorted face following a fall from a tree), the patient is likely to be challenging to intubate.

E—Evaluate 3-3-2. Direct laryngoscopy requires adequate mouth opening to admit the laryngoscope, sufficient space in the floor of the mouth to displace the tongue into the mandibular fossa, and laryngeal placement that is sufficiently "low" (i.e., caudal) that it is not hidden by the base of the tongue. Mouth opening, thyromental distance, and thyrohyoid distance are measured by the 3-3-2 rule. Patients who fail a 3-3-2 assessment may have a challenging direct laryngoscopy (see Figure 19-1)

M—Mallampati scale. The four-class Mallampati scale assesses the important relationship between mouth opening and tongue size. The degree to which an operator can visualize posterior pharyngeal structures predicts the difficulty with laryngoscopy. The Mallampati scale in isolation is not a sensitive assessment tool. It can have limited utility in emergency situations because it requires an awake, compliant patient. Forty percent of emergency department patients cannot yield this assessment.[1]

O—Obstruction or obesity. Upper airway (supraglottic) obstruction can make visualization of the glottis or intubation impossible. Mechanical upper airway obstruction can be caused by head and neck cancer, pharyngeal infection, or anaphylaxis. Any form of airway obstruction should be considered a difficult airway. Obesity can increase the difficulty of laryngoscopy and complicate other aspects of airway management, such as mask ventilation.

N—Neck mobility. Patients with potential cervical spine injury should be placed in cervical precautions. A neutral head position limits direct laryngoscopy because the sniffing position is contraindicated. Neck extension is most important, but the full sniffing position is best for an optimal laryngeal view.[8]

BOX 19-1 LEMON Mnemonic for Evaluation of Difficult Direct Laryngoscopy

Look externally for signs of obvious difficulty
Evaluate the 3-3-2 rule
Mallampati classification
Obstruction or **O**besity
Neck mobility (reduced)

Adapted with permission from The Difficult Airway Course: Emergency and Walls RM, Murphy MF, editors: *Manual of emergency airway management*, 4th ed, Philadelphia, 2012, Lippincott, Williams & Wilkins.

BOX 19-2 MOANS Mnemonic for Challenging Rescue Bag-and-Mask Ventilation

*M*ask seal (beard or altered anatomy)
*O*bstruction or *O*besity
*A*ged (> 55 years old)
*N*o teeth
*S*tiffness (resistance to ventilation or intrinsic lung pathology)

Adapted with permission from The Difficult Airway Course: Emergency and Walls RM, Murphy MF, editors: *Manual of emergency airway management*, 4th ed, Philadelphia, 2012, Lippincott, Williams & Wilkins.

BOX 19-4 SMART Mnemonic for Evaluation of Difficult Cricothyrotomy

*S*urgery
*M*ass (head and neck cancer, hematoma)
*A*ccess/anatomy problems (obesity, edema)
*R*adiation
*T*umor

Adapted with permission from The Difficult Airway Course: Emergency and Walls RM, Murphy MF, editors: *Manual of emergency airway management*, 4th ed, Philadelphia, 2012, Lippincott, Williams & Wilkins.

Predicting Difficult Bag-Mask Ventilation with the MOANS Mnemonic

Attributes of difficult BMV are well validated. They are reflected in the mnemonic MOANS (Box 19-2).[12,13] Patients in whom rescue ventilation by face mask is difficult or impossible typically have features that interfere with an adequate mask seal (e.g., patients with beards or altered lower craniofacial anatomy) or qualities that impair adequate delivery of oxygen to gas-exchanging portions of the lungs. This can be due to advanced age, morbid obesity, airway obstruction, or intrinsic lung pathologic conditions (e.g., asthma, chronic obstructive pulmonary disease).

The difficulty with BVM management of the edentulous patient is the basis of the advice, "Teeth out to intubate; teeth in to ventilate."[6] In patients without teeth, place the mask or a rolled gauze inside the lower lip to limit air leakage and eliminate the risk of aspiration associated with dental prosthetics.

Predicting Difficult Extraglottic Device Placement with the RODS Mnemonic

When faced with difficult rescue mask ventilation due to an inadequate mask seal, consider placing an extraglottic device (EGD) (e.g., intubating laryngeal mask airway [I-LMA], King laryngeal tube). An EGD (internal bagging) is placed directly above the glottic opening. Difficulty with placement and ventilation with an EGD is predicted by the mnemonic RODS (Box 19-3). If the LEMON and MOANS assessments have been completed, only the *D* (*d*istorted anatomy) remains to be evaluated. Distorted upper airway anatomy may result in an incomplete seal and air leakage that cause ineffective ventilation. Restricted mouth opening, airway obstruction, and intrinsic lung pathologic conditions can make ventilation difficult with a mask or EGD.

Predicting Difficult Cricothyrotomy with the SMART Mnemonic

Predicting difficult cricothyrotomy is outlined by the SMART mnemonic (Box 19-4). Difficult cricothyrotomy occurs when there is limited access to the anterior neck or when laryngeal landmarks are obscured. Inspect and palpate the neck for signs of prior surgery, hematoma, tumor, abscess, or radiation changes.

IMMEDIATE ORAL INTUBATION ("CRASH" INTUBATION)

Patients in cardiorespiratory arrest or with agonal vital signs require immediate oral intubation. These patients often have little or no muscular tone and can be intubated without the need for RSI drugs. Attempt immediate intubation without medications. If intubation is unsuccessful (e.g., due to residual muscular contraction and limited mouth opening), a neuromuscular blocking agent (NMBA) (e.g., succinylcholine [1.5 mg/kg intravenously]) can be administered, followed by another intubation attempt. If an ETT has not been placed after three attempts, place an EGD. If at any point the oxygen saturation drops and cannot be maintained with an EGD or rescue ventilation technique, a failed airway has developed and the operator should move quickly to create a surgical airway.

BOX 19-3 RODS Mnemonic for Potentially Difficult Extraglottic Device Placement and Use

*R*estricted mouth opening
*O*bstruction or *O*besity
*D*istorted anatomy
*S*tiffness (resistance to ventilation)

Adapted with permission from The Difficult Airway Course: Emergency and Walls RM, Murphy MF, editors: *Manual of emergency airway management*, 4th ed, Philadelphia, 2012, Lippincott, Williams & Wilkins.

RAPID SEQUENCE INTUBATION

If a patient does not require an immediate (crash) airway intervention and assessment does not predict a sufficiently difficult airway such that neuromuscular blockade might be contraindicated, pursue RSI. RSI follows a coordinated series of steps to allow safe and effective airway management without interposed BVM. It is the method of choice for most acutely ill or injured patients.[3] RSI involves administration of weight-based doses of potent sedative and NMBAs given consecutively by IV push without intervening time delay. Prior to drug administration, a period of preoxygenation creates an oxygen-rich reservoir in the patient's functional residual capacity and helps prevent desaturation during apnea.

RSI is described in discreet steps termed the seven *P*s of RSI (Table 19-2).[25]

Preparation

Prior to the intubation attempt, gather the proper equipment and medications for use during airway management. This may include pretreatment, induction, and paralytic agents (see below). Attach cardiac and oximetry monitors. In an austere environment, this process may be quite limited.

Preoxygenation

The goal of preoxygenation is to prolong the period of safe apnea (from the onset of paralysis to desaturation below 90%) by creating an oxygen reservoir in the patient's lungs. This is typically accomplished by supplying nonrebreather face mask oxygen at approximately 100% for 3 minutes of normal, tidal volume breathing. In a healthy patient, this may allow 6 to 8 minutes of safe apnea. This time will be much less in children, obese patients, and patients with critical illness or injury for whom oxygen use is increased. Preoxygenation is essential to the "no bagging" approach of RSI. If time is insufficient for a full

TABLE 19-2 The Seven Ps of Rapid Sequence Intubation

Time	Action
Zero minus 10 minutes	Preparation
Zero minus 5 minutes	Preoxygenation
Zero minus 3 minutes	Pretreatment
—Time zero—	Paralysis with induction
Zero plus 20-30 seconds	Positioning
Zero plus 45 seconds	Placement with proof
Zero plus 1 minute	Postintubation management

TABLE 19-3 Clinical Characteristics of Induction Agents*

Induction Agent	Induction Dose (Intravenous)	Onset of Action	Duration of Action	Benefits	Precautions
Midazolam	0.2-0.3 mg/kg	30 to 60 seconds	15 to 30 minutes	Readily available Amnestic Anticonvulsant	Slow onset, apnea and hypotension No analgesia Often underdosed for RSI
Etomidate	0.3 mg/kg	15 to 45 seconds	3 to 12 minutes	Decreased intracranial pressure Rarely, decreased blood pressure	Myoclonic jerks Vomiting No analgesia
Ketamine	1 to 2 mg/kg	45 to 60 seconds	10 to 20 minutes	Increased blood pressure and bronchodilation Dissociative amnesia and pain control	Increased secretions Emergence phenomenon
Propofol	1.5 mg/kg	30 to 60 seconds	2 to 5 minutes	Reversible, rapid offset; anticonvulsant	Apnea and hypotension; variable dosing

*All doses should be halved in the setting of profound refractory shock in order to prevent circulatory collapse.

3-minute preoxygenation phase, eight vital capacity breaths with high-flow oxygen can achieve oxygen saturations and apnea times that match or exceed those obtained with traditional preoxygenation. For an obese patient, if contraindications do not exist, preoxygenation should be performed with the patient upright. After neuromuscular blockade, passive oxygenation is accomplished by continuing supplemental oxygen by nasal cannula (at a flow rate of 2 to 6 L/min) during laryngoscopy, and the time to 95% desaturation is extended from 3.5 to 5.3 minutes.[16,26]

Pretreatment

Laryngoscopy may have detrimental physiologic effects (e.g., increased intracranial pressure, heart rate, blood pressure, vascular sheer forces, and bronchospasm). Pretreatment agents are used to mitigate these effects. Pretreatment regimens have evolved, and many formerly traditional methods (e.g., defasciculating doses of competitive neuromuscular blockers before administering succinylcholine; routine use of atropine in children) have largely been abandoned. Patients who may still be considered for pretreatment are those with reactive airway disease, elevated intracranial pressure, or a cardiovascular or neurovascular condition for which increased vascular sheer forces might be dangerous. In patients with asthma, lidocaine has been recommended as a pretreatment drug to limit the bronchospastic response to laryngoscopy. Given that data are limited and beta agonists are universally recommended for acute asthma exacerbations, lidocaine is unlikely to confer benefit. It is reasonable to administer lidocaine (1.5 mg/kg) as a pretreatment drug for asthmatic patients who have not received albuterol. Lidocaine is no longer indicated for pretreatment in head-injured patients with presumed elevated intracranial pressure. A patient intubated in the setting of a vascular emergency (e.g., ischemic coronary disease, aortic dissection) may benefit from a sympatholytic dose (3 μg/kg) of fentanyl to blunt the release of catecholamines caused by laryngeal manipulation. Fentanyl can also be used in patients with primary cerebral processes associated with presumed elevated intracranial pressure if the blood pressure and heart rate are normal.

Paralysis with Induction

Rapidly administer an intravenous (IV) bolus of an induction agent to produce complete loss of consciousness, followed immediately by rapid administration of a NMBA to induce complete motor paralysis.

Induction Agents. With few exceptions, patients should receive an induction agent before neuromuscular blockade. Paralyzing a conscious patient without providing adequate sedation can lead to detrimental physiologic and psychological sequelae. Unless the patient has a Glasgow Coma Scale score of 3 or suffers from profound refractory shock (i.e., those for whom even a small dose of an induction agent might precipitate cardiovascular collapse), induction is mandatory.

Principal induction agents used in the emergency setting are etomidate, propofol, and ketamine. In North America, more than 90% of inductions in adult patients in the emergency department involve etomidate, indicating widespread familiarity and confidence with this drug.[3] Previous controversy regarding the potential harmful effects of etomidate in septic patients has not been substantiated.[10] Clinical characteristics of the most commonly used induction agents and their typical doses are summarized in Table 19-3.

Neuromuscular Blockade. NMBAs induce rapid, transient paralysis to facilitate laryngoscopy and ETT placement. These agents do not provide analgesia, sedation, or amnesia. The ideal NMBA has a rapid onset and short duration of action and few adverse side effects. Succinylcholine, a depolarizing NMBA, comes closest to fulfilling these traits. It is the most commonly used NMBA, although rocuronium is becoming increasingly popular.[3] At the neuromuscular junction, succinylcholine binds tightly to acetylcholine receptors that control potassium channels. Efflux of potassium ions results in motor end-plate depolarization and muscle contraction. Succinylcholine prevents repolarization, causing flaccid paralysis. Clinically, this manifests as muscle fasciculations (10 to 15 seconds following IV bolus administration) followed by complete muscle relaxation and paralysis (at 45 to 60 seconds). It has a short duration of action. Patients may resume spontaneous breathing within 3 to 5 minutes.

Succinylcholine is administered at a dose of 1.5 mg/kg via rapid IV bolus. It is contraindicated in patients with postsynaptic receptor upregulation following neurologic injury (i.e., stroke or spinal cord injury). In this population, succinylcholine depolarization can cause severe hyperkalemia. This risk presents 3 days after a discreet neurologic insult and lasts approximately 6 months. Nondepolarizing NMBAs (e.g., rocuronium) cause paralysis by competing with acetylcholine for receptors at the neuromuscular junction. Rocuronium is the most commonly used competitive NMBA for emergency airway management. It is administered at a dose of 1 to 1.2 mg/kg given via rapid IV push, and provides intubating conditions similar to those created by use of succinylcholine.[15] Vecuronium and pancuronium should not be used for emergency airway management unless neither succinylcholine nor rocuronium is available (Table 19-4).

Positioning

The airway can be considered to have three separate axes: oral, pharyngeal, and laryngeal. In neutral head position, these axes approximate a right angle (Figure 19-13). By combining proper head positioning with head elevation and cervical spine extension, these axes become more aligned and the trajectory to establish an airway is made straighter (Figure 19-14). The sniffing position can be accomplished by placing rolls, a daypack, or even shoes under the posterior occiput (Figure 19-15).

The sniffing position is helpful in all patients. It is crucial in morbidly obese patients, where alignment of upper airway axes can be even more challenging.

TABLE 19-4 Neuromuscular Blocking Agents

Agent	Intubating Dose (Intravenous)	Onset	Duration
Depolarizing Agent			
Succinylcholine	1.5 mg/kg (adult) 2 mg/kg (child) 3 mg/kg (infant)	45-60 seconds	6-12 minutes
Nondepolarizing Agents			
Rocuronium	1 mg/kg	50-70 seconds	30-60 minutes
Vecuronium	0.15 mg/kg	90-120 seconds	60-75 minutes

Adapted from Mahadevan SV, Garmel GM, editors: *An introduction to clinical emergency medicine: guide for practitioners in the emergency department*, Cambridge, UK, 2005, Cambridge University Press.

Patients with potential cervical spine injury should be maintained in neutral position and intubated with cervical spine precautions and manual in-line cervical stabilization. Sellick's maneuver (undirected posterior displacement of the cricoid ring) has been taught as a mandatory step during RSI to prevent aspiration, nominally by blocking the cervical esophagus. It is not clear that Sellick's maneuver prevents aspiration. It is associated with worsened glottic views, distortion of the cricoid ring, and added difficulty with ETT passage.[7,19] It is no longer routinely recommended.

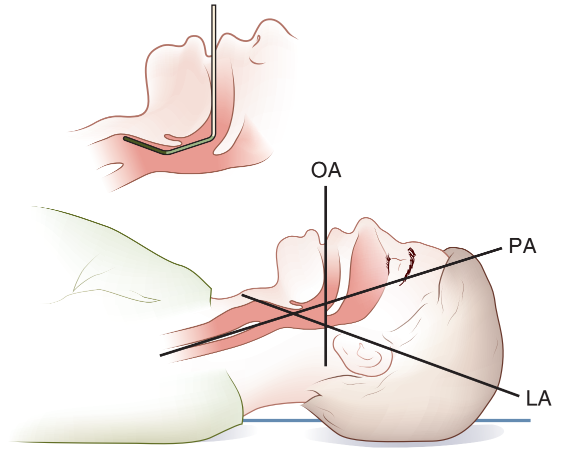

FIGURE 19-13 Head on a bed, neutral position. *LA*, Laryngeal axis; *OA*, oral axis; *PA*, pharyngeal axis. *(Redrawn from Walls RM, Murphy MF, Luten RC, et al, editors:* Manual of emergency airway management, *2nd ed, Philadelphia, 2004, Lippincott Williams & Wilkins.)*

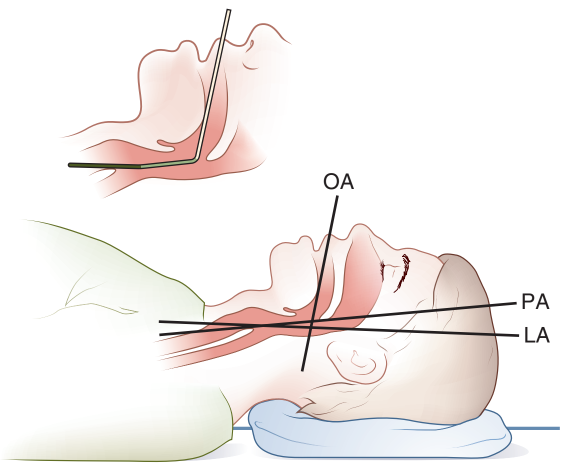

FIGURE 19-14 Head elevated on pad, neutral position. *LA*, Laryngeal axis; *OA*, oral axis; *PA*, pharyngeal axis. *(Redrawn from Walls RM, Murphy MF, Luten RC, et al, editors:* Manual of emergency airway management, *2nd ed, Philadelphia, 2004, Lippincott Williams & Wilkins.)*

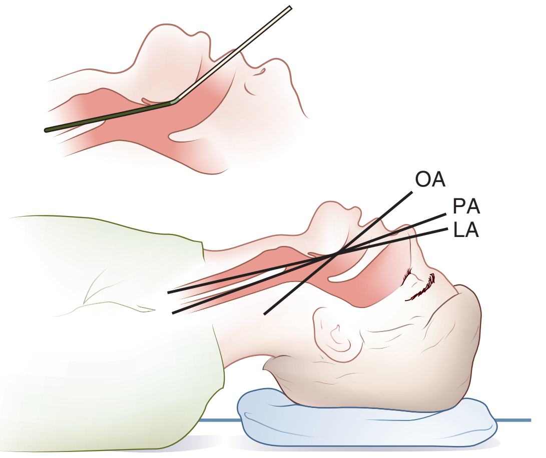

FIGURE 19-15 Head elevated on a pad, head extended on neck. *LA*, Laryngeal axis; *OA*, oral axis; *PA*, pharyngeal axis. *(Redrawn from Walls RM, Murphy MF, Luten RC, et al, editors:* Manual of emergency airway management, *2nd ed, Philadelphia, 2004, Lippincott Williams & Wilkins.)*

Placement

Once the patient is fully paralyzed, perform laryngoscopy, place the ETT, and confirm proper placement by colorimetric or quantitative carbon dioxide detection.

Manage difficult direct laryngoscopy using several augmentation maneuvers. First, ensure that the patient and laryngoscope blade are both optimally positioned. If the glottic aperture is not readily visible, consider manual repositioning of the larynx to improve glottic visualization using optimal external laryngeal manipulation (OELM). In OELM, the operator uses the right hand to move the larynx into optimal viewing position. OELM was previously known as the BURP maneuver. If the glottis is visualized, have an assistant hold the larynx in place while intubation takes place.

Other helpful airway adjunct devices include intubating stylets (e.g., Eschmann intubating stylet, Frova intubating stylet). Stylets (bougies) can be used to help intubate when the only airway structure visible is the epiglottis (Cormack-Lehane grade III view). Place the angled tip of the bougie under the tip of the epiglottis and gently advance it. Correct bougie placement can be confirmed by feeling vibratory transmission of movement over the anterior tracheal rings through the bougie, or feeling the bougie stop after it has been advanced a few inches beyond the glottis, indicating that it has lodged in the right mainstem bronchus.

Proof (Confirmation of Endotracheal Tube Placement)

Immediately after every intubation, confirm proper ETT positioning within the trachea. Monitor through several breaths. Failure to recognize an esophageal intubation can be disastrous. Confirm correct ETT placement by using clinical assessment, pulse oximetry, end-tidal carbon dioxide detection, and aspiration techniques. Clinical assessment alone is insufficient to confirm ETT location, which ideally should always be accomplished by colorimetric or quantitative end-tidal carbon dioxide detection. Chest radiography assesses the ETT position but is highly unlikely to be available in austere settings.

CLINICAL ASSESSMENT

Classic clinical observations used to confirm correct ETT placement include (1) watching the ETT pass through the vocal cords during intubation; (2) auscultation of clear and equal breath sounds over both lung fields; (3) absence of breath sounds when auscultating over the stomach; (4) observation of symmetric chest rise during ventilation; and (5) observation of ETT "fogging" during ventilation. Because any one clinical finding is subject to failure, it is safest to confirm ETT placement with multiple findings.

PULSE OXIMETRY

A drop in oxygen saturation after intubation raises concern for an esophageal intubation. If the patient has been adequately preoxygenated, this drop may be delayed for several minutes. In certain patients (e.g., those with severe hypotension or marked peripheral vasoconstriction from cold exposure), the oxygen saturation measurement may be unreliable or difficult to detect. It is important to monitor pulse oximetry after endotracheal intubation, but one must remember the previous cautionary statement that no one method should be the sole indicator of successful ETT placement.

End-Tidal Carbon Dioxide Detection

When adequate circulation is present, detection of end-tidal carbon dioxide is a highly reliable method for identifying proper ETT placement within the trachea. When unequivocal color change persists after six full breaths, this ensures that the tracheal tube tip is either within or directly above the trachea. Prolonged bagging prior to intubation may result in initially weak but fatigable color change with an esophageal intubation. A false-negative "color change" (no change in color despite correct ETT placement) may occur in some cases of cardiac arrest and circulatory collapse as carbon dioxide delivery to the lungs abruptly declines.

ASPIRATION DEVICES

Bulb and syringe aspiration devices may be used for confirmation of ETT placement. Bulb aspiration devices are round and compressible plastic globes (i.e., turkey baster) that are compressed and deflated, attached to the ETT, and released to allow them to inflate. If the bulb reexpands rapidly, the ETT is likely in the trachea. Failure of or delay in reexpansion suggests that the ETT is in the esophagus. Syringe aspiration devices are large syringes (usually 30 mL [1 oz]) that are attached to the ETT. The syringe plunger is pulled back rapidly. Rapid and easy flow of air suggests tracheal intubation, whereas resistance suggests esophageal intubation. Such devices are reliable at detecting esophageal intubation (sensitivity > 95%); however, false-positive intubations (i.e., a correctly placed tracheal tube is incorrectly labeled as an esophageal intubation) can occur in up to 25% of cardiac arrest patients.

POSTINTUBATION MANAGEMENT

After verification of correct ETT placement within the trachea, secure the ETT (i.e., tape or tie it) to prevent movement or migration. Closely monitor the patient's vital signs. Bradycardia after intubation is worrisome for hypoxia or gastric distention and should prompt detection of a possible esophageal intubation. Hypertension after intubation suggests inadequate sedation. Hypotension after intubation may result from a tension pneumothorax, decreased venous return, large induction agent dose, or cardiac cause.

After intubation, especially if a longer-acting neuromuscular blocker (e.g., rocuronium or vecuronium) is used, sedation is mandatory. An IV benzodiazepine (e.g., midazolam [0.1 to 0.2 mg/kg], diazepam [0.2 mg/kg], or lorazepam [0.05 to 0.1 mg/kg]) may be administered initially for sedation and repeated for any sign of awakening with awareness. Propofol (0.3 mg/kg) and ketamine (1 to 2 mg/kg) are less commonly used, but are becoming more popular both as induction agents and as postintubation sedatives.[3] An opioid agent such as fentanyl (3 to 5 μg/kg) or morphine sulfate (0.1 mg/kg) may also be administered for additional patient comfort. Nondepolarizing NMBAs (e.g., pancuronium [0.1 mg/kg] or vecuronium [0.1 mg/kg]) may be used for long-term paralysis. If any motor activity is detected after 45 to 60 minutes, give a repeat dose that is one-third the initial dose. Ensure adequate sedation when long-acting paralysis is employed. This is especially true when pancuronium is used, because it can render a patient paralyzed for nearly 2 hours. Recent data suggest that emergency department patients are not uncommonly paralyzed without adequate sedation.[5]

ALTERNATIVE STRATEGIES FOR THE DIFFICULT AIRWAY

AWAKE ORAL INTUBATION

Awake oral intubation is an approach that makes use of titrated IV sedation and liberal topical airway anesthesia to allow inspection and intubation of an awake patient's airway. This approach allows the patient's protective airway reflexes and spontaneous respirations to be preserved while the laryngoscopist takes a gentle awake look at the glottis, vocal cords, and internal airway anatomy. This approach is typically used when significant airway difficulty is anticipated and direct laryngoscopy and/or rescue mask ventilation are judged likely to fail. In these patients, use of neuromuscular blockers may result in a failed airway. During awake airway inspection, the clinician can elect to intubate unstable patients (e.g., those with airway burns or anaphylaxis with progressive airway swelling), because that moment may be the most opportune time for definitive airway management. Key components of an awake look are airway preparation, topical anesthesia, and limited sedation. First, prepare the airway by using a topical nasal vasoconstrictor (e.g., oxymetazoline 0.05%) and drying agent (e.g., glycopyrrolate [Robinul] 0.01 mg/kg intravenously). Topical anesthesia is accomplished by using atomized or nebulized aqueous lidocaine. The presence of blood or secretions or distorted anatomy can make topical analgesia and visualization challenging.

NASOTRACHEAL INTUBATION

When oral access is limited (e.g., fractured mandible, severe lingual edema from Hymenoptera envenomation), awake nasotracheal intubation may be a better alternative, because it can be performed while preserving the patient's spontaneous respirations. This technique does not require many of the tools needed for other airway management techniques and so is well suited for austere conditions.

Prepare the mucosa to facilitate tube passage and minimize the risk for epistaxis. Instill 2 to 3 drops of a topical vasoconstrictor agent (e.g., phenylephrine hydrochloride [0.25%] or oxymetazoline [0.05%]) in each nostril. Anesthetize the nasal mucosa using a 4% cocaine pack or 2% lidocaine jelly. After vasoconstriction, use atomized or nebulized 4% aqueous lidocaine to provide topical anesthesia. Select a cuffed ETT that is sized 1 mm smaller than would be selected for orotracheal intubation. Lubricate the tube with a water-soluble lubricant to facilitate its passage. Lidocaine jelly is ideal for simultaneously providing lubrication and topical anesthesia. Insert the ETT into the more patent nostril. The right side is preferred because the ETT bevel will face the septum and so avoid Kiesselbach's plexus, decreasing epistaxis risk. Direct the ETT straight back along the nasal floor toward the occiput, and rotate it 15 to 30 degrees during advancement. When the distal ETT nears the glottis, listen for airflow within the tube with each breath. When maximal airflow is heard, quickly and gently advance the ETT. A cough will likely be heard with successful passage of the tube into the trachea, and the patient will not be able to phonate. Advance the ETT to 32 cm at the nares in adult males and to 27 to 28 cm in adult females. Inflate the cuff. ETT confirmation should be established in standard fashion as described above. When ETT placement is assured, immediately sedate the patient. NTI is contraindicated in patients with apnea, significant midface trauma (i.e., with suspicion for basilar skull fracture or cribriform plate injury), severe coagulopathy, or presumed altered upper airway anatomy.

Epistaxis and nasal turbinate injury from blind nasotracheal intubation can be reduced by pretreatment with vasoconstrictor agents and proper technique. If sufficient topical anesthesia is provided, patients typically tolerate this procedure well. Long-term complications (e.g., sinusitis, turbinate destruction) are uncommon and result from multiple intubation attempts or prolonged intubation.

ALTERNATIVE AIRWAY ADJUNCTS AND TECHNIQUES

In certain wilderness settings, tracheal intubation may be difficult or impossible. Under such circumstances, alternative airway adjuncts or techniques may be employed to provide an airway. Alternative airways that require blind passage of an ETT into the airway may be simpler to master than passing an ETT under direct vision. To achieve good outcomes with these devices and techniques, providers must maintain a high level of knowledge and skills through frequent practice (e.g., simulation) and field use.

LARYNGEAL MASK AIRWAY

The laryngeal mask airway (LMA) is a modified ETT with an inflatable oval cuff (i.e., the laryngeal mask) at its base (Figure 19-16A-D). Blindly insert the LMA into the pharynx and advance it until resistance is felt as the distal portion of the LMA lodges in the laryngopharynx. Inflating the collar seals the LMA around the laryngeal inlet and facilitates tracheal ventilation.

Although LMAs do not ensure protection against aspiration, studies have shown that aspiration is uncommon and regurgitation less likely with an LMA than with a BMV device. LMAs provide ventilation equivalent to that of ETTs. LMA use may be preferred to ETT intubation when access to the patient is limited, when unstable neck injury may exist, or when appropriate victim positioning for tracheal intubation is impossible. With elective anesthesia, the LMA has an extremely high rate of successful insertion and a low rate of complications, including a low incidence of tracheal aspiration. Evaluations of LMA insertion by experienced and inexperienced personnel alike consistently have shown ease of insertion, high rates of successful insertion, and successful ventilation.[20]

The LMA Fastrach is designed to facilitate blind intubation through a specially designed mask employing an epiglottic elevator bar. Placement of the iLMA results in successful ventilation in nearly all cases and successful subsequent intubation in 85% to 95% of cases. When augmented by flexible fiberoptic endoscopy, the rate of successful subsequent intubations rises to approximately 100%. The LMA Fastrach has significant advantages when compared with a standard LMA. It provides a means for rescue ventilation and intubation. The LMA Fastrach comes in adult sizes 3, 4, and 5. It is not suitable for use in patients weighing less than approximately 30 kg (66 lb).

Newer-style LMA devices (e.g., air-Q and Aura-i) perform as well as standard LMAs for ventilation and oxygenation, and can also facilitate blind intubation with standard adult ETTs. Both work well for intubating a difficult airway, especially when augmented by flexible endoscopy.[11]

Combitube

The Combitube is a double-lumen, adult-only, dual-cuffed airway. One lumen contains ventilating side holes at the hypopharyngeal level. The distal end is closed. The other lumen has an open

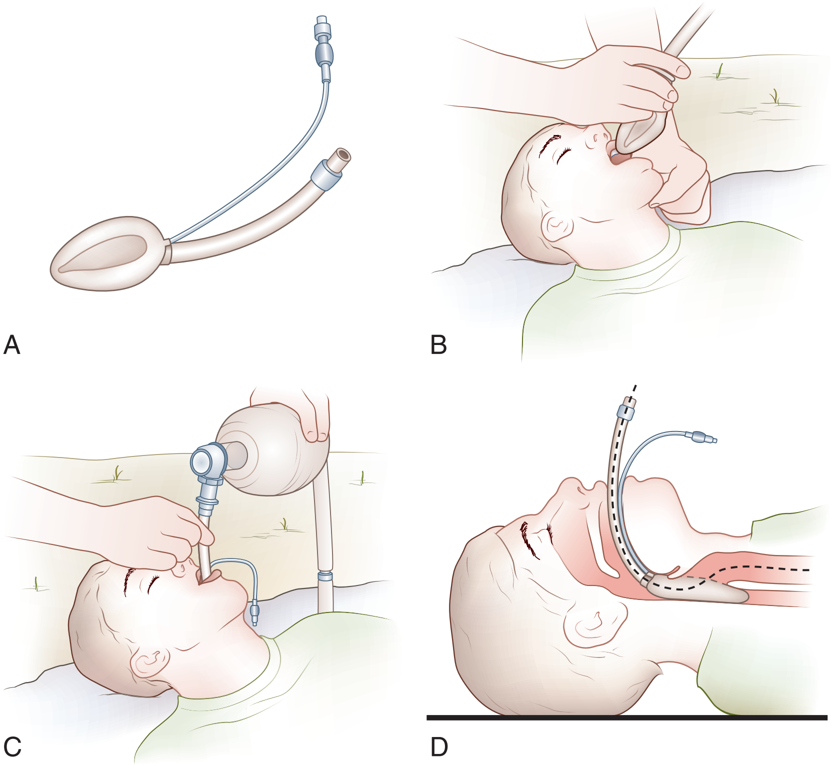

FIGURE 19-16 Laryngeal mask airway (LMA). **A,** The LMA is an adjunctive airway that consists of a tube with a cuffed masklike projection at its distal end. **B,** Introduce the LMA through the mouth into the pharynx. **C,** When the LMA is in position, a clear and secure airway is present. **D,** During insertion, advance the LMA until resistance is felt as the distal portion of the tube lodges in the hypopharynx. Inflate the cuff. This seals the larynx and leaves the distal opening of the tube just above the glottis to provide a clear and secure airway *(dotted line). (Redrawn from American Heart Association: Guidelines 2000 for cardiopulmonary resuscitation and emergency cardiovascular care.* Circulation *102:I95, 2000.)*

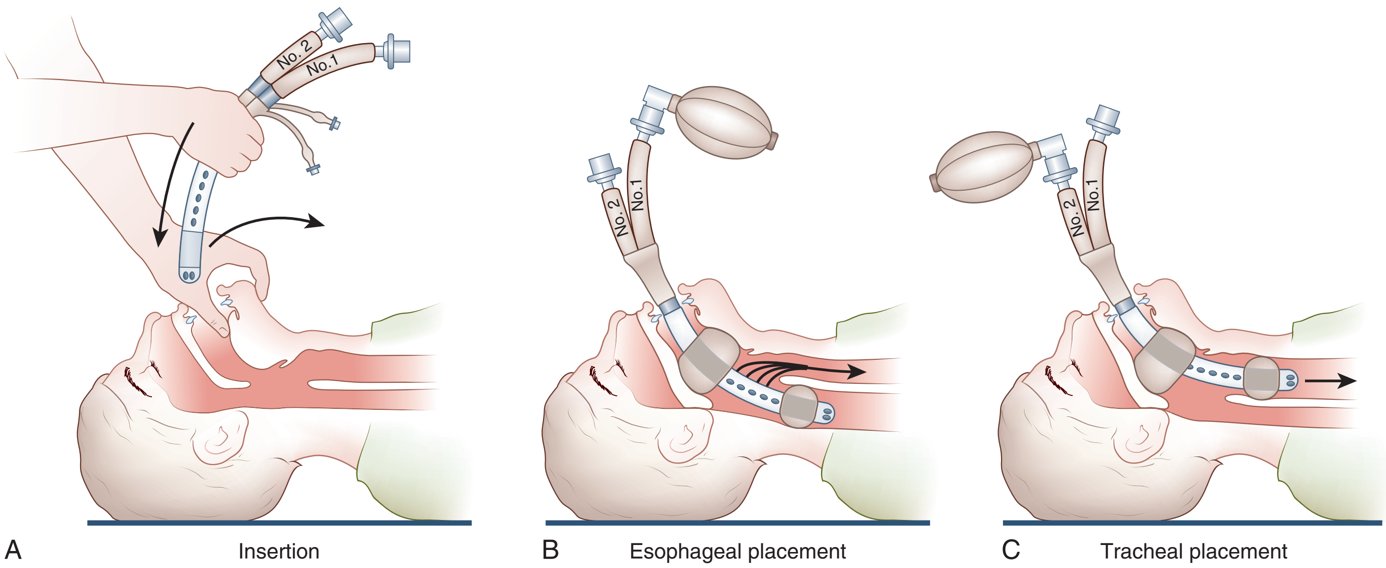

FIGURE 19-17 Esophageal-tracheal Combitube. *(Redrawn from Skinner D, Swain A, Peyton R, et al, editors:* Cambridge textbook of accident and emergency medicine, *Cambridge, UK, 1997, Cambridge University Press.)*

distal end with a cuff similar to an ETT. One lumen functions as an esophageal airway, and the other functions as a tracheal airway (Figure 19-17). A Combitube is typically blindly inserted and advanced until two guide marks printed on the tube reach the patient's teeth. The pharyngeal and distal balloons are inflated. This isolates the oropharynx above the upper balloon and the esophagus or trachea below the lower balloon. The tube's distal end most commonly finds its way into the esophagus. It will intubate the trachea in 3% to 5% of cases. Determine the location (i.e., esophagus or trachea) of the distal orifice and ventilate through the appropriate opening.

Advantages of a Combitube over a BVM include isolation of the airway, reduced aspiration risk, and more reliable ventilation. Disadvantages include large size, more difficulty with placement, and competition with newer and more easily applied devices. Fatal complications with the Combitube may result from incorrect identification of the position (trachea or esophagus) of the distal lumen. An end-tidal carbon dioxide or esophageal detector device should be used in conjunction with the Combitube.

KING LT

The King LT airway is a single-lumen, dual-cuffed airway with ventilation outlets between a large pharyngeal and a smaller esophageal balloon (Figure 19-18). The King LT airway is inserted blindly. A single pilot balloon inflates both cuffs simultaneously. Although it is similar to the Combitube, the King LT is shorter, easier to insert, and easier to inflate, and does not inadvertently intubate the trachea.[4] Newer versions of the King LT have a posterior channel that accepts a nasogastric tube, allowing tube passage through the device to allow aspiration of gastric contents. The device's airway seal may be lost after insertion and requires deflation of the balloons and repositioning. The King LT airway is available in newborn through adult sizes.

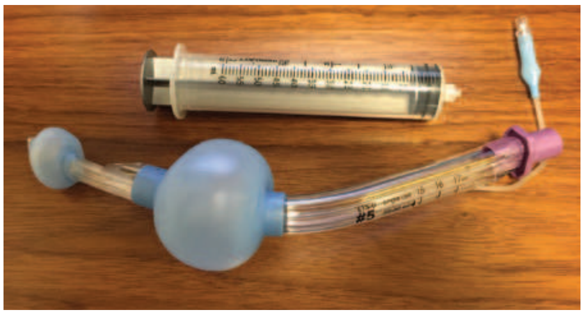

Figure 19-18 King Laryngeal Tube (LT) inflated with the prepackaged syringe.

VIDEO LARYNGOSCOPY

Video laryngoscopes consist of a video camera functionally associated in one of many ways with a laryngoscope blade and handle, or other intubation device. For instance, the blade and handle may be attached by video cable to a high-resolution color display, or a miniaturized display may be attached directly to the handle. This technology effectively places the operator's eye on a screen that transmits an image of the leading edge of the laryngoscopy blade. The blade may have a hypercurved (GlideScope) or traditional (Storz C-MAC) laryngoscope shape (Figures 19-19 and 19-20). The video laryngoscopes with integrated monitors (e.g., McGrath MAC Series 5) on the end of the handle make them attractive options for prehospital providers or other operators in austere settings (Figure 19-21). Compared with conventional laryngoscopes, the video scope improves glottic exposure in both operative and emergency department populations, and it has higher first-pass success rates when compared with conventional laryngoscopes.[3,17,18,21] Video laryngoscopy is replacing direct laryngoscopy as a first-line maneuver. Video laryngoscopes tend to be expensive, but lower-cost devices (e.g., King Vision video laryngoscope) are available (Figure 19-22). The King Vision is powered by three standard AAA batteries that provide 90 minutes of continuous use.

Video screens used in bright outdoor environments are subject to glare and reduced visibility. Modified shade (e.g., using natural

Figure 19-19 GlideScope titanium blades.

Figure 19-20 C-MAC video laryngoscope. *(Photo courtesy Karl Storz GmbH & Co. KG, Germany.)*

Figure 19-21 McGrath MAC Series 5 video laryngoscope.

canopies or blankets) improves visualization. Small, lightweight devices with fixed screens (e.g., McGrath Series 5, King Vision) are attractive options. Visualization may be adversely affected more in conditions of bright light because there is no separate, mobile screen that can be positioned for optimal viewing.

FIBEROPTIC INTUBATION

Fiberoptic techniques for endotracheal intubation (e.g., fiberoptic intubating bronchoscopes and rigid fiberoptic laryngoscopes) are invaluable tools for difficult airway management. Their role in out-of-hospital airway management is negatively affected by low availability, high cost, requirements for power supplies for illumination, and complex cleaning procedures after use. Devices can be used for awake intubation in patients for whom RSI or insertion of a laryngoscope blade may be disadvantageous. In patients with uncontrolled secretions or active bleeding, visualization with fiberoptic devices may be impaired.

Figure 19-22 King Vision video laryngoscope.

New, single-use, lightweight, fully disposable flexible videoscopes (Ambu aScope 3) are available. The cost is low, and the device is portable, so that fiberoptic technology can be used in remote locations. A power supply is required.

DIGITAL INTUBATION

Digital (tactile) intubation is a technique in which the index and long fingers of the nondominant hand are used to identify the epiglottis and manually direct an ETT into the larynx. It may be useful when poor lighting, poor positioning, copious airway secretions, or equipment failure make laryngoscopy difficult or impossible. Digital intubation requires a profoundly unresponsive victim. It is relatively contraindicated in the semiconscious victim with intact oropharyngeal reflexes. Other relative contraindications include caustic ingestion, thermal burns, and upper airway foreign bodies.

SURGICAL AIRWAY MANAGEMENT

Surgical airway management (e.g., cricothyrotomy, needle cricothyrotomy with percutaneous transtracheal ventilation) involves creation of an opening directly into the trachea by surgical means.

CRICOTHYROTOMY

Video laryngoscopy may be reducing the "salvage" surgical airway rate, currently at 0.3% in emergency department populations.[3] Needle cricothyrotomy (i.e., insertion of a large needle through the cricothyroid membrane into the airway for transtracheal jet ventilation [TTJV]) is rarely, if ever, the correct choice for an adult airway emergency. Cricothyrotomy creates an opening in the cricothyroid membrane through which a cannula, usually a cuffed tracheostomy tube, is inserted to permit oxygenation and ventilation. When surgical airway management is required, cricothyrotomy is the procedure of choice in the emergency setting. It is faster, more straightforward, and more likely to be successful than is tracheotomy. Alternate techniques are described elsewhere.[22]

Cricothyrotomy is indicated when oral or nasal intubation fails or is technically impossible to accomplish in the setting of declining oxygen saturation. Cricothyrotomy is relatively contraindicated by altered neck anatomy, hematoma, overlying cancer, or coagulopathy. There is no absolute contraindication to a surgical airway, with the exception of age. The procedure should be avoided in children younger than 10 years, in whom anatomic limitations make it difficult.

A number of commercial kits can be used to perform a cricothyrotomy. When landmarks are clear, cutaneous cricothyrotomy employing the Seldinger's technique (i.e., cricothyrotomes) appears comparable to formal open cricothyrotomy. In patients with poor landmarks, standard open cricothyrotomy is more successful. Bougie-assisted cricothyrotomy may improve surgical airway success rates for inexperienced practitioners. The safety and efficacy of cricothyrotomy kits are not clearly established. Two percutaneous cricothyrotomy sets allow a cuffed tracheostomy tube to be placed. One is a dedicated Seldinger cricothyrotomy set. The other is a combination set with equipment for either a Seldinger percutaneous cricothyrotomy or a standard surgical cricothyrotomy. Complications of cricothyrotomy include incorrect location of airway placement, hemorrhage, tracheal or laryngeal injury, infection, pneumomediastinum, subglottic stenosis, and voice change.

Standard Surgical Cricothyrotomy

Standard surgical cricothyrotomy is performed as follows and as shown in Figure 19-23:

Identify the thyroid cartilage. This is the only V-shaped structure encountered when palpating the anterior neck. The cricothyroid space is the gap immediately below the thyroid cartilage.

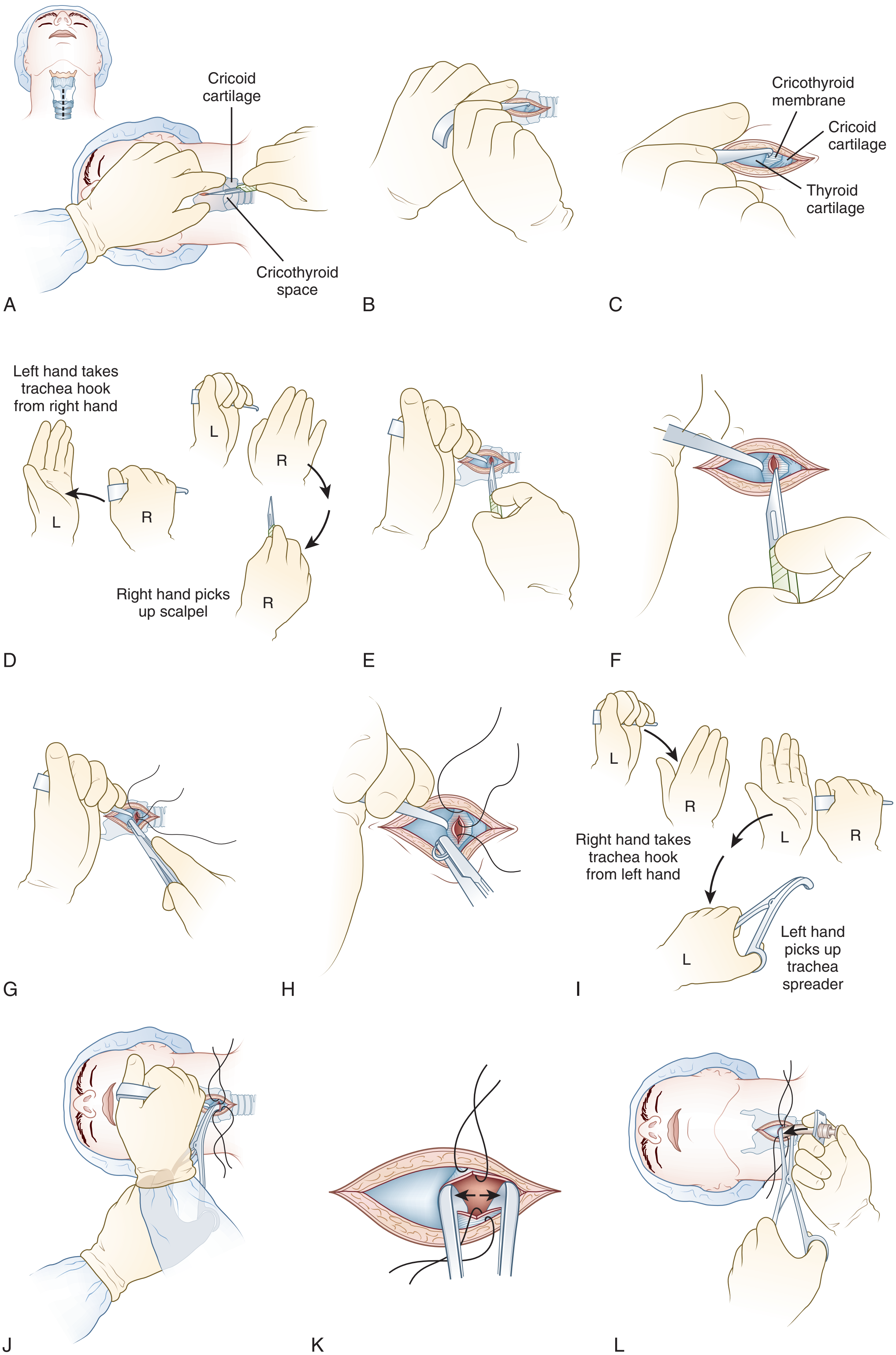

FIGURE 19-23 Standard surgical cricothyrotomy. *(Redrawn from Walls RM: Cricothyrotomy. In Rosen P, Chan TC, Vilke GM, et al, editors:* Atlas of emergency procedures, *St. Louis, 2001, Mosby.)*

Prepare the neck in sterile fashion. With the nondominant hand holding the thyroid cartilage, make a vertical midline incision with a No. 11 scalpel blade from the thyroid cartilage caudad approximately 3 to 4 cm (1.2 to 1.6 inches) (see Figure 19-23A).

Place a tracheal hook through the cricothyroid space. Hold cephalad traction with the nondominant hand (see Figure 19-23B-D).

Make a transverse incision across the exposed cricothyroid membrane (see Figure 19-23E,F). If time permits, insert silk stay sutures in the trachea (see Figure 19-23G,H). Dilate the opening in the cricothyroid membrane using a Trousseau dilator while maintaining traction with the hook (see Figure 19-23I-K).

Place a Shiley cuffed tracheostomy tube through the opening created in the cricothyroid membrane. Initially aim posteriorly and then redirect caudally once through the opening (see Figure 19-23L). The tracheal hook may be removed before insertion of the tube to avoid damaging the tube. If a tracheostomy tube is not available, an ETT may be substituted.

Rapid Four-Step Cricothyrotomy

The rapid four-step cricothyrotomy is accomplished as follows and as shown in Figure 19-24:

From a position at the head of the victim, palpate and identify landmarks, especially the cricoid and thyroid cartilages and cricothyroid membrane.

Using a No. 20 scalpel, incise the cricothyroid membrane and overlying skin simultaneously with a single horizontal 1.5-cm (0.6-inch) incision. While maintaining the blade within the airway, slide a tracheal hook alongside the caudal side of the blade into the wound.

Orient the hook caudally. Place gentle traction on the cricoid ring; this typically widens the incision. Then remove the blade from the airway.

Place the ETT through the opening into the airway. Secure the ETT.

Improvised Cricothyrotomy

If formal cricothyrotomy equipment is not available, a knife and a hollow object (i.e., substitute for the tracheostomy tube) may be used. An improvised cricothyrotomy could be performed using a modified IV macro drip chamber or the cut barrel of a 1-mL or 3-mL syringe (see Chapters 28 and 46). Any small hollow object (e.g., ballpoint pen casing, sports-bottle straw, inflation tube for white-water floatation bag) may be employed as a cricothyrotomy tube. Objects with an internal diameter of at least 3 mm (0.12 inch) provide the best gas exchange.

NEEDLE CRICOTHYROTOMY WITH PERCUTANEOUS TRANSTRACHEAL (TRANSLARYNGEAL) JET VENTILATION

An alternative surgical airway procedure is needle cricothyrotomy with percutaneous transtracheal jet ventilation (TTJV). With this technique, a transtracheal catheter is inserted through the cricothyroid membrane into the trachea and connected to a jet ventilation system consisting of high-pressure tubing, an oxygen source at 50 psi, and an in-line one-way valve to intermittently administer oxygen. One hundred percent oxygen is delivered at 12 to 20 bursts/min. The inspiratory phase should last 1 second. The expiratory phase should last 2 to 4 seconds. Advantages of this technique include simplicity, safety, and speed. In adults, this is an appropriate procedure only in the most dire circumstances; even then, it should be considered a temporizing measure because the tube's small diameter makes oxygenation and removal of carbon dioxide incredibly challenging. In TTJV, there is typically less bleeding than with cricothyrotomy. Age is not a contraindication. In children less than 10 years old, this is the preferred surgical airway technique. During TTJV, the upper airway must be free of obstruction to allow complete exhalation. If not, the patient is at risk for barotrauma from air "stacking." All patients receiving TTJV should have an oral and nasal airway placed.

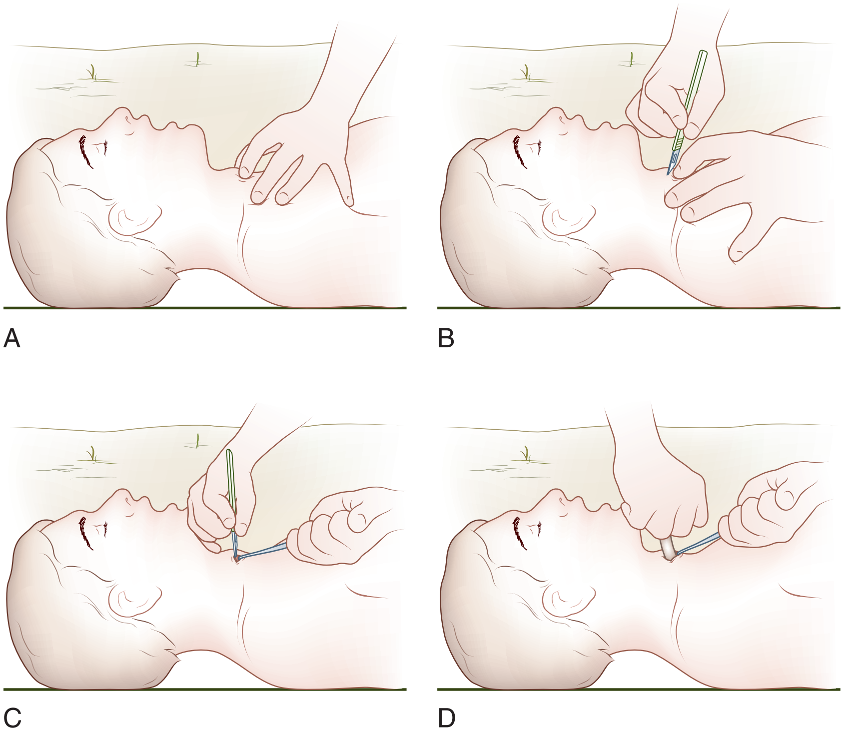

FIGURE 19-24 Rapid four-step cricothyrotomy. **A,** Step 1: Palpation (location of the cricoid membrane externally). **B,** Step 2: Incision (horizontal incision of skin and soft tissues through the cricoid membrane). **C,** Step 3: Traction (application of caudal traction to the cricoid ring). **D,** Step 4: Intubation (passage of the tracheal tube). *(Redrawn from Brofeldt BT, Panacek EA, Richards JR: An easy cricothyrotomy approach: The rapid four-step technique,* Acad Emerg Med *3:1060, 1996.)*

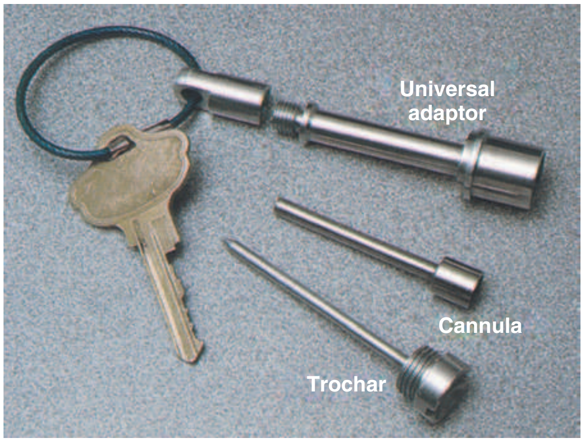

FIGURE 19-25 LifeStat emergency airway device. *(Redrawn from LifeStat product information.)*

The technique for needle cricothyrotomy with TTJV is as follows:

Stand at the patient's side at the level of the neck. Expose the neck, and identify landmarks, especially the cricoid and thyroid cartilages and cricothyroid membrane.

Prepare the neck with an antiseptic solution, and provide local anesthesia if time permits.

Immobilize the larynx between the thumb and middle finger, while the index finger identifies the cricothyroid membrane.

Attach a large-bore (12- to 16-gauge) over-the-needle catheter to a 20-mL syringe. Hold the needle and syringe in the dominant hand. Direct the needle caudally through the cricothyroid membrane at a 30-degree angle to the skin while maintaining negative pressure on the syringe. As soon as the needle tip enters the trachea, the syringe should fill easily with air.

Advance the catheter to its hub while simultaneously removing the needle. Reconfirm the catheter position within the trachea.

Connect the catheter to a jet ventilation system.

In terms of expedition kit portability, one transtracheal puncture emergency airway device deserves special mention. LifeStat (French Pocket Airway, Inc.) manufactures a keychain emergency airway set. It consists of a sharp-pointed metal trocar introducer inside a straight metal cannula that screws into a metal extension with a universal 15-mm (0.6-inch) male adaptor. Lightweight and less than 7.6 cm (3 inches) long, the three-component apparatus is attached to a detachable keychain (Figure 19-25). It is approved by the Food and Drug Administration for surgical access and is for a single use only. The device can be left in place during subsequent attempts at intubation. For circumstances in which a jet ventilator is not readily available, care providers may improvise by using a self-inflating bag-valve device to ventilate the patient through the transtracheal catheter. The bag-valve device may be connected to a 3.0-mm-ID ETT adapter inserted directly into transtracheal catheter or to a 7.5-mm-ID ETT adapter inserted into a 3-mL (0.1-oz) syringe barrel and then into the transtracheal catheter (Figure 19-26). Ventilation with this device is temporary at best, but may have usefulness in children younger than 5 years of age.

AIRWAY EQUIPMENT FOR THE WILDERNESS

Box 19-5 lists standard airway equipment, video devices, and rescue tools for expedition airway management. Emergency medical kits with basic or advanced airway equipment (e.g., Stat Kit) are commercially available.

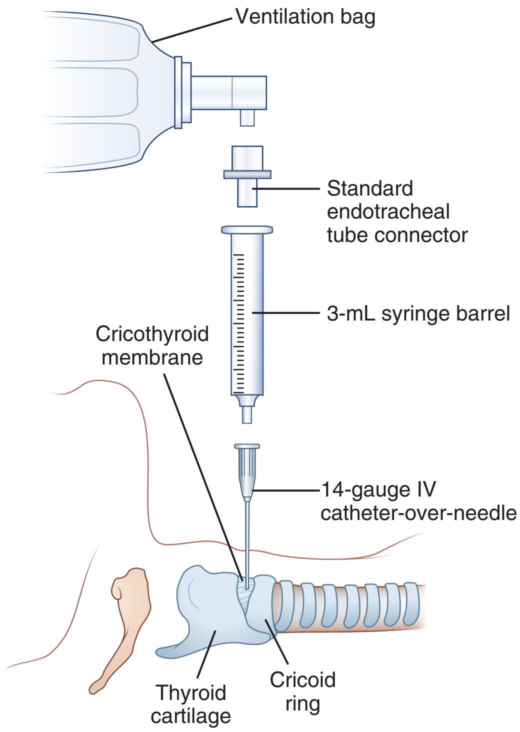

FIGURE 19-26 A simple setup for translaryngeal ventilation using standard equipment found in any emergency department. This setup is inadequate for adults. A high-pressure (50-psi) ventilation system is optimal. Even with the pressure relief valve on the bag-valve device turned off, only suboptimal pressure can be developed. However this technique may be satisfactory for infants and small children. *(Redrawn from Roberts JR, Hedges JR, editors:* Clinical procedures in emergency medicine, *4th ed, Philadelphia, 2004, Saunders.)*

BOX 19-5 Sample Contents of a Wilderness Airway Management Kit

Basic Airway Equipment

Laerdal pocket mask
CPR microshield barrier
Nasal airway kit
Oral airway kit
Stethoscope
Bulb suction device

Advanced Airway Equipment

Bag-mask ventilation device with pediatric and adult masks
Manual suction device
Endotracheal tubes with stylet
Compact and battery-operated video laryngoscope system
Laryngoscope handles and blades
Magill forceps
Esophageal detector device
Colorimetric end-tidal carbon dioxide detector
Laryngeal mask airway, King LT, or Combitube
Needle cricothyrotomy catheter or device
Commercial cricothyrotomy kit
Oxygen cylinder with toggle handle
Nasal cannula, oxygen mask with strap, and nonrebreather bag
Oxygen tubing
Pulse oximeter

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CHAPTER 20

Management of Facial Injuries

DAVID SHAYE, VICKI MAZZORANA, AND ROBIN W. LINDSAY

Wilderness medicine is often defined in part by the amount of time that an individual is in a remote place, far from definitive hospital-based care. This occurs in disaster medicine, military and tactical medicine, rural medicine, and traditional wilderness medicine. These fields have in common environments with constrained resources, the necessity for robust prehospital patient care, and delayed access to definitive care. These conditions require integrating evacuation and rescue training, evaluating environmental threats, and understanding and managing resources during disasters. A more expansive definition of wilderness medicine takes into consideration the type of injury, the setting in which the injury occurred, and how a particular injury relates to human interaction with the environment.[41] In all of these environments and situations, facial injuries occur and require urgent initial management to diminish the morbidity, chance of mortality, and disruption of recreational activities.

The Joint Theater Trauma Registry is responsible for collecting and organizing medical treatment data about patients from combat operations who are treated at U.S. medical facilities. Although the head, face, and neck account for only 12% of the body surface area, approximately 40% of all injuries currently sustained during military conflicts are to these areas. This proportion is higher than reported for previous military conflicts, and most likely results from improved body armor and relative lack of protective devices for the head and face.[32,38,50] Soldiers are at high risk for sustaining oral and facial trauma during training and assaults.[52] Traumatic facial injuries account for significant rates of morbidity and mortality among the U.S. armed forces, so improved functional protection for the vulnerable facial region must be developed. Experience and data gathered during military conflicts have been of tremendous value with regard to further education of medical providers about the emergency care of facial trauma. Military research has been instrumental in advancing trauma care principles and guidelines used to manage trauma in both civilian and military populations.

In addition to military-related injuries, sports-related accidents and outdoor recreational activities are responsible for a significant number of facial injuries. Skiing, bicycling, soccer, and mountain biking account for more than 60% of sports-related accidents. Traumatic injuries from falls, collisions, and self-inflicted injuries result in facial bone fractures, dentoalveolar trauma, and soft tissue damage. The injury pattern depends on the sporting activity, with high-speed and high-impact sports causing more fractures and low-speed and low-impact sports producing more dental injuries.[48]

A growing number of people participate in a wide variety of outdoor recreational activities that take them far away from definitive medical services.[14,46] Wilderness recreation and adventure activities create many situations that place individuals at risk for facial traumatic injuries. The National Outdoor Leadership School collects and publishes data about injuries, illnesses, near-miss incidents, nonmedical incidents, and evacuation profiles among its participants. According to recent unpublished data from the leadership school, facial trauma accounted for 4% of reported injury incidents over a period of 25 years from 1984 to 2009; the majority of these were soft tissue injuries.[26]

HISTORY AND EXAMINATION OF FACIAL INJURIES

Before evaluating and treating a patient in the wilderness, the safety of the setting and situation must be evaluated. Evaluating a patient with facial trauma proceeds as it does with any other medical condition. In emergency situations, the chief complaint and history of the present illness are obtained as one is performing the primary survey, which evaluates and treats inadequacies of airway, breathing, and circulation. The patient's baseline mental status is assessed, and any neurologic disabilities are identified.

Airway assessment begins with examination of the mouth and pharynx for foreign bodies, such as blood clots, tooth or bone fragments, and dentures. If the airway is obstructed, perform a chin lift or jaw thrust, or insert an oropharyngeal airway to hold the tongue forward. If there is a potential cervical spine fracture, keep the head and neck in a neutral position without hyperextension. Position the patient to maintain the airway and facilitate respiration; in many instances, this will be the prone position. Raise the head above the heart to decrease bleeding and swelling, or position the victim seated with the head forward so that blood drains from the mouth or nose. If these measures fail, perform endotracheal intubation or cricothyrotomy. Do not leave the patient unattended, especially when in a supine position.

After the airway is secured and the patient stabilized, perform a secondary survey to obtain an abbreviated history of the present injury or illness and to extract pertinent information, such as a history of allergies, any medications taken, the medical history, the last oral intake, and the events leading up to the injury. If the patient has sustained significant head or facial trauma, determine if the patient experienced loss of consciousness or has symptoms of nausea, vomiting, visual disturbances, or headache. Assess the patient's pain, and ask about its character, onset, location, radiation, duration, and exacerbating or alleviating factors.

A systematic approach to examination in oral and maxillofacial emergencies allows for efficient collection of relevant information. Clean the face, mouth, head, and neck of blood and debris; this unmasks soft tissue injuries and facilitates diagnosis. Next, observe the head, neck, and face, and note any asymmetry. Palpate all facial bones, temporomandibular joints, muscles, and areas of suspected injury for tenderness, crepitus, swelling, instability, dislocation, fracture, and foreign bodies. Bimanually palpate the lips, cheeks, and floor of the mouth. Observe the patient slowly opening the mouth, and examine for the range of motion and any deviation with opening. Evaluate facial soft tissue swelling for hematoma formation, especially in areas associated with underlying cartilage, such as the ear and nose.

Perform an intraoral examination of the lips, cheeks, mouth, tongue, hard palate, soft palate, and pharynx. Examine facial lacerations carefully to determine if they penetrate into the oral cavity or contain foreign material. Gently retract the lips with the teeth closed to examine the soft tissues and occlusion. Examine the dentition for fractures and mobility. Observe the gingiva for bleeding, swelling, trauma, color, firmness, and recession.

DIAGNOSIS AND TREATMENT OF FACIAL INJURIES

TEMPOROMANDIBULAR JOINT DISORDERS

Temporomandibular Joint Dislocation

Temporomandibular joint (TMJ) dislocation is more commonly referred to as *mandibular dislocation*. Dislocation of the mandibular condyles causes inability to close the mouth and may result from external trauma or, more frequently, from mandibular

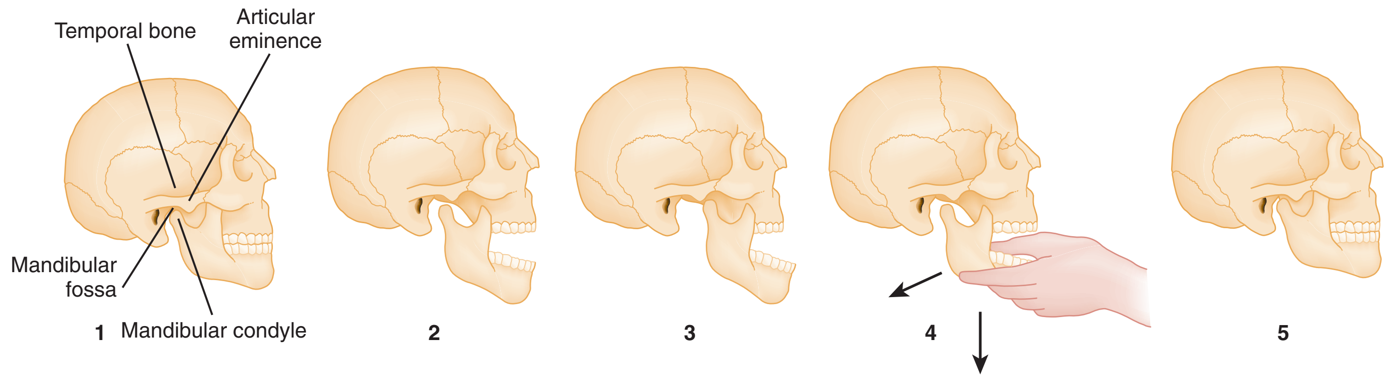

FIGURE 20-1 Reduction of temporomandibular joint dislocation. The temporomandibular joint is shown in both normal and dislocated positions. **1,** Closed position, with the mandibular condyle resting in the mandibular fossa behind the articular eminence. **2,** In maximally open position, the condyle is just under and slightly behind the eminence. **3,** In dislocated position, the condyle moves forward and upward slightly above the eminence; muscle spasm then occurs. **4,** To reduce dislocation, place thumbs intraorally and lateral to the lower molars, and apply downward pressure to the lower molar ridge area near the jaw angle in a downward and backward direction. **5,** When the condyle has cleared the articular eminence, muscle contraction will return the jaw to a normal closed position. The patient sits on a low chair with the back straight. Face the patient, wrap the thumbs with gauze for protection, place them in the mouth on the back molars, and then push down and back. A rocking motion may help. *(From Amsterdam JT: Oral medicine. In Marx JA, Hockberger RS, Walls RM, editors:* Rosen's emergency medicine: concepts and clinical practices, *6th ed, Philadelphia, 2006, Mosby, p 1041.)*

hyperextension. This may occur while yawning, taking a large bite when eating, vomiting, laughing, or performing oral sex. This condition may be bilateral or, less often, unilateral, and it frequently recurs.[8]

Although posterior, lateral, and superior dislocations occur, anterior dislocation is most common, and it occurs when the mandibular condylar heads and their respective cartilaginous discs move anteriorly along the articular eminence out of the glenoid fossa and become locked in the anterosuperior aspect of the articular eminence of the temporal bone. Dislocation is complicated by involuntary spasms of the muscles of mastication, including the masseter, temporalis, and medial pterygoid, thereby making it extremely difficult for the condyles to return to their normal position during reduction.[1,8,37]

Diagnosis. Diagnosis of mandibular dislocation is not difficult, but without the benefit of a medical history the disorder can be confused with an acute dystonic reaction. Patients present with difficulty speaking, acute jaw pain anterior to the ear, malocclusion, and inability to open or close the mouth. They may be extremely uncomfortable and anxious. Patients present with an open mouth and a prominent-appearing lower jaw. In a unilateral dislocation, the chin appears to deviate to the side opposite the dislocation. More frequently, dislocation is bilateral without chin deviation. Clinically, the patient may have a palpably absent condyle within the glenoid fossa and visible periauricular depression.[8,27,28]

Ideally, with traumatic dislocation, radiographs are performed to eliminate a condylar fracture. In the wilderness, radiography is impossible, and fractures are excluded on the basis of clinical examination.

Treatment. A variety of methods may be attempted to reduce anterior mandibular dislocations without procedural sedation or local anesthesia. The goal is to reduce the mandibular condyle to the glenoid fossa from its current location anterior to the articular eminence of the temporal bone. This requires relaxing the muscles of mastication, and is accompanied by properly positioning the provider and patient so that direct pressure can be placed on the mandible during reduction[8] (Figure 20-1).

The classic reduction technique is performed having the patient seated lower than the provider. Stand facing the seated patient, and ask the patient to open the mouth widely against resistance; this reduces muscle tone of the elevator muscles through reciprocal inhibition and allows for concurrent manual reduction. Simultaneously exert a maximal downward reduction force with the use of gloved thumbs on the patient's lower molars or mandibular ridge while exerting steady and constant downward pressure by moving the mandible down, then posteriorly, and then up with the remainder of the fingers and hand around the jaw and chin, levering upward. Downward pressure clears the condyle of the articular eminence, and posterior pressure repositions the condyle within the glenoid fossa. This technique may be difficult if muscle spasm is severe[8,28] (Figure 20-2).

For the recumbent approach, lay the patient on his or her back, and standing either behind or in front of the patient, apply caudal pressure on the mandibular ridge[8] (Figure 20-3).

For the posterior approach, seat the patient either on the floor or in a chair, and stand behind and above the patient. Place the thumbs on the retromolar gums posterior to the patient's last molar along the mandibular ramus, and exert downward pressure on the mandible[8] (Figure 20-4).

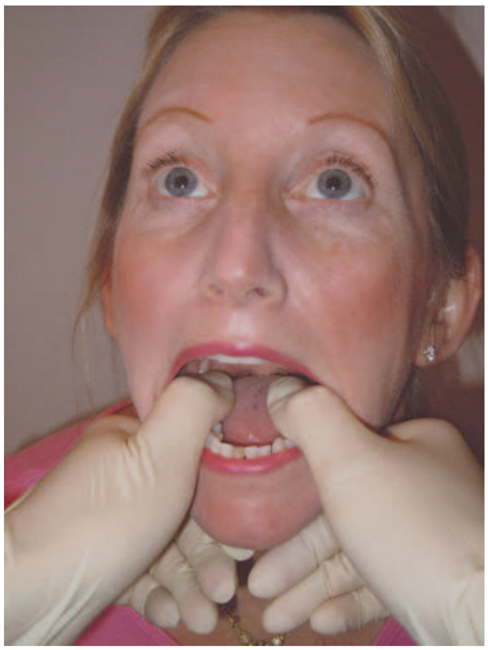

FIGURE 20-2 Classic technique for reduction of anterior mandibular dislocation.

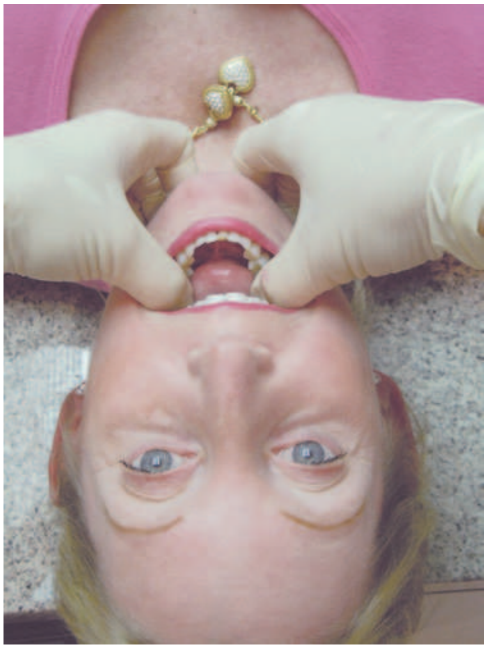

FIGURE 20-3 Recumbent approach for reduction of anterior mandibular dislocation.

FIGURE 20-4 Posterior approach for reduction of anterior mandibular dislocation.

For the ipsilateral approach, use a sequential combination of intraoral and extraoral manipulation. Focus on one side of the jaw at a time. Stand at the patient's side, and, while stabilizing the patient's head with one hand, use the thumb of the other hand to exert external downward pressure on the displaced mandibular condyle, located anterior and inferior to the zygomatic arch. If this is unsuccessful, exert downward pressure intraorally on the ipsilateral lower molar teeth or the mandibular ridge. If this is still unsuccessful, a combination of intraoral downward pressure on the posterior molars, along with external downward pressure on the mandibular condyle, may be successful[8,43] (Figure 20-5).

For an alternative manual method, place your fingers over the periauricularly dislocated condyle and then gently massage the musculature posteriorly and inferiorly to induce relaxation of the muscles and reduction of the condyle into the glenoid fossa.[8,21]

For the wrist pivot method, face the seated patient while standing, and place your thumbs on the apex of the patient's chin while wrapping the remainder of the fingers laterally over the mandible onto the inferior molars of the patient. With this method, push upward with the thumbs on the patient's chin while simultaneously pushing downward on the body of the mandible with the remaining fingers in a pivoting action. Flex your wrists, and move in the direction of ulnar deviation. The pivoting action uses the angle of the jaw as a fulcrum, resulting in rotation of the mandibular condyles back into the glenoid fossa. To prevent mandibular injury, this technique must be applied to both sides of the jaw concurrently[8,27] (Figure 20-6).

For the gag reflex method, elicit the patient's gag reflex by stimulating the soft palate. This results in relaxation of the muscles of mastication and descent of the mandible caudally as part of the reflex. During the gag reflex, jaw muscles relax, causing transient descent of the mandible inferiorly and forcing condyle reduction back into the glenoid fossa.[2,8] Alternatively, have the patient open the mouth widely or against resistance to cause reciprocal relaxation of the elevator muscles to allow for simultaneous manual reduction.

FIGURE 20-5 Ipsilateral extraoral approach for reduction of anterior mandibular dislocation.

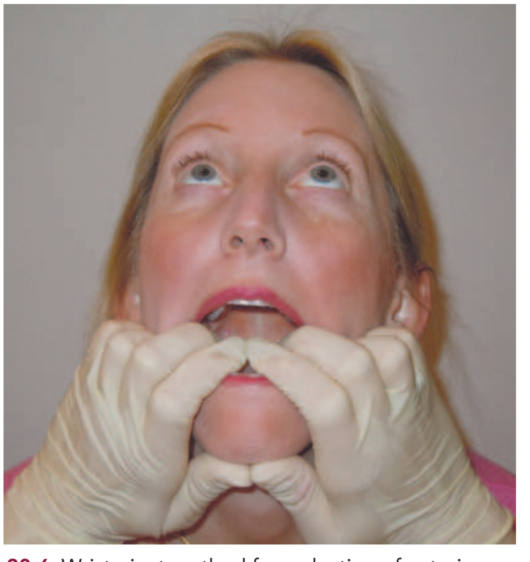

FIGURE 20-6 Wrist pivot method for reduction of anterior mandibular dislocation.

FIGURE 20-7 Masseteric nerve block for reduction of anterior mandibular dislocation. The index finger locates the zygomatic arch and moves inferiorly until it reaches the mandibular notch at a point halfway between thumb and middle finger. The needle is introduced posterior to the index finger to hit the neck of the condyle.

With the nerve block method, the peripheral masseteric nerve is anesthetized where it has passed through the mandibular notch and before it penetrates the masseter. The deep temporal nerve may be anesthetized by locating the anterior temporalis muscle within a depression just above the zygomatic bone. The greater wing of the sphenoid bone is located deep below this portion of the muscle. The anesthetic needle is directed into this area until the needle hits the sphenoid bone and the anesthetic agent is deposited. These blocks result in reduction of pain and muscle spasm, thereby allowing manual reduction. Administration of a local anesthetic agent around the TMJ capsule may diminish joint pain but will not diminish muscular pain or spasm[51] (Figure 20-7).

Complications of reduction techniques include intraoral trauma from significant downward pressure on the teeth and gums, fractures, joint cartilaginous injuries, and torn ligaments and muscles. The provider's fingers may be injured during intraoral reduction techniques when the jaw snaps shut after successful reduction. Using gloves, gauze, bite blocks, and plastic finger splints, as well as placing the thumbs on the mandibular ridge rather than the teeth or gums, during reduction can prevent this complication.[8]

After reduction, advise patients to apply ice or cool compresses to the TMJ, avoid hyperextending the mandible, take a nonsteroidal antiinflammatory agent such as ibuprofen, and maintain a soft diet for 1 week. Wrap a bandage around the head and jaw to prevent mandible hyperextension and to limit jaw movement.[8,16]

Internal Derangements of the Temporomandibular Joint

There is a cartilaginous disc interposed between the articulating components of the movable mandibular condyloid process and articular eminence of the temporal bone. The disc stabilizes the joint and allows for rotational movements.

Diagnosis. The intraarticular cartilaginous disc may displace anteriorly, which results in joint dysfunction and abnormal joint sounds such as clicking or popping. When closing the mouth, if the cartilaginous disc of the TMJ displaces anteriorly relative to the mandibular condyle with reduction to its normal position when the mouth opens, clicking of the joint may occur. This may manifest as a "pop," the sound heard when the condyle moves under the anteriorly displaced disc; this may or may not be associated with joint pain and dysfunction[25] (Figure 20-8).

However, if the cartilaginous disc is displaced but does not return to its normal position with mouth opening, the patient may experience occlusive instability associated with jaw locking. There are two types of lockjaw. With closed lock, the mandibular condyle is unable to slide under the anteriorly displaced disc. With open lock, the mandibular condyle is unable to slide back over the disc into its normal position.[36] Clinically, there is joint tenderness on palpation, and the chin may be deviated toward the affected side on attempted mouth opening. Functionally, the disc is trapped anterior to the mandibular condyle and the ligaments are stretched and become inflamed. This can occur spontaneously while eating or talking, but also may be present on awakening from sleep, or be associated with mandibular trauma.

Treatment. The provider can assist the patient to self-reduce a closed lock. To do this, the patient should close the mouth until the teeth almost touch, move the mandible laterally as far as possible to the affected side, and finally swing the mouth fully open.[36] If these maneuvers fail, consider manual reduction using TMJ reduction techniques. Spasm of muscles of mastication may cause a similar restriction in mandibular function, but typically the affected muscles are firm and extremely tender; alternatively, with closed lock, the muscles are usually normal.

EPISTAXIS

Although most cases of epistaxis are trivial, some become life-threatening, because aspiration can lead to respiratory compromise and extensive blood loss can result in hemodynamic instability. Therefore, the condition should never be neglected. It is more common among the young and the elderly. Most causes are traumatic and occur in the winter.[37] Spontaneous epistaxis is

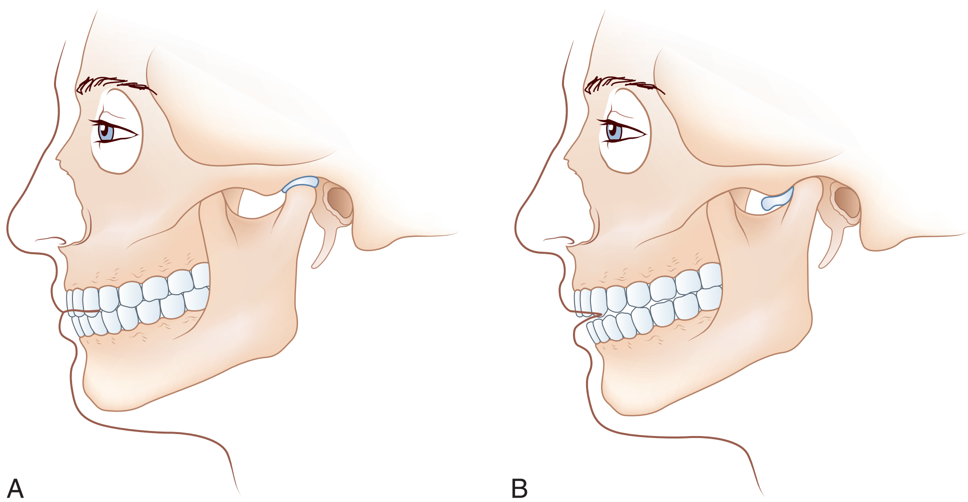

FIGURE 20-8 **A,** The normal temporomandibular joint with cartilaginous disc. **B,** In a closed lock, the ligaments have stretched, and the disc is trapped anterior to the condyle.

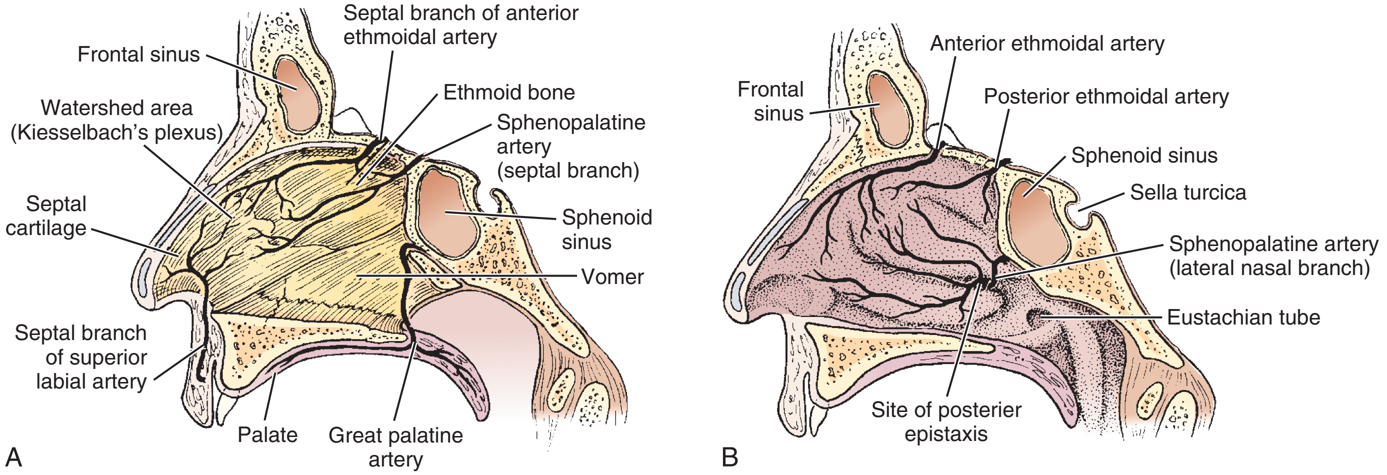

FIGURE 20-9 **A,** Vascular supply to the septum. The most common site of anterior epistaxis is the area labeled *Kiesselbach's plexus.* **B,** Vascular supply to the lateral wall. The most common site of posterior epistaxis is the sphenopalatine artery as it emerges posterior to the middle turbinate. *(From Maceri DR: Epistaxis and nasal trauma. In Cummings CW, editor:* Otolaryngology: head and neck surgery, *2nd ed, St Louis, 1993, Mosby, p 728.)*

more common in cold, dry, dusty, or smoke-filled environments. Epistaxis is normally classified as anterior or posterior, depending on the anatomic location. A particularly rich collection of vessels and common site of anterior nosebleed is Kiesselbach's plexus on the lower anterior part of the nasal septum (i.e., Little's area). Ninety percent of episodes of epistaxis occur in this area. Posterior bleeding originates primarily from a branch of the sphenopalatine artery called the *posterior nasal artery,* which forms part of Woodruff's plexus[19,49] (Figure 20-9). Anterior epistaxis may be managed definitively in the wilderness, but posterior epistaxis requires immediate evacuation because of continued hemorrhage and the potential for airway compromise.[29]

Evaluation

The initial evaluation includes determining if bleeding is unilateral or bilateral and whether it is coming from an anterior or posterior site. A nosebleed usually occurs on one side of the nasal cavity. However, with profuse bleeding, blood can pass behind the nasal septum and also appear on the unaffected side. Most individuals bleed from an anterior site, which is visualized on intranasal speculum examination; with posterior epistaxis, the bleeding site cannot be seen on intranasal examination.

Treatment

Have the patient sit upright with the head tipped slightly forward. This maneuver decreases blood flow through the nasopharynx and allows blood to drip passively out of the nose rather than flowing posteriorly and causing choking, aspiration, and vomiting of swallowed blood. Have the patient blow the nose to remove clots immediately before examination. Warm saline lavage of each nostril may accelerate activation of the clotting cascade and allow for better visualization of the bleeding areas.[49] Bleeding may resume, but there will be improved access and visibility for application of a vasoconstrictor drug or chemical cautery. Ask the patient if he or she has placed anything inside the nose to stop the bleeding, so that it can be removed before additional packing is placed. Examine the nasal cavity with a nasal speculum to determine the site of bleeding. If anterior bleeding is suspected, instruct the patient to pinch the fleshy alae tightly against the cartilaginous septum of the nose between the thumb and index finger for at least 20 minutes. Applying cold compresses to the nose and instructing the patient to suck on ice can improve this.[39] Pinching the bony bridge of the nose does not provide direct pressure on the bleeding vessels. Alternatively, hands-free techniques that involve using commercial or improvised (e.g., from taping together two tongue depressors) external pressure devices or clips work well.[19]

If nose pinching does not stop the bleeding, apply a local anesthetic and vasoconstrictor to the nasal mucosa over Little's area. Anesthetic preparations include topical tetracaine 1%, cocaine 1% to 4%, lidocaine 5%, ephedrine 5%, and aqueous epinephrine 1:1000. Vasoconstrictive nasal sprays include phenylephrine 0.5% (Neo-Synephrine) and oxymetazoline 0.05% (Afrin). Apply anesthetics and vasoconstrictors by drip or spray, on a cotton pledget, or with a cotton-tipped applicator. Objects placed in the nose should be inserted along the floor of the nose and have a string attached or include another method for easy removal. Avoid pushing material laterally into the turbinates or superiorly toward the cribriform plate. Leave the vasoconstrictor in place until it effectively staunches bleeding. This may take from 10 minutes to 24 hours.[29]

Epistaxis refractory to pressure and topical vasoconstrictors may require chemical cauterization using a silver nitrate (75% concentration) stick that reacts to the mucosal lining to produce local chemical damage. After applying a topical anesthetic, apply the cautery stick to the bleeding point with firm pressure for 5 to 10 seconds. Apply cautery only to one side of the septum, and be careful not to perforate the septum by applying too much pressure.[13]

When there is more vigorous anterior nasal bleeding, nose pinching, topical chemical vasoconstrictors, and cautery may not be effective. In such an instance, inject the anterior bleeding site with 0.5 to 1 mL of lidocaine 0.5%, 1%, or 2% that contains 1:100,000 epinephrine. This tamponades bleeding and provides a vasoconstrictive effect. Alternatively, insert into the nares directly over the bleeding site a small piece of absorbable or degradable material that does not require removal. Such materials include oxidized regenerated cellulose (Oxycel or Surgicel), purified bovine collagen foam or paste (Gelfoam), microfibrillar collagen (Avitene), porcine gelatin (Surgiflo), bovine gelatin-human thrombin (FloSeal), QuikClot, recombinant factor VIIa, topical thrombin, hemostatic matrix, nosebleed gauze, and fibrin glue.[19,33,34,39] When bleeding has stopped, instruct the patient not to blow the nose or probe the area for 48 hours. After the bleeding episode is over, increasing the humidity, warming inspired air, and moisturizing the nasal mucosa with topical gels, lotions, and ointments help to prevent recurrent bleeding.

Treat persistent epistaxis by packing the anterior cavity or posterior cavity, or both. If bleeding is not controlled by the previous methods, insert a lubricated anterior nasal sponge or tampon. Improvise with gynecologic tampons, sponges, and gauze. Current commercial options include Merocel, Medtronic, Rapid Rhino, ArthroCare, Weimert Epistaxis Packing, and Rhino Rocket[34] (Figure 20-10).

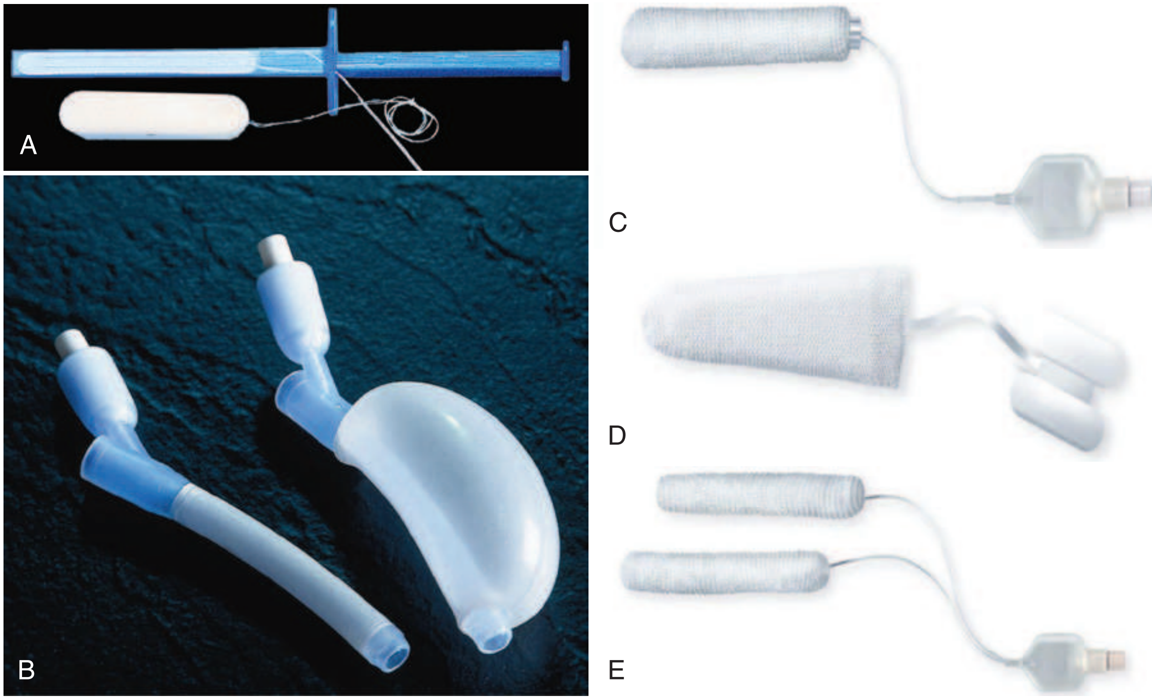

FIGURE 20-10 Commercial nasal packing is commonly used in place of traditional gauze packing. **A,** Rhino Rocket. **B,** Epi-Stop Balloon Catheter. **C,** Rapid Rhino. **D,** Rapid-Pac. **E,** Rapid Rhino Dual Nasal Pack. *(**A** and **B** courtesy Shippert Medical, Centennial, Colorado; **C** to **E** courtesy ArthroCare Corporation, Austin, Texas.)*

If a nasal tampon fails to stop the bleeding, then formal anterior packing is necessary. The basic technique involves placing a 12-mm (0.5-inch) petrolatum- or antibiotic-impregnated strip of gauze into the nasal cavity. An adult patient requires 90 to 120 cm (3 to 4 ft) of such gauze to pack the nose adequately and tamponade bleeding. Layer the gauze in tiers beginning on the nasal floor and proceeding to the roof of the nose. Leave both ends of the gauze outside of the nose and taped to the face to prevent inadvertent aspiration. Improvised anterior nasal tamponade can be accomplished with a Foley catheter (Figures 20-11 and 20-12).

Nasal packing blocks sinus drainage and can predispose to sinusitis. Some studies in the literature contradict the following recommendation when in an emergency department setting, but we recommend that any patient who has the nose packed in the field be placed on a prophylactic antistaphylococcal antibiotic, such as 875 mg of amoxicillin with 125 mg of clavulanic acid (Augmentin) by mouth three times daily, 500 mg of dicloxacillin by mouth four times daily, 150 to 450 mg of clindamycin by mouth four times daily, or 160 mg of trimethoprim and 800 mg of sulfamethoxazole (Bactrim) by mouth twice daily until the packing is removed after 48 hours.[29]

If the bleeding site is posterior and cannot be visualized, insert a formal posterior nasal pack, commercially available nasal balloon device, or Foley catheter. These methods rely on direct pressure or blood accumulation within the nasal cavity, which leads to tamponade. Placing a formal posterior nasal pack is difficult and involves gently inserting a lubricated soft tube into each nostril until the ends can be visualized in the back of the throat and then grasping the pack with a hemostat and bringing it out through the mouth. Use Foley catheters, nasogastric tubes, chest tubes, or improvised substitutes. Prepare a cylindrical pack of 10- by 10-cm (4- by 4-inch) gauze, and hold it in shape by tying three silk sutures around it and leaving the ends approximately 10 cm (4 inches) long. The pack should be the same diameter as a circle made by the patient's thumb and forefinger (i.e., the "OK" sign). Attach the two end sutures to the oral ends of the catheters. Pull the nasal ends of the catheters carefully back out of the nose until the pack is firmly positioned against the posterior aspect of the nasal cavity above the soft palate. Detach the sutures from the catheters, and tie them over a bolster placed underneath the nose. Secure the middle suture outside the mouth to allow for removal 48 hours later (Figure 20-13).

Commercially available preshaped nasal balloons (e.g., Brighton, Nasostat, Naso-Blymp, Simpson plug, and EpiStat nasal catheter) are manufactured specifically for treatment of posterior epistaxis. They have a postnasal balloon and mobile anterior balloon that are inflated independently. These are contraindicated in cases of severe head trauma, basilar skull fracture, or suspected craniofacial fractures that involve cerebrospinal fluid (CSF) rhinorrhea[19,34] (Figure 20-14).

A standard 14F to 16F Foley urinary catheter with a 30-mL balloon can function as a posterior pack. Trim the distal catheter tip to prevent irritation. Insert the lubricated catheter through the nose into the posterior pharynx until it is visualized in the oropharynx; inflate with a minimum of 3 to 5 mL of air or saline, gently pull it forward into the nasopharynx until the balloon engages, and hold it in position by clamping the external end with a hemostat or an umbilical clamp. Balloons filled with air tend to deflate over time, and those filled with water may rupture and cause aspiration.[13,49] Pack the anterior nasal cavity with a nasal sponge or gauze.

Hot water irrigation has been documented as an alternative strategy for posterior epistaxis. Occlude the posterior pharynx with a balloon catheter, and irrigate the nares with heated water (i.e., 45° C to 50° C [113° F to 122° F]). This reduces blood flow by causing mucosal edema and clears blood clots from the nose.[19,34]

FACIAL BONE FRACTURES

Anyone suffering from head or facial injury should be closely examined for facial fractures. Proper management includes a detailed examination for signs and symptoms of bony fractures, stabilizing measures, and a plan for repair. The vast majority of facial fractures are not surgical emergencies, and if they are attended to within 2 weeks, can be properly treated without long-term sequelae. In the acute setting, the level of concern should be higher for facial fractures that occur with visual loss, entrapment of extraocular muscles, CSF leak, and airway edema.

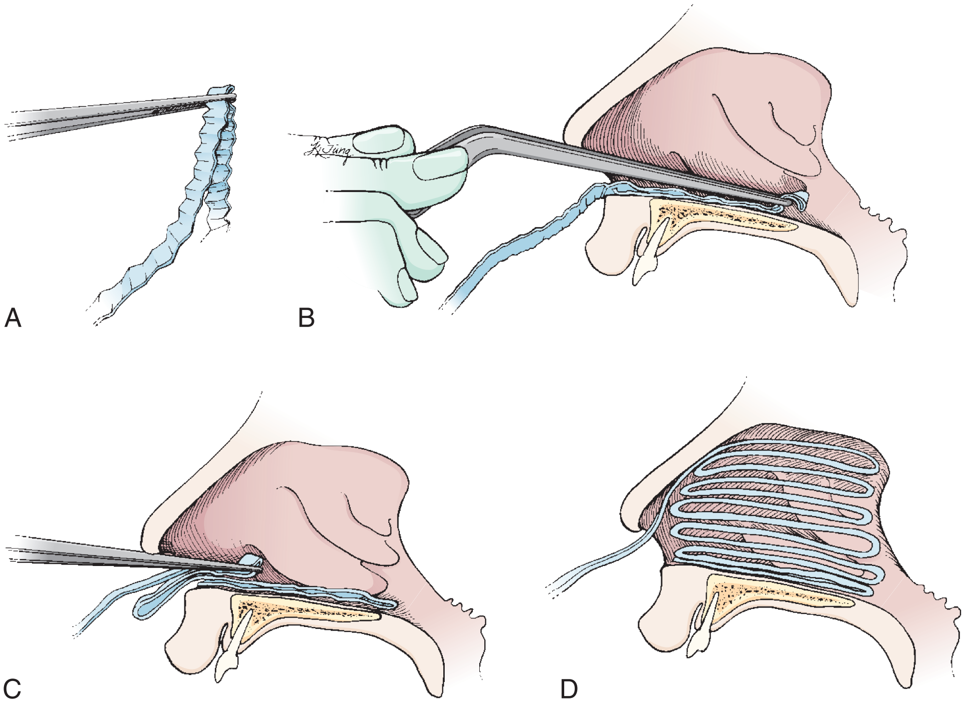

FIGURE 20-11 The key to placing an anterior nasal pack that will control epistaxis adequately and stay in place is to lay the packing into the nasal cavity in an "accordion" manner so that part of each layer of packing lies anteriorly, thereby preventing the gauze from falling posteriorly into the nasopharynx. **A,** Grasp the first layer of 0.25-inch petrolatum gauze strip approximately 2 to 3 cm (0.8 to 1.2 inches) from its end. **B,** Place the first layer on the floor of the nose through the nasal speculum (not pictured), and then withdraw the bayonet forceps and the nasal speculum. **C,** Reintroduce the nasal speculum on top of the first layer of packing, and place a second layer in an identical manner. After several layers have been placed, it is often useful to reintroduce the bayonet forceps to push the previously placed packing down onto the floor of the nose to make it tighter and more secure. **D,** A complete anterior nasal pack can tamponade a bleeding point anywhere in the anterior nasal cavity and will stay in place until the clinician or patient removes it.

Upper Face Fractures

Nasal Fractures. Nasal bones are the most commonly fractured facial bones. The projected and prominent nasal vault is a delicate, pyramid-shaped structure made up of paired nasal bones centrally and the frontal processes of the maxilla laterally. The remainder of the nose is composed of interconnecting cartilaginous structures that provide stability and support.

Nasal fracture typically manifests with midface swelling, epistaxis, periorbital ecchymosis, subconjunctival hemorrhage, and bony nasal deformity. A few hours after injury, facial swelling may preclude appreciation of obvious deformity. Functional changes in breathing and anosmia may also occur. Sweet or salty watery drainage suggests CSF leak.[10]

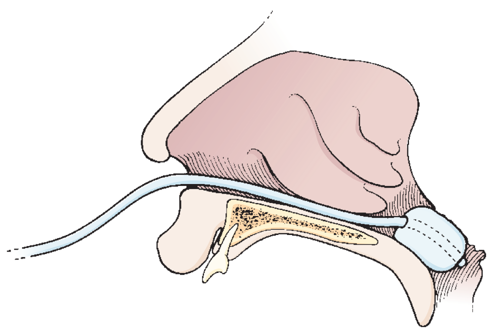

FIGURE 20-12 A Foley catheter is placed into the nasopharynx, inflated with water, and retracted into position. The distal tip of the catheter has been cut off. Place an anterior pack (not shown) around the catheter. Protect the ala and columella with gauze padding, and apply a plastic umbilical clamp or nasogastric clamp to the catheter to maintain slight tension on the balloon.

After soft tissue injuries and epistaxis have been appropriately managed, examine the nose to determine the extent of nasal trauma. This requires an external examination followed by an internal view using a light source. Deviation or fracture of the nasal septum should be noted, along with the presence of a septal hematoma. CSF fluid rhinorrhea, which is appreciated on internal nasal examination as clear fluid, is indicative of skull base fracture and/or intracranial trauma. CSF fluid separates from blood when the liquid is placed on filter paper and produces a clinically detectable double-ringed, or halo, sign (Figure 20-15).

When palpating the nasal bridge, the provider may appreciate bony crepitus, nasal segment mobility, point tenderness, and displacement that may not be visible on external examination. Remove intranasal clots with cotton swabs. Close deep intranasal lacerations with absorbable sutures or cover with Oxycel, Gelfoam, Surgicel, or Avitene to control bleeding.[31]

Advise patients to apply ice to the area and to keep the head elevated to reduce soft tissue swelling. Most surgeons prefer to treat nasal fractures either immediately before significant edema has evolved, or after the edema has subsided, within 5 to 10 days after injury. Immediate treatment and evacuation are not necessary unless there are complications, such as persistent epistaxis, difficulty breathing, or deeper lacerations that require definitive repair. If the nose appears to be straight after swelling has subsided and the patient can breathe easily through both nostrils, further treatment may not be necessary. If the nose remains deformed after swelling has resolved or if the patient experiences breathing problems, refer the patient to an otolaryngologist or a plastic surgeon within 3 to 5 days so that the

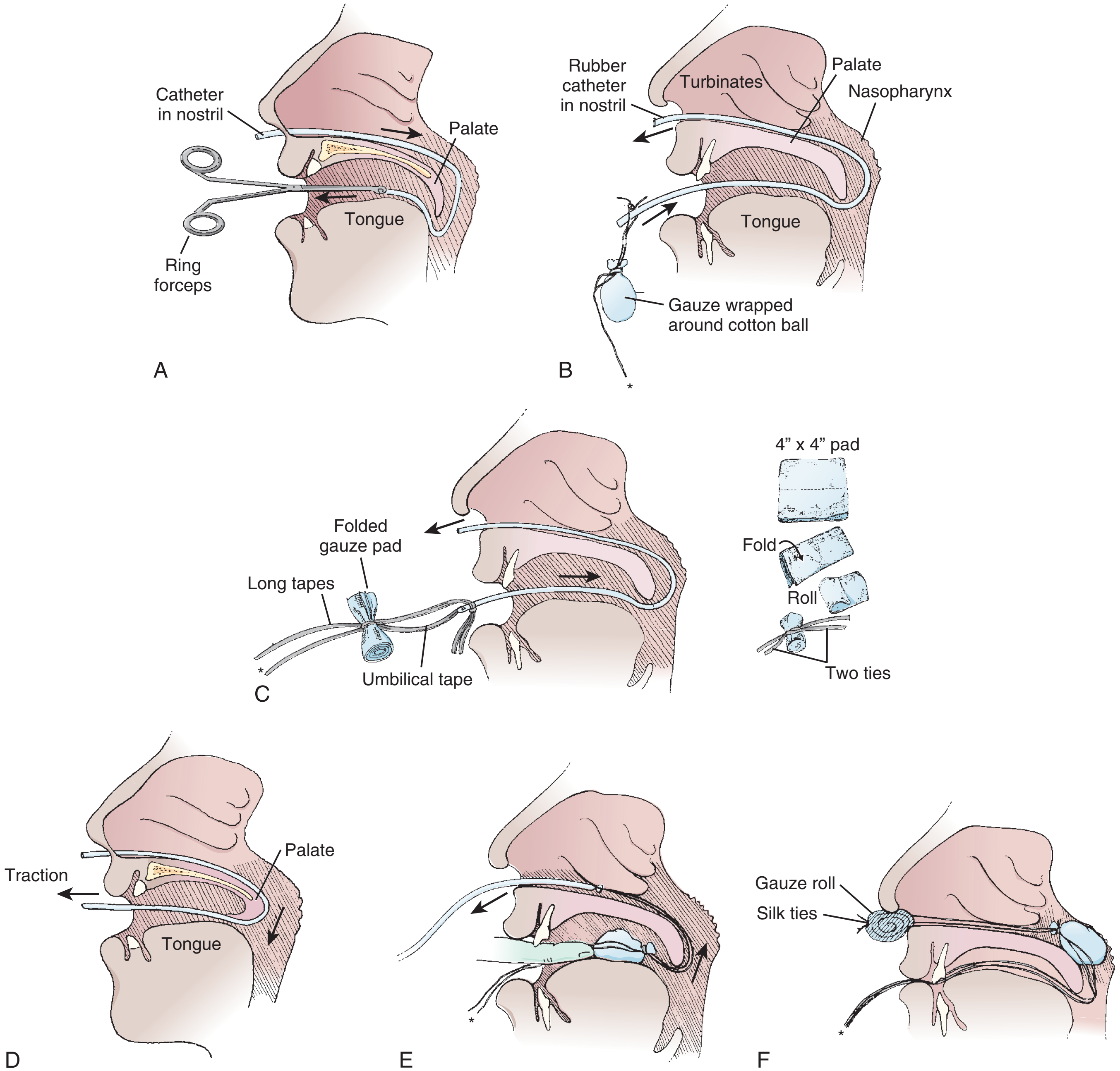

FIGURE 20-13 Traditional posterior nasal pack. **A,** After applying topical anesthesia, pass a red rubber catheter through the nose, carefully grasp it in the oropharynx with ringed forceps, and bring it out through the mouth. **B,** Make a posterior nasal pack by wrapping a cotton ball in a 4 × 4 inch gauze pad and tying two long silk sutures or umbilical tapes around the neck of the pack. Leave one tie long so that it can be taped to the cheek until it is needed for removal of the pack. **C,** Alternatively, fold a gauze pad, roll it into a cylinder, and tie it with two strings. Use two of the long strings to tie the pack to the tip of the catheter, and use the other two to remove the pack. **D,** As an option, use a second catheter that has been passed through the nonbleeding side and brought out through the mouth to retract the palate forward to help with the placement of the pack (not shown). **E,** Remove the optional "retraction" catheter after the pack is in proper position. Digitally guide the pack into the nasopharynx. **F,** Use a gauze roll to secure the pack to the nose, and tape the rescue ties to the cheek.

bones do not heal while misaligned. Children with nasal fractures may have premature closure of sutures and uneven growth; therefore, a consultant should evaluate the injury, preferably within 4 days of its occurrence[10,30] (Figure 20-16).

Digital manipulation of a displaced nasal bone fracture can in some instances quickly reduce the fracture with minimal effort. It is important to note that due to swelling at the time of injury, deformity may result even with proper reduction.[31,37] With any nasal fracture, make a protective splint by cutting a triangular piece of a SAM splint large enough to fit the nasal contours. Rest the splint on the adjacent part of the face without placing pressure on the nasal bridge. Secure the splint with strips of adhesive tape. Do not pack the nose unless it is necessary to control epistaxis or drain a septal hematoma. No antibiotics are needed for a nasal fracture unless packing is placed. If packing is required in a wilderness setting to control epistaxis or after drainage of a septal hematoma, administer 500 mg of penicillin V potassium or amoxicillin by mouth four times a day for 5 days.[10]

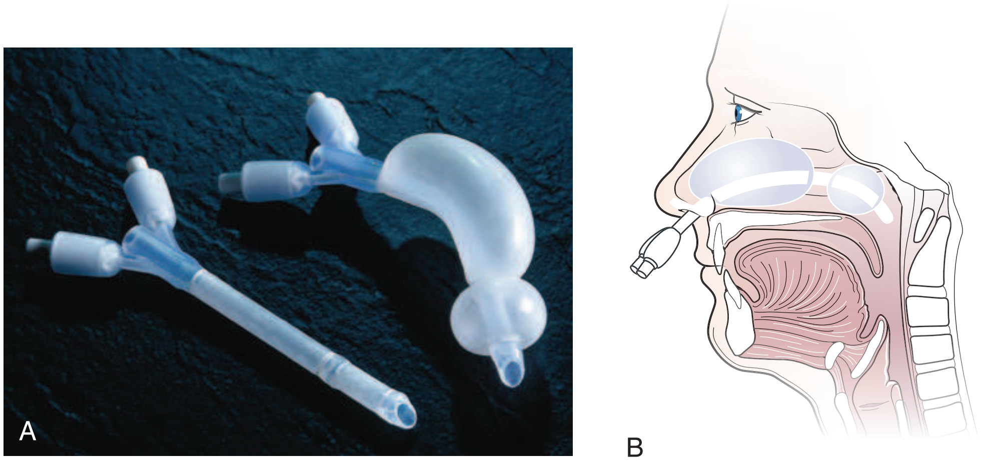

FIGURE 20-14 **A,** The Epi-Max balloon catheter. The balloon tamponade device serves as both an anterior and posterior pack. It is easily inserted and is often successful for temporarily controlling posterior epistaxis in the emergency department. **B,** The inflated Epi-Max. If the balloon pack is used for more than a few days, protect the nasal opening with a piece of gauze, because skin breakdown is possible. *(Courtesy Shippert Medical, Centennial, Colorado.)*

Anterior nasal septal trauma may cause tearing of the submucosal blood vessels. If the mucosa remains intact, blood will accumulate between the septal cartilage and mucoperichondrium and cause formation of a hematoma, either immediately or within the first 24 to 72 hours after injury. Septal hematoma appears as a deviation, bulging, or widening of the nasal septum. Symptoms include nasal obstruction, pain, rhinorrhea, and fever (Figure 20-17).

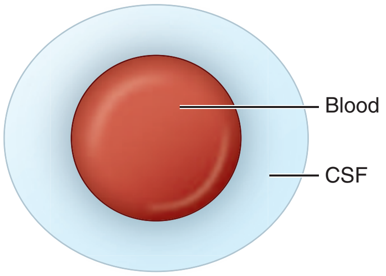

FIGURE 20-15 CSF fluid separates from blood when the liquid is placed on filter paper and produces a clinically detectable double-ringed, or halo, sign.

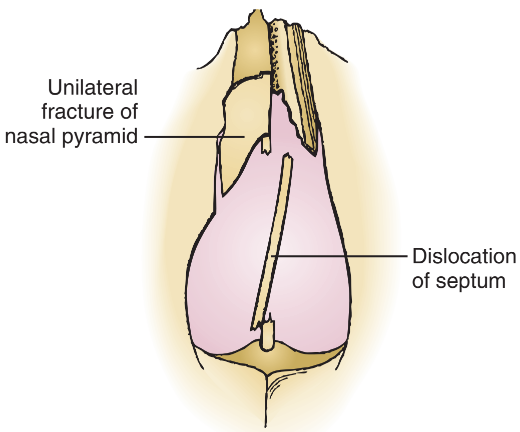

FIGURE 20-16 Nondisplaced and minimally displaced nasal fractures often do not require manipulation, but the true extent of deformity is often difficult to appreciate initially. Note that the septum may require subsequent intervention. Reduction of a depressed and dislocated nasal bone fracture is usually performed after 3 to 7 days, when swelling has subsided and the true deformity is obvious.

Inspect the nasal septum for asymmetry, swelling, pain, and a fluctuant area. The mucosa of the fluctuant area will usually have a bluish or reddish hue. The bulging area of the septum, when compressed with a cotton-tipped applicator, feels boggy and may be temporarily indented by the pressure. Increased mobility that occurs with palpation with the applicator suggests septal fracture. Insert a gloved small finger into each side of the nares, and palpate the entire septum for swelling, fluctuance, and crepitus.

Nasal cartilage receives nourishment from the surrounding perichondrium and the supporting tissues. Septal hematoma separates the cartilage from the nutrient-rich perichondrium and requires urgent drainage to prevent complications such as septal perforation, necrosis, and loss of nasal support, which can result in a saddle-nose deformity. Bacterial growth of *Staphylococcus aureus, Streptococcus pneumoniae,* and group A β-hemolytic streptococcus within stagnant blood may form an abscess, which can destroy the septum.[10]

Before drainage, anesthetize the bulging area by infiltrating with a local anesthetic such as lidocaine 1% or by applying a topical anesthetic such as benzocaine 20%. Aspirate the hematoma with an 18-gauge needle attached to a syringe, or make a small incision at the most inferior (dependent) aspect of the hematoma. Evacuate the blood clot and reapproximate the perichondrium to cartilage, but leave the incision open. It may be necessary to excise a small amount of mucosa to prevent premature closure and blood reaccumulation. Pack the nasal cavity with 0.5-inch antiseptic-impregnated gauze or petrolatum to prevent recurrent bleeding and to maintain apposition of the perichondrium to the cartilage (Figure 20-18).

Frontal Sinus Fractures. The frontal bone is one of the strongest parts of the craniofacial skeleton. It overlies the frontal

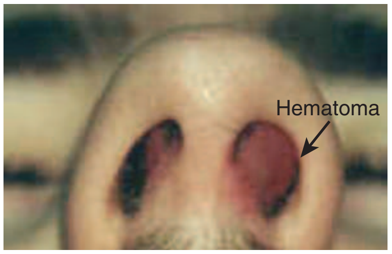

FIGURE 20-17 Nasal septal hematoma requiring drainage.

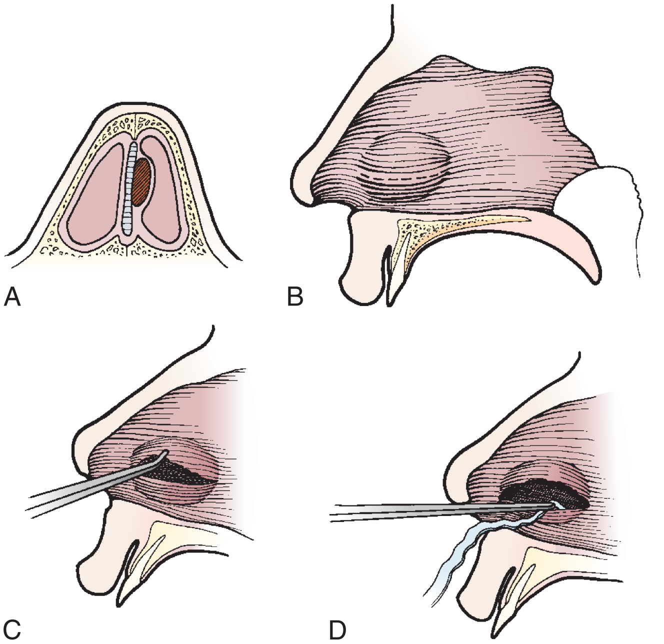

FIGURE 20-18 **A,** A small, left-sided septal hematoma. **B,** After applying appropriate topical anesthesia (which can be supplemented with local infiltration, if necessary), make a horizontal incision through the mucosa and perichondrium that cover the hematoma. **C,** Use a small cup forceps or scissors to remove enough mucosa to prevent premature closure of the wound and reaccumulation of hematoma. **D,** Place a sterile rubber band as a drain, and pack the naris.

sinus, which adds additional protection for the brain. Any frontal bone or sinus fracture should be evaluated for underlying brain, dura, or CSF involvement. If a forehead laceration is present, it is explored for visible bone, and if present, characteristics of the bony fractures are noted. If clear, watery drainage is seen, this could be indicative of CSF leak. These wounds are irrigated and closed in layers until the patient can be seen at a tertiary center for definitive care. The patient will require imaging to investigate the fracture further and to determine whether surgical repair is necessary.

Naso-Orbito-Ethmoid Fractures. Naso-orbito-ethmoid fractures rarely occur. They are extremely complex fractures involving the nasal skeleton, medial orbital walls, and interorbital area. Clinical signs and symptoms include periorbital ecchymosis, proptosis, dystopia, anosmia, nasal obstruction, enophthalmos, subcutaneous emphysema, subconjunctival hemorrhage, edema, lacerations, a flattened nasal bridge, rhinorrhea, and blindness. Medial canthal ligament attachments may become disrupted, resulting in telecanthus or abnormally widely spaced eyes.[22,47] Naso-orbito-ethmoid fractures should be referred to tertiary centers for proper imaging, evaluation, and possible surgical management, which can be extensive.

Midface Fractures

Midface fractures include isolated orbital fractures, zygomaticomaxillary complex (ZMC) fractures, and malar (cheekbone) fractures. Fractures of the lower maxilla can occur in the Le Fort pattern.

Orbital Fractures. An orbital fracture is often part of the ZMC fracture pattern. Orbital fractures can also occur in isolation. An orbital fracture that occurs with a ZMC fracture sometimes has a palpable bony step-off along the infraorbital rim, which represents the anteriormost projection of the orbital fracture. With any orbital fracture, a detailed ophthalmologic examination, including visual acuity, range of extraocular motion, pupillary response, and light perception, should be performed. Orbital fractures can cause diplopia as a result of displacement or herniation of the globe into the maxillary sinus, or extraocular muscle entrapment. Ocular injuries, such as ruptured globe, retinal detachment, vitreous hemorrhage, lens dislocation, and hyphema, may be associated with these fractures (see Chapter 48).

Visual loss (or loss of light perception) should elicit concern for orbital hematoma, a true surgical emergency. A proptotic eye with loss of light perception should be decompressed immediately with a lateral canthotomy and cantholysis. The lateral canthotomy is made by incising sharply through the skin laterally for a distance of approximately 1 to 1.5 cm. Next, the lower lid is grasped and retracted inferiorly to expose the tension of the lateral canthus. The scissors are used to cut sharply through the lateral canthus, performing a lateral cantholysis to relieve or reduce intraorbital and, therefore, intraocular pressure. If one is unsure of the anatomic arrangement of the lateral canthus, an alternative but less aesthetically preferred area of release is the central lower lid. With either release, the patient is monitored for return of light perception.

In the acute setting, orbital injuries can result in intractable vomiting or bradycardia through the oculocardiac reflex. This and entrapment are indications for urgent surgical repair of orbital fractures.

Zygomaticomaxillary Complex Fractures (Malar Fractures). The most common midface fracture patterns are zygomaticomaxillary complex (ZMC) fractures, also known as malar (cheekbone) fractures. These fractures occur across the anterior maxilla, through the infraorbital foramen, through the orbital floor, across the lateral orbital wall, through the zygomaticofrontal sutures, and across the zygomaticomaxillary suture (zygomatic arch). This leaves an unstable, mobile malar segment that may be displaced.

Clinical findings in maxillary fractures should be carefully noted on examination. Inspect the face for asymmetry, hematomas, ecchymosis, swelling, bleeding from the nose or conjunctivae, intraoral tears, and ecchymosis of the palatal mucosa. Palpate for crepitus, deformities, and step-offs of the orbital rims, nasal bones, zygomatic arches, zygomas, and intraoral prominences of the maxilla. It is common for ZMC fractures to pass through the infraorbital foramen, an area of structural weakness. The infraorbital nerve is often injured, leaving the patient with decreased sensation from the lower eyelid down to the upper lip, and over the nose and cheek on the injured side. Reassure the patient that sensation usually returns with time. Malar flattening is commonly found on examination. If the injury has caused retropositioning of the fractured segment, the malar eminence is posteriorly displaced and overlying soft tissue shows loss of malar projection. With isolated ZMC fractures, patients report pain with mastication; however, there should not be dental malocclusion.

Treatment of ZMC fracture is not an emergency, so the patient is stabilized until more definitive imaging and care can be provided. The degree of loss of malar projection, severity of the orbital floor fracture, and trismus are the main indications for surgical repair, which should be performed within 2 weeks of injury prior to bone healing.

Zygomatic Arch Fractures. Zygomatic arch fractures usually result from force to the lateral cheek. Findings include a depression along the lateral zygomatic arch, which can be visualized on examination or palpated. Bony depression results in a flat-appearing face with dimpling over the arch. Trismus and pain with mandibular movement may occur. The coronoid process of the mandible is located beneath the zygomatic arch. Therefore, this fracture may result in inability to fully open the mouth by impingement of the underlying temporalis tendon.[7,18,47] Zygomatic arch fracture is not a surgical emergency and should be repaired within 2 weeks of fracture.

Le Fort Fracture of the Maxilla. The Le Fort classification of maxillary fractures was established based on areas of structural weakness in the maxilla.[22] Le Fort pattern fractures all have separation of the lower maxilla from the craniofacial skeleton in variable locations along the midface. The Le Fort I transverse fracture is the most common maxillary fracture. It occurs above the apices of the teeth and runs transversely across the maxilla; this involves the alveolar process, maxillary sinus walls, palate, and pterygoid processes. The Le Fort II pyramidal fracture starts in the nasal bones and frontal processes of the maxilla and then

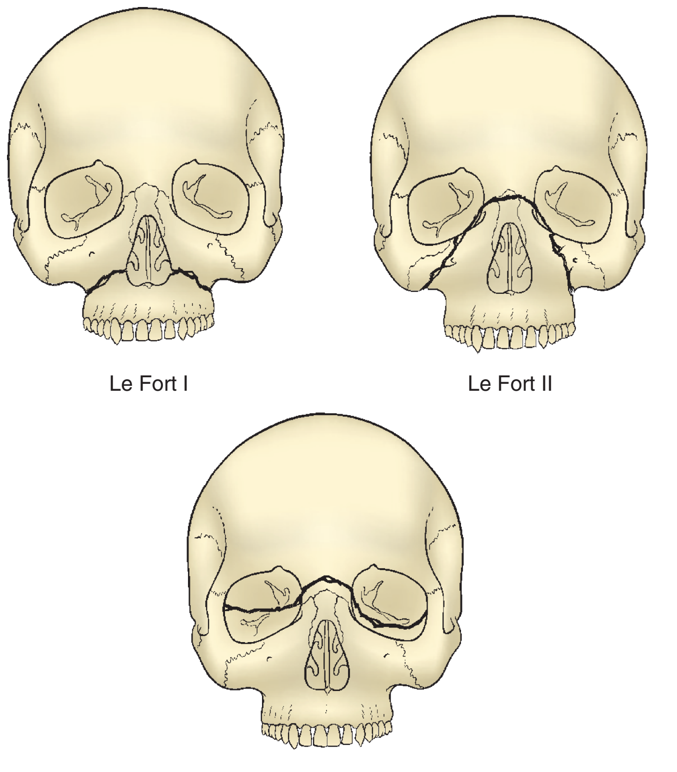

FIGURE 20-19 Classification of midface fractures. *(Redrawn from the American Association of Oral and Maxillofacial Surgeons:* Oral and maxillofacial surgery services in the emergency department, *Rosemont, Illinois, 1992, American Association of Oral and Maxillofacial Surgeons. With permission.)*

passes laterally and inferiorly through the lacrimal bones, inferior orbital rims, and orbital floors near the zygomaticomaxillary suture. It continues posteriorly along the lateral walls of the maxilla, and through the pterygoid plates into the pterygomaxillary fossa. The Le Fort III fracture pattern is frank craniofacial disjunction, occurring through the frontomaxillary, zygomaticofrontal, and orbital floors; nasofrontal sutures; cribriform plate of the nose; and ethmoid and sphenoid sinuses. The fracture forces are so great that there is a complete separation of the facial bones from the cranial base[47] (Figure 20-19).

Examine a patient for a Le Fort I maxillary fracture by grasping the anterior maxillary segment by the central incisors between the thumb and forefinger and gently rocking the maxilla anteroposteriorly. If a Le Fort I fracture is present, the entire maxilla and palate will move in relation to the upper midface. With a unilateral fracture, the two halves of the maxilla may move independently.

With a Le Fort II fracture, palpation will identify movement at the nasofrontal junction and medial portion of the inferior orbital rims where a step-off fracture may be palpated. Rock the maxilla gently while grasping the nasal bridge between the thumb and forefinger of the opposite hand. Any movement of the midface complex is indicative of a Le Fort II pattern fracture. Palpate the infraorbital rim for the presence of a step-off deformity.

Manipulation of a Le Fort III craniofacial disjunction fracture results in separation and movement of the entire midface in relation to the cranium. This injury is often accompanied by intracranial trauma. There is usually subconjunctival hemorrhage, ecchymosis, and bilateral periorbital edema that causes eyelid closure. Fractures that involve dural tears and meningeal laceration cause CSF rhinorrhea. When this is suspected, the nose should not be packed, and prophylactic antibiotics (e.g., 500 mg azithromycin by mouth once a day) should be initiated.

Rarely, a posteriorly displaced Le Fort fracture can cause airway compromise. Only in this case should the maxilla be disimpacted in the field by using forward traction.

Lower Face Fractures

Fractures of the Mandible. Signs and symptoms of mandibular fractures include malocclusion, trismus, mental nerve paresthesias, edema, intraoral and extraoral lacerations, buccal or lingual ecchymosis, crepitus, facial asymmetry, jaw deviation with mouth opening, and palpable step-off deformity along the inferior mandibular border.[6,18] Mandibular fractures are described based on anatomic location within the mandible[47] (Figure 20-20).

Inspect the skin, mucosa, dentition, and associated alveolar and basilar structures. If there is no obvious tooth or bony displacement, perform a bimanual examination. Note any loose teeth. If any teeth are completely dislodged, remove them because they pose an airway risk. Place the thumbs on the occlusal edges of the teeth and the forefingers bilaterally on the inferior border of the mandible to evaluate for crepitus, instability, tenderness, and mobility. In addition to abnormal movement, a grating sound can occasionally be heard when a fracture is present. It is particularly important to evaluate any area of soft tissue contusion. Palpate the inferior border of the mandible for step-off defects and the mandibular condyles for limitation of mobility. Evaluate the TMJ by placing a finger in the external auditory canal.[44] Normally, the condyles can be palpated by placing a forefinger in front of the external auditory meatus. If the condyle cannot be palpated or does not move significantly when the mouth is opened, a fracture may be present. Place a tongue blade in the patient's mouth across the posterior molars, and ask him or her to bite down and then to resist when you attempt to pull out the blade. If this is accomplished without too much pain, a fracture is unlikely to be present. A unilateral condylar fracture is suspected when there is a shift of the mandibular midline to the fractured and painful side on mouth opening. Bilateral condylar fractures often result in an anterior open bite and premature contact of the posterior teeth (Figure 20-21). Asking the patient if the teeth do not properly align is a highly sensitive way of assessing malocclusion. If there is malocclusion, a cross bite, or an anterior open bite, there is a high likelihood of a mandibular fracture.

Hemotympanum and external auditory meatus lacerations indicate fractures of the temporal bone with condyle retrodisplacement. To evaluate occlusion, have the patient bite down. Any deviation of the bite or change in level of the occlusal plane, especially in the mandible, should raise suspicion for a fracture. There will sometimes be a gingival tear with bleeding and ecchymosis at the site of discontinuity. Sublingual hematoma is a common sign of mandibular fracture. In edentulous areas, there will also be a discrepancy in the level of the bone, sometimes accompanied by a disruption in the mucosa[18] (Figure 20-22).

Definitive repair of a simple mandibular fracture is not usually a surgical emergency. However, it is wise to note that airway distress may occur with bilateral mandibular fractures or complex/comminuted mandibular fractures in which significant edema has arisen in the floor of the mouth. Delay in repair does not increase the risk of infectious complications, but persons who are treated after 3 days have a higher incidence of operative technical complications, such as infected hardware, nonunion, or malunion.

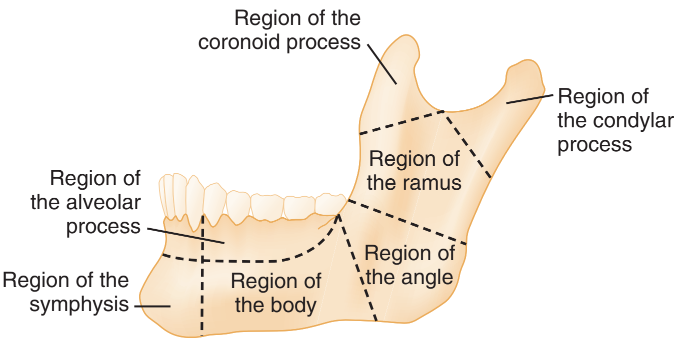

FIGURE 20-20 Anatomic regions of the mandible. *(Modified from Dingman RO, Natvig P:* Surgery of facial fractures, *Philadelphia, 1964, Saunders.)*

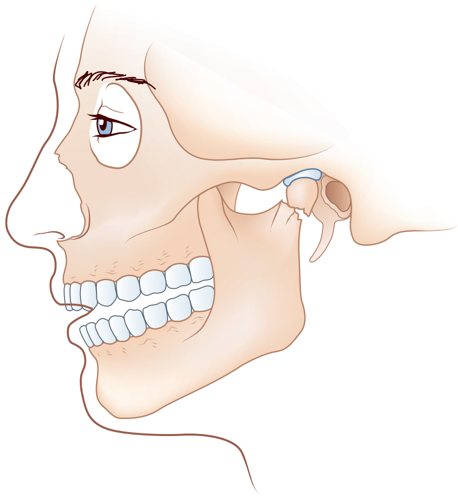

FIGURE 20-21 Condylar fracture. With a condylar fracture, the joint is positioned normally, but the muscles of mastication have pulled the posterior portion of the mandible upward to create premature contact of the posterior teeth.

FIGURE 20-22 Mandibular fracture. **A,** Note the malocclusion before reduction. **B,** Normal.

Treatment within 24 to 36 hours after injury minimizes patient discomfort and avoids significant soft tissue edema and fibrinous deposition within the fracture.[4,22] Even if perfect alignment is not achieved, fixation makes the patient more comfortable, reduces bleeding, and avoids further fracture fragment displacement. Fractures that pass through the tooth-supporting portion of the mandible are quickly stabilized with a bridle wire or more securely held with an arch bar. More rigid fixation can be obtained with intermaxillary wiring, which involves placing arch bars on the upper and lower arches, placing teeth in the proper occlusion, and connecting the upper arch bar to the lower bar with elastic bands or 22- or 24-gauge wire.[30]

Temporarily immobilize more posteriorly located fractures with a Barton bandage; this pulls the mandible in a superior direction, obtains dental occlusion, and diminishes pain. Form the bandage by wrapping a 0.25- to 0.5-inch gauze bandage or ace wrap underneath the jaw and alternating around the top of the head and back of the neck, with care taken to supply enough force to maintain occlusion.[16] Do not pull the chin posteriorly, because this may displace the fracture and compromise the airway (Figure 20-23).

All mandibular fractures are considered open fractures because the gingiva is fixed to the underlying bone and mucosal disruptions, visible or not, allow for oral flora to communicate with the fracture zone. Prophylactic antibiotics are suggested, especially in a setting where the time until surgical fixation may be unknown. The most frequently recommended treatments are 500 mg of penicillin V or 150 to 450 mg of clindamycin by mouth four times daily for 5 to 7 days. The patient should remain on a soft, pureed diet until surgical fixation has been accomplished.

Facial fractures are usually not immediate surgical emergencies but should be seen by a specialist to allow for potential surgical repair before 2 weeks has elapsed, at which point bone healing begins. Pediatric patients experience faster bone healing and should be seen within 1 week of injury. Pending evacuation, apply ice to reduce edema and medicate for pain.[17] Strong narcotics are avoided if there is an associated head injury to avoid respiratory depression in an obtunded patient.

SOFT TISSUE INJURIES

During evaluation and treatment of facial soft tissue injuries, it is important to remember that these wounds may have significant psychosocial and emotional impacts on the patient, with cosmetic outcome and function being priorities. Treatment of these wounds in the wilderness environment must take into consideration long-term sequelae associated with an unfavorable cosmetic result. A patient may recover from a traumatic experience only to be reminded of it daily by a large scar or deformity.

Contusions, abrasions, and superficial lacerations are repaired primarily or treated with wound debridement and wound care. More complex lacerations that involve underlying muscles, nerves, and ducts that must be identified at the time of injury are referred for appropriate definitive care, especially if the injury involves the facial nerve or salivary glands and ducts.[24]

Treatment

Abrasions and contusions can be treated topically. Manage contusions with cool compresses or ice, and have the patient sleep with the head elevated to diminish periorbital edema and ecchymosis.[23] Abrasions can be cleaned with mild soap and warm water to prevent infection and remove crusting. Once thoroughly

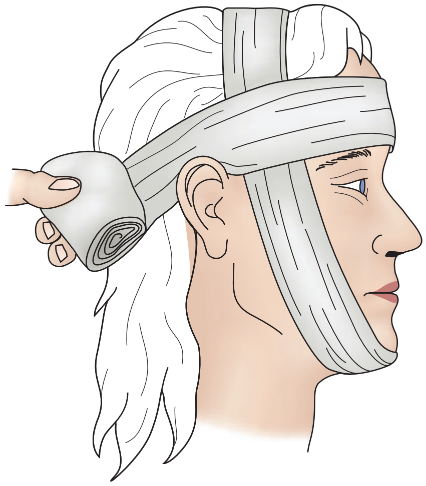

FIGURE 20-23 Barton bandage. A simple bandage can be used to temporarily stabilize a jaw fracture.

cleaned, abrasions should be covered with antiseptic ointment, such as mupirocin or bacitracin, and a sterile dressing. Infection rates do not differ between wounds cleaned with decontaminated water or sterile saline.[12] Hydrogen peroxide can be used to remove crusts that form on the wound surface.

Complicated wounds with associated devitalized tissue may necessitate delayed primary closure or closure by secondary intention. Thoroughly clean, irrigate, and debride all soft tissue injuries with a soft brush and decontaminated water to remove foreign material and prevent traumatic tattooing and infection.[42] Consider using a local or topical anesthetic agent so the patient can tolerate adequate scrubbing. Keep tissue debridement to a minimum. Significant tissue loss or avulsion usually necessitates specialty referral to achieve the best cosmetic result.

Clean, simple, superficial, and uncontaminated facial wounds less than 6 hours old may be closed with surgical glue or adhesive tape strips if they are not under tension.[20] Irrigate and explore complex deeper wounds for underlying foreign bodies or fractures. A layered closure using 4-0 or 5-0 absorbable interrupted subcuticular sutures and 5-0 or 6-0 nonabsorbable monofilament interrupted skin sutures will remove tension from skin edges and improve the appearance of the scar if sutures are removed after 5 to 7 days. Adhesive tape strips can be used to stabilize wound margins after suture removal.

The face has an excellent vascular supply, which allows for wound closure with minimal risk of infection if treatment can be accomplished within 6 hours of the injury. Topical antibiotics are useful, but prophylactic oral antibiotics should not be initiated, because these wounds rarely become infected. More complicated wounds, including those that involve ear or nose cartilage, through-and-through lip or buccal mucosa lacerations, bites, and wounds with any evidence of maceration, contamination, or devascularization, require prophylactic oral antibiotic treatment against normal bacterial flora associated with the affected site and consideration for the mechanism of trauma. Inspect all facial wounds frequently for evidence of vascular compromise or infection, or both. Significant infections require bandage removal, possible surgical drainage, and intravenous antibiotics.

Any injury that involves the eyelids, auricular helical rims, nasal alar rims, or vermilion border has potential significant cosmetic and functional implications and must be evaluated and managed with extreme caution.

INJURIES TO THE LIPS

Lips are mobile muscular folds that have three distinct regions: oral mucosa, skin, and a noncornified layer of stratified epithelium called the *vermilion*. The vermilion border is the junction between the skin and the dry vermilion. Realigning the border and restoring the natural architecture of the philtrum are crucial to successful cosmetic repair.

During repair of a through-and-through lip laceration, first close the muscular layer with 5-0 absorbable sutures, and then realign and stabilize the vermilion border with a vertical mattress nonabsorbable suture. Next, close the inner mucosal layer with 4-0 absorbable sutures, the wet and dry vermilion with 5-0 absorbable sutures, and the external skin with 6-0 nonabsorbable sutures. Through-and-through lacerations of the lower lip that do not involve the vermilion border occur when lower incisors impale tissue during facial blunt trauma. First, cleanse and close the mucosal layer from an intraoral approach. Irrigate to remove foreign material and oral bacteria, and then rescrub the extraoral wound. Close the remaining layers, finishing with the skin. Large soft tissue lip avulsions may require plastic surgery to achieve the best cosmetic result (Figure 20-24).[5]

A mental nerve block anesthetizes the chin and lower lip; an infraorbital nerve block anesthetizes the cheek, upper lip, lower eyelid, and lateral aspect of the nose. These blocks provide adequate anesthesia without tissue distortion and are easily performed. The mental nerve exits the mandible through the mental foramen in the midpupillary line 1 cm (0.4 inch) inferior to the apex of the second bicuspid. While retracting the lower lip with the nondominant hand, insert the needle 5 mm (2 inches) inferior to the tooth, and inject 2 mL of anesthetic. The infraorbital nerve exits the infraorbital foramen 1 cm (0.4 inch) below the infraorbital ridge. Place the third finger of the nondominant hand on the infraorbital foramen, and use the second finger and thumb to lift the upper lip. Insert the needle over the canine tooth at the level of the gingival buccal sulcus. Aspirate while advancing toward the foramen, and inject 2 mL of anesthetic (Figures 20-25 and 20-26).

FIGURE 20-24 Lip laceration involving the vermilion border.

TONGUE LACERATIONS

Tongue lacerations may be difficult to suture because of poor visualization. Simple, small, linear lacerations less than 1 cm (0.4 inch) long and located centrally usually heal well without suturing. All lacerations that are deep or gaping or that bisect the tongue should be closed with absorbable 4-0 or 5-0 suture.[5] Sufficient local anesthesia can be provided by a combination of topical lidocaine and a nerve block. Apply local anesthesia by applying gauze soaked with lidocaine 4% to the tongue for 5 minutes, and then locally infiltrate the wound with lidocaine 1% with epinephrine, and/or perform an inferior alveolar or lingual nerve block. The inferior alveolar and lingual nerves are terminal branches of the trigeminal nerve. Palpate the vertical ridge of the anterior border of the mandibular ramus with your thumb. Using a tongue blade, push away the buccal surface of the cheek to expose the target area. Position the syringe barrel over the opposite premolar and parallel to the occlusive surface of the lower teeth. Insert the needle into the oral mucosa medial to the ridge, 1 cm (0.4 inch) above the occlusive surface of the mandibular third molar. Aspirate while slowly advancing the needle 2 cm (0.8 inch), and inject 2 mL of anesthetic to block the inferior alveolar nerve. The lingual nerve runs with the inferior alveolar nerve at the mandibular foramen. It supplies the anterior two-thirds of the tongue, floor of the mouth, and gums. Block the lingual nerve by withdrawing the needle 1 cm (0.4 inch) while aspirating, and then injecting another 1 mL of anesthetic. Prescribe a liquid or soft diet after any intraoral repair. Advise the patient to gently swish and spit four times a day and after eating with warm saline, antiseptic mouthwash, chlorhexidine gluconate 0.12%, or half-strength hydrogen peroxide (Figure 20-27).

INJURIES TO THE EYELID

It is essential that providers recognize eyelid lacerations that require referral to an ophthalmologist. Simple upper and lower lid lacerations may be managed without consultation, but complex lacerations that involve tissue avulsion or the tarsal plate, lid margins, orbital septum, levator palpebrae superioris, or lacrimal drainage system may require semiurgent ophthalmologic referral for definitive care. The presence of a penetrating globe injury must be identified.[24] Upper eyelid lacerations with exposure of orbital fat and ptosis in the presence of a horizontal

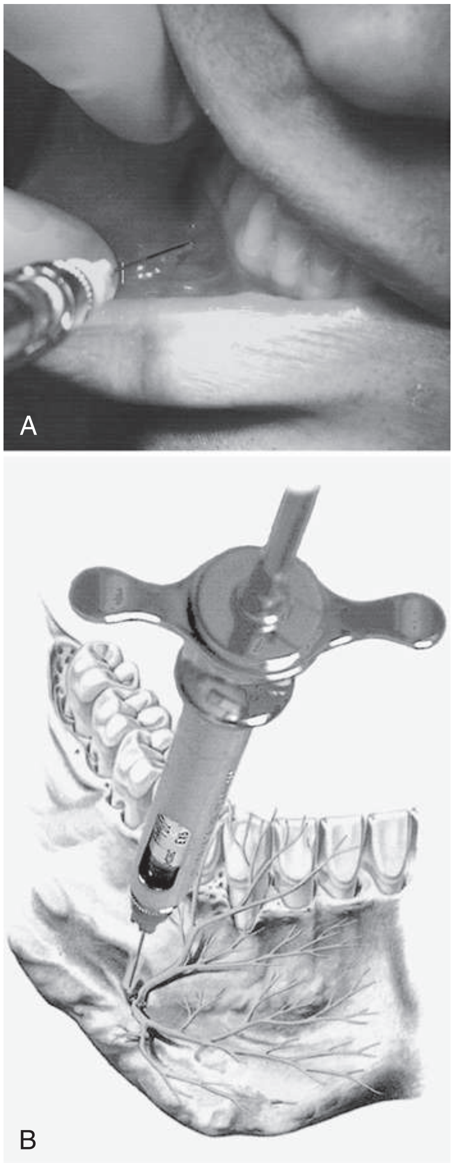

FIGURE 20-25 Mental nerve block. **A** and **B,** Infiltrate anesthetic at the mental foramen opening. To prevent neurovascular damage, do not introduce the needle into the foramen.

lid laceration suggest levator palpebrae superioris muscle damage.[9] Lacerations involving the lateral aspect of the upper lid may involve the lacrimal gland, which may be mistaken for orbital fat and inadvertently excised. Evaluate for laceration of the canalicular drainage system by instilling fluorescein into the eye and assessing for its presence within the wound.[5] Any laceration that involves the medial portions of the upper and lower eyelid or that is medial to the puncta should be assumed to involve the canalicular system and requires evacuation and ophthalmology referral. If unrecognized or untreated, laceration or obstruction of the lacrimal ducts will cause tears to overflow.[42] Stenting the canalicular system is required to prevent obstruction.

Superficial lacerations of less than 25% of the lid are candidates for healing by secondary intention and may be treated conservatively without suture repair. Clean and irrigate wounds with clean, disinfected water, and instill topical antibiotic drops (e.g., ciprofloxacin, ofloxacin, tobramycin) into the wound.[5] Apply tape strips to approximate wound edges if the laceration cannot be properly sutured. Lid margin lacerations require a three-layer closure. Close the conjunctival side and tarsal plate with 6-0 or 7-0 absorbable sutures, and close the external surface with a nonabsorbable monofilament suture. Repair other simple superficial lacerations that do not involve the lid margin with either 6-0 or 7-0 absorbable or nonabsorbable sutures (Figure 20-28).

INJURIES TO THE NOSE

Superficial nasal lacerations can be repaired with interrupted 5-0 or 6-0 nonabsorbable sutures, but complex nasal lacerations involving the nasal mucous membrane and cartilaginous framework require layered closure. Lacerations involving the nostril margin or alar rim require precise alignment and eversion of skin edges for a satisfactory cosmetic result and to prevent alar notching (Figure 20-29). Close full-thickness lacerations involving cartilage with a three-layered closure. First, suture the cartilage together to restore the normal anatomic configuration. Next, meticulously close the skin with nonabsorbable 6-0 sutures. Finally, close the mucosa with absorbable 5-0 sutures. Contraction and retraction of the nasal margin may occur if there has been poor approximation of the mucosa, or with scar contraction. All patients with nasal lacerations should be instructed that scar revision may be required and appropriate referral recommended.

Most nasal laceration repairs are facilitated by performing an infraorbital nerve block with lidocaine 1% with epinephrine[5] or injection of local anesthetic into the area of injury. If the nasal laceration involves the superior aspect of the nose or forehead, a supraorbital nerve block may be useful. The supraorbital nerve exits the skull at the supraorbital foramen, and then branches cephalad into the medial and lateral branches to supply the forehead and anterior scalp. The supratrochlear nerve supplies the midforehead and lies under the medial 1 cm (0.4 inch) of the eyebrow. It exits the skull 0.5 to 1 cm (0.2 to 0.4 inch) medial to the supraorbital foramen. The infratrochlear nerve exits the orbit superior to the medial canthus and travels inferiorly to supply the medial eyelid, lateral nose superior to the medial canthus, medial conjunctiva, and lacrimal apparatus. Use the nondominant hand to locate the supraorbital notch, insert the needle into the lateral edge of the middle one-third of the eyebrow, and advance the needle while aspirating toward the medial canthus. Then, inject 2 mL of anesthesia (Figure 20-30).

INJURIES TO THE EAR

External ear injury may be associated with hearing loss, facial nerve palsy, tympanic membrane rupture, and temporal bone fracture. Evaluate ear trauma with an otoscope to observe the integrity of the external canal and assess for hemotympanum and otorrhea, which suggests underlying temporal bone injury that requires evacuation. External cartilaginous ear trauma may result in lacerations, tissue avulsion, and formation of a hematoma within the ear itself.

Local ear anesthesia can be used to close lacerations or drain auricular hematomas. Innervation of the ear is by the greater auricular nerve, lesser auricular nerve, auricular branch of the vagus nerve, and auriculotemporal nerve. Partial or complete anesthesia of the ear can be accomplished using a variety of field blocks. Inject approximately 2 to 4 mL of lidocaine 1% without epinephrine, or bupivacaine 0.25% with a 25- to 27-gauge needle subcutaneously into the skin around the ear (Figure 20-31).

To repair through-and-through lacerations, cleanse and irrigate the ear without dissecting the cartilage from the perichondrium. Debridement should be minimized to prevent a poor cosmetic result. Reapproximate the cartilage with 5-0 or 6-0 clear nonabsorbable sutures. Place sutures through the anterior and posterior perichondrium as well as through the cartilage to re-create the normal auricular contour. Suture the anterior and posterior skin with 6-0 or 7-0 nonabsorbable interrupted sutures. Simple superficial ear skin wounds are closed in a single layer with 6-0 or 7-0 nonabsorbable sutures. Repairing complex ear lacerations requires adequate coverage of the exposed cartilage to prevent infection, chondritis, and cartilage necrosis. Lacerations of the auricular helical rim are repaired with a three-layer process that involves precisely realigning the auricular cartilage

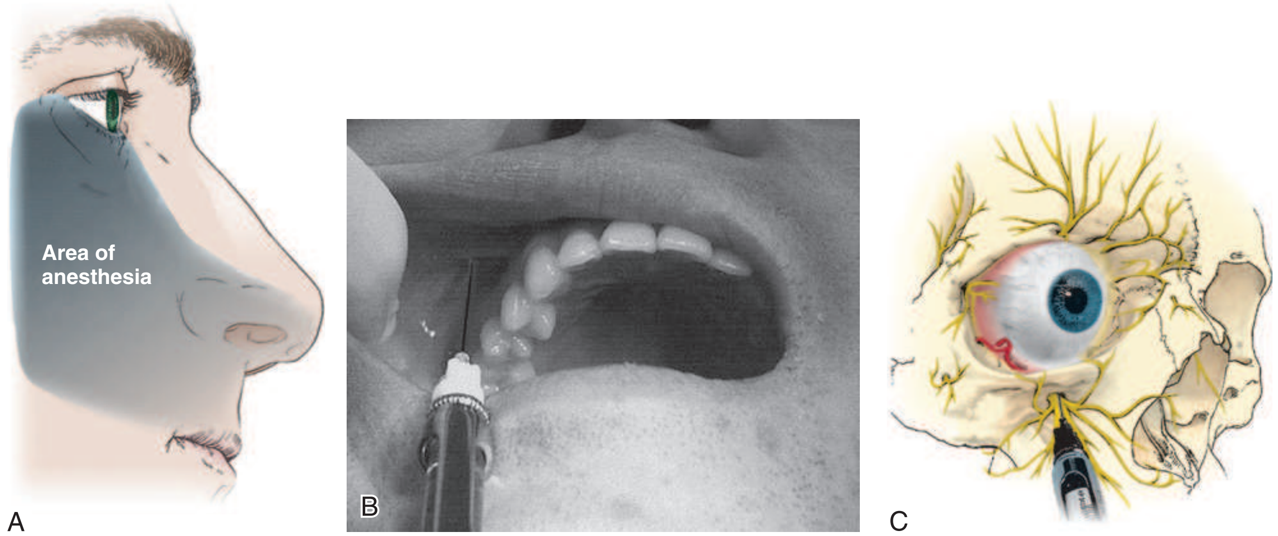

FIGURE 20-26 Infraorbital nerve block. **A,** The unilateral infraorbital nerve block anesthetizes the lower eyelid and upper lip. **B,** The nerve is located directly under the pupil when the patient is looking forward. **C,** Avoid the orbit by keeping the needle tip under the orbital rim. *(From Roberts JR, Hedges JR:* Clinical procedures in emergency medicine, *5th ed, St Louis, 2009, Saunders.)*

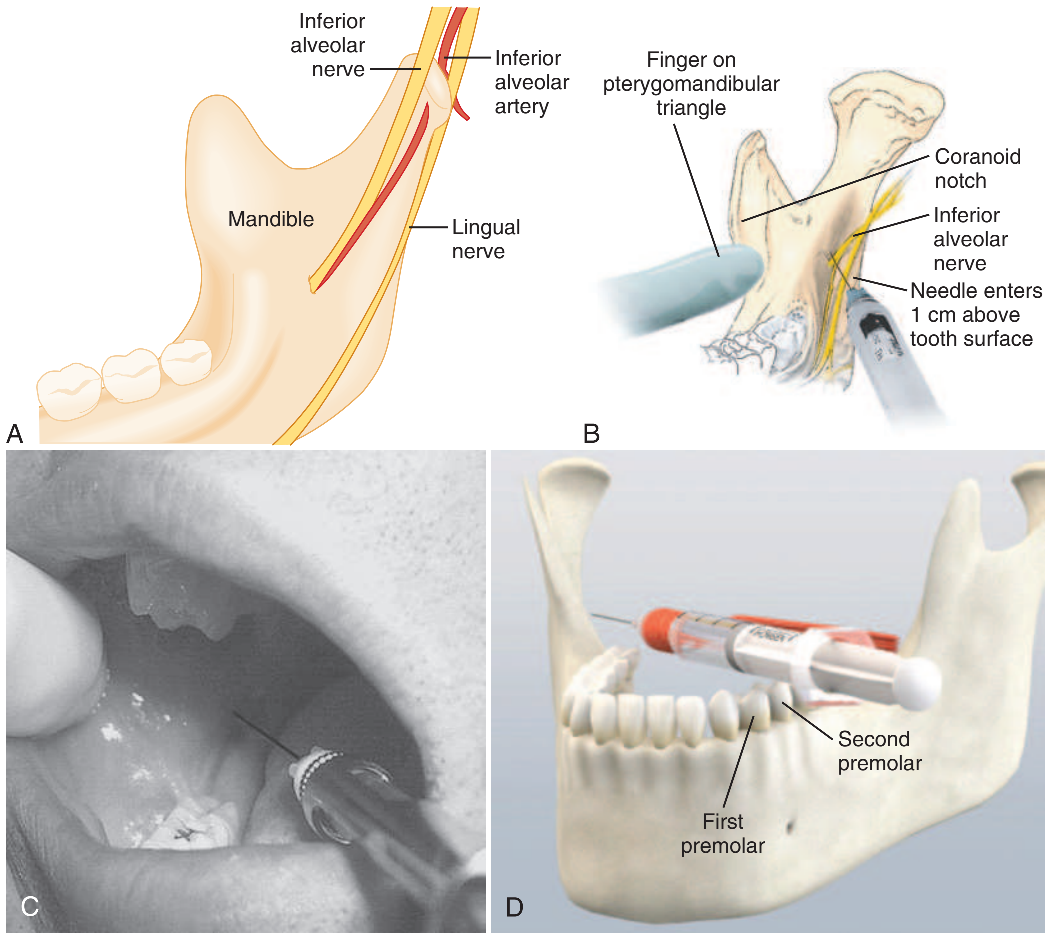

FIGURE 20-27 Inferior alveolar and lingual nerve blocks. **A,** Pterygomandibular triangle. **B,** Identify the anterior border of the ramus of the mandible with the left index finger or thumb. **C,** Grasp the ramus with the intraorally placed thumb and an extraorally placed index finger to allow visualization of the pterygomandibular triangle. **D,** The syringe is angled, with the barrel of the syringe overlying the first and second premolar teeth on the opposite side of the mandible. *(From Roberts JR, Hedges JR:* Clinical procedures in emergency medicine, *5th ed, St Louis, 2009, Saunders.)*

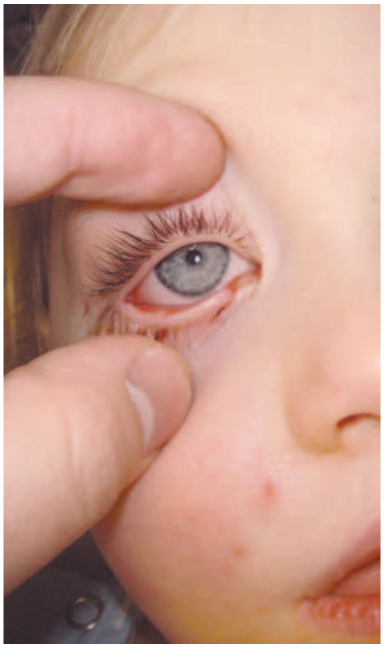

FIGURE 20-28 Eyelid laceration involving the tarsal plate and lacrimal apparatus. *(Courtesy Dr. Chang Hee Kim.)*

FIGURE 20-29 Nasal laceration involving the alar cartilage. *(Courtesy Dr. Ross Stutman.)*

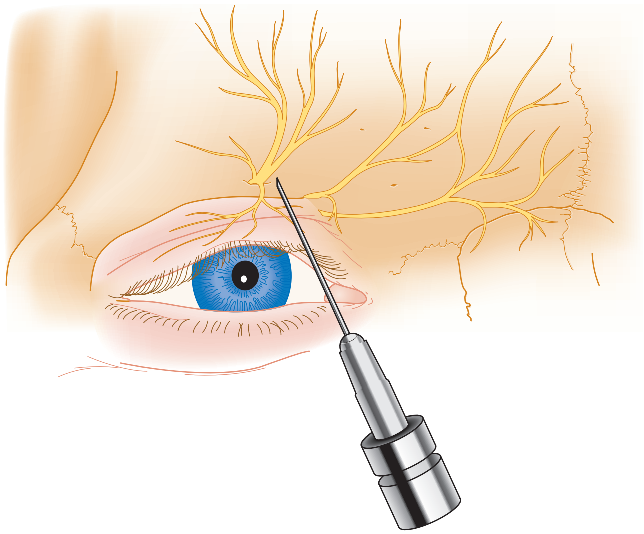

FIGURE 20-30 Supraorbital, supratrochlear, and infratrochlear nerve blocks. This is the site for local injection of the supratrochlear and infratrochlear nerves, as well as for the lateral and medial branches of the supraorbital nerve. *(From Roberts JR, Hedges JR:* Clinical procedures in emergency medicine, *5th ed, St Louis, 2009, Saunders.)*

to prevent notching (Figure 20-32). Precise realignment of the helix and antihelix is vital for a good cosmetic result.

A potential space exists between the avascular cartilage and perichondrium, where blood can accumulate. Shearing forces of moderate intensity, which occur frequently during fights, wrestling matches, and mixed martial arts activities, may cause blood extravasation and hematoma formation in the subperichondrial potential space, thereby separating perichondrium from cartilage. If the hematoma is not drained acutely, neocartilage formation develops at the site of the clot, subsequently deforming the ear and leading to a "cauliflower ear."[30]

Treating an auricular hematoma involves complete evacuation of the subperichondrial hematoma, elimination of dead space, and reapproximation of the perichondrium to the underlying cartilage. Prevent reaccumulation of hematoma by applying a compressive dressing, and reexamine this frequently, with reaspiration as necessary. If the provider does not have the tools necessary to drain or aspirate the hematoma within 7 to 10 days, patient evacuation is necessary because new perichondrial growth must be debrided to prevent ear disfigurement and deformity caused by cartilaginous necrosis, chondritis, or fibrosis[35] (Figure 20-33).

An auricular hematoma may be drained either by aspiration or by incision. Aspirate by perforating the hematoma with a 20-gauge needle, and compress the hematoma between the thumb and forefinger until all blood is evacuated (Figure 20-34). If the hematoma is less than 7 to 10 days old and if aspiration is unsuccessful, incision and drainage may be required. With a No. 15 scalpel blade, incise the hematoma by following along a natural anatomic crease or curvature of the pinna. The incision should be sufficiently long that simple compression adequately drains the hematoma. After completely evacuating the hematoma, irrigate the remaining pocket with normal saline (Figure 20-35).

Next, apply a topical antibiotic or antiseptic ointment. Reexamine the ear frequently for reaccumulation of hematoma. Create a bolster dressing by placing petrolatum-coated cotton within all fissures and folds of the ear until the dressing is level with the helix, and then place a dry cotton gauze behind the ear to provide padding and prevent the ear from being compressed against the skull. Then, place dry cotton gauze anterior to the ear and secure it with a circumferential compressive head bandage that does not include the other ear. Another technique is to suture dental rolls over the area to create a compressive bolster dressing. The dressing should firmly reapproximate the perichondrium to the cartilage without vascular compromise.[40] Evacuate the patient for consultation and definitive repair if there is significant tissue and cartilage loss that precludes cosmetic closure (Figure 20-36).[30,42]

A number of methods are available to eliminate dead space and prevent hematoma recurrence. However, incision and drainage of hematoma followed by placement of absorbable mattress sutures has been shown to result in fewer reaccumulations and complications. In addition, this technique eliminates the need for a bulky bolster. Perform this technique after incision, drainage, and irrigation of the hematoma, followed by manipulation of the ear into its normal anatomic appearance. Weave absorbable 4-0 chromic or plain gut suture from posterior to anterior through the skin and cartilage as many times as is necessary to achieve appropriate ear contour while apposing skin to cartilage. Place topical antibiotic or antiseptic ointment on both sides of the ear, and apply a loose head dressing (rather than a compressive dressing) for the next 24 to 48 hours.[15]

If medical-grade soft silicone putty is available, the lateral part of the external auditory meatus and contours of the lateral pinna surface are filled with putty, which hardens after a few minutes. From the anterior aspect of the pinna, fold the malleable silicone backward to cover the medial surface and mold to the pinna before placing a head bandage.[11]

INJURIES TO THE CHEEK

Contusions and lacerations of the cheek or parotid region may involve other structures, including the external auditory meatus, TMJ, underlying zygomatic or maxillary bones, parotid gland,

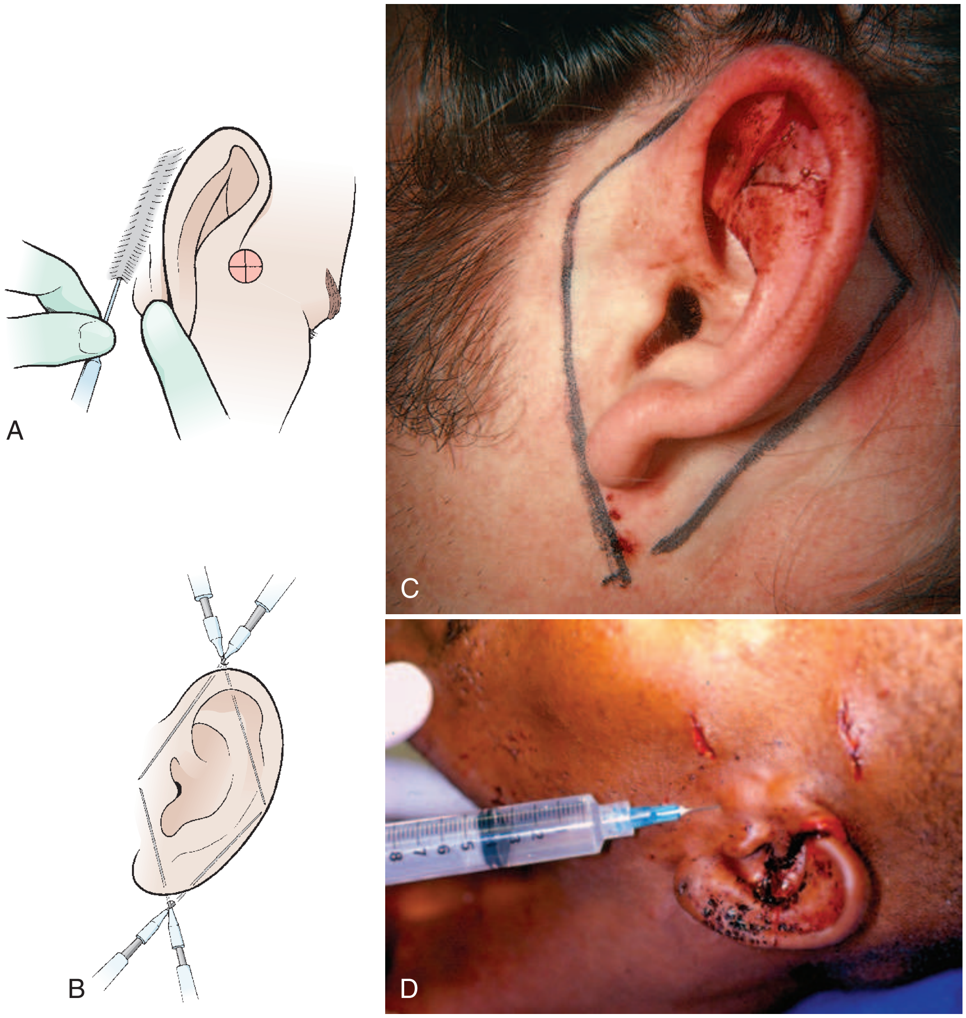

FIGURE 20-31 Field blocks of the auricle. **A,** One method makes use of approximately 3 to 4 mL of anesthetic, both in the posterior sulcus and at a point just anterior to the tragus. **B,** An alternative field block technique that involves depositing 2 to 3 mL of anesthetic with each needle pass. **C** and **D,** The locations of anesthetic injections. *(From Roberts JR, Hedges JR:* Clinical procedures in emergency medicine, *5th ed, St Louis, 2009, Saunders.)*

FIGURE 20-32 Ear laceration involving auricular cartilage. *(Courtesy Dr. Ross Stutman.)*

FIGURE 20-33 Auricular hematoma that requires drainage. *(Courtesy Dr. Alicia Pilarsky.)*

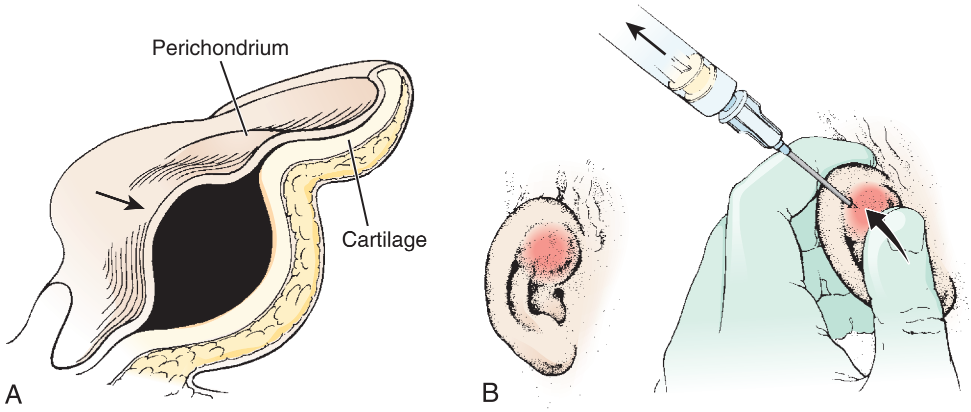

FIGURE 20-34 Auricular hematoma aspiration. **A,** Subperichondrial hematoma within the concha of the ear. **B,** Needle aspiration of auricular hematoma. A topical antiseptic is used to clean the ear, but local anesthesia is seldom required. While stabilizing the pinna between thumb and fingers, puncture the most fluctuant part of the hematoma with a 20-gauge needle. Use the thumb to "milk" the hematoma into the syringe until the entire hematoma has been evacuated. Be careful not to puncture your thumb with the needle. The thumb maintains continuous pressure on the ear for 3 minutes after the needle has been withdrawn. A pressure dressing is then applied, and the ear is checked for reaccumulation of blood in 24 hours. Repeated aspirations may be required, and persistent accumulations require incision and drainage. *(**B** redrawn from Ruddy RM: Aspiration of an auricular hematoma. In Fleisher GR, Ludwig S, Henretig FM, et al, editors:* Textbook of pediatric emergency medicine, *5th ed, Philadelphia, 2006, Lippincott Williams & Wilkins, p 1889.)*

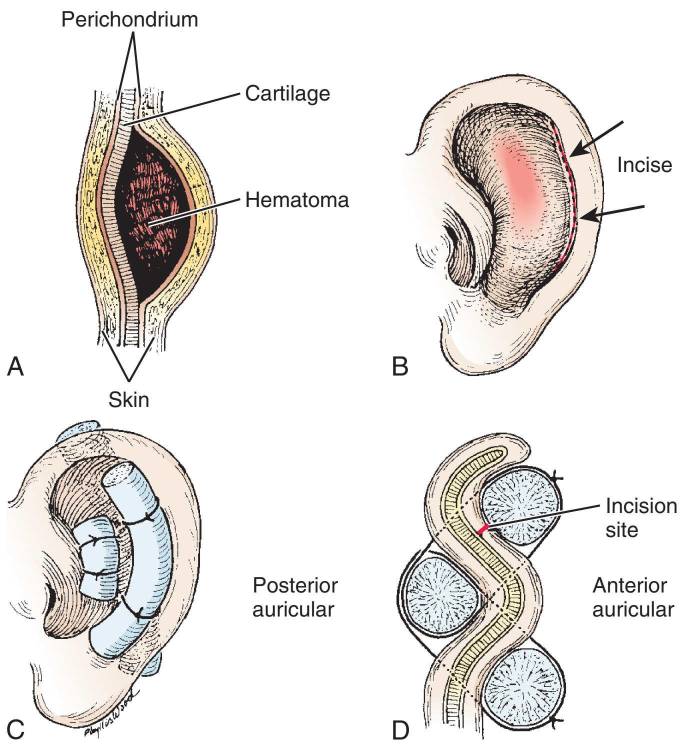

FIGURE 20-35 Auricular hematoma incision. **A,** Hematoma separates the perichondrium from the cartilage. **B,** Incision *(arrows)* made along the skin curvature at the posterior edge of the hematoma. The hematoma is evacuated, and the area is irrigated. **C,** Two anterior dental rolls are secured with sutures to a posterior dental roll to maintain normal anatomy of the pinna. **D,** A side view illustrates the position of sutures and dental rolls in relation to the incision site. Note that the perichondrium is in apposition to the cartilage. *(From Clemons JE, Seveneid LR: Otohematoma. In Cummings CW, editor:* Otolaryngology: head and neck surgery, *2nd ed, St Louis, 1993, Mosby, p 2866.)*

Stensen's duct, branches of the facial nerve, and transverse facial artery. Failure to recognize these injuries may lead to significant morbidity. Injuries to these structures require repair that occurs concurrently with laceration repair.

The parotid duct arises from the anterior aspect of the parotid gland and runs superficially over the masseter muscle. The duct pierces the buccinator muscle and oral mucosa at the level of the second maxillary molar. A line that connects the midportion of the upper lip with the tragus delineates the path of the parotid duct over the cheek. The duct runs in proximity to the transverse facial artery and buccal branch of the facial nerve. Suspect parotid duct damage if there is saliva leakage from the wound when the Stensen's duct is irrigated with saline. A sialocele, cutaneous fistula, or salivary duct cyst may occur from salivary fluid retention if a parotid duct injury is not initially recognized[45] (Figure 20-37). Evacuation is required for definitive repair if a cheek laceration involves Stensen's duct.

Injuries to branches of the facial nerve (e.g., cranial nerve VII) frequently occur in association with parotid duct injury. Delay injection of local anesthetic until facial nerve function has been evaluated. Evaluate facial nerve damage by observing the patient move the eyebrows, eyelids, and mouth. Evacuate any patient for immediate repair of facial nerve injury lateral to a vertical line through the lateral canthus of the eye, because nerve transection requires early repair to maximize recovery of facial nerve function.

FOREIGN BODIES IN THE NOSE AND EAR

In contrast with children, who insert foreign bodies for no apparent reason, adults insert foreign bodies into the nose and ear deliberately to control epistaxis or to clean and relieve irritation.[3] Insects may find their way into the nose or ear and prove to be quite distressing, although not associated with trauma. The patient can usually blow out insects from within the nostril by occluding the unaffected nostril and blowing, and this rarely requires provider instrumentation. Insects within the ear may be problematic, because the inner ear canal is extremely sensitive. The patient is usually aware that something is in the ear. If the insect is alive, the patient may be extremely agitated and feel movement of the insect or hear buzzing. This may be associated with pain, fullness, impaired hearing, itching, canal edema, and drainage. The insect may damage the canal and cause bleeding,

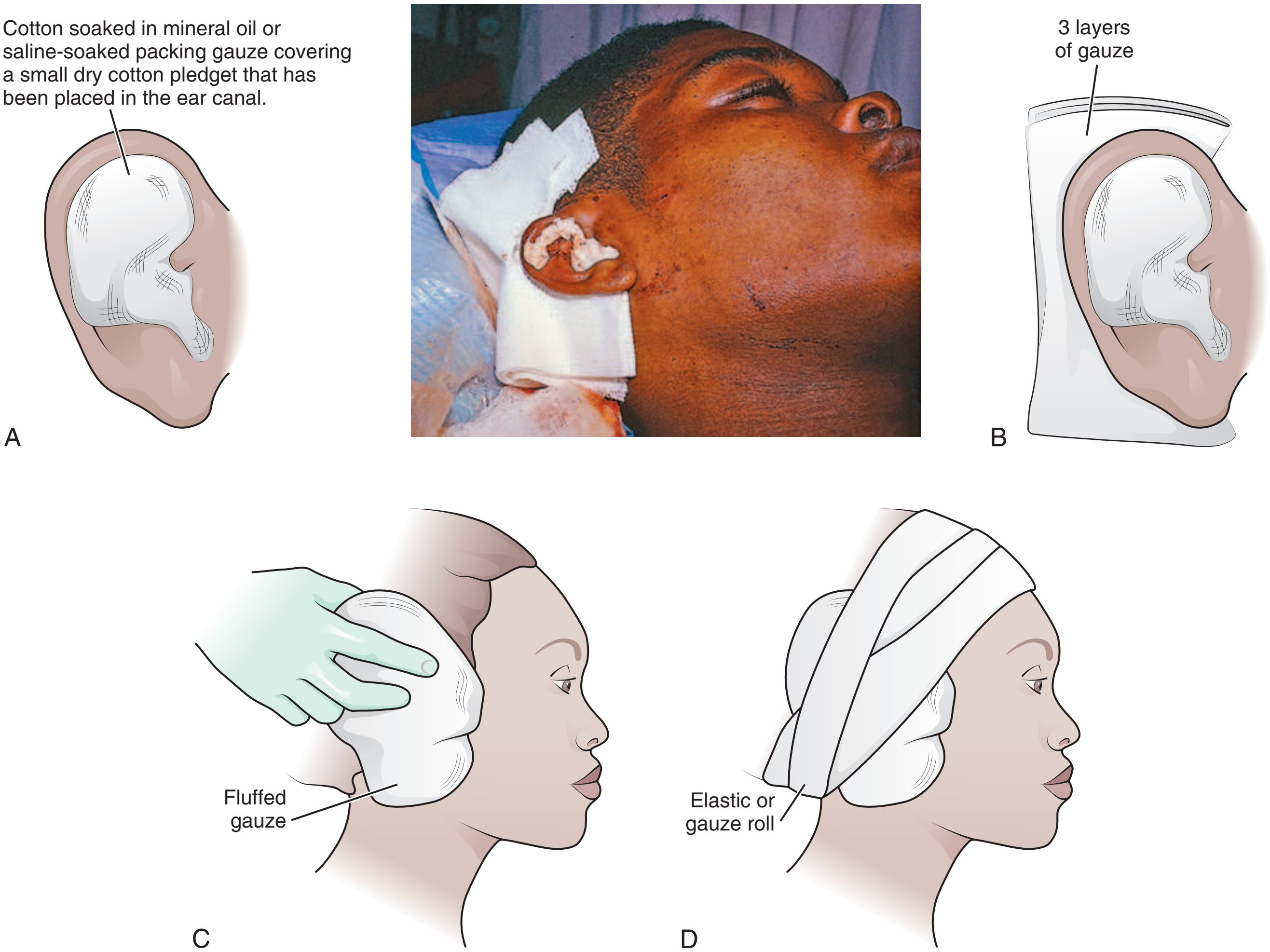

FIGURE 20-36 Compression dressing of the ear. After successful aspiration of an auricular hematoma, use a compression dressing to prevent reaccumulation of the hematoma or fluid. **A,** First, place dry cotton into the ear canal, then carefully mold a conforming material into all of the convolutions of the auricle. One may use petroleum jelly–impregnated gauze, saline-soaked 0.25-inch packing gauze, or cotton soaked in mineral oil or saline. *Inset,* Note the gauze pack behind the pinna and use of saline-soaked packing gauze to conform to the auricle. **B,** When the convolutions are fully packed, place a posterior gauze pack behind the ear. A V-shaped section has been cut from the gauze to allow it to fit easily behind the ear. **C,** Place multiple layers of fluffed gauze over the packed ear, and hold the entire dressing in place with Kling Gauze or an elastic gauze roll. Do not wrap this too tight. **D,** The ear is thus compressed between two layers of gauze, and the packing ensures even distribution of pressure to all parts of the auricle. *(From Roberts JR, Hedges JR:* Clinical procedures in emergency medicine, *5th ed, St Louis, 2009, Saunders.)*

tympanic membrane perforation, and infection. Tympanic perforation may cause tinnitus, vertigo, and hearing loss.

Before examining the ear, it is important to ascertain if attempts have been made to remove the foreign body by the patient, because this may have caused ear canal injury, tympanic membrane perforation, or worsening foreign body impaction. Ear canal irrigation may cause enlargement of some foreign bodies.

Within the external auditory ear canal, there are two areas of anatomic narrowing where foreign objects usually become stuck. These include a point of bony narrowing called the *isthmus* at the junction between bone and cartilage, and a point near the inner end of the cartilaginous portion of the canal lateral to the tympanic membrane.[37] Examine the ear with adequate lighting, an otoscope, and a large-size speculum to visualize the ear canal and allow injection of a local anesthetic. Grasp the superior pinna and retract it in a posterosuperior direction to straighten the tortuous canal and to achieve a more complete view of the external auditory canal.

Anesthetize or immobilize an insect within the ear canal to decrease patient distress and facilitate removal. Immobilizing agents include lidocaine 2% gel, lidocaine 10% spray or liquid, mineral oil combined with lidocaine 2% or 4%, and alcohol. If attempts are made to remove a moving insect, the insect or device may cause ear damage.

With appropriate tools, foreign body removal may be attempted in the wilderness. Instill a topical anesthetic, such as lidocaine 1% to 2%, into the canal. Unfortunately, topical anesthetics are poorly absorbed through the impermeable keratinized epithelial surface of the external auditory canal. Auralgan, a topical combination of benzocaine and other ingredients, does not provide adequate anesthesia for painful procedures. Local anesthetic injection within the canal is painful and difficult to perform, and frequently does not provide adequate anesthesia of the inner ear and tympanic membrane.

A common technique to provide local anesthesia of the canal requires insertion of a large speculum immediately inside the auditory meatus to facilitate use of a 25- to 27-gauge needle that is 3 to 5 cm (1.2 to 2 inches) in length in order to inject 0.25 to 0.5 mL of lidocaine 1% or a 1:10 mixture of sodium bicarbonate 8.4% with lidocaine into the subcutaneous tissue, stopping after a small bulge in the skin is raised. Inject all four quadrants, as well as deeper tissues along the anterior wall and at the posterior wall of the bone–cartilage junction (Figure 20-38).

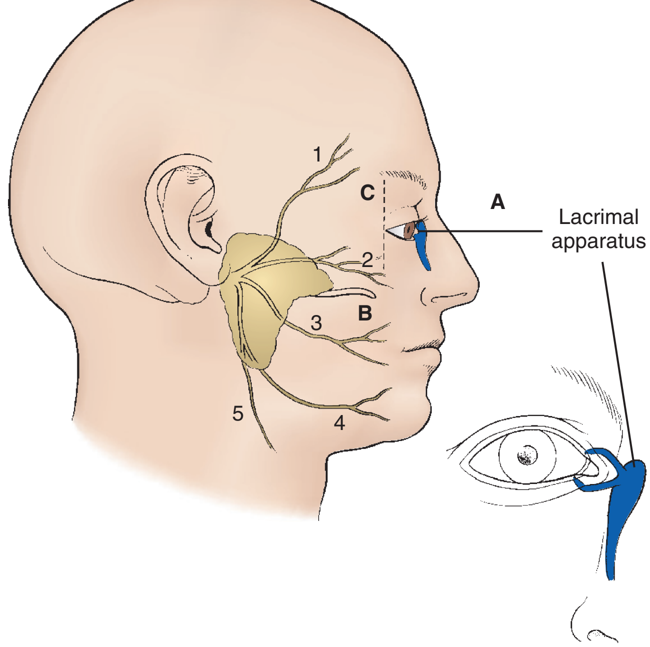

FIGURE 20-37 Structures that may be injured by facial lacerations. *A,* The lacrimal drainage system. *B,* The parotid duct. *C,* A line drawn through the lateral canthus of the eye. Facial nerve injuries posterior to this line should be repaired as soon as possible. *1* through *5,* Branches of cranial nerve VII. *(Redrawn from the American Association of Oral and Maxillofacial Surgeons:* Oral and maxillofacial surgery services in the emergency department, *Rosemont, Ill, 1992, American Association of Oral and Maxillofacial Surgeons.)*

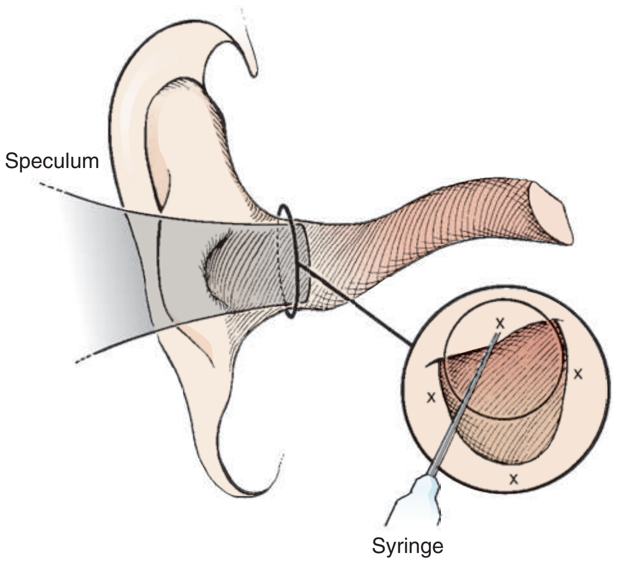

FIGURE 20-38 Four-quadrant field block anesthesia of the external auditory canal. Local anesthetic is injected subcutaneously into the four quadrants of the lateral portion of the ear canal. The largest speculum that will fit is used to guide injections. The speculum is withdrawn slightly and tilted toward each of the four quadrants; the needle is then inserted subcutaneously. Inject a very small amount of anesthetic (i.e., 0.25 to 0.50 mL) to produce a slight bulge in the soft tissue. A total of 1.5 to 2 mL of anesthetic is usually sufficient to anesthetize the ear canal and allow for painless removal of a foreign body. *(From Roberts JR, Hedges JR:* Clinical procedures in emergency medicine, *5th ed, St Louis, 2009, Saunders.)*

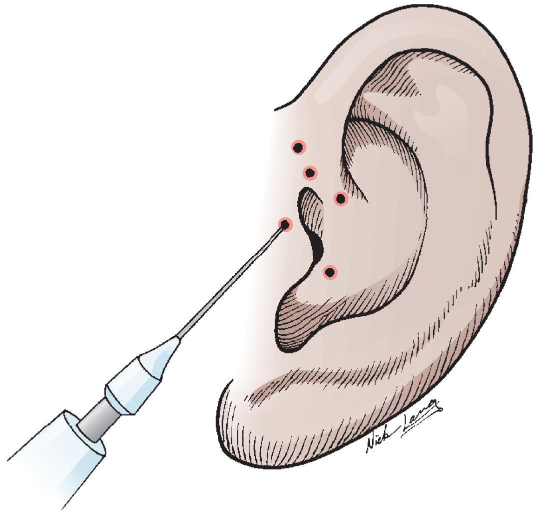

FIGURE 20-39 External auditory canal anesthesia; diagram of injection sites for an alternative technique to anesthetize the ear canal and central concha. Each site should be injected with approximately 0.5 mL of lidocaine 1%. Do not perform these injections if external signs of infection are present. *(From Roberts JR, Hedges JR:* Clinical procedures in emergency medicine, *5th ed, St Louis, 2009, Saunders.)*

Another technique involves injecting approximately 0.5 to 1 mL of lidocaine 1% externally into each of five points around the auditory meatus and the tragus (Figure 20-39).

Various instruments can be used to successfully remove a foreign body from the ear canal. Alligator forceps, bayonet forceps, and right-angle probes are frequently used.

Foreign body removal is often successful using indirect irrigation of the canal. If tympanic membrane perforation is suspected, this technique is contraindicated. Using a 20-mL syringe and a 14- or 16-gauge catheter, direct a stream of room-temperature water or saline around the (nonvegetable) foreign body. Irrigation directed past the object will collide with the tympanic membrane and bounce against the posterior aspect of the foreign body, thereby driving it out of the canal. This technique has a low complication rate and is well tolerated.[3]

Cyanoacrylate adhesive–tipped swabs have been used to remove foreign objects from the ear. Complications associated with this method include contaminating the ear canal with glue that is difficult to remove and accidental perforation of the tympanic membrane.

After successfully removing an insect, inspect the external auditory canal for trauma and retained material. Evaluate the tympanic membrane for perforation caused by the insect itself or by removal attempts. Confirm that there is not tympanic membrane perforation. If irrigation was implemented, instill several drops of isopropanol within the canal to facilitate moisture evaporation. Initiate a prophylactic oral antibiotic (e.g., 500 mg of cephalexin by mouth twice daily) if the tympanic membrane was ruptured or perforated, because the middle ear is at risk for infection. Administer topical steroid–containing antibiotic suspension drops (e.g., hydrocortisone with ciprofloxacin) to alleviate pain and potentially decrease the risk of developing otitis externa as a result of the foreign body and removal efforts.

WILDERNESS MEDICAL KIT FOR FACIAL TRAUMA

The wilderness medical kit, described in Box 20-1, should be prepared to anticipate treating facial trauma.

PREVENTION OF FACIAL TRAUMA

Prevent significant head and facial trauma by wearing a helmet for recreational activities such as technical rock climbing, rock scrambling, mountaineering, caving, skiing, snowboarding, biking, whitewater kayaking and rafting, and horseback riding. Wear

BOX 20-1 Wilderness Medical Kit for Facial Trauma

Temporomandibular Joint Relocation Supplies
Bite blocks
Plastic finger splints

Mandibular Dislocation and Fracture Supplies
Barton bandage
0.25- to 0.5-inch bandaging gauze

Nasal Fracture and Epistaxis Supplies
Nasal speculum and light source
Nasal clips and tongue depressors
Cotton pledgets and cotton-tipped applicators
Silver nitrate–tipped sticks
Topical anesthetics:
- Tetracaine 1%
- Cocaine 1% to 4%
- Lidocaine 5%
- Ephedrine 5%
- Aqueous epinephrine 1 : 1000
- Benzocaine 20%

Vasoconstrictive nasal sprays:
- Phenylephrine 0.5% (Neo-Synephrine)
- Oxymetazoline 0.05% (Afrin)

Commercial nasal tampons or sponges
Nasal balloon devices
Petroleum jelly–impregnated gauze
Absorbable degradable nasal packing materials
Foley urinary catheters

Wound Evaluation and Repair
Nonabsorbable nylon 6-0 and 7-0 sutures
Absorbable chromic 6-0 and 7-0 sutures
Surgical tissue glue
Adhesive strips
No. 15 scalpel blade
18-gauge needles
Ophthalmoscope
Fluorescein paper and blue light

Traumatic Ear Injury Evaluation
Otoscope
Alligator forceps, bayonet forceps, and right-angle probes
Viscous lidocaine
Medical-grade soft silicone putty
Cotton pledgets

Prophylactic Antibiotics
Oral antibiotics:
- Cephalexin
- Amoxicillin-clavulanate
- Dicloxacillin
- Clindamycin
- Trimethoprim-sulfamethoxazole
- Penicillin V
- Amoxicillin

Topical steroids containing antibiotic suspension drops:
- Hydrocortisone with ciprofloxacin

Topical antibiotic drops:
- Ciprofloxacin
- Ofloxacin
- Tobramycin

safety goggles and custom-fitted mouth protective devices when training for and participating in contact sports or any activity that may injure the eyes, mouth, and face. Wear properly fitted protective equipment, such as helmets, face masks, padded chin straps, and mouth guards, for all sporting activities to prevent orofacial trauma.

REFERENCES

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

CHAPTER 21

Wound Management

RAMIN JAMSHIDI

Management of wounds sustained in remote and wilderness environments requires special preparation and knowledge. The basic elements of wound care can be outlined so that a provider in a remote, austere, or wilderness environment can safely manage the acute wound and thereby limit secondary injury.

In the care of acute trauma, attention is frequently focused on wound closure. In truth, most traumatic wounds fare well if left open to heal by secondary intention because this allows drainage of infected or necrotic tissue.[21] However, open wounds incur a prolonged healing time, wound care discomfort, and vulnerability to further injury, and they leave larger scars. The critical goals of immediate wound care are to stop hemorrhage and limit complications related to infection. Secondary goals are to promote rapid healing and optimize the cosmetic outcome.[55]

TYPES OF WOUNDS AND DEFINITIONS

Abrasions result from tangential (shearing) forces. Although abrasions are most commonly superficial, they can be extensive and involve deep tissues. Superficial abrasions pose no threat to the patient but may require use of analgesics. Deep abrasions that have completely obliterated skin and denuded underlying fascia are at increased risk for infection and must be kept clean. By virtue of the mechanism of injury, abrasions involve more surface area than they do depth. As a consequence, they are not amenable to suture closure. Abrasions are treated with extensive irrigation to remove all debris (often dirt or gravel) and with application of nonadherent dressings. Topical antiseptic solutions are not necessary but are useful adjuncts in preventing gauze dressings from adhering to raw tissue. Such dressings should be

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changed once daily or more frequently as needed for soilage or adherence (drying out). Abrasions do not form abscesses, because they have no deep spaces to contain infection. They may become superinfected and develop cellulitis; although this is uncommon, the possibility is more real in the exposed wilderness environment. Diagnosis and management of cellulitis are discussed later in this chapter.

Burns (see Chapter 15) may be caused by thermal, chemical, or radiation sources. These injuries span a spectrum from trivial sunburn to deep tissue necrosis. The first principle of management is to limit further injury by extinguishing the source, seeking shade, washing out chemicals, and moving the person away from the source. For chemical exposures, voluminous irrigation is the key to limiting further injury. This should be done with clean (not necessarily sterile) water, and the run-off irrigant should be prevented from injuring more skin.[8,19,43] Chemical quenchers (i.e., alkaline solution for an acid burn) should never be used because the resulting exothermic reaction will cause secondary injury. The practice of avoiding chemical quenchers has a long history. There is some animal evidence to suggest that this may not be such a problem, but accepted practice is to avoid use of chemical quenchers and concentrate on dilution and removal. Once the burning process is arrested, burn care must focus on antisepsis because infection poses the single most important immediate threat.

Burn wounds should be fastidiously cleaned to remove all foreign material and devitalized skin. Depth was formerly described as first, second, or third degree, but modern description relies on the descriptors *partial thickness* and *full thickness* (Figure 21-1). Blisters should be left intact unless they interfere with function. There is some debate about the management of blisters, but in a wilderness environment, the “biologic bandage” provided by an intact blister supersedes any academic debate about the presence of inflammatory mediators in the blister fluid. Blisters over the palms or joints are exceptions to this rule, because their presence will significantly limit motion and potentially engender contraction or decrement in function. One school of thought is that these blisters should be unroofed and gently scrubbed away with moistened gauze or trimmed with scissors. Once cleaned, burns should be dressed and kept clean. Topical antiseptic agents should be applied to burns with invasion deep enough to result in blistering or erosion through the skin to white tissue or burned muscle underneath. Silver sulfadiazine is an excellent agent, and can be reapplied once or twice daily to prevent the wound from desiccating. In the absence of silver sulfadiazine (and for burns < 1% of the body surface area), antibiotic or antiseptic ointment (e.g., bacitracin) can be employed.

Lacerations can be deep or superficial, or simple or irregular (Figure 21-2). Generally, lacerations are amenable to primary repair (i.e., closure at the time of injury). Closure simplifies wound care and optimizes cosmetic outcome. Much of the following discussion is dedicated to management of lacerations.

FIGURE 21-1 Campfire burns, mostly partial-thickness burns, with both intact and ruptured blisters. The distal forearm is pale white without capillary refill, representing full-thickness injury. *(Courtesy Ramin Jamshidi, MD.)*

FIGURE 21-2 A deep and irregular laceration that is suitable for irrigation and multilayer closure with interrupted mattress sutures (see text). *(Courtesy Ramin Jamshidi, MD.)*

Punctures are lacerations with a very small entry site injury but an extended depth. Generally these injuries should not be closed, because they cannot be adequately cleansed. There is little cosmetic benefit to closure, whereas there is significant risk for trapping infectious agents deep within the wound because of the inherent difficulty of properly irrigating the tract.

CLINICAL PRESENTATION

Immediate evaluation of traumatic wounds should include determination of the type of injury. Focused assessment includes determination of the surface area and apparent depth. Distal sensation and passive and active range of motion must be assessed to elucidate any associated nerve injury, tendon disruption, or fracture. Nerve and tendon injuries will not affect acute management but are important as a baseline examination. Fractures require immobilization, a topic discussed in Chapter 22. Distal perfusion must be assessed to determine the likelihood of vascular injury. If there is suspicion of vascular injury based on examination, depth of the wound, or blood at the scene, the wound should not be probed (nor blood clots dislodged) until one is prepared to place direct pressure to control hemorrhage and potentially ligate or suture the injured vessel.

Time since injury is very important when considering wound closure. Within several hours of injury, traumatic wounds become colonized with bacteria. Even without frank infection, heavy colonization impedes proper wound healing.[21,28,56] A bacteria-laden wound that has its edges approximated will generally not heal and has increased risk for developing an abscess. Historically, the accepted dogma has been that traumatic wounds older than 6 hours should not undergo primary closure, but this is based only on animal experiments by P.L. Friedrich that date back to 1898. Efforts to establish a firm time limit beyond which traumatic wounds should not be closed have previously yielded inconsistent results.[4,12,34,60] More recently, a randomized prospective trial in the Netherlands demonstrated no increase in infection rates between wounds closed before or after 6 hours from injury.[62]

With copious irrigation and removal of foreign bodies, most wounds that are otherwise suitable for closure (see earlier discussion) can be closed if this is accomplished within 6 hours of injury.[25] This deadline may be extended in the hospital setting, where thorough sharp debridement can be undertaken in a controlled environment. In some circumstances, wounds may be closed days or even weeks after they have been initially generated, but this involves sophisticated surgical care.[35] This situation should not be confused with an acute wound in the wilderness, which in all circumstances should be thoroughly irrigated, have foreign bodies removed, and have dressings applied. These elements are critical, whereas closure is usually optional.

Acute wounds in the wilderness should be closed only if they are clean, if suitable materials and instruments are at hand, and

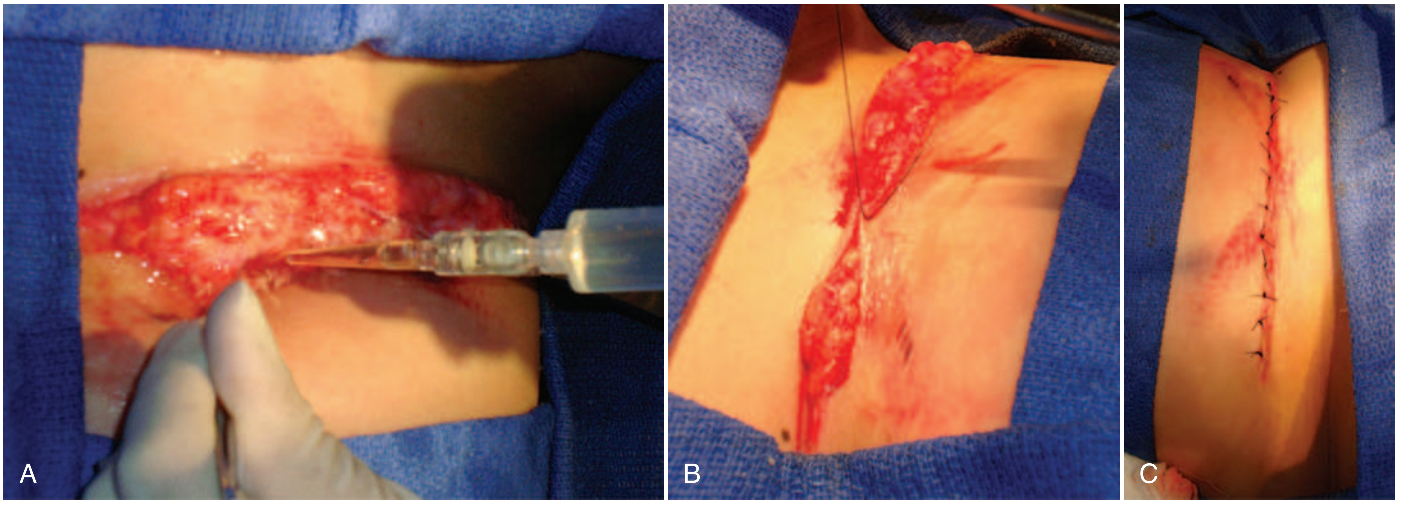

FIGURE 21-3 **A,** Irrigation of a deep inguinal wound to remove debris. **B,** Placement of an interrupted vertical mattress suture to approximate the deep tissue defect with eversion of the edge and relief of tension. **C,** Completed interrupted closure. *(Courtesy Ramin Jamshidi, MD.)*

if the care provider has had proper training. If less than 6 hours have passed since injury, closure is generally safe. If conditions are fitting and the provider has sufficient experience, this author supports closure up to 24 hours after injury. An intermediate option is partial wound closure, in which the "corners" and/or deeper layers of tissue are reapproximated while a portion of the wound is left open to heal by secondary intention. This helps minimize wound morbidity and discomfort while allowing drainage if infection were to develop.

TREATMENT

Personal protective equipment should be donned before interrogating, preparing, possibly closing, and dressing a wound. Eye shields and gloves are considered mandatory equipment. Eye shields are particularly important in preventing exposure of mucous membranes to bodily fluids. Gloves are essential; they should be made of a material other than latex and should contain no talcum or other lubricant. Talcum, calcium carbonate, and cornstarch are common glove lubricants, and all have been shown to cause wound granulomas, foreign body reactions, adhesions, and chronic sinuses. Sterile gloves are less cumbersome to work with but are not required, because they do not reduce the incidence of infection in an austere setting.[47] Use of a mask has also not been demonstrated to reduce rates of acute wound infection but certainly provides a protective barrier for the care provider. Hair coverings are not necessary, because studies have failed to demonstrate reduction in wound infection rates.

CLEANSING TECHNIQUES

Cleansing involves removing devitalized tissue, clearing debris, and copiously irrigating the area.[25] This may involve vigorous manipulation of painful and sensitive tissues, so if oral analgesics are available, they should be used. Constricting jewelry and equipment should be removed from the affected area (e.g., rings, piercings). Ideally, hair around the wound is trimmed because the roots harbor bacteria. Hair should be trimmed to a few millimeters in height because shaving at the surface increases wound infection rates by causing superficial skin trauma.[3] Eyebrow hair is an important exception, because trimming or shaving can result in permanent abnormal hair growth. If hair trimming is not possible, an antiseptic ointment can be used to paste the hair down away from the wound.

Water should be used to clean the wound. There is no demonstrated benefit to use of saline solutions, and there is no absolute need for the irrigant to be sterile.[8,19,43] Although some persons mention use of dilute (1%) povidone-iodine as an irrigant, this has not proved to be more efficacious. Whatever the method available to generate potable water (e.g., iodine tablets, mechanical filter, irradiation, boiling), it is sufficient to generate irrigation fluid for wound care. Hydrogen peroxide is injurious to deep tissues and should not be used as an irrigant.

The greatest impact on wound cleanliness is gained from the volume of irrigant and simple mechanical debridement. Debridement is achieved by removal of obvious foreign material (as with forceps) and also by pulsing irrigant at the wound (the fluid agitation is an effective debrider) (Figure 21-3).[37] The available volume should be used in successive bursts rather than a single "gush," because dilution of wound contaminants is far superior with small serial volumes. Although the matter has not been systematically researched, a guideline that is often used is a minimum of 100 mL per centimeter of wound length. Optimal stream pressure has been determined to be 5 to 10 psi, but in a remote setting, use of pressure gauges or regulators is unnecessarily cumbersome; it is sufficient to realize that excessive pressures are not required.[54,60] A large (20- to 60-mL) syringe attached to a 19- or 20-gauge needle or catheter is an effective instrument for this purpose, and will approximate that pressure. Alternatively, holes can be punched into the cap of a squeezable water bottle to generate a similar effect. A splash shield at the tip of the instrument decreases the risk of personal exposure. If not available as a specific commercial product for this purpose, one can easily be fashioned from a paper or plastic plate, or the base of a disposable water bottle or drinking cup.

Preparing for the actual wound closure, the skin edges may be prepared with an iodine, povidone-iodine, chlorhexidine, hydrogen peroxide, or isopropyl alcohol solution, but these antiseptic agents should not be used within the wound itself because of potential toxicity. If concentrated ethyl alcohol (i.e., liquor) is available, it may be effective in reducing wound contamination, but this has not been systematically evaluated. These agents should be used to cleanse the skin surrounding the wound, using gauze soaked with the liquid to paint an overlapping spiral from the wound outward to a distance of approximately 5 cm. The cleansed skin must be allowed to dry to achieve the full effect; this takes 3 to 5 minutes at 20° C (68° F).

Honey has been used for thousands of years as an antimicrobial dressing, but only in recent years has it been scientifically evaluated for effects on wound healing. The antibacterial effects are believed to be due to acidity, osmolarity, and chemical factors such as hydrogen peroxide and methylglyoxal. The latter is present only in manuka honey (a generally edible honey), which has been formulated into commercial wound care products. Despite regulation by the Food and Drug Administration (FDA), purity and potency vary greatly among honey products, and clinical research into their efficacy is ongoing.[41] Some of the commercial dressings available are lightweight, weather-resistant, and useful adjuncts for wilderness wound care. For example, Medihoney (Derma Sciences) and TheraHoney (Medline Industries) are manuka honey products that come in a variety of formulations, including hydrocolloid gel, adhesive bandage, and combination alginate dressings. Some of these can be left in place for 5 days at a time and reduce the need for frequent dressing changes.

Honey in wound care is a promising and evolving area but cannot be recommended as a routine adjunct at this time.[31] If honey products are employed in wound care, this author recommends verified products regulated by the FDA. It is estimated that more than 80% of products labeled as manuka honey are counterfeit. Furthermore, while there is allure to this centuries-old practice, simply pouring table honey onto a wound, especially in the austere environment, is not advised. Modern honey products contain a variety of natural and synthetic products that do not necessarily provide medicinal benefit. There is also potential harm to pouring a "sealing" gel of honey into a wound because this may encourage bacterial proliferation and limit drainage of exudate or pus.

VASCULAR INJURIES

Evaluation of hemorrhage is a major component of acute wound management; even if bleeding has stopped, there may be a risk for delayed rebleeding. The wound should be irrigated vigorously so that if bleeding is to occur, it happens while the wound is being interrogated and one is poised to address it. Inadequate hemostasis during initial treatment comes at the cost of avoidable delayed blood loss, which can be particularly hazardous in the wilderness setting.

Bleeding from wounds can almost always be controlled with direct pressure. The most common reason for failure of direct pressure to control bleeding is too short a compression time. Initial pressure should be applied for 5 minutes (checked with a timepiece to ensure accurate timing). If bleeding persists, pressure should be reapplied for 10 minutes or pressure should be applied at both the wound and a proximal inflow point (e.g., popliteal, femoral, or brachial artery).[29] The second most common reason for failure of direct pressure is that pressure is not applied in a focused manner over the site of bleeding. A broadly applied towel over a large wound will not be as effective at controlling bleeding as will finger-point pressure applied over the actual site of greatest bleeding.

In the face of profuse diffuse bleeding (as from a large raw wound), topical adjuncts are available to promote thrombosis.[5,9,36] The original such product is QuikClot, a granular coagulant powder designed to be poured onto wounds to stop diffuse bleeding. The mechanism of action of the original product is adsorption of water onto zeolites, which activates factor XII and catalyzes platelet aggregation. However, the granular form of this material was difficult to use for two reasons: the poured material is unwieldy and difficult to control in windy situations, and the reaction is exothermic, causing pain and risking burn injury. QuikClot has now been modified and integrated into a gauze dressing (also marketed as Combat Gauze). The active element is now kaolin, an alumina silicate that activates and accelerates the enzymatic clotting cascade. The solid consistency of Combat Gauze is more manageable and generates no heat on application. Celox Gauze is based on chitosan, a natural product derived from shellfish. Initial versions of this product, too, were granules to be poured into a wound, but it is now embedded into an actual gauze dressing and also has no exothermic properties. HemCon bandages are also chitosan based and not exothermic. These agents are all designed to be applied directly to bleeding wounds and compressed with direct pressure. Before wound closure, these dressings must be removed and bulky gelatinous deposits in the wound irrigated out (although mild residual coatings are reportedly safe to leave in place). All of these agents are supported by anecdotal reports of success and are clearly superior to simple gauze dressings, reducing bleeding by nearly an order of magnitude. To date, head-to-head studies of these agents have been underpowered and are difficult to interpret, but these agents have found widespread use in the military and are becoming increasingly popular in civilian prehospital trauma care.

In contrast to the above products, which are designed to control gross hemorrhage, there are adjuncts intended to assist with lower-volume bleeding within the wound. Surgicel products are procoagulant materials composed of a scaffold of cellulose polymer. They have been in clinical use for more than 60 years and are manufactured in fibrillar consistency as well as woven sheets. The major benefit of these agents is that they are totally absorbable, so they can be left on or within the wound; the wound can even be sutured closed over them. Gelita-Cel is a procoagulant dressing that is similar to Surgicel. It is a knitted sheet of resorbable cellulose that boasts complete dissolution in as little as 96 hours (more rapidly than Surgicel and therefore theoretically less likely to result in an encapsulated collection within the wound).

Tourniquets have often been considered a last resort to stop life-threatening hemorrhage. Considerable debate continues over the use of tourniquets and who should be allowed to apply them (laypersons, emergency first responders, midlevel health care providers, physicians, or even specialty-specific physicians). The more proximal a tourniquet is applied, the greater the risk of devastating tissue or limb loss. With experience from recent military and civilian terrorist attacks, tourniquet use is making a comeback and garnering support from authoritative groups. The best potential use of a tourniquet is for a traumatic amputation in which there is copious, diffuse bleeding at the open end that cannot be controlled by other means (such as direct pressure). In this case, a tourniquet can be firmly applied just proximal to the open wound so that distal ischemic tissue is minimized (Figure 21-4). This practice has been supported by the American College of Surgeons Committee on Trauma.[12]

Commercial tourniquets such as the Combat Action Tourniquet are available, but a blood pressure cuff can serve as an effective instrument. Whatever device is employed, it should be applied and intensified until pressure exceeds arterial pressure and then increased at least another 20 mm Hg or until bleeding stops. Controversy also exists as to whether tourniquets should be intermittently released during prolonged application. This debate is fueled by contradictory experimental evidence.[40,46] Nonetheless, most groups now suggest avoiding intermittent release because of the possibility of additional blood loss without a clear benefit.[15] If a tourniquet is released (as when testing whether hemorrhage has been controlled and it is no longer necessary), it should be done slowly over a minute or two, because recirculation of stagnant, acidic, and hyperkalemic blood from the nonperfused distal limb can lead to hemodynamic instability. If dysrhythmia is noted, the tourniquet should not be released further until the patient stabilizes. Hypotension and even cardiac arrest may result when a tourniquet is released; these dangers are sometimes overlooked and can cause tragic outcomes.

FIGURE 21-4 Severe complex crush injuries of both legs. These wounds mandate immediate evacuation, but profound hemorrhage may require tourniquet placement to prevent exsanguination until advanced surgical care is available. *(Courtesy Ramin Jamshidi, MD.)*

TABLE 21-1 Relative Indicators of Vascular Injury	
Hard Signs	**Soft Signs**
Active or pulsatile hemorrhage	Hypotension or shock
Pulsatile or expanding hematoma	Neurologic deficit immediately following injury
New thrill or bruit	Stable, small, nonpulsatile hematoma
Limb ischemia or compartment syndrome	Proximity of wound to major vessels
Diminished or absent distal pulse	

Although profuse external hemorrhage is easy to localize, ischemic complications of vascular injuries are more subtle and sometimes overlooked. Examination findings are classically divided into "soft" and "hard" signs of vascular trauma, indicating the relative likelihood of a significant vascular injury (Table 21-1).[29] The presence of a hard sign is more than 90% predictive of the need for vascular intervention. Only about one-third of patients with a single soft sign have an abnormality on arteriography, and few of these require emergent intervention. Any patient with a hard sign of vascular injury requires immediate evaluation by a surgeon. A simple, reliable, classic evaluation is the arterial pulse index (ratio of systolic blood pressure in the affected extremity to the contralateral side). An index of less than 0.9 is 95% sensitive for major arterial injury, and an index of more than 0.9 rules out injury, with a negative predictive value of 99%.[30]

ANESTHESIA

Manipulation of traumatic wounds can be painful and provoke anxiety. Studies have demonstrated that music can reduce procedural anxiety.[39,52] For most patients, explaining the steps involved can improve tolerance by guiding expectations.[65] If vigorous debridement or suture closure is to be attempted, infiltration of local anesthetic can provide tremendous comfort for the patient and thus facilitate technically superior closure. Anesthetic solutions can be applied locally within tissue, as topical agents or as regional nerve blocks.

Direct intradermal or subcutaneous injection is the most common technique of local anesthetic use. These agents are synthesized in two related chemical classes: aminoamides (lidocaine, bupivacaine, dibucaine, etidocaine, mepivacaine, prilocaine, and ropivacaine) and aminoesters (chloroprocaine, procaine, tetracaine, and cocaine). Characteristics of the most commonly used local agents are listed in Table 21-2. Inclusion of epinephrine in the solution causes local vasoconstriction by α_1-adrenoceptor agonism and nearly doubles the duration of the local effect of the medication. By slowing systemic absorption of the anesthetic, epinephrine also increases the maximum allowable total dose. Inclusion of epinephrine in the anesthetic solution is believed by some to improve local hemostasis, but this is a minor contribution relative to the effect of increased tissue turgor from infiltration of the solution. Conventional teaching is that epinephrine-containing local anesthetic solutions should not be used in end-vascular beds such as the nose, fingers, toes, and penis because of concern for ischemia. However, there is literature to support safe use of these solutions for digital blocks.[57,63] Using anesthetics without epinephrine allows maximum flexibility in terms of allowable location of use. Pain of injection for any local anesthetic can be attenuated by mixing 1 mEq of sodium bicarbonate with each 9 mL of anesthetic to buffer the solution. It should be noted that this delays the onset of action by approximately 5 minutes.

The most common reasons for apparently ineffective local anesthetic effect are use of an insufficient dose and inadequate time allowed for onset of effect. Time to onset depends on the agent's ability to cross cell membranes, which is determined by the compound's intrinsic pK_a. In general, a minimum of 3 minutes is required for onset of effect (as with lidocaine), but sometimes as much as 15 minutes is required (as with bupivacaine). This chemistry explains the delayed onset of action when the anesthetic is mixed with bicarbonate.

For all agents, intravascular administration or overdose will first cause agitation, tremor, and tinnitus, then seizures, and, finally, cardiac arrest through aberrant conduction.[23] These risks are particularly important to consider in children, in whom toxicity occurs at lower doses. Table 21-2 lists maximum doses of commonly employed local anesthetics, along with weight-based guidelines for children. Although ample anesthetic should be administered, caution must be exercised to ensure that no intravascular administration occurs and to avoid nearing the maximum dose. This principle is complicated by the fact that maximum doses are ill defined and are set at different levels in different nations.[48] Of note, patients with liver disease and those taking medications (such as systemic antifungals) interfering with cytochrome P-450 metabolism will have decreased capacity to metabolize aminoesters. In patients with renal failure, the metabolism of bupivacaine is altered, which requires a dose reduction of 15% to 20%. Concern frequently arises over administration of epinephrine-containing local anesthetics to patients with heart disease. However, these dilute local or regional doses do not cause significant systemic hemodynamic effects.

Local anesthetics can be applied topically as well and have demonstrated efficacy in numbing the skin, although 20 to 30 minutes is required for onset. Topical anesthetics are particularly useful for superficial wounds over a large surface, such as burns and abrasions.[33] A variety of formulations are available: TAC (0.5% tetracaine, 0.027% epinephrine, 11.8% cocaine), LET (4% lidocaine, 0.1% epinephrine, 0.5% tetracaine), and EMLA (2.5% lidocaine, 2.5% prilocaine in a eutectic mixture containing a thickener, emulsifier, and distilled water buffered to pH 9.4), and 5% lidocaine jelly. Characteristics of these agents are summarized in Table 21-3. Care must be taken to avoid application near mucous membranes because of the potential for systemic absorption and toxicity. Compared with TAC, LET has less potential for toxicity, is not a controlled substance, and is less expensive.[1] LET should be stored in a light-resistant container and is stable for 6 months if refrigerated and 4 weeks at room temperature. It should be discarded if the solution becomes discolored. Near mucous membranes, 3 mL of LET solution can be combined with 150 mg of methylcellulose (4000 cps) by stirring for a few minutes, to create a gel preparation that should be used immediately. This lessens the likelihood of having the topical preparation run onto the mucous membranes.

True IgE-mediated allergic reactions to local anesthetics are very rare, particularly with aminoamide anesthetics.[14,23,48] Typically these reactions are actually caused by preservatives such as methylparaben in multidose vials. One alternative is to use an aminoester anesthetic such as chloroprocaine. However, the principal metabolite of the aminoesters is paraaminobenzoic acid, which is chemically similar to methylparaben and can induce the same reactions. A reasonable approach to a reported allergy to a particular anesthetic is to use a preservative-free anesthetic of the other class.

Use of diphenhydramine has been described as an alternative to traditional local anesthetics.[45] At 1% concentration, it can be

TABLE 21-2 Properties of Select Local Anesthetics

Agent*	Duration	Maximum Dose	Weight-Based Dose
Amide Class			
Lidocaine	30-60 minutes	300 mg	5 mg/kg
with epi	60-120 minutes	500 mg	7.5 mg/kg
Bupivacaine	90-240 minutes	175 mg	2 mg/kg
with epi	180-360 minutes	225 mg	3 mg/kg
Ester Class			
Chloroprocaine	15-30 minutes	800 mg	7 mg/kg
with epi	30-60 minutes	1000 mg	10 mg/kg

**With epi*, epinephrine 1:200,000 (5 μ/mL).

TABLE 21-3 Properties of Topical Anesthetics

Agent	Composition	Time to Onset	Notes
TAC	0.5% tetracaine 0.057% epinephrine 11.8% cocaine	30 minutes	Seizures and cardiac arrest reported; controlled substance; avoid mucosal surfaces
LET	0.5% tetracaine 0.14% epinephrine 4% lidocaine	15-30 minutes	Inactivated by extensive light exposure
EMLA	2.5% lidocaine 25% prilocaine	30-120 minutes	Longer duration; requires occlusive dressing; methemoglobinemia reported; do not place over open wound
LMX 4 or 5	4% or 5% liposomal lidocaine	15-40 minutes	

injected subcutaneously or subdermally but causes more pain from injection than do the classic anesthetics, and this pain is not diminished by dilution or mixing with bicarbonate.[49] More importantly, diphenhydramine injection can result in vesicle formation and tissue necrosis.[22] Because of these characteristics, it is not recommended as a local anesthetic. In the absence of any pharmacologic anesthetics, ice may be applied around the wound edges for 5 minutes to diminish sensation.

Regional anesthetic techniques can be useful for dealing with extremity wounds or fractures. This involves infiltrating the anesthetic around the nerve(s) innervating the affected region.[27] These techniques rely on specific anatomic landmarks and are beyond the scope of this chapter.

WOUND CLOSURE TECHNIQUES

The first determinant of whether or not to close a wound is the type of trauma sustained. The next is the degree of contamination and time since injury. If the wound clearly has foreign material that cannot be removed or devitalized tissue that cannot be completely debrided, the wound should be left open to heal by secondary intention. Critical factors are the experience of the health care provider and availability of instruments. Wound closure is almost never so necessary that an untrained provider should attempt it. Even in experienced hands, wound closure in remote settings may beget serious complications, including cellulitis, abscess, wound dehiscence, necrotizing soft tissue infection, and systemic sepsis.[53]

A variety of materials and approaches may be taken to close wounds. Sutures are generally required to approximate deep tissues, but the superficial aspects of wounds can be addressed with adhesive strips, sutures, glues, or staples, or some combination thereof.[26]

Small superficial lacerations in areas with modest skin tension may be amenable to reapproximation with dressing strips such as Steri-Strips, Leukostrips, or Episeal. This can also be achieved with clean, semiporous medical paper tape. These strips of tape are laid perpendicular to the direction of the wound while holding the edges together. Small gaps should be left between strips to ensure ventilation. Different manufacturers boast superior adhesiveness, but the greatest impact on tape adherence is the use of liquid adhesive on the skin before applying the tape. Tincture of benzoin and Mastisol are equally effective for this purpose as long as they are allowed to dry for a minute before the strips are applied. The modern genesis of these products was the use of plastic medical tape to approximate wounds in remote locations when providers found the skin too thin or delicate to retain sutures. Modern adhesive strips can still be used for this purpose, or even in a hybrid fashion; strips can be placed along wound edges to reinforce the skin and help it “hold” suture. This practice actually dates back to the 16th century, when Ambroise Paré pasted linen strips to wound edges to reinforce suture closure.

Modern cyanoacrylate skin glues are effective, affordable, and more versatile than adhesive strips.[10,26,50] Although they do not provide as much wound strength as does suture closure, they boast the added benefit of sealing the incision, which may be particularly useful in a wilderness setting involving exposure to the elements. Available agents include Dermabond, SurgiSeal, Indermil, and Histoacryl. Each of these differs slightly in time to drying, maximum tensile strength, and viscosity. In general, the butyl agents (Indermil and Histoacryl) dry more quickly, but the octyl agents (Dermabond and SurgiSeal) are more flexible. The variability in clinical worth is relatively slight, so the selection should be based on availability and cost. Although many are stable at lower than 30° C (86° F), it should be noted that storage of Indermil for longer than 4 weeks requires refrigeration (Table 21-4). In the absence of a medical glue, Krazy Glue can be applied a ways distant from tender areas or mucosal surfaces. It will not remain in place as long as the glues that are approved by the FDA for clinical use, and some of the breakdown products can be injurious if they enter a wound. In clinical practice, however, it can be useful, particularly in areas such as the hands and fingers.

Improvised wound closure has been described using only tape, needle, and thread. Two strips of adhesive tape are cut to 2.5 cm (1 inch) longer than the wound. One-quarter of each strip of tape is folded over lengthwise (sticky to sticky) to create a long nonsticky edge on each piece (Figure 21-5). One strip of the tape is attached to each side of the wound, 0.6 to 1.3 cm (0.25 to 0.5 inch) from the wound, with the folded (nonsticky) edge toward the wound. Using a needle and thread, the folded edges are sewn together, cinching them tightly enough to bring the wound edges together properly (Figure 21-6). The tape will

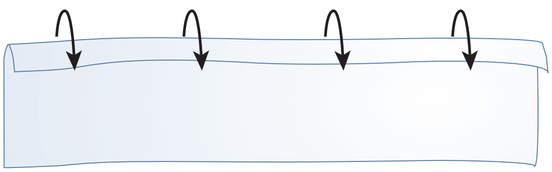

FIGURE 21-5 Folding a longitudinal piece of tape to prepare for a suture anchor strip.

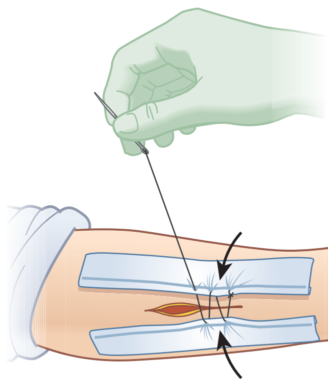

FIGURE 21-6 Sewing the tape suture strips together to close the wound.

TABLE 21-4 Characteristics of Selected Topical Adhesives

Product (Manufacturer)	Chemical Class	Layers of Application	Storage Recommendations	Comments*
Butyl-CA Polymers (Faster to Dry)				
Histoacryl (Aesculap)	n-butyl-CA	1 layer	Store at 22°C (72°F) Not more than 8 hours at 40°C (104°F)	Low viscosity
SwiftSet (Covidien)	n-butyl-CA	1 layer	5°C (41°F) to 25°C (77°F)	
Octyl-CA Polymers (More Flexible)				
Dermabond (Ethicon)	2-octyl-CA	1-3 layers	Below 30°C (86°F) Away from direct heat or moisture	Applies a thick coat
LiquiBand Exceed (Advanced Medical Solutions)	2-octyl-CA	1 layer	5°C (41°F) to 25°C (77°F)	Leaves a flexible seal
Skin Affix (Medline Industries)	2-octyl-CA	1 layer	5°C (41°F) to 25°C (77°F)	
SurgiSeal (Adhezion Biomedical)	2-octyl-CA	1-2 layers	N/A	
Butyl-CA/Octyl-CA Blends				
Dermaflex (Derma Sciences)	60% 2-octyl-CA 40% n-butyl-CA	1 layer	Room temperature	
GLUture (Abbott Labs)	60% 2-octyl-CA 40% n-butyl-CA	1 layer	Below 30°C (86°F)	Marketed for veterinary applications Multiple-use tube Low cost
Other				
Krazy Glue (Krazy Glue)	ethyl-CA	N/A	N/A	Not marketed for medical application Multiple-use tube Low cost

*Comments are the opinion of the author, based on personal experience.
CA, cyanoacrylate; N/A, not available.

stick much better if a thin layer of benzoin is applied to the skin before beginning.[6] This use of tape can also be employed when suturing delicate skin, as in elderly patients or those receiving chronic steroid therapy. Preparing the skin with adhesive and tape adds strength to the closure and decreases the likelihood of the suture tearing through the skin. This is performed as described above except that the entire tape length is applied to the skin without creation of a nonsticky edge. Full-thickness sutures are then passed through skin and tape as though they were one tissue layer.

Sutures are the workhorse of wound closure because of durability and versatility; characteristics of the most versatile sutures for acute traumatic wounds are listed in Table 21-5.[16,20,51] When suturing deep tissue, absorbable materials of immediate durability, such as polyglactin (e.g., Vicryl) or copolymeric glycolic, and lactic acids (e.g., Polysorb) should be used. At 2 weeks, these materials retain approximately three-quarters of their original strength.[13,18] Nondyed varieties are preferred within 5 mm (0.2 inch) of the skin surface to avoid wound tattooing. For mucosal lesions (such as within the mouth), rapid-absorbing gut suture is

TABLE 21-5 Properties of Select Sutures

Suture	Material	Structure	Tensile Strength	Absorption	Uses
Chromic gut	Bovine intestinal serosa treated with a chromium salt	Monofilament	0% at 2 weeks	21 days	Mucosal repair
Biosyn	Glycolide and dioxanone	Monofilament	75% at 2 weeks; 40% at 3 weeks	90-110 days	Skin
Vicryl	Polyglactic acid	Braided	75% at 2 weeks; 50% at 3 weeks	55-70 days	Deep tissue, including ligation of small bleeding vessels
Polysorb	Glycolic and lactic acid copolymer	Braided	80% at 2 weeks; 30% at 3 weeks	55-70 days complete absorption	Deep tissue, including ligation of small bleeding vessels
Prolene, Surgipro, Surgilene	Polypropylene	Monofilament	Long-term hydrolysis	Not absorbed	Skin or full-thickness wound; major vessel ligation/repair
Ethilon, Dermalon, Monosof	Nylon	Monofilament	Long-term hydrolysis	Not absorbed	Skin or full-thickness wound
Nurolon, Surgilon	Nylon	Braided	Long-term hydrolysis	Not absorbed	Skin or full-thickness wound (holds knots better than monofilament nylon)
Sofsilk	Silk	Braided	Poorly defined	Permanent	Can be used to ligate vessels, but falling out of use because of high tissue reactivity

the most suitable.[11] In all these cases, a tapered-tip needle should be used so that deep tissue is not lacerated. Ideally, skin suturing should be done with monofilament nonabsorbable material attached to a cutting needle. Nylon (e.g., Ethilon, Dermalon) and polypropylene (e.g., Prolene) are typical nonabsorbable sutures. Polypropylene is blue but does not tattoo skin as noted above for absorbable sutures. If proper materials are not available, nondyed absorbable suture with a tapered needle can be used on the skin, but nonabsorbable suture should not be buried within the wound; in this case, deep mattress sutures should be placed so that deep tissue is approximated but the suture can still be removed once healing is complete. Size selection is based on visibility and the degree of tension expected on the wound. For skin approximation, the recommended sizes are 5-0 or 6-0 for the face, neck, or ears; 5-0 or 4-0 for the fingers or hand; 4-0 or 3-0 for the scalp, arms, legs, feet, chest, or abdomen; and 3-0 or 2-0 on the back or over a major joint. Deeper layers (below the skin) generally require suture one size larger than or the same size as is being used for the skin (e.g., a deep upper arm laceration receives 4-0 absorbable suture to approximate the deep layer, followed by 4-0 for the skin).

The goals of deep tissue closure are to take tension off the skin closure and to obliterate the gap in the deep tissue so that a seroma or abscess is less likely to form.[16,20,51] Muscle sheaths (i.e., fascia) should be reattached, and subcutaneous tissues should be sutured together in interrupted fashion. A deep wound may require multiple layers of suture before skin closure, but usually one or two suffice. Each "layer" of suture is indicated not by the absolute depth of the tissue but by the presence of distinct anatomic "planes" (e.g., separate fascial sheaths) that must be approximated. If significant muscle, tendon, or nerve injuries are recognized, suture repair should not be attempted in the acute setting, but written notes should be recorded for long-term follow-up (Figure 21-7). If required later, these repairs are performed in an elective setting after healing has occurred and functional deficits are delineated.

Traumatic wounds are typically irregular in shape and thus lend themselves to closure by interrupted technique. Running closure may be employed if there is a truly linear laceration. A straight or smoothly curved incision may be closed with a running suture to save time. An irregularly shaped wound should be closed with interrupted sutures to achieve optimal alignment (Figure 21-8, *A*; see Figure 21-3, *B* and *C*). Mattress techniques can be applied for deep wounds, thin skin, or wounds under tension.[51,66] *Vertical mattress sutures* approximate the wound at two depths and evert wound edges for optimal healing (see Figure 21-8, *B*). *Horizontal mattress sutures* close a single depth, evert wound edges, and distribute tension along the length of the incision (see Figure 21-8, *C*). More complex wounds can benefit from application of advanced techniques, such as local rotational or advancement flaps.[59,61]

Mechanical clips can be applied more rapidly than can sutures. Ancient Hindus used ant mandibles to pinch skin edges together and then twisted off the ant bodies.[64] Modern skin staplers are

FIGURE 21-7 Deep laceration over the wrist that is likely to involve nerve, tendon, and vascular injury. There is no role for attempting tendon or nerve repair in the field; care should focus on irrigation, control of hemorrhage, and aseptic aftercare. *(Courtesy Ramin Jamshidi, MD.)*

made by various manufacturers and are useful for rapid closure of wounds on thick skin such as the scalp or back. They can be particularly effective for rapidly achieving hemostasis in the scalp, which is richly perfused and frequently rebleeds after direct pressure is released.

Wounds of the abdomen and chest have the potential to involve the viscera. If air is felt, heard, or seen emanating from a chest wound, or if the patient is complaining of shortness of breath, some form of pneumothorax must be present. The wound should not be closed tightly but rather should be covered with a nonocclusive dressing. This will minimize contamination while allowing outflow of air so that tension pneumothorax does not develop. If intestine or omentum protrudes from an abdominal wound, there is considerable likelihood of visceral injury (Figure 21-9). Such a wound should be covered with a moist, secure dressing and not be sutured. Both of these conditions require prompt evaluation by a surgeon.

Scalp wounds occur frequently, can be very bloody, and have unique management options. The scalp is richly perfused, so even superficial lacerations can bleed profusely. Initial care should include firm direct pressure for several minutes. If bleeding does not abate, secure scalp closure is necessary to assist in local pressure and minimize the potential space for hematoma formation. If the galea aponeurotica is lacerated and suture is available, the tissue should be primarily repaired to further limit the space available for hematoma expansion. For skin closure, staplers are excellent in this circumstance because staples are rapidly applied and effective and the scars are less noticeable on the scalp. Sutures may be used but are not necessary. If a scalp

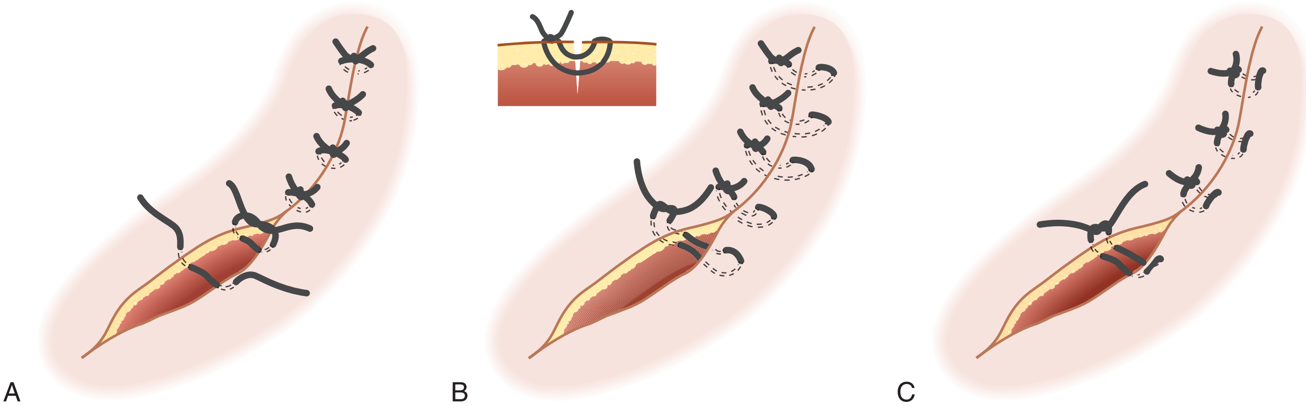

FIGURE 21-8 **A,** Interrupted simple sutures. **B,** Interrupted vertical mattress sutures. **C,** Interrupted horizontal mattress sutures.

FIGURE 21-9 Abdominal laceration with omentum emanating from the wound. This signifies the possibility of serious visceral injury and mandates immediate surgical evaluation. *(Courtesy Ramin Jamshidi, MD.)*

wound is bleeding and needs to be closed but no instruments are available, a hair tie may be performed. Hair is parted along the incision and twisted into cords on either side of the incision. Cords opposing one another across the laceration are tied together to approximate the wound edges[6,32] (Figure 21-10).

The timing of skin suture and staple removal depends on the individual wound. Healing and wound remodeling are gradual processes; at 1 week after injury, a typical wound has just 5% to 10% of the original tensile strength. Most of the healing process takes place over the first 6 weeks, at which point the tensile strength reaches 70% of baseline.[21,55] Leaving skin closure material in place longer keeps tension off the wound but increases the likelihood of visible scarring from the suture or staple itself; therefore, the timing of removal varies based on the durability and visibility of the affected area. On the face or neck, sutures are removed at 3 to 5 days; on the fingers or hand, at 5 to 7 days; on the scalp, leg, chest, or abdomen, at 7 to 10 days; on the back, arms, or feet, at 10 to 14 days; and across any major joint, at 14 days. For each site, sutures should be left in place longer if scar integrity seems poor, malnutrition has been involved, or the orientation of the wound subjects it to excessive tension. Sutures are removed with scissors, and staples are removed with a staple remover or by laterally spreading a hemostat between the skin and the staple. Once the sutures or staples are removed, the healing wound may be reinforced with adhesive strips or skin glue (as described earlier) to minimize tension while healing continues, especially in a wilderness environment where vigorous activity may strain the wound. Visibility of the resulting scar is minimized by keeping it out of direct sunlight, particularly for the first 3 months following injury.

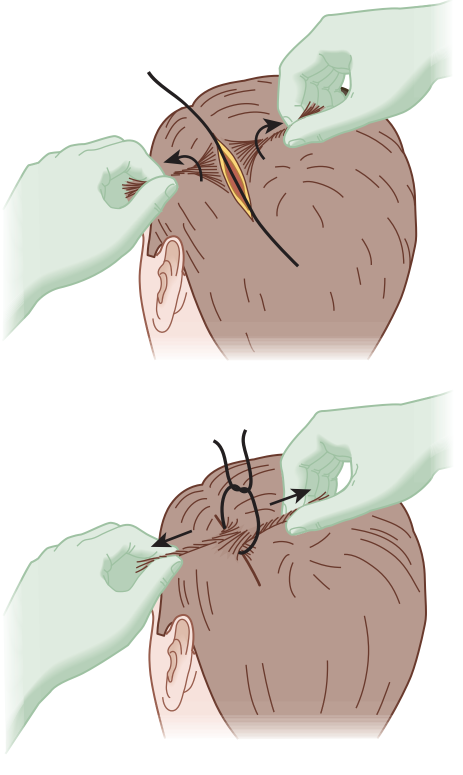

FIGURE 21-10 String and hair-tying method for closing a scalp wound.

DRESSINGS AND AFTERCARE

Wounds should be kept as clean as possible. Any wounds addressed in austere environments are at increased risk for infection and should be carefully monitored for cellulitis or abscess (see Complications). The incidence of infection obviously depends on the specific wound characteristics, anatomic location, and context of injury. Although up to 25% of acute wounds reveal *Streptococcus, Staphylococcus,* or *Escherichia* when cultured, most studies have revealed just a 5% rate of infection. Weighing this against the risk for adverse reactions and the effect of selecting resistant species, antibiotics are not prescribed for all traumatic wounds.[42] The decision to administer prophylactic or empirical antibiotics must be individualized to each situation. Patient factors that should encourage consideration of antibiotics include poorly controlled diabetes mellitus, malnutrition, recent chemotherapy, prosthetic valve or organ transplant recipient, peripheral vascular disease, renal failure, chronic liver disease, chronic corticosteroid use, or other types of immunocompromise. Wound factors include delay to cleansing and repair, extensive devitalized tissue, heavy contamination or retained debris, bites, oral lacerations, foot wounds, open fractures, or injury to poorly perfused tissue (bone, joint, tendon).[4,34,42]

Tetanus is caused by *Clostridium tetani,* an organism found in soil and the excrement of humans and animals. The often fatal disease can be prevented by immunization, but 40% of Americans age 60 years or older lack seropositivity.[38] Tetanus immunization status must be evaluated for all patients with traumatic wounds, and a booster dose of toxoid and/or immune globulin administered if the patient is at risk for infection (Table 21-6). The formulation of tetanus toxoid booster depends on the age of the patient and the vaccination history (Table 21-7).[1,10] Recent updates to the recommendations from the Centers for Disease Control and Prevention include expansion of Tdap administration beginning at 7 years of age, and inclusion of pregnant women and adults 65 years of age and older.[2]

TABLE 21-6 Postinjury Tetanus Prophylaxis

History of Immunization (Doses of Adsorbed Tetanus Toxoid Previously Received)	Clean and Minor Wound	All Other Wounds*
Unknown or less than series of 3 doses	Toxoid†,‡,§	Toxoid and TIG‡,§,‖
Three or more doses		
Last within 5 years	No prophylaxis	No prophylaxis
Last within 10 years	No prophylaxis	Toxoid
Last over 10 years earlier	Toxoid	Toxoid and TIG‡,§,‖

*Such as contaminated with dirt, soil, saliva, or feces. Includes punctures, avulsions, missile injuries, crushing injuries, burns, and frostbite.
†Tetanus toxoid formulation depends on the age of the patient (see Table 21-7).
‡No toxoid should be administered to infants younger than 6 weeks of age.
§Patients with acquired immunodeficiency syndrome should receive TIG regardless of immunization history.
‖TIG 250 units intramuscularly (for both adults and children). Toxoid should not be administered at the same site.
TIG, Tetanus immune globulin.

TABLE 21-7 Recommended Tetanus Toxoid Types

Age	Tetanus Toxoid Formulation
<6 weeks	No toxoid
>6 weeks and <7 years	DTaP
7 years or older	Tdap if never received; Tdap Td if previously received Tdap

DTaP, pediatric diphtheria and tetanus toxoids and acellular pertussis; Td, tetanus and diphtheria toxoids; Tdap, tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis.

Dressings serve a few limited purposes; they protect the wound from the elements and contamination, absorb fluid from the wound and thereby protect the surrounding skin, and provide an environment conducive to healing. Generally these goals can be achieved by dry gauze secured with a bit of tape. Gauze dressings should be changed once daily or more frequently as needed when soiled.

For wounds left open to heal by secondary intention, episodic dressing changes are required to provide gradual debridement and prevent desiccation. The simplest and most traditional approach is to apply gauze moistened with water, normal saline, or lactated Ringer's solution directly onto the wound and cover it with a layer of dry gauze. These dressings should be changed 3 times daily as the outer dry gauze wicks fluid away from the wound surface. In the absence of infection, this process can be simplified by the use of hydrogels that do not evaporate as quickly as do crystalloid solutions. Tegagel and Curafil are two of the most widely used hydrogels available in an amorphous form (gel in a squeezable tube). This is a more effective formulation for a wilderness provider (as opposed to prepackaged individual gauze and hydrogel dressings). If hydrogels are used, moist-to-dry gauze dressings can be changed just once a day.

The last few years have witnessed a proliferation of wound care products intended to accelerate healing and increase the simplicity of care. One of the most notable and applicable to wilderness care is Mepilex. This is a silicone foam dressing designed to wick exudates away from wounds while keeping them hydrated to allow healing. This versatile adjunct self-adheres to the skin surrounding the wound and can be left in place for up to 5 consecutive days to manage open or weeping wounds. The foam should be trimmed to cover the wound and overlap onto surrounding skin by about 2 cm (0.8 inch). It should be stored in dry conditions at a temperature under 35°C (95°F); sunlight will discolor the material but not alter its function.

Antiseptic ointment is produced in a variety of formulations by many manufacturers. These greasy or gelatinous materials contain povidone-iodine, bacitracin, polymyxin B, or a combination of topical antimicrobials; no substantive evidence exists for the superiority of one formulation over another. However, one must be sure that the patient is not allergic to any of the agents in the ointment. Antiseptic ointments are useful topical agents for injured areas that do not penetrate the skin but are predisposed to desiccation (e.g., superficial abrasions or burns). The viscosity of these ointments makes them particularly effective in areas that are difficult to dress and are in constant motion (such as the face or hands).

COMPLICATIONS

Cellulitis is diagnosed by the presence of a blanching erythema around and spreading away from the edges of a wound and may demonstrate proximal streaking along lymphovascular channels. It is important to distinguish this condition from the hyperemia that commonly surrounds the edges of a healing wound. Erythema associated with normal wound healing is not as bright red as is cellulitis, has less dramatic blanching with pressure, is symmetric around the edges of the wound, and extends not more than a centimeter from the wound edges. If erythema is not limited by these characteristics or if it progresses in size, wound infection is present. The treatment for cellulitis is a systemic antibiotic. The chosen antibiotic (first-generation cephalosporin or antistaphylococcal penicillin) should cover typical skin flora but also take into consideration any particular exposures (e.g., open water injury, animal bite, soil contamination) that may be associated with the trauma and dictate coverage of different microbes.[7] Cellulitis without abscess does not require suture removal. If cellulitis persists or progresses after 36 hours of the above treatments, the antibiotic spectrum should be broadened and the wound reevaluated to ensure that there is not an underlying abscess.

Abscess is a suppurative soft tissue infection. Pus is a mixture of dead organisms, leukocytes, and debris contained within a deep tissue space. An abscess will continue to expand, causing progressive pain, surrounding cellulitis, and potential systemic illness until drained (Figure 21-11). Antibiotics may stunt the growth or spread of associated cellulitis, but abscesses require drainage. This is accomplished by removing any sutures, staples, or tape keeping the wound closed. The abscess cavity is copiously irrigated, and a soft probe is used to ensure that any loculated collections are properly drained. An excellent probe is a cotton-tipped swab dipped in antiseptic ointment to prevent deposition of cotton threads.

Necrotizing soft tissue infections are true emergencies and require surgical intervention. These can take the form of superficial infections or deep fasciitis. The superficial variety can be easily recognized by the foul-smelling, gray (dirty dishwater) drainage, but necrotizing fasciitis can develop surreptitiously because skin findings are often subtle and mistaken for simple cellulitis. The signs of deep infection include pain on passive motion, woody induration, and rapid spread.[24] Antibiotics may stall the pace of progression, but these conditions are uniformly fatal if not addressed by a general surgeon. The definitive treatment is wide incision and drainage along with fluid resuscitation and intensive supportive care. This typically results in large, disfiguring wounds.

Compartment syndrome results from elevated pressures within a contained compartment; as pressure rises, it exceeds venous pressure and, eventually, arterial pressure, resulting in tissue ischemia. In the wilderness setting, this is most likely to occur from blunt trauma, particularly with crush injury or a closed fracture. The classic evidence of increased compartment pressures is pulselessness, pallor, pain on passive motion, poikilothermia, and paresthesia.[58] Pain on passive motion is the most sensitive and earliest sign to develop, but all are relatively late signs of compartment syndrome. Immediate surgical evaluation is needed because the definitive intervention is incision and release of the involved compartment. If signs of compartment syndrome develop from a penetrating injury, it suggests that there was an occult vascular injury and an expanding hematoma is trapped beneath the closure. The closure should be opened, the blood or hematoma evacuated, and a fresh attempt made to control bleeding. If compartment syndrome is not addressed, irreversible tissue necrosis begins by 6 hours.

Persistent bleeding is a common concern of wilderness medical providers. Typically this indicates a missed injury or

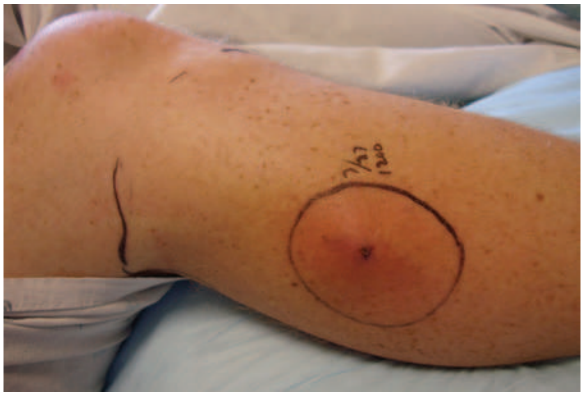

FIGURE 21-11 Minor puncture wound that has developed a secondary abscess and associated cellulitis. *(Courtesy Ramin Jamshidi, MD.)*

TABLE 21-8 Wound Care First-Aid Kit

Function	Core Items	Optional Items
Personal protection	Gloves (nonlatex)	Sterile gloves (nonlatex, nonpowdered)
	Eye shield	Surgical cap
	Mask	
	Headlamp	
Instruments	Needle driver (15.2 cm [6 inches])	Hemostats (curved)
	Scissors (iris tip)	
	Toothed forceps (Adson type)	
	Nontoothed forceps (DeBakey type)	
Wound preparation	60-mL syringe	Splash shield
	18-gauge needle or blunt cannula	Chlorhexidine surgical scrub brush
	21-gauge needle	
	Water filtration system	
	Povidone-iodine swab packets	
Closure materials	2-0 nylon (cutting needle)	5-0 nylon (cutting needle)
	4-0 nylon (cutting needle)	6-0 nylon (cutting needle)
	3-0 Vicryl (tapered needle)	4-0 Vicryl (tapered needle)
	Skin stapler	Mastisol (15 mL)
	Dermabond skin glue vials	
	Adhesive strips (1.3 cm [0.5 inch])	
Dressings	Gauze (10 × 10 cm [4 × 4 inches])	Elastic roll (7.6 cm × 4.6 m [3 inches × 5 yards])
	Porous paper tape (1.3 cm [0.5 inch])	Mepilex (10 × 20.3 cm [4 × 8 inches])
	Gauze roll (11.4 cm × 3.7 m [4.5 inches × 4 yards])	Surgicel Nu-Knit (2.5 × 8.9 cm [1 inch × 3.5 inches])
	Flexible, reusable splint	QuikClot (10 × 10 cm [4 × 4 inches])
Medications	0.25% bupivacaine (10-mL vials)	Silver sulfadiazine 1% cream (50 g [1.8 oz])
	Antiseptic ointment (30 g [1 oz])	5% lidocaine jelly (35 g [1.2 oz])
	Cephalexin (500 mg)	
	Ciprofloxacin (500 mg)	

inadequate direct pressure. If a wound continues to bleed through a dressing, the bandage should be removed to allow direct inspection. Consider that a discrete vascular injury may have been missed and that an exposed vein or artery requires direct pressure or ligation.[29] If a prolonged period of direct pressure does not stop the hemorrhage, one may need to use hemostatic adjuncts or tourniquet application as discussed earlier.

Many wounds can be managed in a backcountry environment without interrupting the activities. However, some injuries mandate evacuation. These include open fractures, compartment syndrome, persistent bleeding, tourniquet use, progressive loss of sensation or motor function, progressive infection, and full-thickness burns that are circumferential or involve more than 5% of the body surface area. Many wilderness-acquired wounds that do not necessitate evacuation still require formal medical evaluation upon the return to civilization.[44] These include any persistent detriment in motor function or sensation, ongoing drainage from the wound, a persistent open wound, burns over the face or genitals, and burns over joints.

WOUND CARE KIT

Many adjuncts are available to facilitate wilderness wound care, but a kit with core supplies will suffice in most circumstances. Table 21-8 lists suggested components of such a kit.

REFERENCES

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

CHAPTER 22

Wilderness Orthopedics

JULIE A. SWITZER, RALPH S. BOVARD, AND ROBERT H. QUINN

Life is sweeter nearer to the bone. Henry David Thoreau

The textbook discussion of orthopedic trauma in wilderness medicine has traditionally focused on discrete musculoskeletal injury to individuals or small groups in the mountain, sea, or desert setting. The scope of wilderness medicine today has widened significantly to include injuries caused by terrorism, military engagement, and forces of nature. Recent disasters, such as the Great Indian Ocean tsunami of 2004, Hurricane Katrina in August 2005, and the Haiti and Chile earthquakes of 2010, serve as powerful examples of situations in which orthopedic injuries were myriad and provision of care was limited in

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FIGURE 22-1 Improvised traction following the 2010 earthquake in Haiti. *(Courtesy Sam Slishman.)*

significant part by the remoteness of setting or inaccessibility of resources.

The wilderness practitioner needs to approach trauma outside the normal clinic or hospital setting with a sense of anticipation and improvisation. One needs to be prepared for a scenario of chaos, inadequate medical supplies or support, sepsis, and limited or delayed evacuation of patients. The tidy fractures of individual sport injury or accidental trauma in a civilized society have little in common with massive crush injuries, limb mangling with segmental loss, and severed limbs of natural or terroristic disasters. Issues of triage and prioritization become paramount. Successful organization of resources and mobilization of personnel often determine the outcome of the operation. Improvisation in splinting to stabilize or immobilize shattered limbs can minimize neurovascular compromise and reduce morbidity and mortality (Figure 22-1).

SCOPE OF THE PROBLEM

Musculoskeletal injuries account for 70% to 80% of injuries that occur in a wilderness setting.[11,20] Presumably as a result of the use of flak jackets and core protective gear that shield axial and central anatomic structures, bone and soft tissue injuries have become more common, accounting for 70% of injuries in the Iraq and Afghanistan wars.[17] In the initial management of a musculoskeletal injury that occurs in a wilderness or austere setting, the following must be considered: cause and time of injury, direction of the causative force in relation to the individual or limb, and environment where the accident occurred. These factors may indicate the severity of the injury and help determine the examination and treatment priorities that can affect the outcome.

Stabilization of a victim's cardiovascular and pulmonary status is critical. Cardiovascular stabilization includes control of massive hemorrhage. Once this has been accomplished, examination of the musculoskeletal system should be undertaken in a systematic manner. Careful initial attention should be devoted to the spine. After the cervical, thoracic, and lumbar regions of the spine have been evaluated and stabilized (or cleared), the focus is brought to bear on the pelvis and extremities.

PHYSICAL EXAMINATION

The physical examination should address circulatory, nerve, skeletal, and joint function.

VASCULAR FUNCTION

Penetrating or blunt trauma can injure major vessels that supply the limbs. Fractures can produce vessel injury by stretching, which can produce intimal flap tears, or by direct laceration. Intimal injuries can occlude distal flow or lead to platelet aggregation and delayed occlusion. Therefore, examination of vascular function should be performed and repeated at regular intervals before the victim's arrival at the definitive care center. The color and warmth of the skin or distal extremity should be assessed; pallor and asymmetric regional hypothermia may indicate vascular injury. In the upper extremity, the brachial, radial, and ulnar arteries should be palpated. In the lower extremity, the femoral, popliteal, posterior tibial, and anterior tibial arteries should be palpated. If blood loss, hypothermia, or obesity makes these pulses difficult to assess, the temperature, color, and capillary refill must be relied upon to determine vascular integrity. Any suspected major arterial injury mandates immediate evacuation, after appropriate splinting.

NERVE FUNCTION

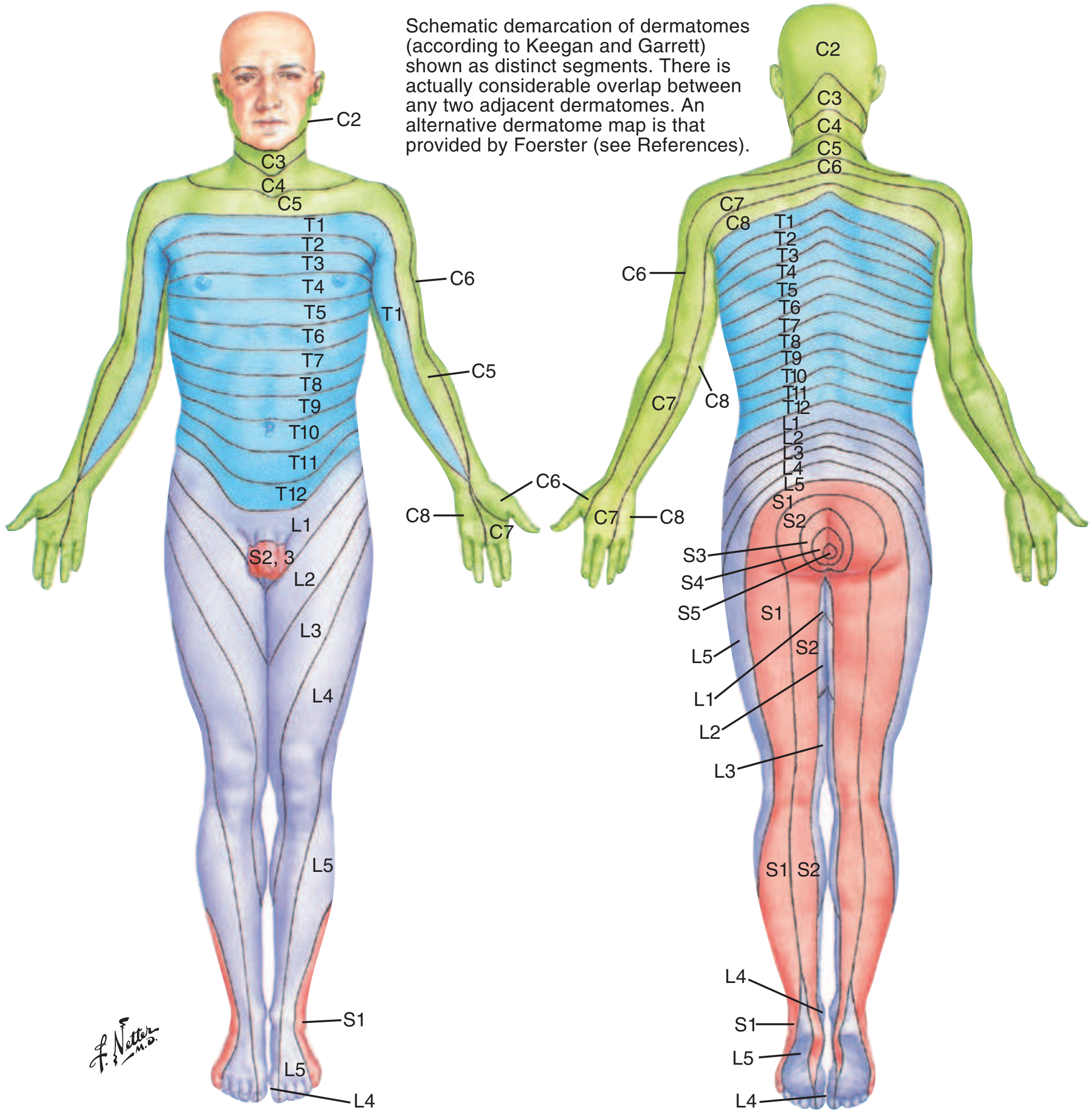
Nerve function may be impossible to assess in an unconscious or uncooperative person. In the conscious person, the results of light touch and pinprick tests should be carefully documented. For spinal and pelvic injuries, the dermatomal distribution of spinal nerves is assessed and muscle function is evaluated by observing active function and grading the strength of each muscle group against resistance (Figure 22-2). If possible, once the victim's condition has been stabilized, nerve function to the distal extremities is documented. Initial findings should be compared periodically, with repeat examinations during transport. Any change and, in particular, any deterioration in condition should be noted.

SKELETAL FUNCTION

The skeletal anatomy should be carefully inspected and palpated. Angular deformity suggests a fracture; palpable crepitus confirms the diagnosis. The health care provider in the field should perform appropriate splinting after placing the limb in anatomic alignment using gentle axial traction. After noting the degree and orientation of the limb's position when the victim is found, there should be no delay in aligning and splinting fractures. The risk-benefit ratio of fracture reduction and realignment in the wilderness of protecting the neurovascular status and reducing pain substantially outweighs the common in-hospital routine of imaging before manipulation. Distinguishing intraarticular or very proximal or distal fractures must wait for the definitive care facility, where imaging studies can be done. Similarly, distinguishing a wrist or ankle ligamentous injury from a fracture is not required for initial treatment.

Diagnosis is usually made by palpation of the limb and fracture location. If a tuning fork is available, it can be used in the following manner: the tuning fork is struck and placed on one end of a limb in question. If the vibration cannot be auscultated at the other end of the bone, or if the vibration is significantly diminished when compared with the other limb, a discontinuity (fracture) may exist. Ultrasound can also be employed if doubt remains regarding the existence and location of a fracture.

Palpation of long bones begins distally and proceeds across all joints. A splint should be applied if there is palpable crepitus, swelling, deformity, or resistance or block to motion.



Levels of principal dermatomes

C5	Clavicles
C5, 6, 7	Lateral parts of upper limbs
C8, T1	Medial sides of upper limbs
C6	Thumb
C6, 7, 8	Hand
C8	Ring and little fingers
T4	Level of nipples
T10	Level of umbilicus
L1	Inguinal or groin regions
L1, 2, 3, 4	Anterior and inner surfaces of lower limbs
L4, 5, S1	Foot
L4	Medial side of great toe
S1, 2, L5	Posterior and outer surfaces of lower limbs
S1	Lateral margin of foot and little toe
S2, 3, 4	Perineum

FIGURE 22-2 Sensory dermatomes. *(Netter illustration. Copyright Elsevier Inc. All rights reserved.)*

In general, one can trust that an alert and cooperative patient will not consciously participate in maneuvers that will cause further harm. Unless the patient is being stoic or purposefully overriding pain, the patient will not attempt to stand or ambulate with a potentially unstable spine, or bear weight on a fracture at risk for displacement or instability. A patient who can comfortably perform a range of motion or bear weight on an injured extremity, either before or after immobilization, is generally acting safely. The rescuer needs to be particularly cautious with someone who is attempting to "play through the pain."

JOINT FUNCTION

Each joint has a normal range of and limits to motion to ensure stability. Making the diagnosis of a joint injury in the field allows appropriate splinting and prevents further damage during transport. If the victim can cooperate, each joint is taken through an active range of motion to quickly locate any injury. When this is not possible, passive motion of each joint is evaluated after palpation in order to detect swelling and/or crepitus.

Any dislocation should be promptly reduced after completing the neurovascular examination. This generally considerably relieves the victim's discomfort. Once relocation has occurred, stability is evaluated by careful controlled motion. Joints with associated fractures or interposed soft tissues may still be unstable after reduction. Care should be taken during splint application to prevent recurrent dislocation or further soft tissue injury. A report of details of the reduction or relocation maneuver, including orientation of the pull, amount of force involved, amount of sedation, and residual instability of the joint, should be provided to the definitive care physician (see Reduction and Relocation Maneuvers, p. 458).

POTENTIALLY LIFE-THREATENING MUSCULOSKELETAL INJURIES

SPINAL INJURIES

Cervical Spine Injuries

In the wilderness, cervical spine fractures or dislocations can be the result of a fall from a height, high-velocity ski crash, combat injury, or diving accident. Because head and cervical spine injuries are highly correlated, a victim with a significant head injury should be considered to have a cervical spine injury, especially if the individual is unconscious. Ideally, a person with a suspected cervical spine injury is placed on a backboard with neck immobilization to prevent further injury and then promptly evacuated. Approximately 28% of persons with cervical spine fractures also have other spinal fractures[3]; therefore, the person providing care should protect the entire spine.

When a cervical spine injury is suspected, field examination involves grading motor strength, documenting sensory response to light touch and pinprick, and noting the presence or absence of the Babinski reflex (see Figure 22-2). When appropriate supplies are available, a rectal examination should be done. Complete lack of tone and failure of the sphincter muscles to contract when pulling on the penis or clitoris (bulbocavernosus reflex) indicates spinal cord injury.

Neurologic deficit often results from a cervical spine fracture. Catastrophic spinal cord injury caused by a cervical spine fracture from the occiput to the C4 level is usually fatal because of paralysis of the diaphragm and respiratory muscles. The corollary to this is that surviving victims often have partial deficits or are neurologically intact. Axial cervical spine fractures may result from flexion forces (most common), extension forces, or rotational forces, or a combination of these. Cervical spine fractures most commonly occur at C5-C6.[3] Fracture of the C1-C2 complex results from axial loading (C1 ring fracture, or Jefferson's fracture) (Figure 22-3) or from an acute flexion injury (C2 posterior element fracture, or hangman's fracture) (Figure 22-4). A pure flexion event may dislocate one or both posterior facets, producing neck pain and limitation of motion. Because the interspinous ligament is ruptured and this fracture-dislocation is highly unstable, victim transport must be done with the neck rigidly immobilized to reduce the risk for posterior motion.

Fractures and dislocations may result in neurologic insult distal to the bony injury. Because flexion is the mechanism that most commonly causes cervical spine injuries, the neurologic deficit is generally an anterior spinal cord syndrome. In this setting, the victim suffers complete motor loss and partial sensory loss but retains proprioception.

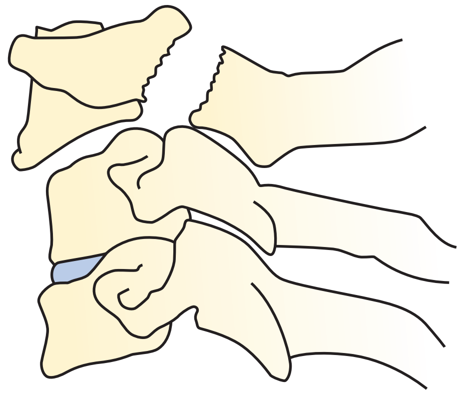


FIGURE 22-4 C2 hangman's fracture.

Thoracolumbar Spine Injuries

Thoracolumbar spine fractures occur most frequently at the T12-L1 junction. Because the thoracic spine is well splinted by the thoracic cage, when an axial or flexion force is applied, the ribs diminish forces on the thoracic vertebral bodies and transmit the forces to the upper lumbar levels. In the wilderness, falls from significant heights or a high-velocity sporting vehicle crash may produce these fractures (Figure 22-5). Thoracolumbar spine fracture may also be associated with other fractures that occur with axial loading, such as femoral neck fracture (Figure 22-6) and calcaneus fracture (Figure 22-7). These injuries commonly occur when there is an axial force, such as a fall onto the lower limbs from a height. Therefore, an individual who sustains a presumed hip fracture or calcaneus fracture because of a fall from a height should be carefully evaluated for possible associated spine injury.

When a thoracolumbar spine fracture is suspected, careful neurologic examination should be performed as part of the secondary survey, and close attention paid to motor function, the presence or absence of cord level reflexes, and any dermatomal pattern of diminished light touch and pinprick. Because significant fluctuations in sympathetic tone may occur, the rescuer should monitor the blood pressure and body temperature, taking appropriate steps to cool or warm the victim. If evacuation cannot be performed immediately, hemodynamic and neurologic function should continue to be noted and documented. The victim should be logrolled, maintaining perfect spinal alignment, and carefully placed on a backboard. A scoop stretcher may be used in this situation (see Chapter 23).

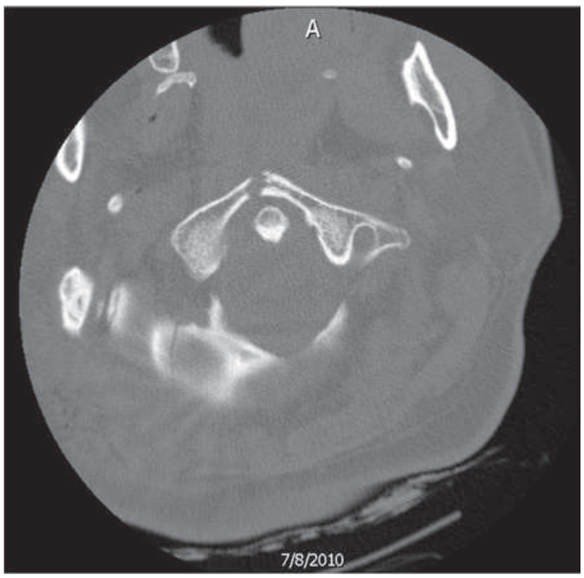


FIGURE 22-3 C1 ring, Jefferson's fracture.

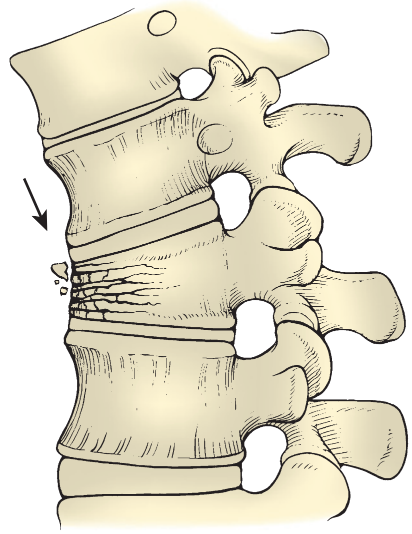


FIGURE 22-5 Wedge compression fracture from axial or flexion loading at the thoracolumbar junction.

FIGURE 22-6 High-energy basic cervical femoral neck fracture with greater trochanter fracture after a 40-foot fall while rock climbing.

Spinal Assessment (Clearing the Spine)

Asymptomatic patients without a distracting injury or neurologic deficit who are able to complete a functional range-of-motion examination may safely avoid immobilization without radiologic imaging. Furthermore, in an austere environment, a decision to

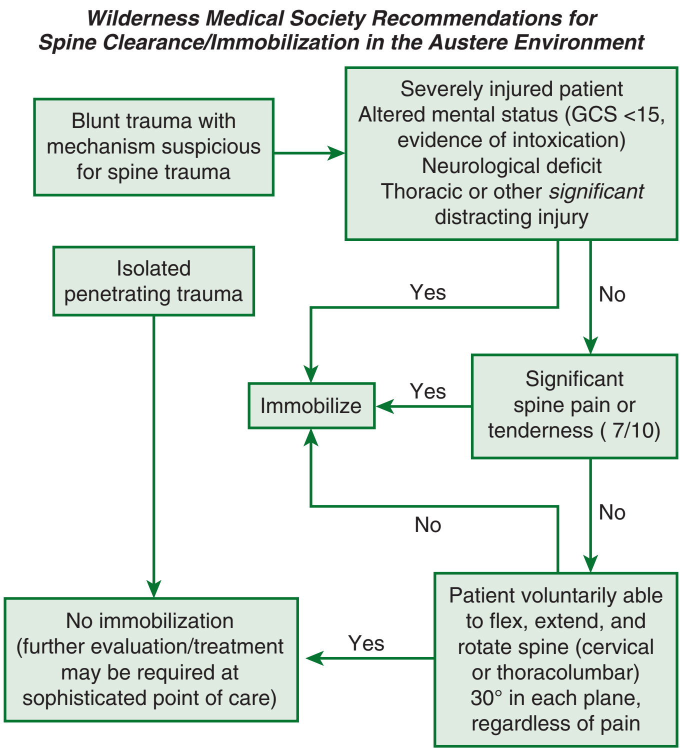


FIGURE 22-8 Wilderness Medical Society recommendations for spine clearance and immobilization in the austere environment. *(From Quinn R, Williams J, Bennett B, et al: Wilderness Medical Society Practice Guidelines for Spine Immobilization in the Austere Environment: 2014 Update, Wilderness Environ Med 25:S118, 2014.)*

subject a patient to immobilization may result in unnecessary use of scarce and expensive resources and may place the patient, as well as rescuers, at increased risk for further injury. In this setting, a more aggressive algorithm may be appropriately used to clear the spine (Figure 22-8).[24]

Spinal Immobilization

Sound evidence is lacking to support reliance upon effectiveness of spinal immobilization in every situation.[24] Many methods, improvised and otherwise, provide reasonable immobilization of the spine but should not be assumed to be protective, should not unnecessarily delay or complicate urgent evacuation, and

FIGURE 22-7 Calcaneus fracture.

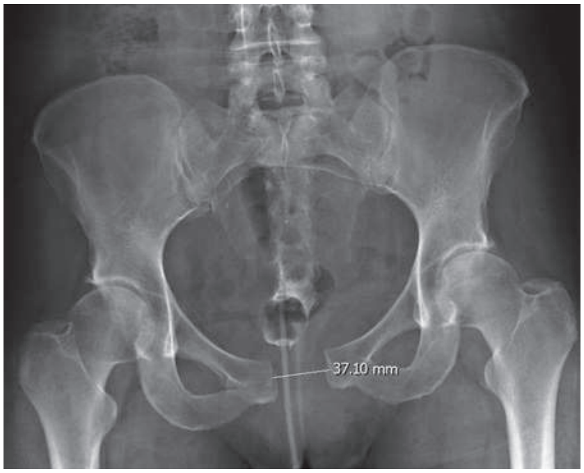


FIGURE 22-9 Pelvic injury after being thrown from a horse. Pubic symphysis widening of greater than 2.5 cm (1 inch) is generally considered to be unstable.

should not cause significant patient discomfort or respiratory compromise or impede access to the airway or sites of hemorrhage. Cervical spine immobilization that involves attainment of standard neutral alignment is contraindicated (and generally unnecessary) in the presence of certain circumstances of penetrating trauma, as well as in ankylosing spondylitis. In these situations, if the intent is to prevent further motion of the head and neck, it is reasonable to achieve immobilization of the victim in the position in which she or he is found.

PELVIC INJURIES

Pelvic fractures generally occur with a fall from a significant height, high-velocity ski accident, or vehicle crash. The Young and Burgess classification of pelvic fractures is based on the mechanism of injury. Pelvic fractures are categorized as anteroposterior compression, lateral compression, or vertical shear injuries.[5] These fracture patterns have been shown to correlate with blood loss, associated injuries, multisystem morbidities, and mortality.[5,7,35] Anteroposterior compression injuries can result in rotational instability if there is more than 2.5 cm (1 inch) of pubic symphysis separation (Figure 22-9). Furthermore, if the posterior pelvic ring is disrupted, there can be both rotational and vertical instability. These injuries, which may include acetabular fractures, are often accompanied by hemorrhagic, neurologic, urologic, gynecologic, and gastrointestinal injuries (Figures 22-10 and 22-11).

The posterior pelvic ring accounts for approximately 60% of pelvic stability. With a suspected pelvic fracture, it is important

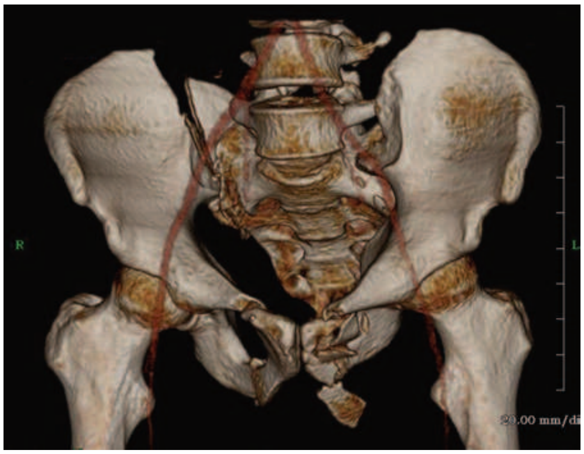


FIGURE 22-10 Highly unstable pelvic ring injury with pubic rami fractures and displaced iliac wing fracture. This patient also had a severe bladder injury.

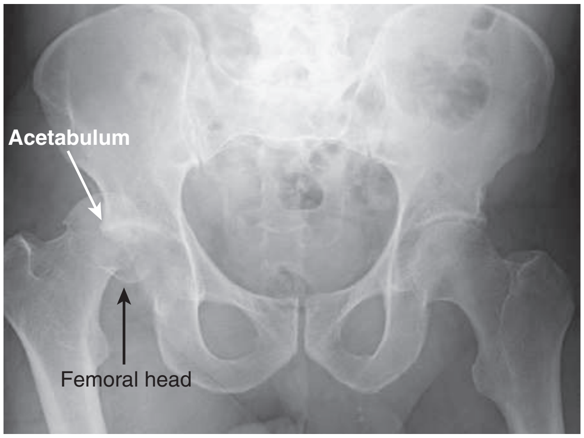


FIGURE 22-11 Right hip dislocation with acetabular and femoral head fractures.

to determine whether there is injury to the posterior pelvis. Posterior pelvic fractures are identified by instability of the pelvis associated with posterior pain, swelling, and ecchymosis. This victim should be immediately evacuated on a backboard, taking care to minimize leg and torso motion.

Hemodynamic instability may occur with pelvic fractures, particularly if the injury is the result of translational or shear forces or if posterior pelvic structures are primarily involved. Bleeding associated with a pelvic injury is usually from fractured cancellous bone, retroperitoneal lumbar venous plexus injury, or, rarely, pelvic arterial disruption. Military antishock trousers (MAST), a SAM Pelvic Sling II, or even a bed sheet wrapped and tightened with a windlass around the pelvis of an individual with a suspected unstable pelvic fracture may provide stability and accomplish adequate tamponade of bleeding from the fracture[25] (Figure 22-12). Other similarly intended devices (e.g., T-Pod Responder Pelvic Stabilization Device, VBM Pelvic Sling) are available or may be improvised. The applied sling belt (pelvic binder) or improvised contrivance should be left in place until definitive care is available (Figure 22-13). Degloving injuries can also be seen in high-energy pelvic injuries (Figure 22-14).

In addition to these high-energy injuries, simple nondisplaced inferior or superior ramus fractures and avulsion fractures can occur. On clinical examination, these pelvic fractures are generally appreciated as areas of tenderness without instability. Lateral compression injuries are usually stable, with impaction of the posterior structures.

GENERAL CONSIDERATIONS IN EXTREMITY INJURIES TECHNIQUES FOR MANAGING EXTREMITY INJURIES

Splinting Techniques

Splinting is performed so that alignment is maintained, further soft tissue injury is minimized, and pain is substantially reduced.

FIGURE 22-12 SAM Sling.

FIGURE 22-13 Appropriate application of a sheet for an unstable pelvic fracture (centered at the greater trochanters, as opposed to the iliac wings).

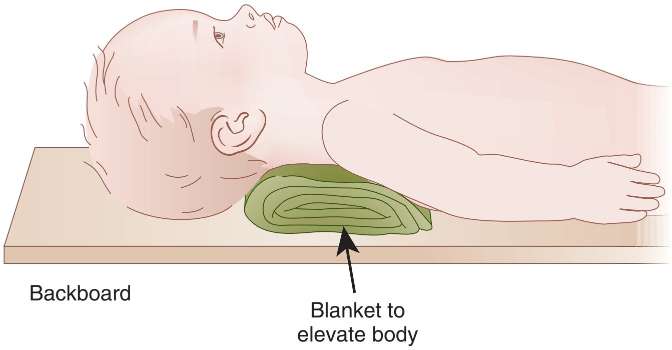


FIGURE 22-15 Child with suspected spine injury should be transported on a backboard with the child's body slightly elevated relative to his or her head.

A victim with suspected cervical or thoracolumbar spine trauma should be transported on a firm surface. Backboards or scoop stretchers (see Chapter 23) are most effective, but improvisation with hard pieces of wood, fiberglass, or straight tree limbs lashed together may be needed. If cervical spine injury is suspected, a roll of clothes or a water bottle can be placed as high as the victim's midface on both sides of the head and secured into position to prevent rotational movement. Tape applied from the supporting stretcher across the objects and the victim's forehead adds stability. A child with a suspected spine injury should be transported on a backboard, with the child's body slightly elevated relative to the head (Figure 22-15). Any victim with a suspected major pelvic injury is transported in a similar fashion, stabilizing the pelvis with a circumferential sheet, piece of clothing, or special belt and holding the lower extremities as immobile as possible, with knees slightly flexed (see Figure 22-12).

Many different extremity splints are available for the wilderness setting. These splints are lightweight, compact, and easy to use. They are more elaborate than a simple hiking pole or branch that is more readily available. Intricate devices may have considerable advantages for larger-scale evacuations involving multiple victims in the setting of a natural disaster. Some are designed to provide traction applied to the injured extremity. With proper splint application, the injured limb can be immobilized securely in a functional position until definitive care is reached (Figure 22-16).

Air splints are generally manufactured in one shape. In the setting of injured tissues and environments that might include wide temperature variability, these splints can cause compression-induced damage to an extremity. Therefore, an air splint is used only if it has an automatic adjustment valve to compensate for atmospheric pressure variability. These splints should be stored in a minimally inflated state when the temperature is below freezing, to prevent ice from causing splint dysfunction. Bead-filled vacuum splints can be used. However, temperature and altitude variations can make adequate and consistent inflation less reliable. When bead-filled vacuum or air splints are used, one must be vigilant to ensure that no excessive pressure is applied to the already injured soft tissues.

Upper extremity splints may be made from plaster or fiberglass, which can be applied over a soft cotton roll. Lightweight prefabricated fiberglass splints are easy to use and effective for initial management of injuries (Figure 22-17). These splints are prepadded and can be applied with either cold or warm water, or even directly out of the package if water is not readily available. The warmer the water, the faster the fiberglass sets and the

FIGURE 22-14 Prone patient with an unstable pelvic fracture and a large degloving (Morel-Lavallee) flank lesion.

FIGURE 22-16 Lower extremity splints.

FIGURE 22-17 Water-activated FareTec splint for distal radial fracture, with wrist and hand in position of function.

FIGURE 22-18 Swimmer in Exos fracture brace.

FIGURE 22-20 SAM Splint.

greater the exothermic reaction. Hot water should be avoided because it may generate an excessively exothermic reaction that might burn the skin. The fiberglass is immersed in water, excess water is gently wrung out, and the splint is applied. An elasticized bandage helps hold the splint in place until the fiberglass hardens. Air splints can adequately splint an upper extremity in a stable position. Wooden or metal splints, custom made or improvised, can be used to stabilize an injured extremity. New thermoplastic casts and braces may be used in a wet outdoor environment and immersed in water without compromising function or stability (Figure 22-18).

Hand splints are applied with the metacarpophalangeal (MCP) joints flexed to 70 to 90 degrees and the interphalangeal (IP) joints extended. This places the collateral ligaments at maximal length and prevents joint contracture (Figure 22-19). Wrist or forearm splints are applied with the wrist in neutral position; excessive wrist flexion or extension might detrimentally affect median or ulnar nerve function in an already compromised limb. The elbow is positioned in a splint or sling at 90 degrees.

For shoulder fractures, a commercially available sling or improvised triangular bandage should be used to take the weight of the arm off the injured structures. For dislocations, a swathe should be added. Although it may be difficult to place an injured elbow in 90 degrees of flexion and neutral rotation, the upper extremity should be splinted in the position of function and comfort whenever possible.

For the lower leg, air splints provide adequate immobilization of tibia or fibula fractures and of ankle fractures and dislocations. Splints made from plaster or fiberglass may be applied over cotton padding and held in position with elasticized bandages. The SAM Splint, an excellent first-aid item that can be molded to immobilize a wide variety of injuries, provides stability and strength through its aluminum and foam core (Figures 22-20 and 22-21). The aluminum structure can be bent into three fundamental configurations (C-curve, reverse C-curve, and T-curve; Figure 22-22) to provide different degrees of stability, flexibility,

FIGURE 22-21 Versatile splint for upper or lower extremity.

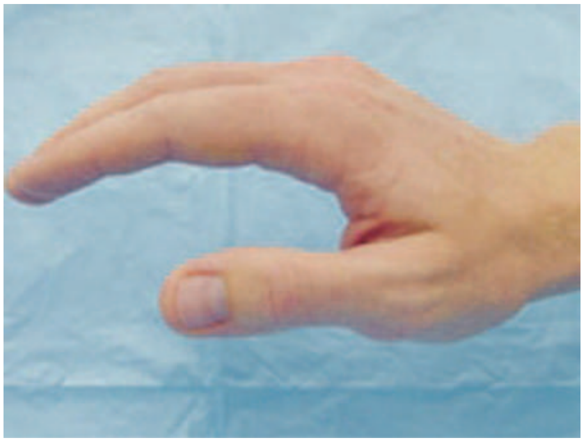


FIGURE 22-19 Hand and wrist in position of function.

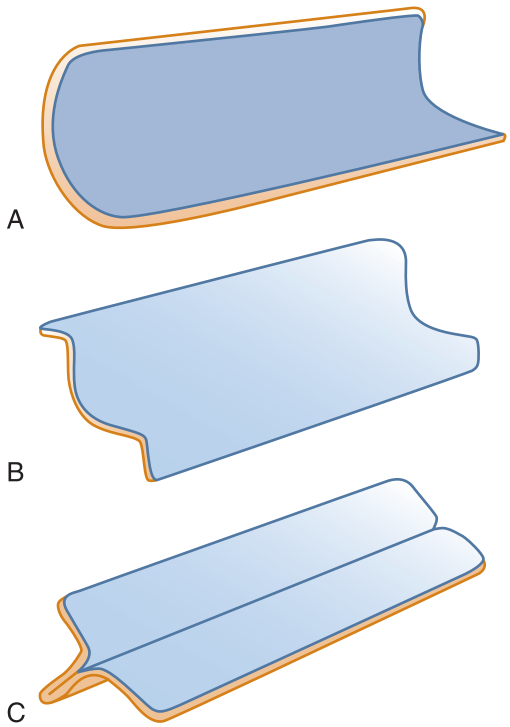


FIGURE 22-22 Basic SAM Splint adaptations. **A,** C-curve. **B,** Reverse C-curve. **C,** T-curve (maximum strength). *(Courtesy SAM Medical Products.)*

FIGURE 22-23 Slishman splint applied for femoral fracture following the 2010 earthquake in Haiti. *(Courtesy Sam Slishman.)*

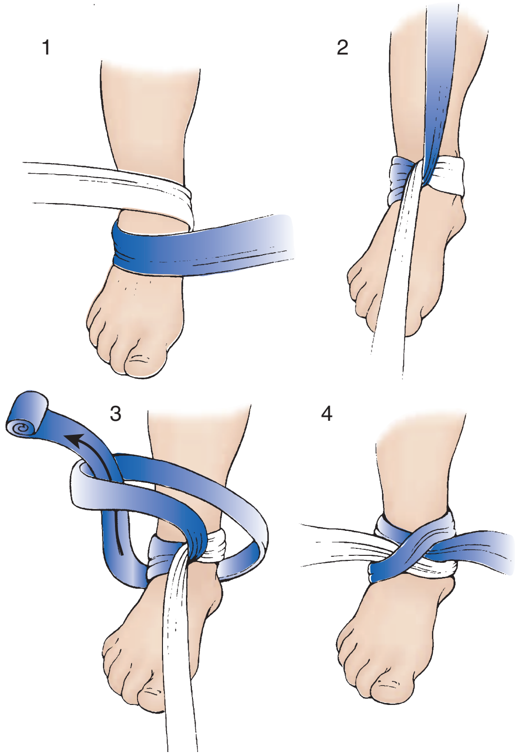


FIGURE 22-25 Improvisation of an ankle wrap to be used for traction.

and immobilization. The ankle is held in neutral position and the splint applied firmly. For transport, the lower extremity is positioned with the hip and knee extended and the ankle in neutral position. Victims with unstable lower extremity fractures or dislocations are transported in the recumbent position with the afflicted limb elevated.

For hip or femoral fracture or dislocation, properly applied traction can decrease blood loss from hemorrhage into the fracture site and substantially decrease pain. If proper traction cannot be applied, splinting (particularly with a vacuum mattress) can provide reasonable stability and pain control. Multiple portable traction devices are commercially available (Figures 22-23 and 22-24). The ischium and/or pubis are proximal structures against which the splint is set. The ankle is usually the structure through which traction is applied (Figure 22-25). Lightweight splints that may be of use in the wilderness setting include those known either by their manufacturer or developer, such as Donway, Thomas, Kendrick, Slishman, Reel, FareTec, Sager, CT-6, and Hare splints (see Chapter 23). It behooves a backcountry health care provider to be thoroughly familiar with any splinting device being carried. If commercial splints are unavailable and effective improvised splinting is not possible, the injured leg can be strapped to the noninjured leg, with a tree limb or walking stick placed between the legs. If possible, the victim is transported on a backboard or similar device that limits motion of the pelvis and lower extremity.

Reduction and Relocation Maneuvers

Even in the wilderness, the four principles of fracture reduction should be followed:

FIGURE 22-24 Lower extremity splint.

- *Traction:* in-line or longitudinal force application
- *Fracture fragment disengagement;* included in this step is recreation of the forces that created the fracture
- *Reapposition* of fracture ends
- *Counteraction* of forces that led to deformity

Steady traction and patience are the mainstays of fracture and dislocation reduction and relocation maneuvers.[4]

For distal radial fracture, the usual dorsiflexion deformity is reproduced and a flexion force is applied through the fracture. Steady traction can assist with reduction (Figures 22-26 to 22-28).

For ankle fracture, traction is applied. Most fractures are caused by an eversion and external rotational force. Reduction is undertaken and a splint applied so that the ankle can be splinted in inversion and internal rotation, known as the Quigley maneuver. Care must be taken so that excessive force is not exerted on a limb that has already sustained significant vascular or nerve injury (Figure 22-29).

Traction Pins

Skeletal traction is applied in the setting of a fractured pelvis (including the acetabulum) or femur. This mode of stabilization can be used for temporary or more definitive treatment. This technique can be used in a natural disaster setting (see Figure 22-1).

A distal femoral traction pin is inserted from medial to lateral. The knee is flexed during insertion to facilitate access to the medial aspect of the distal femur and to allow for flexion of the knee once the pin has been placed; if the pin is placed with the knee in extension, the iliotibial band might be tethered and thereby prevent knee flexion. The pin is placed approximately two fingerbreadths proximal to the adductor tubercle. If the pin is placed too far distally, it can enter the intercondylar notch of the knee. If the pin is placed too far proximally, it can injure the superficial femoral artery near its exit from the adductor hiatus, or one of the branches of the superficial femoral artery near the knee.

A proximal tibial traction pin is inserted from lateral to medial. The pin is placed approximately two fingerbreadths distal to the tibial tubercle and two fingerbreadths posterior to the anterior tibial crest. These pins should not be placed in children, because

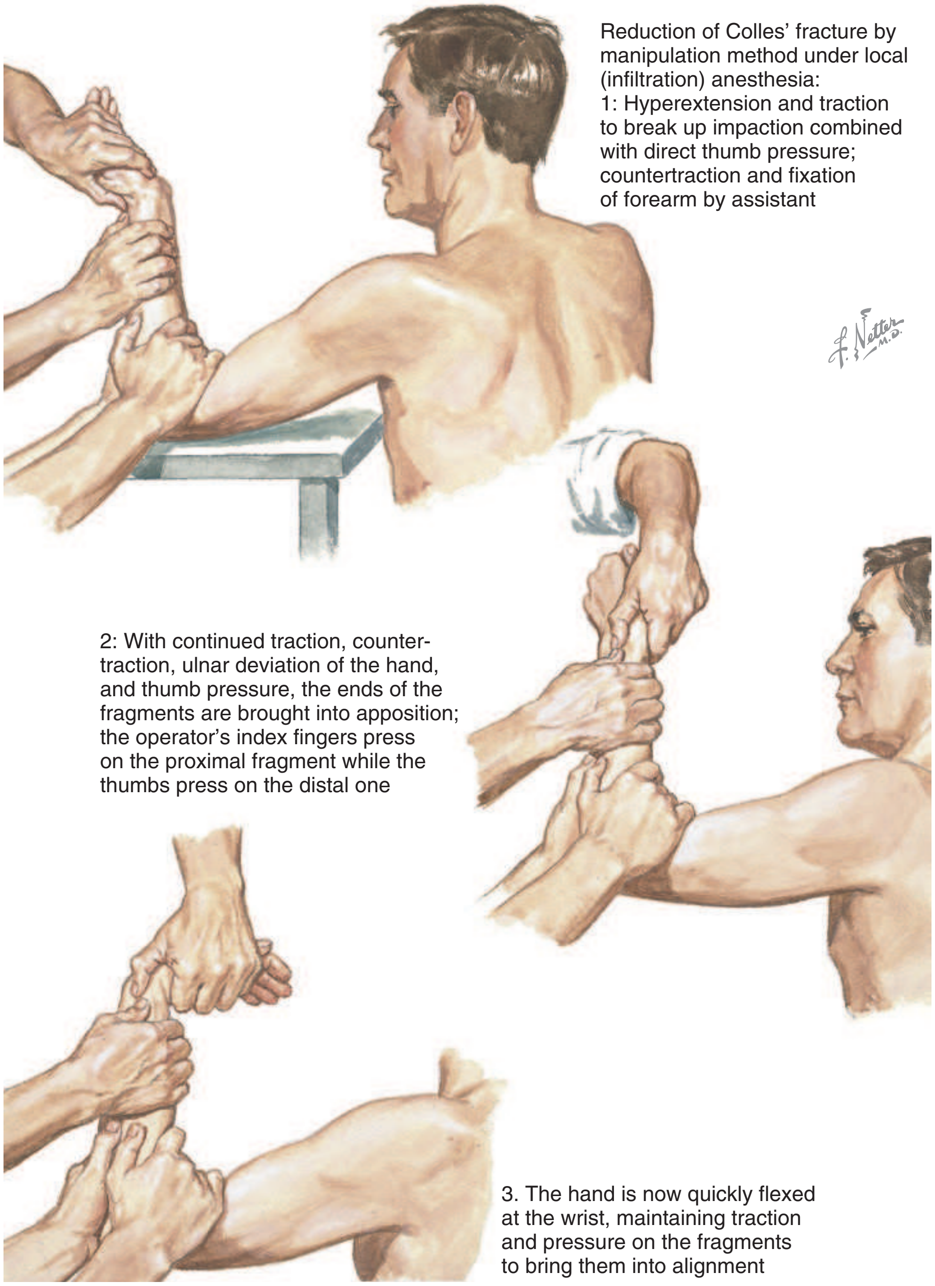


FIGURE 22-26 Reduction maneuver for the most common distal radial fracture (dorsally angulated). *(Netter illustration, copyright Elsevier Inc. All rights reserved.)*

proximity of the tibial tubercle apophysis puts this important structure at risk during insertion of the pin (Figure 22-30).

A calcaneal pin can also be used to apply lower extremity traction. This type of traction pin may be of particular benefit in the setting of ipsilateral femoral and tibial injuries. It is usually placed medial to lateral, with care being taken to avoid the posterior tibial neurovascular bundle. The pin is driven through the calcaneus and exits laterally (Figure 22-31).

If possible, balanced traction should be maintained. This helps to counteract deforming forces and allows relatively comfortable movement in bed. There are no hard-and-fast rules for the amount of weight to apply. If balanced traction is employed, the rule of thumb is for enough traction to be applied that the ipsilateral buttock is elevated slightly off the bed. When radiography is available, traction is applied until the fracture fragments are well aligned and nearly out to length. For an average-sized adult, this likely will be between 6.8 and 13.6 kg (15 and 30 pounds).

External Fixators

External fixator application for fracture may be of benefit in the setting of a natural disaster. For example, in the aftermath of the earthquakes in Haiti in 2010, external fixator application for femoral or tibial fracture was one of the most commonly employed fracture treatment procedures. External fixators applied in the field or in the setting of limited resources are usually applied in a manner consistent with the use of the fixator as a neutralization device. The external fixator maintains the relative position of bone fragments, resists external deforming forces, and prevents significant soft tissue injury (by the bone ends).

Principles of external fixator application are use of sterile technique for threaded pin insertion; avoidance of critical

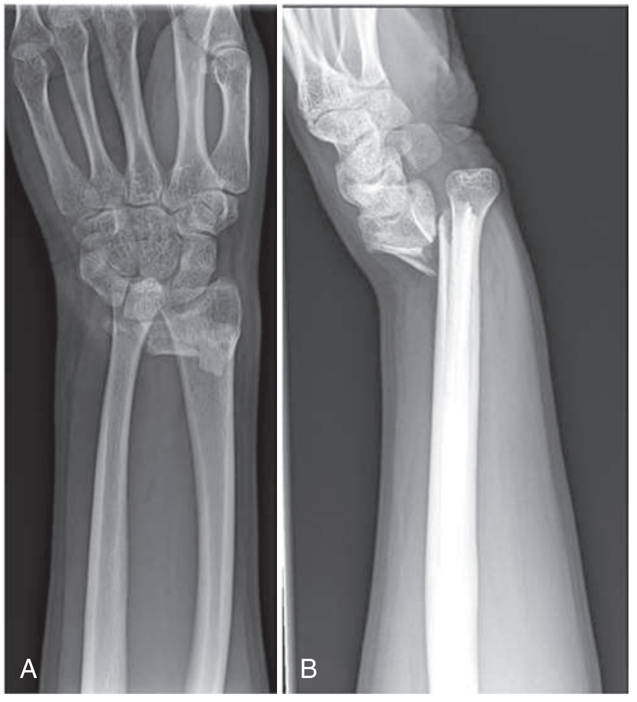


FIGURE 22-27 Distal radial fracture with distal radioulnar joint dislocation sustained after a fall on an outstretched hand.

structures during threaded pin placement; and creation of a fixator construct that is as rigid as possible.

Characteristics that contribute to increasing external fixator stability include

- Threaded pins of greater diameter
- Shorter distance between side bars and bone
- Double, as opposed to single, side bars
- Threaded pin placement closer to the fracture
- Greater number of threaded pins
- Stronger side bar material

Appropriate external fixator application is possible when the pertinent cross-sectional anatomy is known. Safe zones in the tibia are primarily along the medial aspect of the tibia. Safe zones

FIGURE 22-28 Reduced fracture-dislocation.

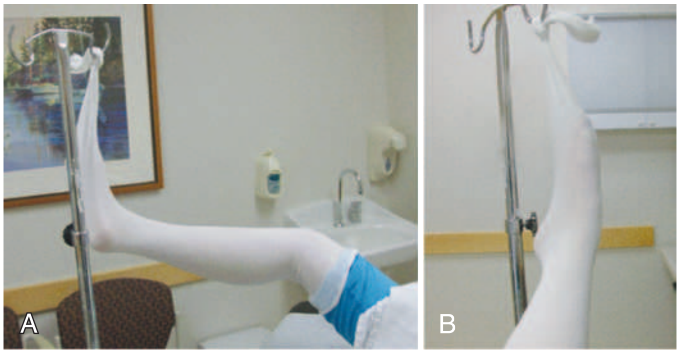


FIGURE 22-29 Quigley's maneuver for ankle fracture reduction. Anterior and inversion forces on the foot and ankle created by hanging leg by the great toe, held medial to midline of the body (or hung with stockinette as depicted).

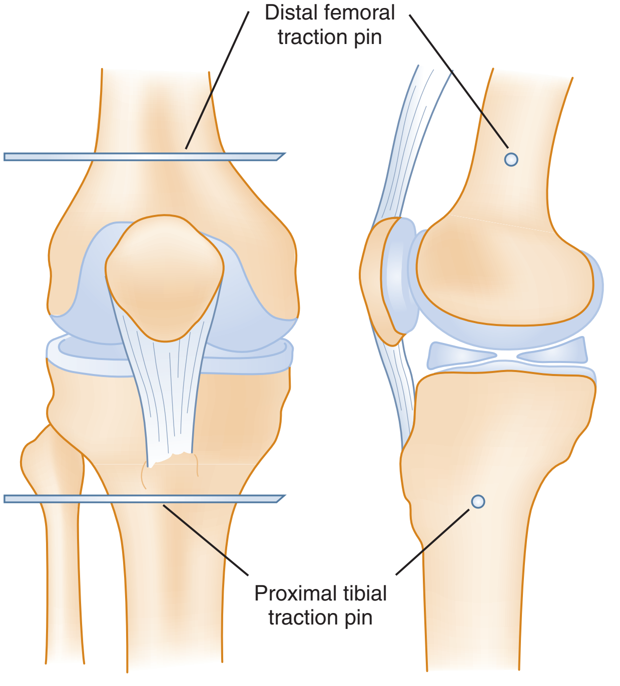


FIGURE 22-30 Proper positioning of distal femoral and proximal tibial traction pins.

FIGURE 22-31 Calcaneal traction pin placement in the setting of subtalar dislocation.

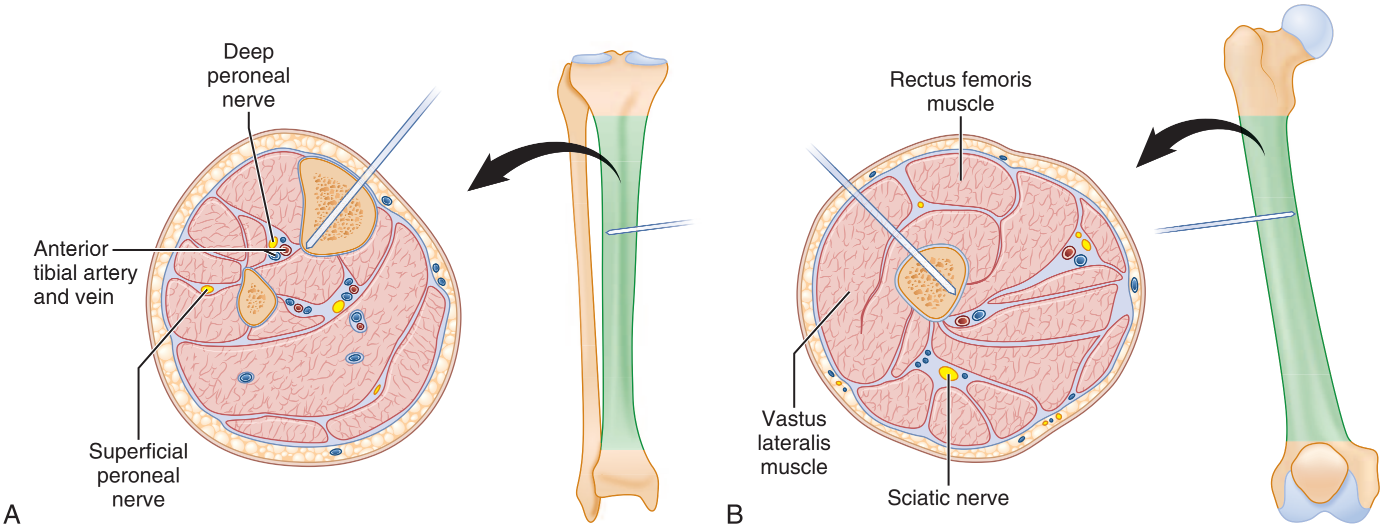


FIGURE 22-32 **A,** Cross-sectional area of leg. Tibial safe zone for external fixator pin placement is medial. **B,** Cross-sectional area of thigh. Femoral safe zone is anterior and lateral.

in the thigh are at the anterior and lateral aspects of the femur (Figure 22-32).

A few simple techniques may contribute to the longevity of the fixator. The position and length of stab wound incisions in the skin should not result in tension between the threaded pin and skin interface. To prevent osteonecrosis, holes in the bone for the threaded pins should be predrilled. Threaded pins should be bicortical; however, to reduce the risk of nerve or vessel injury, care should be taken not to advance the pins more than a few millimeters beyond the far cortex.

OPEN FRACTURES OF THE EXTREMITIES

Recognizing an open fracture is imperative; without prompt surgical treatment, the incidence of osteomyelitis in this setting is high.[13] With an open fracture, the fractured bone communicates with a break in the skin. With subcutaneous bones (e.g., tibia), open fractures are easily identified, but with other bones that have more surrounding soft tissue (e.g., humerus, femur, pelvis), recognition is more difficult because the fractured bone end usually retracts after it punctures the skin and is then covered by soft tissue. A laceration near a fracture may be an indication of an open fracture. Most open fractures persistently ooze blood or fat globules from the laceration (Figure 22-33). Clothes should be removed to allow the skin to be examined.

FIGURE 22-33 Type IIIB open tibia-fibula fracture that occurred as a result of a fall while the individual was holding a chainsaw.

Classification of Open Fractures of the Extremities

Familiarity with the Gustilo-Anderson open fracture classification system is useful. This assigns musculoskeletal trauma to one of three major categories (types I to III) depending on the mechanism of injury, extent of soft tissue damage, and degree of skeletal involvement.

Type I Fracture

- Wound is less than 1 cm (0.4 inch), with minimal soft tissue injury.
- Wound bed is clean.
- Fracture is usually a simple transverse, short oblique fracture, with minimal comminution.

Type II Fracture

- Wound is greater than 1 cm (0.4 inch), with moderate soft tissue injury.
- Wound bed may be moderately contaminated.
- Fracture is usually a simple transverse, short oblique fracture, with minimal to moderate comminution.

Type III Fracture. Type III fractures involve extensive damage to soft tissues, including muscle, skin, and neurovascular structures. They often result from a high-velocity injury or have a severe crushing component. The following special patterns are classified as type III fractures:

- Open segmental fracture, irrespective of the size of the wound
- Gunshot wound (high-velocity or short-range shotgun injury)
- Open fracture with neurovascular injury
- Farm injury or other highly contaminated wound, irrespective of size
- Traumatic amputation
- Open fracture more than 8 hours old
- Mass casualties (e.g., war and tornado victims)

Subtype IIIA Fracture. The wound is less than 10 cm (3.9 inches) with crushed tissue and contamination, or is the result of high-energy trauma, irrespective of the size of the wound. This includes segmental fractures or severely comminuted fractures. Adequate soft tissue coverage is usually possible despite soft tissue laceration or flaps.

Subtype IIIB Fracture. There is extensive soft tissue loss (> 10 cm [3.9 inches]) with periosteal stripping and bony exposure. This is usually associated with massive contamination and typically requires regional or free-flap reconstruction.

Subtype IIIC Fracture. Subtype IIIC is a fracture in which there is a major arterial injury requiring repair for limb salvage. The Mangled Extremity Severity Score can provide prognostic considerations for limb salvage versus amputation.[15]

BOX 22-1 Antibiotic Options

Intravenous Solutions
Cefazolin (Ancef) 1 g q 6 hr and gentamicin (5 mg/kg) q 24 hr or piperacillin with tazobactam (Zosyn) 3.375 g q 6 hr

Intramuscular Injections
Ceftriaxone (Rocephin) 1 g q 24 hr

Oral
Ciprofloxacin 750 mg bid and cephalexin (Keflex) 500 mg qid

Water Exposure
Ciprofloxacin 400 mg IV or 750 mg PO bid; or a sulfonamide and trimethoprim combination (Bactrim DS: 800 mg sulfamethoxazole and 160 mg trimethoprim) with either cefazolin (Ancef) 1 g IV q 8 hr or cephalexin (Keflex) 500 mg PO q 6 hr

Dirt or Barnyard Exposure
Add penicillin 20 million units IV daily or 500 mg PO q 6 hr

If Penicillin Allergy
Use clindamycin 900 mg IV q 8 hr or 450 mg PO q 6 hr in place of penicillins and cephalexin (Keflex)

Alternatives
Erythromycin 500 mg PO q 6 hr or amoxicillin with clavulanic acid 875 mg PO bid

Bid, twice a day; *IV*, intravenously; *PO*, orally; *qid*, 4 times a day.

Management of Open Fractures of the Extremities

General care of an open fracture outdoors depends on evacuation time. An open fracture requires prompt operative irrigation, debridement, and stabilization. If evacuation can be completed within 8 hours, realign the fracture, administer a broad-spectrum antibiotic, and splint the extremity. If bone ends extrude through the skin, try to reduce the exposed bone back into the wound below soft tissue coverage and cover with a moist (preferably normal saline) gauze sponge, splint the extremity, and arrange for prompt evacuation. If the evacuation time exceeds 8 hours, in addition to antibiotic administration and splinting, irrigation and debridement may be attempted in the field. Antibiotic options are listed in Box 22-1. If tetanus vaccine is available and has not been given in the past 5 years, this should also be provided.

The likelihood of infection developing in the presence of an open fracture is directly related to the volume and virulence of bacteria present in the wound at the time of definitive wound coverage or closure.[19] Interventions in the field can be performed in an effort to lower the eventual bacterial load and, therefore, risk of infection. Organic debris should be removed from the wound. Irrigation can be performed. Ample data have shown that potable water is equivalent to sterile saline in reducing wound infection, and relatively low volumes (< 1 L) can be effective if irrigation is promptly accomplished. High-pressure irrigation (> 8 psi) is generally effective at removing bacteria and can be accomplished in the field with a pin hole in a hydration bladder or by using a 19-gauge needle coupled with a 35-mL syringe. Additives (povidone-iodine, hydrogen peroxide, hexachlorophene, sodium hypochlorite) to the irrigant solution, including antibiotics, are generally ineffective or even harmful. Surfactants, such as castile soap, can be helpful in removing bacteria, provided the soap can be completely removed with irrigation. After cleansing, the wound should be covered and the dressing left in place until definitive management. Each exposure of the wound increases the chance of infection. Dressings soaked with blood should be reinforced with a pressure dressing rather than repetitively changed.

SIGNIFICANT SOFT TISSUE INJURIES OF THE EXTREMITIES

Degloving injuries (sometimes referred to as Morel-Lavallee lesions when associated with pelvic injury) and/or crush injuries can occur in the wilderness (see Figure 22-14). Although they are seen more commonly in high-energy urban accidents, they can also occur as the result of a significant fall or crushing force. Natural disasters and warfare can also result in a mangled or crushed limb. Splinting, monitoring for compartment syndrome, and expeditious evacuation are imperative.

TOURNIQUETS FOR EXTREMITY INJURIES

Although use of tourniquets outside of a medical facility historically has been considered anathema, there has been a resurgence in their use in the field by the military. In the Iraq and Afghan theaters, soldiers are trained in application of tourniquets on themselves and others; tourniquet use in the setting of a mangled or badly injured extremity has saved many lives. Sacrificing a limb to save a soldier is a difficult but clear decision.[21] A tourniquet should only be applied in the presence of a life-threatening injury and should be left inflated until definitive care can be instituted. Ischemia lasting for more than 2 hours risks permanent limb damage and for more than 6 hours will generally lead to amputation. The time of inflation should be conspicuously marked on the patient's limb or forehead. An improvised tourniquet may be employed; it should be at least 4 cm (≈ 1.6 inches) in width and be applied with sufficient pressure (generally using a windlass technique) to completely obstruct arterial flow.

AMPUTATION OF INJURED EXTREMITIES

In the wilderness, the amputation victim requires immediate evacuation. Control hemorrhage by direct pressure, clamping or ligation of severed vessels, or application of a tourniquet. Using pressure points is generally ineffective. Without cooling, an amputated part remains viable for 4 to 6 hours. Cleanse the amputated part with saline or water, wrap it in moistened sterile gauze or a towel, place it in a plastic bag, and transport the bag in an ice water mixture. Do not use dry ice. Keep the amputated part with the victim throughout the evacuation (Figures 22-34 and 22-35).

COMPARTMENT SYNDROME

A compartment syndrome begins when locally increased tissue pressure reduces capillary blood flow to a muscle compartment. When local blood flow is unable to meet metabolic demands of the tissue, ischemia ensues. In the wilderness, compartment syndrome most frequently occurs in association with a fracture, crush injury, or severe contusion. It can also occur when the victim has been lying for a period of time across an extremity so that the body weight occludes the arterial blood flow. Elevated local tissue pressure (compartment pressure within 10 to 20 mm Hg of diastolic arterial blood pressure) can also occur with acute hemorrhage or after revascularization of an ischemic extremity. Because perfusion pressure is the most important variable in development of compartment syndrome, hypotension can increase the risk.

FIGURE 22-34 Thumb amputation/avulsion as a result of a rider's thumb getting caught in a horse's reins before he fell off the horse.

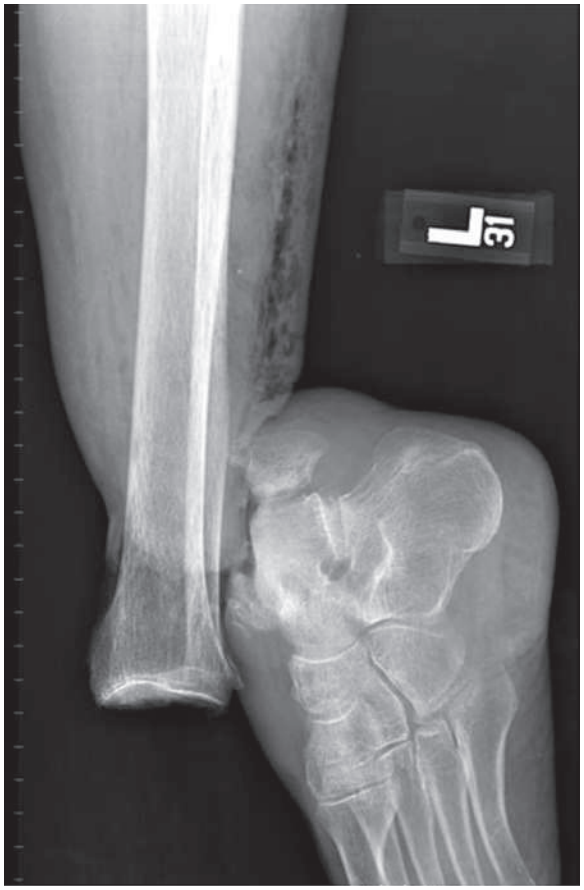


FIGURE 22-35 Traumatic near-amputation of a foot that occurred in a boating accident. Patient was treated with below-the-knee amputation.

Compartment syndrome can occur in the thigh, hand, foot, and gluteal regions. It is more common, however, in the lower leg and forearm, because of tight fascia in these regions. The conscious victim complains of severe pain out of proportion to the injury. The muscle compartment feels extremely tight, and applied pressure increases pain. There may be deceased sensation to light touch and pinprick in the areas supplied by the nerves traversing the compartment. Stretching muscles within the compartment produces severe pain. The most reliable signs of a compartment syndrome are pain, tight compartments, hypesthesia, and pain on passive stretch. Pulselessness, pallor, and slow capillary refill may not be observed, even with a severe compartment syndrome (Figure 22-36).

Emergency evacuation is required when compartment syndrome is suspected. The victim must be definitively treated in the first 6 to 8 hours after onset to optimize return of function. Emergency fasciotomy, the treatment of choice, relieves the pressure. If a compartment syndrome develops and evacuation cannot occur within 8 hours, one must decide whether the treating individual possesses the skill to perform a fasciotomy and whether it can be performed in an aseptic manner. Fasciotomies can convert a closed fracture into an open fracture and can provide a conduit for limb- or life-threatening infection. If a limb has nonfunctioning nerves and muscles resulting from compartment syndrome months after the syndrome has occurred, the limb can be salvaged with tendon transfers, whereas a limb that becomes infected after fasciotomy performed in the wilderness often must be amputated.

If a fasciotomy is being contemplated, antibiotics should be administered if available. In the forearm, the procedure usually involves making volar and dorsal incisions and splitting the underlying fascia. In the lower leg, the procedure usually involves making two long incisions, one on the medial aspect and another on the lateral aspect of the leg, and splitting, in a vertical fashion, the compartmental fascia in each of the four lower leg compartments.

If fasciotomy for compartment syndrome cannot be done within 12 hours of the syndrome's development, it should not be undertaken. A retrospective analysis of individuals who underwent late (> 35 hours after the injury) release for compartment syndrome demonstrated significant complication and amputation rates. Therefore, even in an urban trauma hospital, delayed compartment release for compartment syndrome is not recommended.[10]

RICE PRINCIPLE

The general principle for acute management of extremity injuries is *r*est, *i*ce, *c*ompression, and *e*levation (RICE). For unstable fractures, immobilization is also indicated. Avoid heat for the first 72 hours after injury. Chemical cold packs work well, as do cold packs made from ice or snow. If cold packs are unavailable, the extremity can be immersed intermittently in a cold mountain stream. If ice is used, mix some water in a bag with the ice to more evenly distribute the cold. The cold pack to the injured area may be held in place with an elasticized bandage. A piece of fabric is placed between the cold pack and the victim's skin to prevent frostbite. The ice is applied to the elevated extremity (above the level of the heart) for 30 to 45 minutes every 2 hours. A compressive dressing helps decrease swelling but should not be used if development of a compartment syndrome is possible. In this situation, keep the limb at the level of the heart and avoid compressive dressings.

UPPER EXTREMITY INJURIES

In the wilderness, without benefit of radiographic images, determination of the exact anatomic structures affected by an injury can be a challenge. The following sections have been divided in a manner based on location of the suspected pathologic condition.

SHOULDER GIRDLE INJURIES

Clavicular Fracture

Clavicular fracture usually occurs in the middle or lateral one-third of the bone and is associated with a direct blow or fall onto the lateral shoulder (Figure 22-37). Clavicular fracture is common in snow skiing and mountain biking accidents. The victim complains of shoulder pain, which may be poorly localized. Arm or shoulder motion exacerbates the pain. To localize the injury, gently palpate the clavicle to identify the area of maximal tenderness. Crepitus confirms the diagnosis. A pneumothorax can be associated with a clavicular fracture if the cupola of the lung is punctured; therefore, auscultate the chest. Shortness of breath and chest pain on inspiration increase suspicion for a pneumothorax.

FIGURE 22-36 Developing compartment syndrome in the setting of a tibia-fibula fracture, 6 hours following a crush injury.

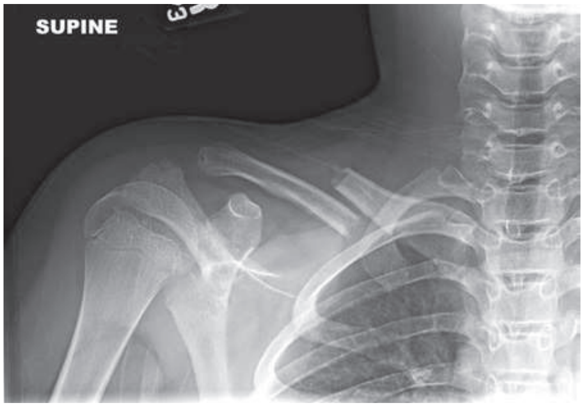


FIGURE 22-37 Midshaft clavicular fracture sustained by a 13-year-old snowboarder riding in the backcountry with his friends. Proximal humerus demonstrates physis normal growth plate, often mistaken for a fracture. Comparison view of the opposite shoulder may be obtained if proximal humerus fracture is suspected.

Clavicular fracture may also be accompanied by injury to the brachial plexus, axillary artery, or subclavian vessels. Thorough neurovascular examination of the affected extremity is performed, and the skin is examined carefully. Up to 5% of clavicular fractures may be open because of the bone's subcutaneous location. The victim should be evacuated if there is a significant open wound, suspected pneumothorax, or nerve or vascular injury. Field treatment for a clavicular fracture consists of a sling or figure-of-eight bandage and analgesics.

Scapular Fracture

Injury to the scapula is uncommon in the wilderness, but it may result from a direct blow or fall onto the back. Confirmation of the injury often requires x-ray or computed tomography evaluation (Figure 22-38). Scapular fracture can be seen in isolation or, with high-energy injuries, in conjunction with thoracic injuries, such as rib fracture or pneumothorax. Palpation and auscultation for breath sounds assist in making the associated diagnoses.

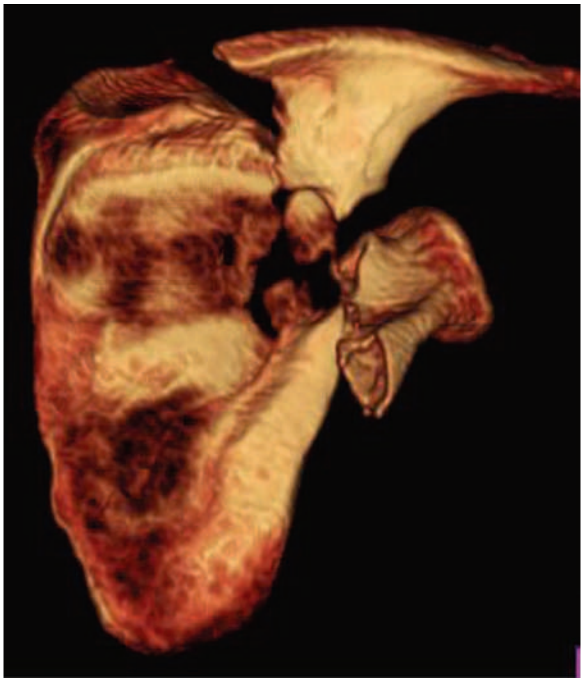


FIGURE 22-38 Three-dimensional computed tomography view of scapula fracture. Complete disassociation of the glenoid from the scapular body is present.

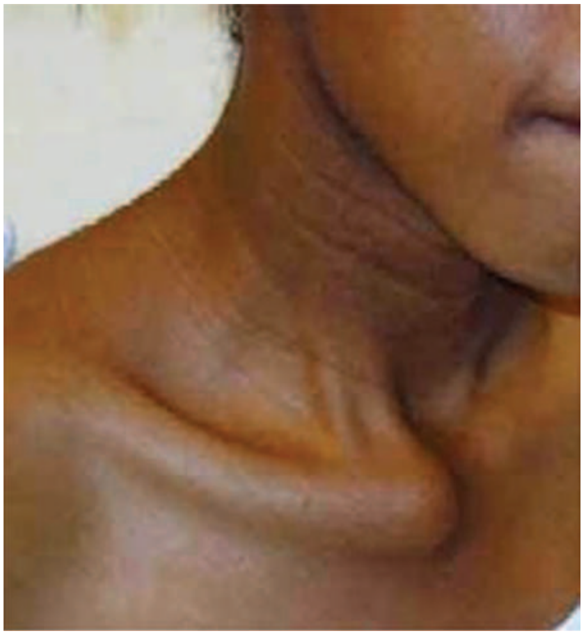


FIGURE 22-39 Anterior sternoclavicular dislocation.

Symptomatic, nonoperative treatment for a scapular fracture is usually the course.

Sternoclavicular Joint Dislocation

Traumatic dislocation of the sternoclavicular joint generally requires tremendous force, either direct or indirect, applied to the shoulder. Consequently, it is rare. Anterior dislocation is most common, with the medial head of the clavicle going anterior to the manubrium of the sternum (Figure 22-39). The victim complains of pain around the sternum and frequently has difficulty taking a deep breath. When the dislocation is posterior, significant pressure may be placed on the esophagus and superior vena cava. The victim may complain of difficulty swallowing and have engorgement of the veins of the face and upper extremities, representing superior vena cava obstruction syndrome. A step-off between the sternum and the medial head of the clavicle (compared with the uninjured side) confirms this diagnosis.

Unreduced anterior dislocation does not produce neurocirculatory compromise and is treated with a sling. Reduction of a posterior sternoclavicular dislocation should be attempted as soon as possible if neurocirculatory compromise is present. The victim is placed supine with a large roll of clothing or other firm object between the scapulae. Traction is applied to the arm against countertraction in an abducted and slightly extended position. The medial end of the clavicle may need to be manually manipulated to dislodge it from behind the manubrium (Figure 22-40). If this fails, forceful pressure is applied posteriorly to both shoulders. This may need to be abruptly applied, in a manner that "bows" the patient backward. This maneuver is repeated several times, with a larger object placed between the scapulae if reduction attempts are initially unsuccessful. Alternatively, with the victim seated and the caregiver's knee against the back between the shoulders, both shoulders are pulled back. Although it might seem macabre, if the victim becomes in extremis, the medial end of the clavicle is grasped with a towel clip or pliers and forcefully pulled out of the thoracic cavity. Once reduced, the injury is usually stable. Posterior sternoclavicular dislocation requires evacuation.

Acromioclavicular Joint Dislocation

Injuries to the acromioclavicular joint are commonly known as shoulder "separations," to be distinguished from a shoulder (glenohumeral) "dislocation." Acromioclavicular separations are classified as grade I, II, or III (Figure 22-41). These injuries are acutely painful, but surgery rarely improves the clinical outcome. The

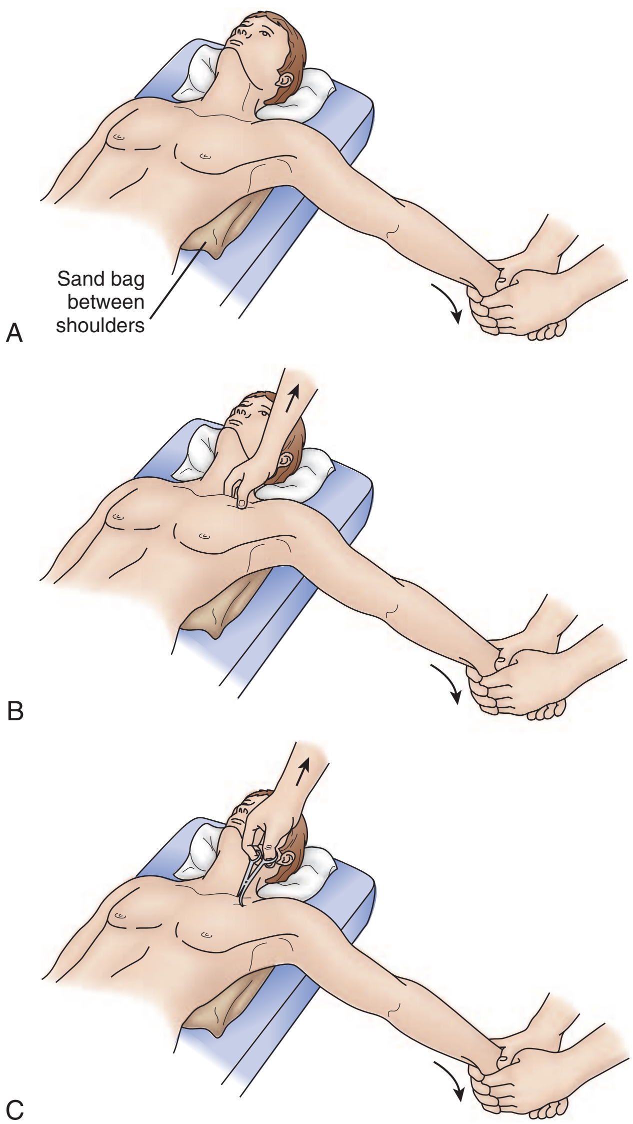


FIGURE 22-40 Technique for closed reduction of the sternoclavicular joint. **A,** The patient is positioned supine with a sandbag placed between the shoulders. Traction is applied to the arm against countertraction in an abducted and slightly extended position. For anterior dislocation, direct pressure over the medial end of the clavicle may reduce the joint. **B,** For posterior dislocation, in addition to the traction, it may be necessary to manipulate the medial end of the clavicle with the fingers to dislodge the clavicle from behind the manubrium. **C,** For a stubborn posterior dislocation, it may be necessary to prepare the medial end of the clavicle in a sterile fashion and use a towel clip to grasp around the medial clavicle and lift it back into position. *(From Rockwood CA Jr, Green DP, Bucholz RW, editors:* Rockwood and Green's fractures in adults, *ed 3, Philadelphia, 1991, JB Lippincott.)*

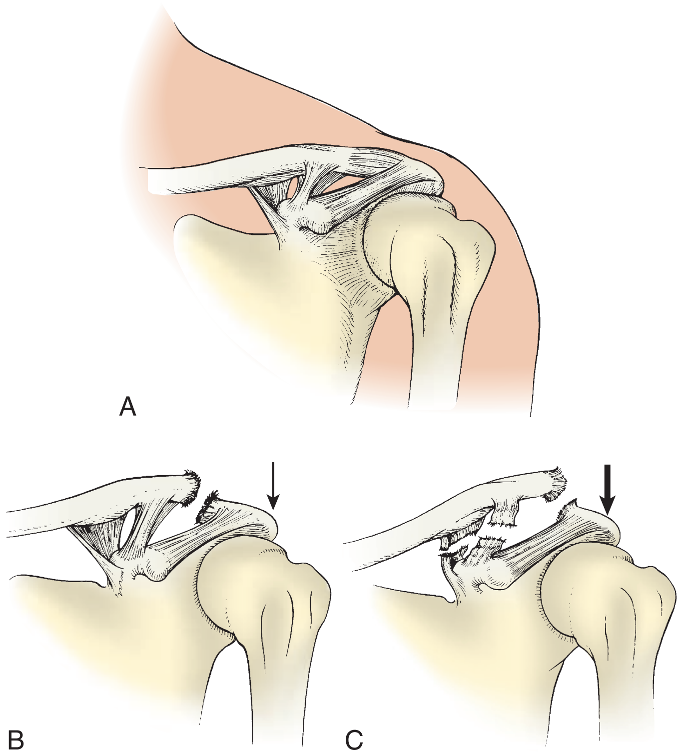


FIGURE 22-41 Acromioclavicular joint injury. **A,** Normal anatomy. **B,** Grade 2 injury. **C,** Grade 3 injury.

FIGURE 22-42 Grade 3 acromioclavicular separation of the left shoulder after a fall from a mountain bike.

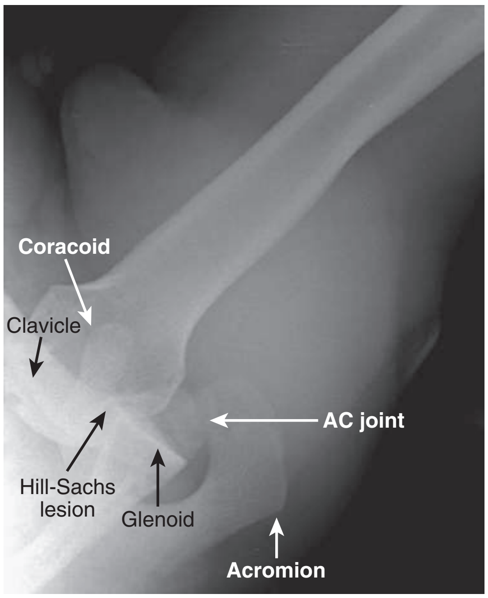


FIGURE 22-43 Axillary lateral radiograph demonstrating anterior glenohumeral dislocation that resulted following a fall while the patient was skiing in the backcountry.

acromioclavicular joint is usually injured by a blow or fall onto the shoulder (Figure 22-42). Because using the hand increases pain, the arm on the affected side is placed in a sling. As long as the individual can tolerate the discomfort associated with such an injury, evacuation is not necessary.

Glenohumeral Joint Dislocation

Dislocation of the glenohumeral joint is the most common bony dislocation. Ninety-five percent of glenohumeral dislocations occur in an anteroinferior direction (Figure 22-43). The usual mechanism of injury is a blow to the arm in the abducted and externally rotated position. This frequently occurs during downhill skiing when a person crosses the ski tips or falls forward over a mogul and lands face down with the arm(s) akimbo. It is also a common injury in kayaking. When a posterior

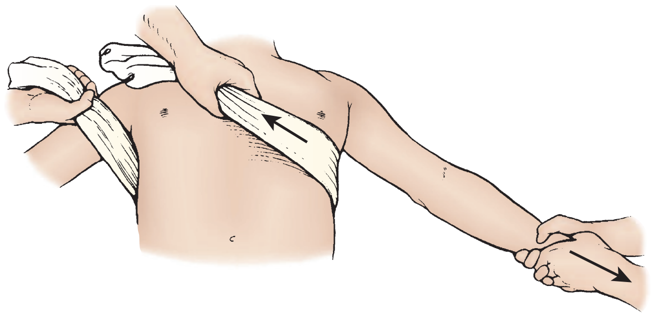


FIGURE 22-44 Traction and countertraction for dislocated shoulder reduction.

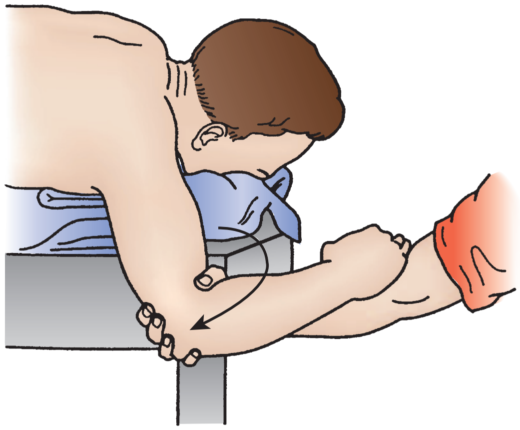


FIGURE 22-46 Milch technique of closed reduction of anterior glenohumeral dislocation with the patient prone. The arm can be manipulated in the same manner with the patient supine. *(Redrawn from Lacey T II, Crawford HB: Reduction of anterior dislocations of the shoulder by means of the Milch abduction technique,* J Bone Joint Surg Am *34:108, 1952. In Browner BD, Jupiter JB, Levine AM, et al:* Skeletal trauma, *vol 2, ed 2, Philadelphia, 1998, Saunders.)*

glenohumeral dislocation occurs in the wilderness, it is often in the setting of seizure or lightning strike. Usually, external rotation is completely lost. Palpation of the shoulder reveals posterior fullness that is not found on the uninjured side.

Recurrent dislocations and those in younger patients may be easier to reduce than first-time dislocations in older patients. Thorough motor, sensory, and circulatory examination of the involved extremity is performed. The axillary and musculocutaneous nerves are the nerves most commonly injured with anterior dislocation and therefore must be assessed carefully. Serial examinations of distal pulses, capillary refill, and forearm compartments are performed.

Treatment of shoulder dislocation requires manual reduction. Common techniques include the Kocher, Milch, Stimson, Spaso, and Legg maneuvers, scapular manipulation, and snowbird maneuver[2,8,9,22,33] (Figures 22-44 to 22-50). Self-reduction has been proposed but is arguably a challenging procedure. The technique favored by the authors uses sustained, gentle traction-countertraction to overcome muscle spasm, minimize rotational maneuvers, and avoid leveraging (Figure 22-51).

Of interest to the wilderness caregiver might be the "Eskimo technique" used by natives of Greenland, in which the patient is lifted from the ground by the affected arm (while lying on the unaffected side) so that the patient's body weight serves as a countertraction.[26] Mel Gibson, in his *Lethal Weapon* films, demonstrates a body-slam technique that may be performed, in the absence of an assistant or physician, against any solid stationary object. The recurrence rate is evidently high with this maneuver.

Regardless of the method employed, patient relaxation is critically important. The greatest barrier to successful reduction is generally muscular forces.

Greater tuberosity or glenoid fracture may accompany acute glenohumeral dislocation. Transient musculocutaneous and/or axillary nerve neurapraxia occurs in approximately 20% of shoulder dislocations.[31]

Dislocation of the glenohumeral joint remains an injury of potential long-term consequence for the patient. It is especially important for the younger individual, whose risk for recurrent dislocation may exceed 50%, to visit an orthopedic surgeon.[31] Arthroscopic or open repairs of the damaged anterior capsule and labrum may be appropriate in some cases after the first injury, and recurrent dislocations of the glenohumeral joint warrant surgical intervention to lessen the risk for further shoulder instability and progressive arthritic change. Individuals over 40 years of age have a significant risk for associated rotator cuff

FIGURE 22-45 Repositioning a dislocated shoulder. Attached to the victim's forearm with a strap, rope, or sheet, the rescuer uses his body weight to apply traction, leaving his hands free to manipulate the victim's arm. A second rescuer applies countertraction, or the victim can be held motionless by fixing the chest sheet to a tree or ground stake. *(From Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

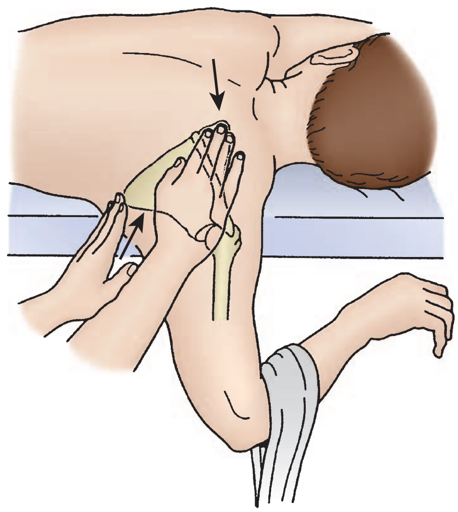


FIGURE 22-47 Scapular manipulation technique for closed reduction of anterior glenohumeral dislocation. *(Redrawn from Anderson D, Zvirbulis R, Ciullo J: Scapular manipulation for reduction of anterior shoulder dislocation,* Clin Orthop Relat Res *164:181, 1982. In Browner BD, Jupiter JB, Levine AM, et al:* Skeletal trauma, *vol 2, ed 2, Philadelphia, 1998, Saunders.)*

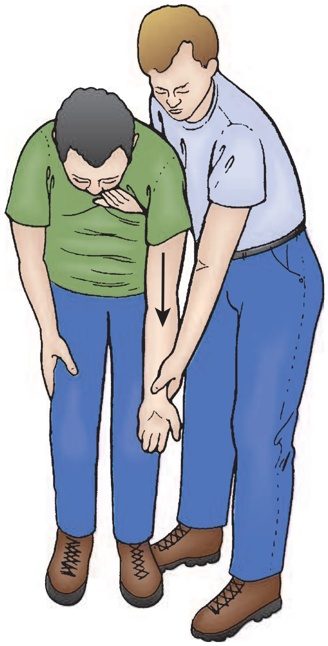


FIGURE 22-48 Pulling on the hanging arm to relocate a dislocated humerus. *(From Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

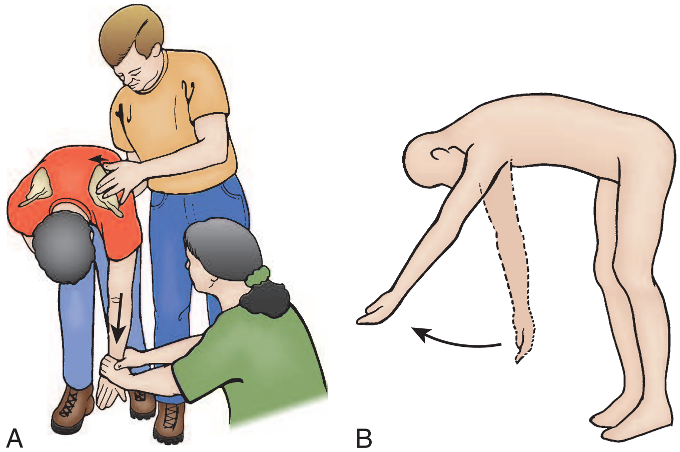


FIGURE 22-50 **A,** Pushing the lower edge of the scapula toward the spine while an assistant pulls downward on the affected arm to assist in relocation of a dislocated humerus. **B,** The downward pull on the arm may be slightly forward to help reposition the humerus back in the glenoid. *(From Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

injury in the setting of glenohumeral dislocation and should be evaluated for this injury if, after a week or two, active forward elevation or abduction is impaired.

If the reduction maneuver is successful, the arm is placed in a sling until definitive care is reached. If possible, a posterior dislocation is held in neutral or slight external rotation. Because of the significant incidence of fractures with these injuries, radiologic examination is required to make the diagnosis and evacuation is mandated. If the reduction maneuver is not successful, the injured extremity is placed in a sling and evacuation is arranged as soon as possible.

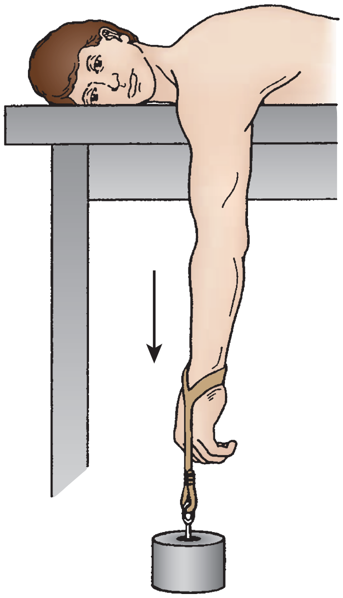


FIGURE 22-49 Stimson technique for closed reduction of anterior glenohumeral dislocation. *(Redrawn from Rockwood CA, Green CP, editors:* Fractures in adults, *vol 1, Philadelphia, JB Lippincott, 1984. In Browner BD, Jupiter JB, Levine AM, et al:* Skeletal trauma, *vol 2, ed 2, Philadelphia, 1998, Saunders.)*

ARM AND ELBOW FRACTURES

Proximal Humeral Fracture

Proximal humeral fracture can be difficult to differentiate from shoulder dislocation. The mechanism often is a high-velocity fall onto an abducted, externally rotated arm or a direct blow to the anterior shoulder. The victim complains of severe pain around

FIGURE 22-51 Reducing an anterior shoulder dislocation with steady traction. Dr. Steve Paul demonstrates a proper controlled traction-countertraction technique for reduction of a glenohumeral shoulder dislocation.

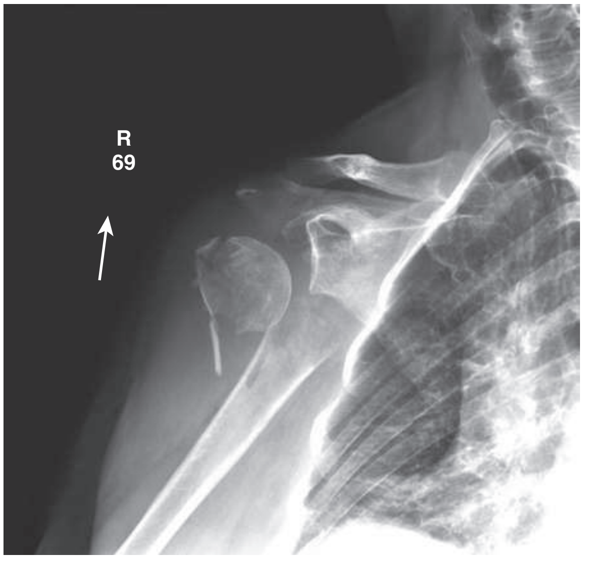


FIGURE 22-52 Proximal humeral fracture sustained in a 75-year-old hiker following a fall.

the shoulder with palpation or any arm motion. Palpable crepitus confirms the diagnosis. Although the inclination to attempt reduction may be compelling (this injury may be mistaken for a shoulder dislocation), acute reduction is not routinely required; application of an arm sling is appropriate field management (Figure 22-52).

Fracture-dislocation of the proximal humerus can occur. Although most dislocations with fracture are anterior, some can be posterior (Figure 22-53). Anterior or posterior fullness with crepitus on the injured side, compared with the uninjured side, suggests the diagnosis. This is a more severe injury than a simple shoulder dislocation, so very careful neurovascular examination should be performed. Any significant nerve or vascular injury should prompt evacuation to a definitive care center.

Humeral Fracture

Fracture of the shaft of the humerus may result from a direct blow or torsional force on the arm. This fracture frequently occurs with a fall, rope accident, or skiing accident. Fracture of the midshaft or junction of the middle and distal thirds of the humeral shaft can violate the spiral groove, the path of the radial nerve (Figure 22-54). If there is arm pain with deformity and crepitus, the arm is stabilized and the sensory and motor functions of the radial nerve are carefully checked as part of the overall neurovascular examination (Figure 22-55). Radial nerve function is evaluated by checking sensation in the dorsal thumb web space and documenting active wrist extension. When fracture of the humeral shaft is suspected, a coaptation splint made of plaster, fiberglass, a SAM Splint, or wood is firmly applied with an elastic bandage on the medial and lateral sides of the humerus. A sling is useful for comfort. Acute reduction of the fracture is not required in the field.

Fracture Around the Elbow (Distal Humerus, Olecranon, Radial Neck or Head)

Elbow pain, crepitus, deformity, and swelling after a fall could represent a distal humerus, olecranon, or radial head or neck fracture. A neurovascular examination is performed, and then a splint is applied with the elbow at 45 or 90 degrees of flexion, depending on the victim's comfort. Reduction should not be attempted without radiographic confirmation, unless deformity is gross, because crepitus is more often associated with a fracture than with a dislocation. Evacuation should be performed promptly if there is an open fracture or a neurocirculatory deficit.

Fracture of the distal humerus is frequently extraarticular in children and intraarticular in adults (Figure 22-56). Children generally sustain supracondylar fractures after falls from heights. The

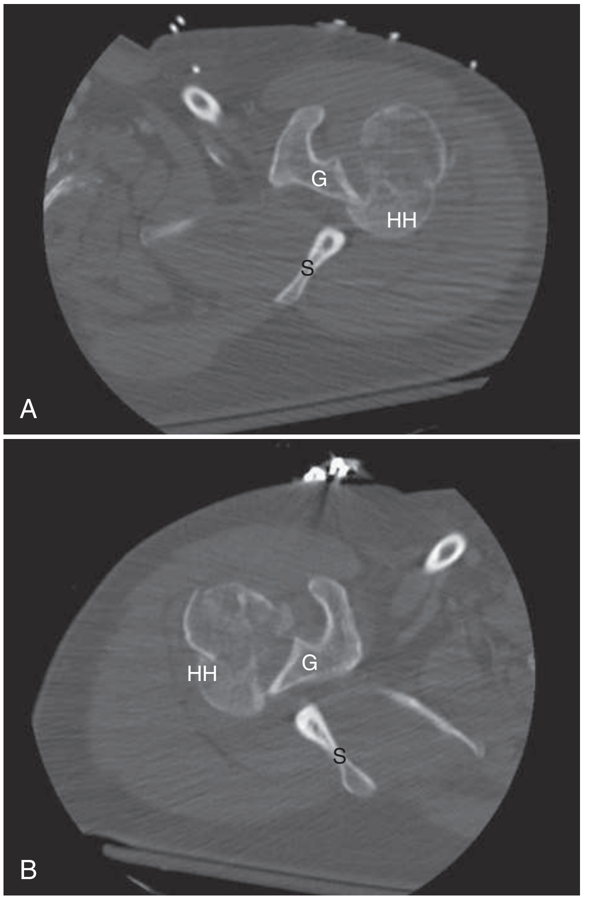


FIGURE 22-53 Bilateral proximal humeral fractures and posterior dislocations that occurred when an ultramarathoner suffered a seizure during a race. Computed tomography scan of right and left shoulders demonstrating posteriorly dislocated humeral heads, perched on respective glenoids. *G*, Glenoid; *HH*, humeral head; *S*, scapula.

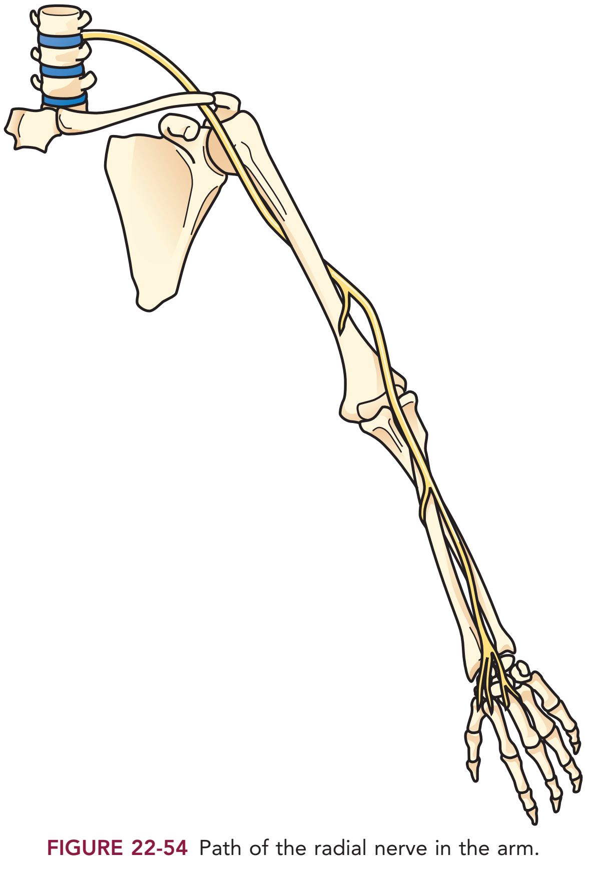


FIGURE 22-54 Path of the radial nerve in the arm.

PART 4 TRAUMA

FIGURE 22-55 Midshaft humeral fracture in a 45-year-old man who fell while ice climbing. He presented with radial nerve palsy.

FIGURE 22-57 Closed, displaced olecranon fracture-dislocation. A sling or posterior splinting is appropriate for this injury until definitive care can be provided.

extension type of injury is much more common than the flexion type, and it usually occurs in children age 4 to 8 years. Deformity, swelling, pain, and crepitus are present, and the diagnosis of fracture is fairly obvious. A careful neurovascular examination should be performed, focusing on motor examination of flexion of the thumb and distal IP joint of the index finger, because injury to the anterior interosseous nerve, which supplies innervation to these muscles, is frequently associated with these fractures. If the radial pulse is absent, an attempt should be made to flex or extend the elbow while palpating the radial pulse. If the pulse improves, the limb is splinted in that position for transport. If the pulse does not improve and definitive care is more than an hour away, reduction is performed. After available sedation is given, the supinated forearm is extended with gentle longitudinal traction. The fracture is reduced by flexing the elbow while maintaining longitudinal traction, and the elbow is splinted in 90 degrees of flexion. Evacuation should be prompt.

Fracture of the proximal ulna (olecranon) results from a fall onto the posterior elbow, or from violent asymmetric contraction of the triceps muscle. The victim may be unable to extend the elbow actively against gravity if the triceps is dissociated from the forearm with a complete olecranon fracture. On initial examination, the victim has pain, significant swelling, and a palpable gap in the olecranon. With severe trauma, olecranon fracture may be associated with elbow dislocation or intraarticular fracture of the distal humerus, which can only be diagnosed radiographically (Figure 22-57). A complete distal neurovascular examination should be performed. The shoulder and wrist should be examined, and a splint applied in the position of function and comfort. Open fracture, absent pulse, severe swelling, or neurologic deficit should prompt immediate evacuation.

Fracture of the radial head and/or neck generally occurs in young to middle-aged adults who fall onto an outstretched hand. The victim complains of pain around the elbow with loss of full extension, and pain at the radial head on the lateral side of the elbow with direct gentle pressure and rotation of the forearm. Fracture of the radial head or neck frequently produces elbow hemarthrosis, which is characterized by fullness posterior to the radial head and anterior to the tip of the olecranon (Figure 22-58). The elbow is gently moved through a range of motion and placed

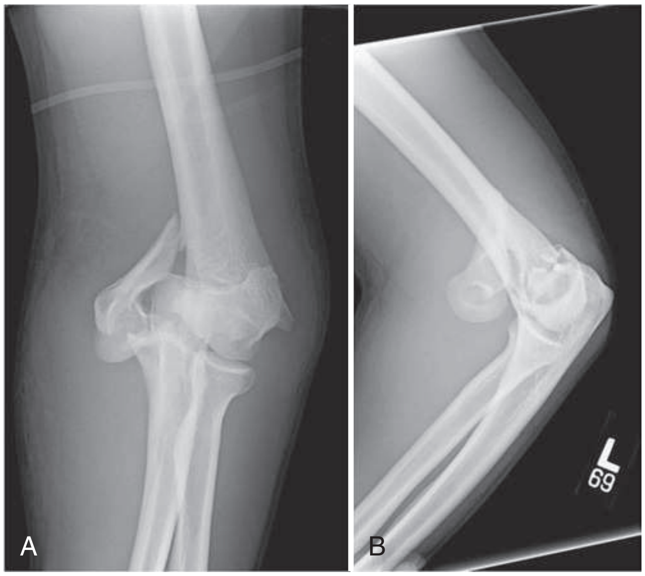


FIGURE 22-56 Anteroposterior **(A)** and lateral **(B)** views of intraarticular distal humeral fracture-dislocation sustained in a fall from an all-terrain vehicle.

FIGURE 22-58 Fracture of the neck of the radius, sustained in a fall. Pain on palpation at the lateral aspect of the elbow, in the region of the radial neck and head, would be anticipated.

in a posterior splint in 90 degrees of flexion with the forearm supinated. On a prolonged expedition when definitive care cannot be reached, the splint is removed after 3 to 5 days so that the victim can perform intermittent range-of-motion exercises (both flexion-extension and pronation-supination). With more comminuted radial head fractures, attempts at motion produce pain and crepitus, and motion remains restricted. These injuries require operative treatment. Although most individuals lose some extension and pronation-supination, early motion may prevent permanent loss of motion when the radial head fracture is nondisplaced or minimally displaced. The arm is splinted in supination to prevent contracture of the intraosseous ligament and loss of supination.

Elbow Dislocation

Dislocation of the elbow occurs with hyperextension or axial loading from a fall onto an outstretched hand. The direction of dislocation is generally posterior and lateral. The diagnosis is clear, with posterior deformity at the elbow and foreshortening of the forearm. After carefully assessing distal sensory, motor, and vascular status, reduction is performed. With countertraction on the upper arm, linear traction is applied with the elbow slightly flexed and the forearm in the original degree of pronation and supination. Downward pressure on the proximal forearm to disengage the coronoid from the olecranon fossa may be helpful. Hyperextension should be avoided. Adequate analgesia can be extremely helpful. An alternative method (Parvin's method) is to place the patient prone over a log or makeshift platform and apply gentle downward traction on the wrist for a few minutes. As the olecranon begins to slip distally, the arm is lifted up gently. No assistant is needed, and if the maneuver is done gently, no anesthesia is required (Figure 22-59). A modification of this maneuver (Meyn and Quigley's method) is to hang only the forearm over the platform while applying gentle downward traction via the wrist and guiding reduction of the olecranon with the opposite hand (Figure 22-60). Reduction provides nearly complete relief of pain and restoration of the normal surface anatomy. A posterior splint is applied with the elbow in 90 degrees of flexion and the forearm in neutral position. Collateral elbow ligament injuries and possible interposed bone or cartilage fragments are often a consequence of elbow dislocation. Follow-up evaluation and monitored therapy for range of motion are essential to avoid chronic instability or possible arthrofibrosis. A sling is provided for comfort. If reduction is not successful after three attempts or if a nerve injury is suspected, a splint is applied to the arm as it lies and evacuation performed.

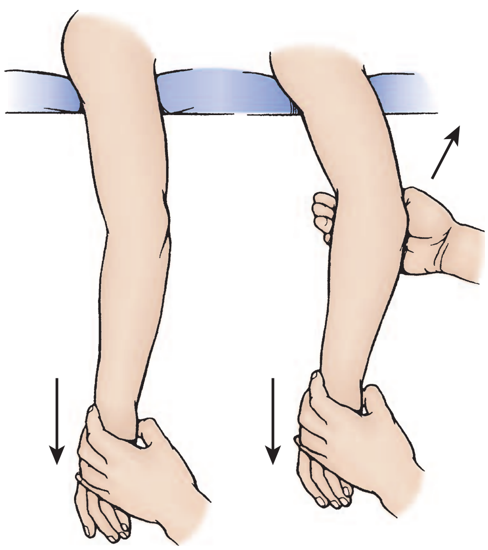


FIGURE 22-59 Parvin's method of closed reduction of an elbow dislocation. The patient lies prone on a stretcher, and the physician applies gentle downward traction on the wrist for a few minutes. As the olecranon begins to slip distally, the physician lifts up gently on the arm. No assistant is required, and if the maneuver is done gently, no anesthesia is required. *(Redrawn from Parvin RW: Closed reduction of common shoulder and elbow dislocations without anesthesia,* Arch Surg *75:972, 1957. In Rockwood CA Jr, Green DP, Bucholz RW, editors:* Rockwood and Green's fractures in adults, *ed 3, Philadelphia, 1991, JB Lippincott.)*

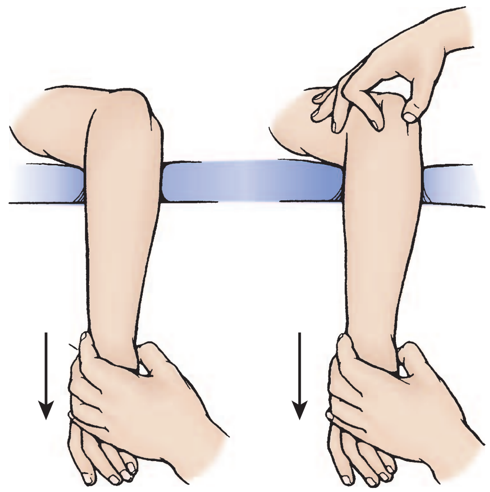


FIGURE 22-60 In Meyn and Quigley's method of reduction, only the forearm hangs from the side of the stretcher. As gentle downward traction is applied on the wrist, the physician guides reduction of the olecranon with the opposite hand. *(Redrawn from Meyn MA, Quigley TB: Reduction of posterior dislocation of the elbow by traction on the dangling arm,* Clin Orthop Relat Res *103:106, 1974. In Rockwood CA Jr, Green DP, Bucholz RW, editors:* Rockwood and Green's fractures in adults, *ed 3, Philadelphia, 1991, JB Lippincott.)*

Subluxation of the radial head in children (nursemaid's elbow) occurs when a longitudinal pull is applied to the upper extremity (Figure 22-61). The orbicular ligament partially tears, allowing a portion of it to slip over the radial head. An audible snap may be heard at the moment of injury. The initial pain from the injury subsides rapidly, and the child does not seem distressed but refuses to use the extremity. Any attempt to supinate the forearm brings a cry of pain and distress. If a definitive care center is nearby, the injury is splinted and evacuation is arranged. Otherwise, if the history and examination are consistent with the diagnosis, reduction can be attempted. First, the slightly flexed forearm is supinated; if this fails to produce the characteristic snapping sensation of reduction, the elbow is gently, maximally flexed in supination until the snapping sensation occurs (Figure 22-62). If the reduction is successful, the child is usually content

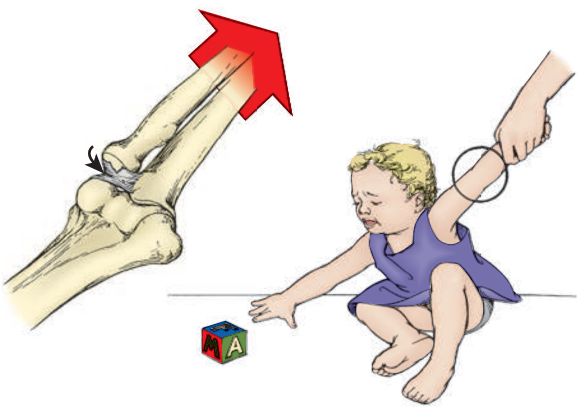


FIGURE 22-61 Nursemaid's elbow most commonly occurs when a longitudinal pull is applied to the upper extremity. Usually the forearm is pronated on presentation. There is a partial tear in the orbicular ligament, allowing it to subluxate into the radiocapitellar joint. *(From Rockwood CA Jr, Wilkins KE, King RE, editors:* Fractures in children, *ed 3, Philadelphia, 1991, JB Lippincott.)*

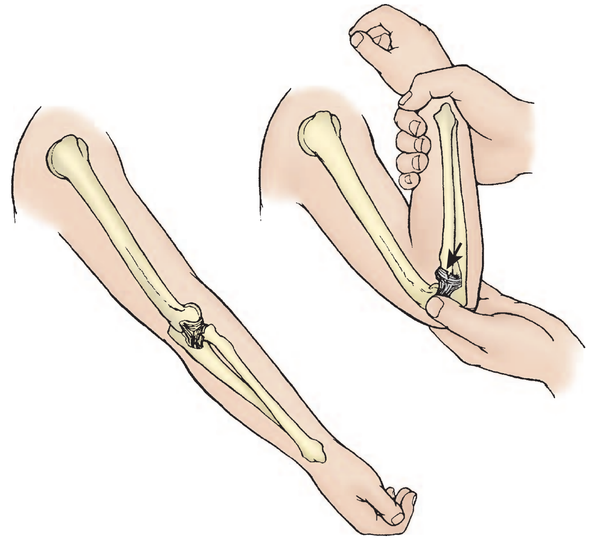


FIGURE 22-62 Reduction of nursemaid's elbow injury. *Left,* The forearm is supinated. *Right,* The elbow is then hyperflexed. The rescuer's thumb is placed laterally over the radial head to feel the characteristic "snap" as the ligament is reduced. *(From Rockwood CA Jr, Wilkins KE, King RE, editors:* Fractures in children, *ed 3, Philadelphia, 1991, JB Lippincott.)*

FIGURE 22-63 Both forearm bones are fractured following a fall while snowboarding.

and playing within 5 to 10 minutes, and no immobilization of the joint is indicated. If the reduction is unsuccessful, the child continues to avoid using the involved arm and should be evacuated for definitive care.

FOREARM, WRIST, AND HAND FRACTURES

Radial Fracture

Radial shaft fracture occurs with a fall involving angular or axial loading of the forearm. A radial shaft fracture may be associated with dislocation of the distal radioulnar joint (Galeazzi fracture) (see Figure 22-27). Therefore, in the setting of known or suspected radial shaft fracture, the wrist should be examined for tenderness, swelling, and deformity. The victim generally complains of pain. Deformity and crepitus are noted over the radial shaft after a fall or direct blow. Any arm motion exacerbates the pain. When both the radius and ulna are fractured, forearm instability is marked (Figure 22-63). The joint above (elbow) and joint below (wrist) should always be examined for tenderness, crepitus, and deformity. Once a fracture of the radius or both bones of the forearm is identified, the wrist, forearm, and elbow are splinted in the position of function.

Fracture of the distal metaphyseal radius is generally associated with a fall onto the outstretched hand (FOOSH injury) (Figure 22-64). Ulnar styloid fracture may accompany intraarticular fracture of the distal radius. Pain and crepitus are present, and often deformity associated with displacement. When this injury is suspected, distal neurovascular examination is performed, focusing on sensory function of the median nerve. Median nerve injury or compression at this level of injury manifests primarily as decreased sensation in the volar palm and fingers (thumb, index finger, middle finger, and radial half of the ring finger). Weakness in the opponens and abductor pollicis muscles might also be noted. If there is neurovascular compromise and definitive care is more than 2 hours away, reduction should be attempted. One hand is placed on the forearm to provide countertraction and the other around the wrist of the involved extremity. The wrist is dorsiflexed, and longitudinal traction is applied as the wrist is returned to a neutral position. A splint is applied to immobilize the wrist and elbow.

Distal radial and ulnar fractures occur commonly in children. They are seen most frequently in girls age 11 to 13 years and boys age 13 to 15 years. Familiarity with the Salter-Harris fracture classification system is important (Figure 22-65). These fractures are not usually comminuted but can be difficult to reduce (Figure 22-66). In cases involving an open fracture, significant distal neurologic deficit, or abnormal circulatory examination, splinting and evacuation should be prompt. The limb should be kept elevated above the level of the heart during transport.

Ulnar Fracture

Ulnar shaft fracture is most often associated with fracture of the radial shaft at the same level. When isolated, it usually occurs as a result of a direct blow, the so-called nightstick fracture (Figure 22-67). Fracture of the ulnar shaft can be associated with dislocation of the radial head (Monteggia lesion); therefore, elbow function should be carefully assessed. In the wilderness, the most

FIGURE 22-64 Distal radial fracture after fall.

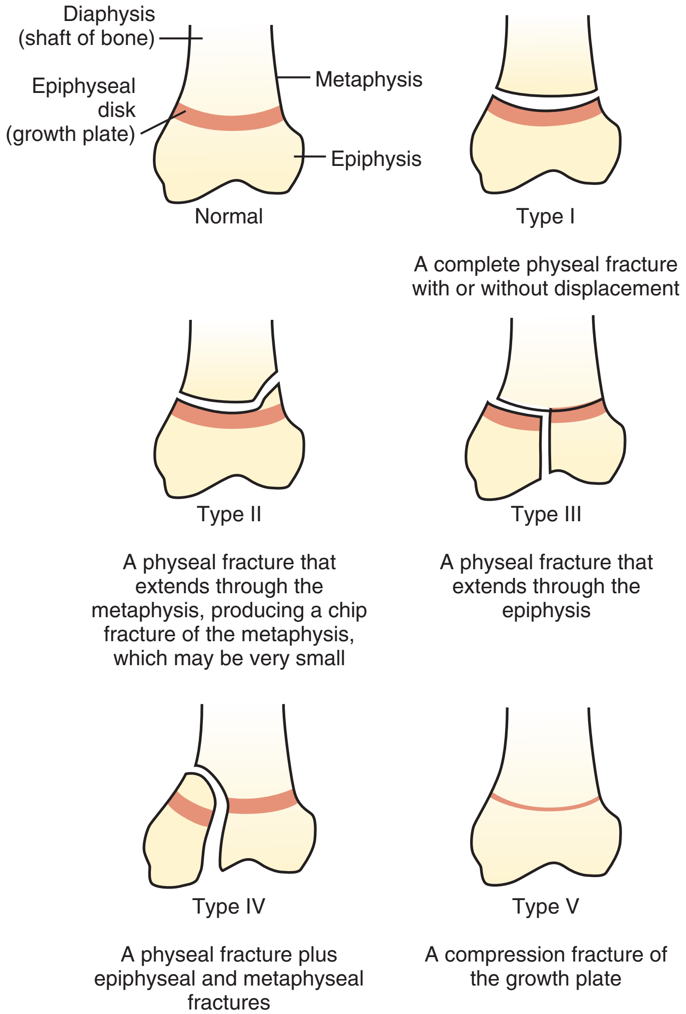


FIGURE 22-65 Salter-Harris pediatric fracture classification.

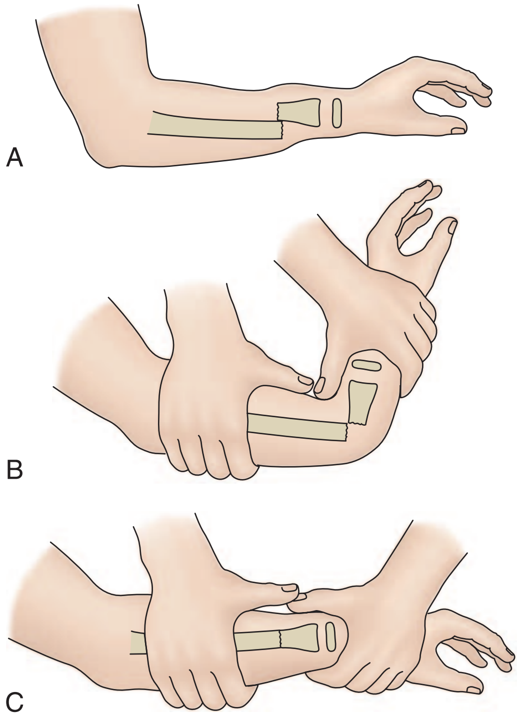


FIGURE 22-66 Technique for reduction of a distal radial fracture. **A,** Initial fracture position. **B,** Hyperextend fracture to 100 degrees to disengage the fracture ends. **C,** Push with the thumb on the distal fragment to achieve reduction. *(From Green N, Swiontkowski MF:* Skeletal trauma in children, *vol 3, ed 2, Philadelphia, 1998, Saunders.)*

frequent mechanism of injury is bracing against a fall or collision with the forearm. Pain, localized swelling, and crepitus are present. A long-arm splint is applied in the position of function. Open fracture is an indication for prompt evacuation.

Wrist and Carpal Fractures

Wrist fractures occur with significant rotational forces or high axial loading forces, as occur in falls onto the hand. The victim first complains of pain and later of wrist swelling. Hand use or forearm rotation produces significant pain. Many carpal bone fractures are associated with wrist dislocation.

Carpal bone fractures cannot be accurately diagnosed without radiographs. Scaphoid (navicular) fracture is the most common fracture and is suspected when maximal tenderness is in the "anatomic snuffbox" (Figures 22-68 and 22-69). If appropriate splinting materials are available, a thumb spica splint is applied, immobilizing both the radius and entire thumb. With fracture of the hook of the hamate bone, the victim complains of pain at the base of the hypothenar eminence (Figure 22-70). This injury occurs when the hand is used to apply significant force to an object with a handle on it, such as an ax or hammer, and great resistance is met. A short-arm splint suffices for this injury, and for other suspected carpal injuries, until definitive treatment is obtained. With open fracture or one accompanied by median nerve dysfunction, the victim should be promptly evacuated.

Metacarpal Fracture

Fracture of the metacarpal base or shaft occurs with crush injuries or axial load, as when a rock or other immovable object is struck. Fracture at the bases of the metacarpal is suspected when tenderness, crepitus, and occasionally deformity (sunken knuckle sign) are present (Figure 22-71). This fracture should be managed with a short-arm or ulnar gutter splint.

Fractures of the metacarpal necks occur by the same mechanism and usually involve the fourth and fifth metacarpals. These

FIGURE 22-67 "Nightstick" ulnar fracture.

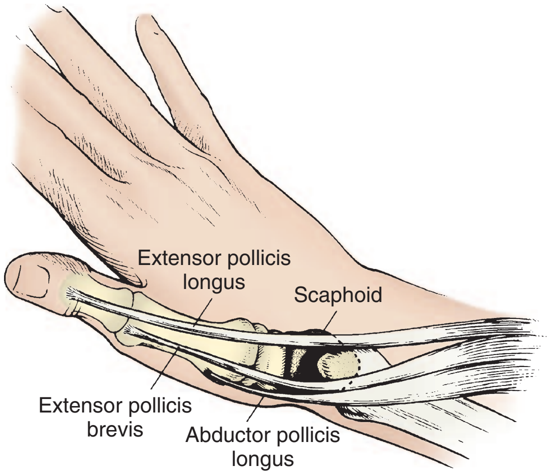


FIGURE 22-68 The scaphoid (navicular) bone sits in the anatomic snuffbox of the radial aspect of the wrist.

FIGURE 22-69 Scaphoid fracture with scapholunate widening.

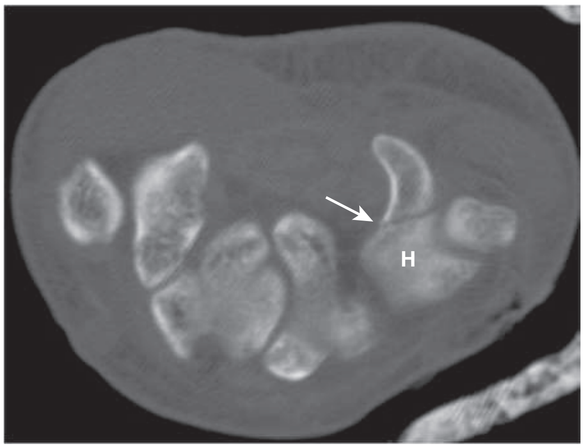


FIGURE 22-70 Hook of hamate *(H)* fracture.

FIGURE 22-71 Sunken knuckle sign, fourth metacarpal.

fractures can be associated with significant flexion deformity. Up to 40 degrees of flexion in the fourth and fifth digits can be accepted without compromising hand function, so these fractures seldom require surgical reduction and fixation. Rotational deformity of the metacarpal is poorly tolerated, however, and should be anticipated with suspected metacarpal fractures. With the MCP and the IP joints flexed 90 degrees, the fingernails should be parallel to one another and perpendicular to the orientation of the palm. The terminal portions of the digit should point to the scaphoid tubercle in an anatomic "cascade." If this is not noted, rotational deformity should be strongly suspected.

When malalignment or significant shortening with a suspected shaft fracture is noted, the fracture is reduced with longitudinal traction on the involved digit. A fractured metacarpal shaft or neck is immobilized by applying an aluminum splint (or stick) to the volar surface of the finger and palm and taping the involved digit to the adjacent digit, with the MCP joint at 70 to 90 degrees. This position provides optimal length of the collateral ligaments. Immobilizing the joint in this position prevents contractures that can lead to subsequent loss of motion.

Fracture of the base of the thumb metacarpal often occurs with an axial force directed against a partially flexed thumb metacarpal (Figure 22-72). If the fracture extends into the joint, it often requires operative fixation. If this fracture is suspected, the thumb and wrist are immobilized in a thumb spica splint. An open metacarpal fracture needs cleansing, debridement, and antibiotic therapy for 48 hours or until definitive care is obtained.

Metacarpophalangeal Joint Dislocation

MCP joint dislocation is rare and may be produced by a crush injury or when the hand is caught in a rope. This dislocation may be dorsal or volar, with dorsal dislocation more common. Clinically, the joint is hyperextended and the phalanx shortened. Most dorsal dislocations are easily reduced. First, the proximal phalanx is hyperextended 90 degrees on the metacarpal, and then the base of the proximal phalanx is pushed into flexion, maintaining contact at all times with the metacarpal head to prevent entrapment of the volar plate in the joint (Figures 22-73 and 22-74). Straight longitudinal traction is avoided because it may turn a simple dislocation into a complex dislocation. The wrist and IP joints are flexed to relax the flexor tendons. The joint usually reduces easily with a palpable and audible "clunk." A dorsal-volar splint is applied with the joint held at 90 degrees of flexion.

Irreducible or complex dislocations occur when the volar plate is interposed in the joint. The joint is only slightly hyperextended, and the volar skin is puckered over the joint. These dislocations are most common in the index finger, thumb, and small finger. A single attempt at reduction using the technique just described is indicated, but these dislocations usually require open reduction. If reduction of an MCP joint dislocation is unsuccessful, the joint should be splinted in the position of comfort and definitive treatment obtained as soon as possible.

FIGURE 22-72 Fracture of base of the first metacarpal.

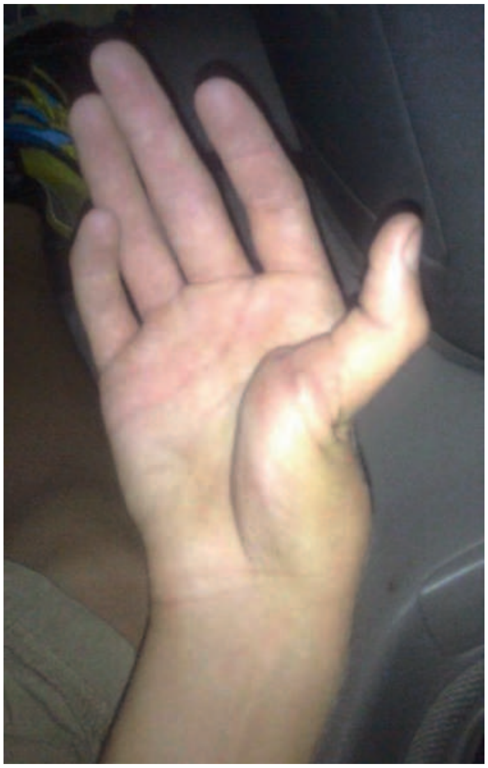


FIGURE 22-74 Dislocation of the right thumb; first metacarpophalangeal joint.

The thumb MCP joint is most commonly injured. Dislocations are reduced as already described. Injury to the ulnar collateral ligament of this joint (skier's or gamekeeper's thumb) results from a valgus stress, as may occur when an individual falls holding an object in the first web space. The victim complains of tenderness over the ulnar aspect of the MCP joint. There may be instability to radial stress with the joint held in 30 degrees of flexion, an indication for surgical repair. Often the adductor aponeurosis becomes interposed between the ligament and its bony attachment, resulting in a Stener lesion (Figure 22-75). In the field, a thumb spica splint is applied and definitive care sought within 10 days. If splinting material is not available, the thumb is taped until definitive care can be obtained (Figure 22-76).

Fractures of the Phalanges

Fractures of the digital phalanges occur with crush injuries or when the digits are caught in ropes or equipment being used to haul objects. Angular or rotational deformity and crepitus make these fractures obvious. Without radiographs, intraarticular fracture with subluxation or dislocation is difficult to differentiate from IP joint dislocation (Figure 22-77). Angular deformities in these fractures can be reduced using a pencil or thin stick placed in the web space as a fulcrum to assist with reduction. Fracture of the shaft of a phalanx is reduced by applying traction and

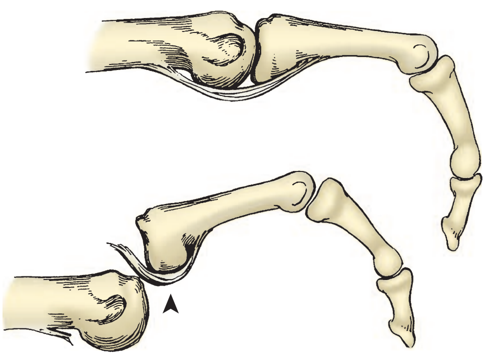


FIGURE 22-73 The single most important element preventing reduction in a complex metacarpophalangeal dislocation is interposition of the volar plate within the joint space. It must be extricated surgically. *(From Rockwood CA Jr, Green DP, Bucholz RW, editors:* Rockwood and Green's fractures in adults, *ed 3, Philadelphia, 1991, JB Lippincott.)*

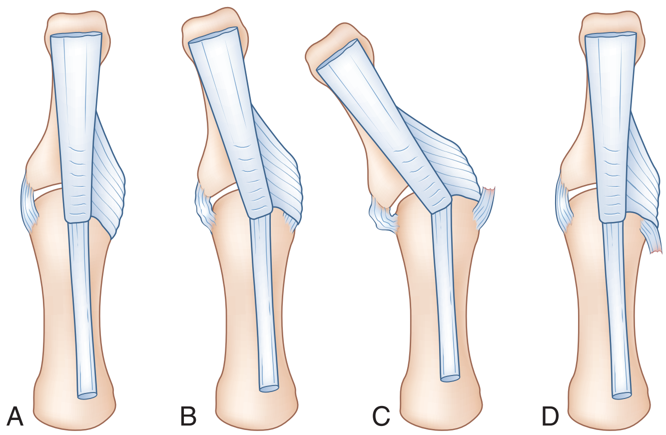


FIGURE 22-75 Diagram of the displacement of the ulnar collateral ligament of the thumb metacarpophalangeal joint. **A,** Normal relationship, with the ulnar ligament covered by the adductor aponeurosis. **B,** With slight radial angulation, the proximal margin of the aponeurosis slides distally and leaves a portion of the ligament uncovered. **C,** With major radial angulation, the ulnar ligament ruptures at its distal insertion. In this degree of angulation, the aponeurosis has displaced distal to the rupture and permitted the ligament to escape from beneath it. **D,** As the joint is realigned, the proximal edge of the adductor aponeurosis sweeps the free end of the ligament proximally and farther away from its insertion. This is the Stener lesion. Unless surgically restored, the ulnar ligament will not heal properly and will be unstable to lateral stress. *(Redrawn from Stener B: Skeletal injuries associated with rupture of the ulnar collateral ligament of the metacarpophalangeal joint of the thumb: a clinical and anatomical study,* Acta Chir Scand *125:583, 1963.)*

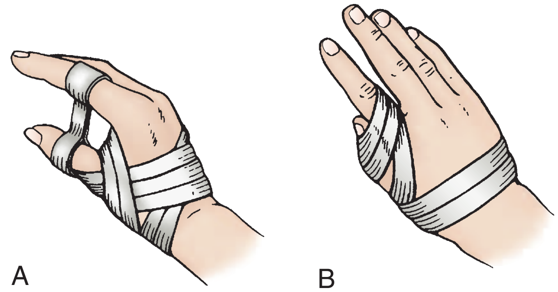


FIGURE 22-76 Taping the thumb for immobilization. **A,** The buddy-taping method. **B,** A thumb lock. If possible, padding should be placed between the thumb and forefinger. *(From Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

correcting the deformity. The fractures are immobilized by taping the injured digit to the neighboring uninjured digit or to a volar splint. Nailbed fractures or crushes are cleansed with soap and water, covered with a clean dressing, and protected with a volar splint. IP joint dislocations are relatively common and can usually be reduced with gentle axial traction on the digit (Figures 22-78 and 22-79). Reduction is often accompanied by an audible "pop" and improved ability to flex and extend through the IP joint. After reduction, the finger should be buddy taped to the adjacent digit. Prolonged (> 3 days) immobilization of the digit in a rigid splint should be avoided to prevent finger stiffness.

Dorsal IP dislocations can cause a tear in the skin volar to the joint. Although this tear may appear benign, the wound should be cleaned as well as possible, because contamination of the adjacent flexor tendon sheath can result in severe infection.

Soft Tissue Injuries of the Wrist, Hand, and Digits

Injuries to the volar or dorsal aspect of the hand or wrist can result in nerve and tendon injuries. A deep laceration over the volar palm or digits often extends to the digital flexor tendons and nerves (Figure 22-80). Loss of sensation or inability to flex the digit should prompt medical evaluation, because these structures will not recover without surgical intervention. Any wounds should be carefully cleaned and bandaged and the fingers splinted in flexion to prevent further retraction of the lacerated tendons and nerves. Lacerations on the dorsum of the hand may disrupt digital extensor tendons, although the functional loss may be less apparent due to interconnections with adjacent intact tendons.

FIGURE 22-77 Ring finger proximal interphalangeal joint dislocation that occurred while diving.

FIGURE 22-78 Middle finger proximal interphalangeal joint dislocation.

FIGURE 22-79 Radiograph demonstrating dorsal displacement of base of the middle phalanx.

HIP AND LEG INJURIES

FEMORAL FRACTURE

In general, healthy, active individuals sustain fractures of the proximal femur only in falls from significant heights or from

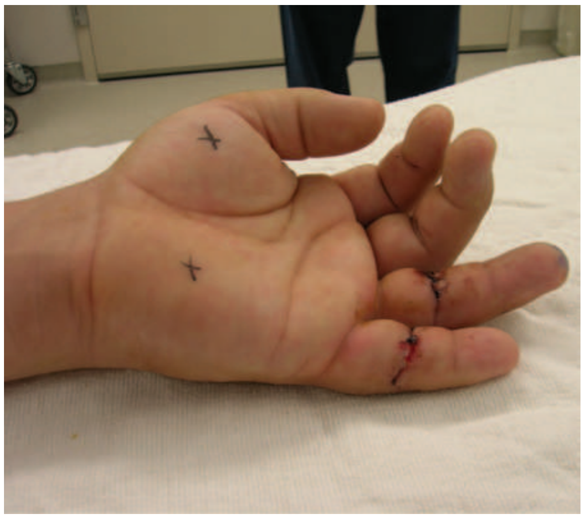


FIGURE 22-80 Extended posture of ring and small fingers that strongly suggests traumatic flexor tendon lacerations.

FIGURE 22-81 Comminuted femoral shaft fracture in a 30-year-old who rolled his all-terrain vehicle and hit a tree. Subcutaneous pieces of bone laterally suggest how close this injury was to being an open fracture.

high-velocity injuries sustained, for example, in motorized vehicle accidents or snow skiing or snowboarding. These fractures occur in the femoral neck or intertrochanteric or subtrochanteric regions (Figure 22-81; see also Figure 22-6). The victim complains of severe pain within the proximal thigh. There may be generalized swelling or deformity around the hip region. Movement of the affected limb, which is noticeably shortened and externally rotated, produces significant pain. After a careful sensory, motor, and circulatory examination, the limb is realigned, and a splint is applied if available. An improvised traction splint may need to be fabricated. If none is available, the victim is transported on a backboard, with the limbs strapped together or tied to a board with a tree limb placed between them.

Femoral neck fracture is associated with significant risk for posttraumatic femoral head necrosis (see Figure 22-6). Without a radiograph, this fracture is impossible to distinguish from a subtrochanteric or intertrochanteric hip fracture. Because there is evidence that emergency treatment of a fracture of the femoral neck in a young person decreases the risk for posttraumatic avascular necrosis,[28,30] rapid evacuation should be arranged for any victim in whom this injury is suspected.[18]

Femoral shaft fracture occurs by similar mechanisms (see Figure 22-81). Crepitus and maximal deformity are noted in the midportion of the thigh. After neurovascular examination, the limb is placed in traction or protected as noted previously. Gross deformity of the shaft is corrected with gentle traction, and the neurovascular examination is repeated. This fracture may be an open injury, so the victim's pants should be opened or cut to complete the examination. Discovery of an open wound should prompt rapid evacuation.

HIP DISLOCATION

Posterior hip dislocation is produced by axial loading of the femur with the hip flexed and adducted[13] (Figure 22-82). It generally occurs in a motor vehicle crash but can follow a fall or a sledding or skiing accident. With posterior dislocation, the victim complains of severe pain around the hip, and the affected limb appears shortened, flexed, internally rotated, and adducted. Any hip motion increases the pain. It is not clinically possible to determine if there is an associated acetabular or femoral neck fracture. With the rare anterior dislocation, the limb is externally rotated, slightly flexed, and abducted. This type of dislocation is generally produced by wide abduction of the hip caused by significant force.

The victim is placed in the supine position for complete survey of all organ systems. The distal limb is carefully examined for associated fractures, and a thorough sensory and motor examination is performed. The peroneal division of the sciatic nerve is most susceptible to injury with a posterior hip dislocation. Hip dislocation is an orthopedic emergency, because time to reduction is directly linked to incidence of avascular necrosis of the femoral head.[6] Immediate transfer to a definitive care center is desirable because hip radiographs may reveal an associated femoral neck fracture that could become displaced if closed reduction is attempted. However, if it will be more than 6 hours before the victim can be evacuated to a definitive care center, closed reduction should be attempted. To perform the Allis technique (Figure 22-83), the victim is positioned supine on the ground or a stretcher. If available, analgesic medication is administered. The caregiver stands above the victim and applies in-line traction on the extremity while an assistant applies countertraction to the iliac wings. Posterior dislocations are reduced by flexing the hip 60 to 90 degrees. Internal rotation and adduction of the hip facilitate relocation. With anterior dislocation, traction is applied with the leg slightly abducted and externally rotated and the hip gently extended. Successful reduction is usually indicated by an audible "clunk" and restoration of limb alignment. As with any reduction or relocation maneuver, adequate analgesia and a slow, progressive increase in traction force are helpful. This is not a technique that involves a sudden jerking movement; gradual fatiguing of the muscles that, in spasm, may be maintaining the hip in a dislocated position remains the most likely means of achieving relocation.

Another technique for relocating a posteriorly dislocated hip has been described.[14] The Captain Morgan technique is named for the similarity of the pose of the person executing this maneuver and the posture that "Captain Morgan" assumes on the eponymous bottle of rum. The caregiver maintains the patient in the supine position. The caregiver flexes the patient's hip and knee to 90 degrees. The caregiver places his or her thigh under the calf of the flexed, dislocated hip. With one hand pressing downward on the ipsilateral ankle of the dislocated hip and the other hand lifting upward behind the ipsilateral knee of the dislocated hip, the caregiver plantarflexes her or his own ankle of the leg that is under the patient's thigh. This slow plantarflexion, along with the concomitant downward pressure distally and upward pressure proximally, allows the caregiver's thigh to be used as a fulcrum to facilitate the hip relocation (Figure 22-84).

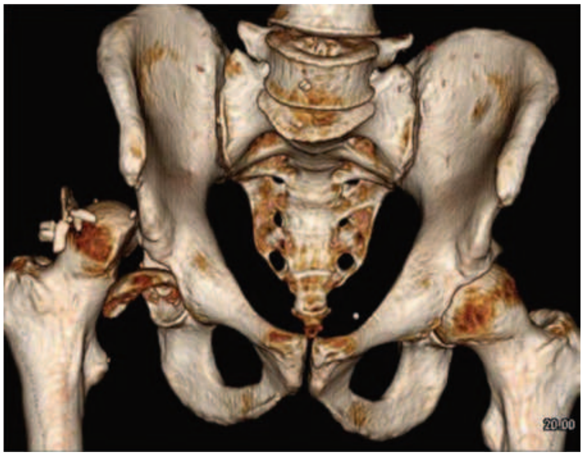


FIGURE 22-82 Right hip dislocation with femoral head fracture.

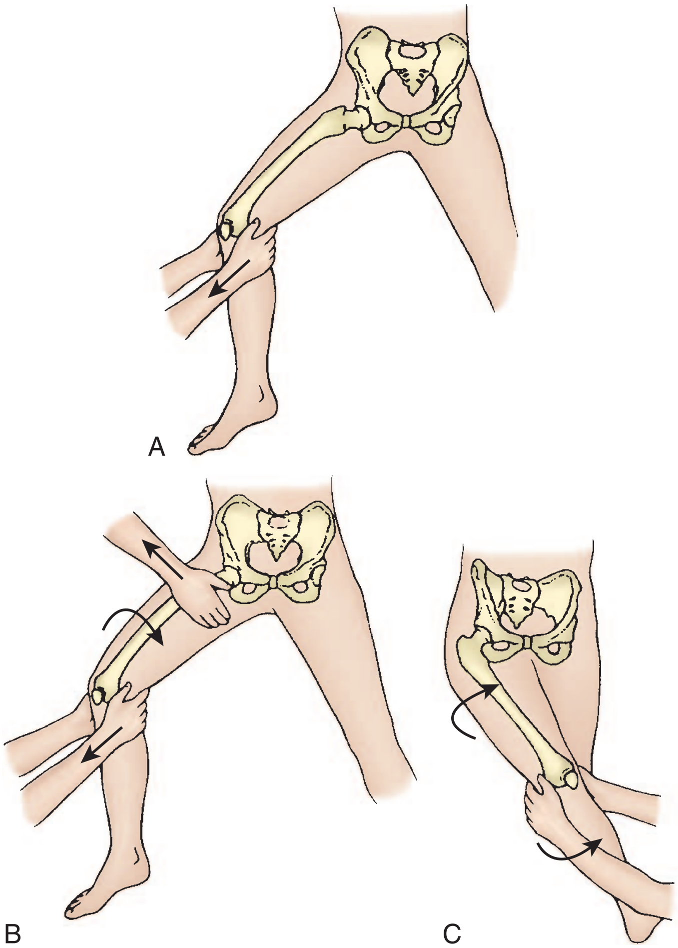


FIGURE 22-83 A combination of Allis's and reverse Bigelow's maneuvers for reduction of a hip dislocation. **A,** The health care provider's position must provide a mechanical advantage for the application of traction. In-line traction with hip flexed. **B,** Internal and external rotations are gently alternated, perhaps with lateral traction by an assistant on the proximal thigh. **C,** Adduction is often a helpful adjunct to in-line traction. *(Redrawn from Rockwood and Green:* Fractures in adults, *vol 2, ed 3, Philadelphia, 1991, JB* Lippincott.)

KNEE AND LOWER LEG INJURIES

Distal Femoral or Patellar Fracture

Fracture of the distal femur is frequently intraarticular and occurs with high-velocity loading when the knee is flexed. With axial loading on the femur, the patella becomes the driving wedge and the femoral condyles suffer a direct impact, producing either patellar fracture or fracture of the femoral condyles or distal femoral metaphysis (Figures 22-85 and 22-86). Occasionally, with high-energy trauma, a distal femoral fracture and ipsilateral proximal tibial fracture can occur concurrently.

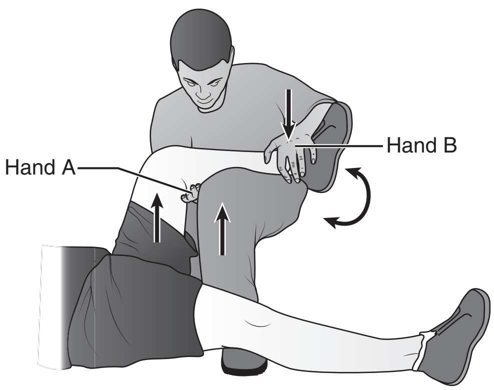


FIGURE 22-84 Captain Morgan technique for reducing a dislocated hip. *(From Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

FIGURE 22-85 Patellar fracture as a result of a direct blow to the anterior knee.

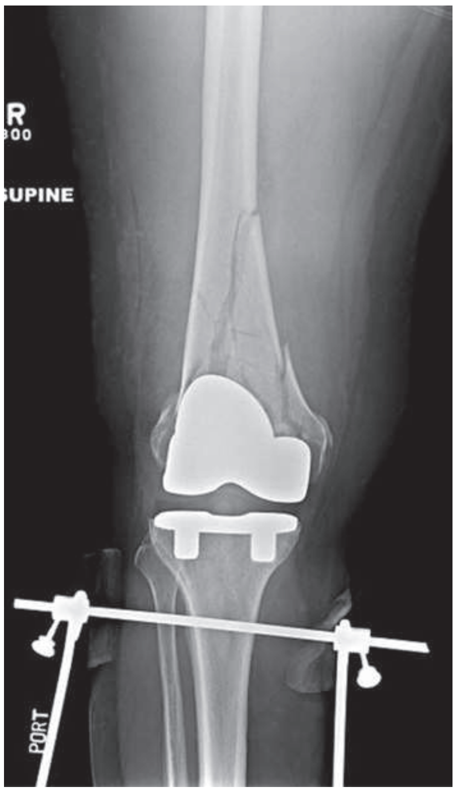


FIGURE 22-86 A 70-year-old woman with a total knee arthroplasty sustained a periprosthetic distal femoral fracture when she fell while hiking.

FIGURE 22-87 Open patellar fracture wound with typical stellate appearance.

With a patellar fracture, the injury may be obvious on deep palpation. This is often an open injury because there is very little soft tissue overlying this sesamoid bone (Figure 22-87). After an initial neurovascular examination, the limb is realigned. A posterior splint is applied to the realigned limb for transportation. As with all fractures, open wounds in the region of the fracture or an abnormal nerve or vascular examination should prompt immediate evacuation.

Knee Dislocation

Knee (tibial-femoral) dislocation is a high-energy injury. It is usually obvious because of the amount of deformity (Figure 22-88). The most common dislocation directions are anterior and posterior. Knee dislocation represents a true emergency because 5% to 40% of these injuries have associated vascular injuries.[1,29,34] A large series reported an above-knee amputation rate of 86% for vascular injuries associated with knee dislocations that were not repaired within 8 hours of injury.[12] The vascular injury occurs because of tethering of the popliteal vessels by the soleus fascia along the posterior border of the tibia. When this injury is suspected, a careful screening neurovascular examination must be performed. Intact distal pulses do not definitively rule out arterial injury. Intimal flap tears can produce delayed popliteal artery thrombosis. Injury to the peroneal nerve can also occur.

FIGURE 22-88 Anterior knee dislocation. Significant attention should be devoted to relocation, if possible, and to assessment of the neurovascular structures that run posterior to the knee joint, such as the popliteal artery and the tibial and common peroneal nerves.

Many knee dislocations spontaneously reduce and may lead the examiner to underestimate the seriousness of the injury. Instability in extension to either varus or valgus stress indicates disruption of at least one of the cruciate ligaments and signifies the potential for a knee dislocation.

After initial examination, the persistent dislocation should be reduced. Anterior dislocation is reduced with traction on the leg and gentle elevation of the distal femur. Posterior dislocation is reduced with traction in extension and anterior elevation of the tibia. Posterolateral rotatory dislocation (which occurs when the medial femoral condyle buttonholes through the medial capsule) can be very difficult to reduce and usually requires open reduction. A transverse furrow on the medial aspect of the knee is pathognomonic for this injury. For transport, a posterior splint is applied to the limb, and the victim is moved on a backboard. The possibility of an arterial lesion or emerging compartment syndrome requires vigilance. Emergency evacuation is advised because of the risk for amputation related to vascular injury.

The patellofemoral joint is more commonly dislocated than is the tibial-femoral joint. Generalized ligamentous laxity may predispose to this problem. Patellofemoral dislocation, especially recurrent, is more common in females than males and may be associated with an accentuated Q angle, the angle created between a line drawn from the anterior superior iliac spine to the center of the patella and a line drawn from the tibial tubercle to the center of the patella. Dislocation of the patella may result from a twisting injury or asymmetric quadriceps contraction during a fall. These mechanisms can occur with hiking, climbing, and skiing accidents. The patella usually dislocates to a position lateral to the articular surface of the distal femur. Although neurovascular injuries rarely occur in association with a dislocated patella, a screening examination should be conducted.

The patella can often be reduced by simply straightening the knee. If this is not successful, gentle pressure is applied to the patella to push it back up into the distal femoral articular groove. A knee splint is applied with the joint in extension; weight bearing is allowed. The knee is kept in extension until definitive care can be obtained. A radiograph is ultimately required to rule out osteochondral fractures, which can be associated with this injury.

Tibial and Fibular Fractures

The tibial plateau is the broad articular surface and metaphysis of the upper tibia that articulates with the distal femur. This area can be fractured in a fall or leap from a height. A valgus moment of force produces fracture of the lateral tibial plateau, whereas a varus moment of force produces medial plateau fracture (Figure 22-89). Pain, swelling, and deformity are obvious on initial examination. With a tibial plateau fracture, significant hemarthrosis develops quickly. Because of anatomic tethering of the popliteal artery by fascia of the soleus complex, arterial injury may result from this fracture, especially when it is associated with a knee dislocation. Distal pulses and capillary refill should be assessed at 1-hour intervals for a minimum of 8 hours or until evacuation occurs. After an initial examination, the limb is carefully realigned and a posterior splint applied for transportation.

Tibial shaft fractures may or may not be associated with fibular fractures. These fractures result from high-impact trauma. They were the most common ski injuries before the advent of modern, higher, anatomically conforming ski boots; improved binding-release systems; and shorter parabolic skis that reduced the lever arm of skis. The injury was sustained when the body rotated around a fixed foot (a ski caught against a rock, a tree stump, or the slope), which produced a torsional spiral fracture of the tibia and fibula.

Tibial shaft fracture is a common type of open fracture in the wilderness setting (Figure 22-90). When this injury is suspected, the entire limb should be inspected for distal sensory, motor, and vascular function before realignment. A posterior splint is applied for transport. The limb should be serially examined for the onset of compartment syndrome.

FIGURE 22-89 Tibial plateau fracture sustained in fall from a height.

FIGURE 22-91 Distal tibia-fibula fracture in a young Enduro rider: Salter-Harris II fracture.

ANKLE AND FOOT INJURIES

Ankle and Foot Fractures

The articular distal tibia (pilon), medial malleolus, and distal fibula, or any combination of these, may be involved in an ankle fracture, which is generally produced by torsional moments of force around a fixed foot (Figure 22-91). With the pilon tibial fracture, axial loading from a fall or jump may also be involved. Any significant pain and swelling should be noted as the footgear is removed. Palpation along the medial and lateral malleoli confirms the clinical suspicion. After footgear is removed to inspect the skin for open wounds, neurovascular examination is performed.

If there is a rotational deformity in the ankle, it should be realigned with gentle traction before applying a posterior splint with the foot and ankle in neutral position. During transport, the limb is elevated above the level of the heart.

FIGURE 22-90 Tibia fracture sustained in a snowmobile accident.

Ankle Dislocation or Sprain

Ankle dislocation is almost always accompanied by fractures of one or more malleoli. This dislocation generally occurs with falls onto uneven surfaces or with twisting injuries of moderate velocity. The area about the ankle is carefully examined for open injuries, and a neurovascular examination is conducted. The ankle joint is aligned by grasping the posterior heel, applying traction with the knee bent (to relax the gastrocnemius-soleus complex), and bringing the foot into alignment with the distal tibia. As with all reduction maneuvers, sustained gentle traction to fatigue the muscles that are in spasm is most effective. After this maneuver, the foot is reexamined, the wounds are dressed, and a posterior splint is applied. During transport, the limb is elevated above the level of the heart.

The most common musculoskeletal injury occurring in the wilderness setting is ankle sprain. Inversion injuries usually damage the lateral ligament structures, most commonly the anterior talofibular ligament. The calcaneal fibular ligament and posterior talofibular ligaments are less commonly injured. Eversion injury to the medial ankle may strain the large medial deltoid ligament (Figures 22-92 to 22-94).

An ankle sprain is often considered to be a minor injury, "just an ankle sprain." However, if a sprain is improperly rehabilitated or if someone returns to activity too soon, it may result in a chronically unstable joint. Ligament sprain, or tearing of the fibers, is differentiated (or categorized) into three grades. Grade 1 injury is partial disruption of some of the ligament fibers. Grade 2 injury is significant disruption of a portion of the ligament fibers. The main substance of the ligament remains intact, and the injury is characterized by moderate hemorrhage. Grade 3 injury is complete disruption of the ligament fibers, which can result in instability of the ankle joint.

The amount of discoloration and swelling of the ankle and foot usually is consistent with the degree of injury. Even grade 3 injuries usually heal without surgery if treated appropriately. An ankle stirrup for 3 to 6 weeks may be adequate for grade 1 injury. A walking boot or cast is often indicated for grade 2 to 3

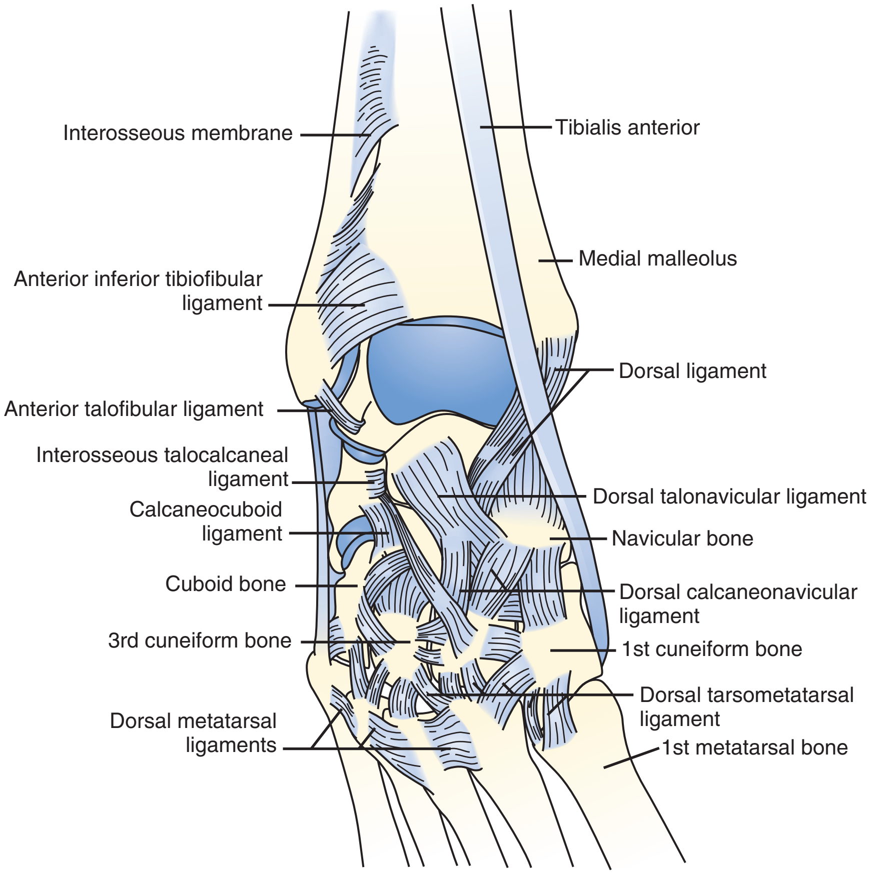


FIGURE 22-92 Ligaments of the anterior ankle.

injuries, with protected motion for 6 to 8 weeks. Ligament injury, depending on degree, typically requires at least 6 and often 12 weeks for complete healing.

When ankle sprain is suspected, the footgear and sock are removed and a screening neurovascular examination is conducted. Ankle ligaments and bone are palpated to help distinguish between ankle fracture and sprain. The ankle is evaluated for instability with the anterior drawer test. This is performed by stabilizing the tibia with one hand and grasping the posterior heel to pull the foot forward with the other hand. If the talus slides forward within the ankle mortise (using the uninjured side for comparison), the injury is likely grade 3. The foot and ankle are placed into a posterior splint or air splint. If possible, the victim is kept from bearing weight on the limb. If the anterior drawer test does not reveal instability and indicates a grade 1 or 2 sprain, an elasticized bandage is applied or the ankle is taped. All injuries should be acutely treated using RICE principles. Commercially available stirrup air splints aid ambulatory management of these injuries.

In the field, the ankle is taped to decrease pain and limit swelling (Figure 22-95; see also Chapter 23). During taping, the victim's ankle is held perpendicular to the tibial shaft. This makes

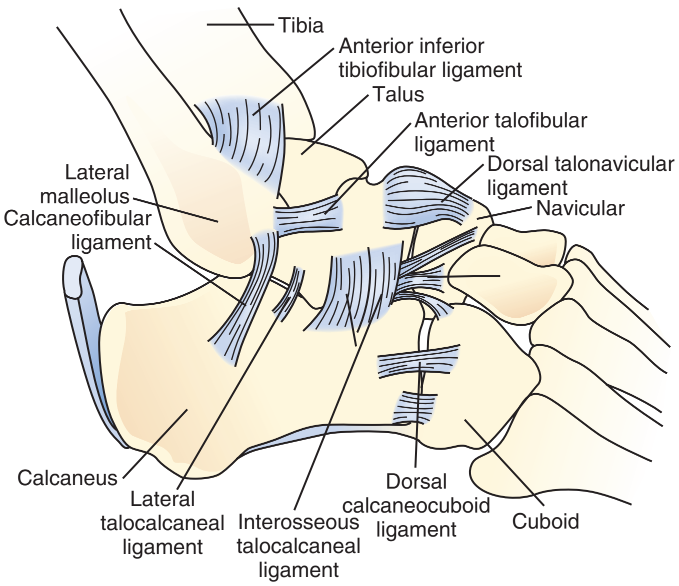


FIGURE 22-93 Ligaments of the lateral ankle.

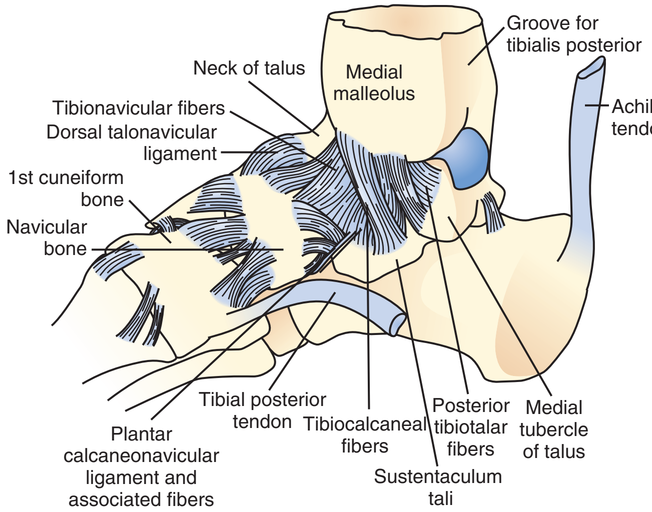


FIGURE 22-94 Ligaments of the medial ankle.

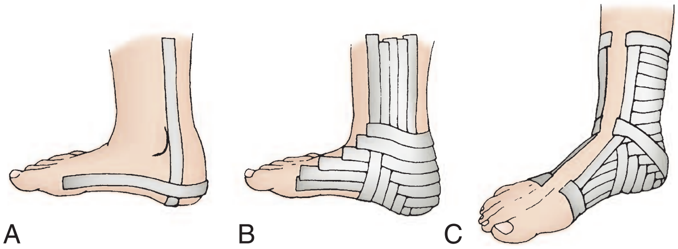


FIGURE 22-95 Taping sprained ankle. Strips of adhesive tape are placed perpendicular to each other **(A)** to lock the ankle with a tight weave **(B).** The edges are covered to prevent peeling **(C).** *(From Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

walking easier, because the ankle is not plantarflexed, and helps prevent development of Achilles tendon contracture. If available, an Aircast ankle brace provides additional ankle support and can be used with a shoe or boot.

Fracture of the lateral process of the talus, which is a fairly common lower extremity fracture in snowboarders, may be confused with lateral ankle sprain, so radiographs are generally needed to rule out this injury.[9] Inversion injuries are also infrequently associated with fractures at the insertion of the peroneus brevis tendon. This injury can be identified by point tenderness at the base of the fifth metatarsal, but a radiograph is required for definitive diagnosis. Early management is the same as for an ankle sprain. The eponym *Jones fracture* is used to describe the more worrisome transverse fracture to the metaphyseal portion of the fifth metatarsal; nonunion is a concern with this injury (Figure 22-96).

Hindfoot Dislocation

The subtalar joint may infrequently be dislocated in a significant fall or jump when an individual lands off balance or on an uneven surface. The calcaneus may be dislocated medially or, more commonly, laterally relative to the talus (Figure 22-97). The position of the heel relative to the ankle is assessed. With either dislocation, a reduction is attempted if it will be more than 3 hours until the victim will reach a definitive care center.

Medial dislocation is reduced more easily than is lateral dislocation, in which the posterior tibial tendon frequently becomes displaced onto the lateral neck of the talus, blocking the reduction. The maneuver is the same for both: The heel is grasped with the knee flexed (relaxing the gastrocnemius-soleus complex), the deformity is accentuated, linear traction is applied, and the heel is brought over to the ankle joint. This maneuver is generally successful for medial dislocation, but lateral dislocation, especially when associated with open wounds, often requires open treatment. After reduction is attempted, a posterior splint is applied and the limb is elevated above the level of the heart. Even if reduction is successful, the victim must not be allowed to bear weight until definitive care is obtained.

FIGURE 22-97 Subtalar fracture dislocation.

Midfoot Dislocation

Midfoot fracture-dislocation (Lisfranc injury) is described in the metatarsal fracture section (Figure 22-98).

FIGURE 22-96 Base of fifth metatarsal fracture. This technically is not a Jones fracture because it is in the metaphyseal region, not the metadiaphyseal region.

FIGURE 22-98 Lisfranc midfoot fracture-dislocation.

FIGURE 22-99 Fracture-dislocation of left ankle that occurred during a fall while bouldering. **A,** Anterior view with lateral displacement of foot at subtalar joint. **B,** Medial aspect of lateral subtalar dislocation.

Tarsal Fracture

The calcaneus and talus can be fractured when the victim lands on the feet following a fall or jump from a significant height (see Figure 22-7). With a calcaneus fracture, severe heel pain, deformity, and crepitus are immediately evident after the boot is removed. Talus fracture usually occurs when the foot is forced into maximal dorsiflexion. Talus fracture may be impossible to differentiate from ankle fracture on clinical grounds. One rule of thumb is that an ankle fracture is tender at the malleolus level, whereas a talus fracture is tender distal to the malleoli. Knowing the point of the foot's impact with the ground is also helpful in differentiating a talus fracture from an ankle fracture. An ankle fracture more commonly occurs as the result of a twisting injury, wherein the ankle is inverted or, occasionally, everted. A talus fracture most often occurs as the result of a high-energy mechanism, such as a fall from a height. The load sustained by the midfoot is axial and the ankle is dorsiflexed.

Talus fracture may be associated with subtalar or ankle joint dislocation (Figure 22-99). Emergency evacuation should be arranged when this injury is suspected because the injury is very difficult to reduce closed, and pressure on the skin from the displaced talar body can produce significant skin slough.

Fractures of the other tarsal bones are exceedingly rare but can be defined by localizing tenderness to a specific site. A short-leg splint with extra padding is applied, and the limb is elevated during transportation.

Metatarsal Fracture

Fractures at the base of the metatarsals often accompany midfoot dislocation, a so-called Lisfranc injury. The mechanism usually occurs with axial loading of the foot in maximal dorsal flexion as a result of a motor vehicle crash, most frequently with snowmobiling (see Figure 22-98). The victim complains of midfoot pain and swelling. On removing footgear, crepitus and tenderness are noted at the bases of the metatarsals (especially the first, second, and fifth metatarsals), and plantar ecchymosis may be present. Overall foot alignment is maintained, but stressing the midfoot by stabilizing the heel and placing force across the forefoot in the varus and valgus directions reveals instability. The foot is placed in a well-padded posterior splint and elevated. The patient is not allowed to ambulate. Swelling associated with Lisfranc dislocation can produce a foot compartment syndrome.

Metatarsal shaft fracture occurs with crush injury or a fall or jump from moderate height. Midshaft metatarsal fractures also occur as "fatigue" (or "march") fractures. These classic overload injuries may result from prolonged hiking or running with poor preconditioning. Pain and localized tenderness are hallmarks of this diagnosis. The dull pain at the midshaft of a metatarsal (often the second or fifth) may be converted to more severe pain with associated crepitus by a jump from a log or a rock. These fractures can be temporarily managed with a stiff-soled boot or orthotic insert. If there is fracture instability or extreme pain, a short-leg splint is applied, and no further weight bearing is allowed until more definitive evaluation and treatment can be obtained.

Fracture of the Phalanges of the Toes

Toe phalanges are usually fractured by a crush mechanism that can be prevented by use of steel-toed or hard-toed boots. A great toe phalanx fracture can be a significant problem because force is placed on this digit during the toe-off phase of gait (Figure 22-100). Phalanx fractures are managed by buddy taping the toe to an adjacent uninjured digit with cotton placed between the toes. Displaced intraarticular fracture of the proximal phalanx of the great toe may need operative fixation. Stiff-soled boots minimize discomfort during weight bearing.

Metatarsophalangeal and Interphalangeal Joint Dislocations

MTP joint dislocation of the toe is relatively uncommon but can occur when a moderate axial force is directed at the great toe. Crush injuries and rock-climbing accidents while the victim is wearing flexible-soled shoes can produce this injury; wearing boots with reinforced toe boxes of adequate depth generally prevents it. Injuries of this type at the great toe may be associated with fractures of the metatarsal joint or phalanx. The dislocation

FIGURE 22-100 Great toe proximal phalanx fracture.

FIGURE 22-101 Gustilo type II open great toe dislocation occurred during a fall while hiking in sandals.

is generally dorsal. Because these may be open injuries, the foot must be inspected carefully. The joint is reduced in a manner similar to that used for dorsal proximal IP joint dislocation of the hand. MTP dislocation of the great toe can occasionally require open reduction if the head of the metatarsal buttonholes through the sesamoid–short flexor complex.

The lesser MTP joints are generally dislocated laterally or medially. The most common mechanism for this injury is striking unshod toes on immovable objects. The toes are relocated by applying linear traction with the victim supine and using the weight of the foot as countertraction. Similar mechanisms produce dislocations of the IP joints, which are also reduced by applying linear traction with gentle manipulation (Figure 22-101). Once reduced, the injured toe is taped to the adjacent toe for 1 to 3 weeks, and the victim wears a protective boot with a stiff sole and deep toe box.

OTHER SOFT TISSUE AND MUSCULOSKELETAL INJURIES

INTRAARTICULAR KNEE DISRUPTION

Sprains or tears of knee ligaments are common occurrences in sporting events and other vigorous activities. They often involve a sudden fall or a twisting mechanism.

The anterior cruciate ligament (ACL) restrains the tibia from forward displacement relative to the end of the femur. The posterior cruciate ligament (PCL) restrains the tibia from posterior displacement relative to the femur. ACL injuries are most common in pivot-twisting sports, such as basketball, soccer, and alpine skiing, but can occur with simple falls or work injuries (Figure 22-102). PCL trauma is often seen in "dashboard" injuries, in which the anterior knee is suddenly pushed backward. ACL injuries are more commonly seen than are PCL injuries, and the incidence is higher in female than in male athletes. Biomechanical issues in jumping and landing are thought to be largely involved and more relevant than is the hormonal or intrinsic knee anatomy ("notch" size).

The individual who sustains this injury often sustains concomitant knee injuries, such as meniscus tear or injury to another ligament in the knee. Tearing the ACL may be accompanied by the sound of a "pop" in the knee. Usually, but not always, the knee becomes swollen secondary to hemarthrosis. A sense of instability is common. On examination, there may be marked laxity to anterior stress on the tibia relative to the femur (Lachman's test).

Although it may be easy to produce anterior tibial translocation in extension, ACL injuries do not necessarily require immobilization. Grading of sprains is based on laxity or translocation anteriorly of the tibia on the femur: grade 1, less than 5 mm (0.2 inch); grade 2, 5 to 10 mm (0.2 to 0.4 inch); and grade 3 (complete tear), greater than 10 mm (0.4 inch). If the mechanism of a knee injury suggests that it is more likely to be ligamentous than bony, weight bearing as tolerated and range of motion as tolerated are safe recommendations. Nonsteroidal antiinflammatory drugs (NSAIDs), compression dressing, and cold (e.g., ice) application are palliative methods that may enhance the victim's ability to ambulate in the wilderness setting.

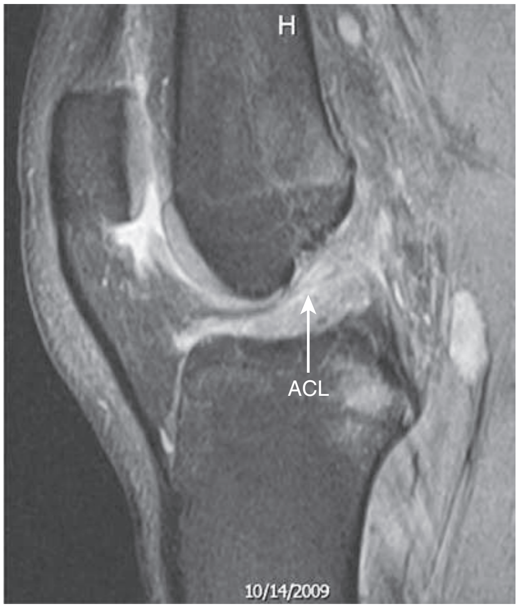


FIGURE 22-102 Anterior cruciate ligament (ACL) tear.

The collateral ligaments stabilize the knee in the lateral and medial directions (Figure 22-103). The medial collateral ligament (MCL) is more commonly injured than is the lateral collateral ligament (LCL), because collisions to the knee usually occur on the outer aspect or lateral side, which causes the medial joint to "book" open. The opposite leg usually protects the knee from being struck medially so that the LCL of the contralateral knee is often spared. Collateral ligament injuries are graded as 1, 2, or 3. A strain causing pain but having less than 5 mm (0.2 inch) of discernable joint space opening compared with the uninjured knee is consistent with a grade 1 injury. A joint space opening of 5 to 10 mm (0.2 to 0.4 inch) is consistent with a grade 2 injury.

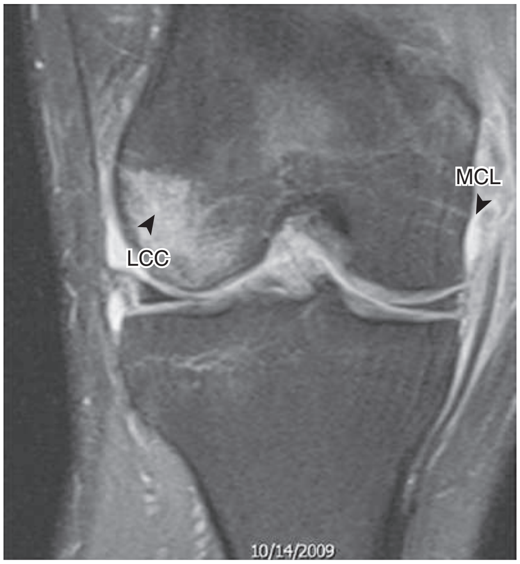


FIGURE 22-103 Medial collateral ligament (MCL) tear with lateral condyle contusion (LCC).

A joint space opening of more than 10 mm (0.4 inch) or the absence of an end point with valgus stress applied to the knee is consistent with a grade 3 injury. The MCL is attached to the medial meniscus, so injury to the medial knee may also cause injury to the medial compartment cartilage. If symptoms do not improve in a timely fashion, further evaluation to rule out a meniscal tear is appropriate.

MCL injury is typically treated with conservative management. A hinged knee brace that stabilizes the knee from varus and valgus stress is indicated.

Isolated injury to the LCL is less common than is that of the MCL. It typically occurs when the outstretched leg is struck from the medial or inner aspect, producing varus stress to the knee. The LCL can be strained or torn. The LCL may be injured in association with a cruciate ligament injury. Complex injuries to the posterior lateral corner of the knee may also involve the popliteus tendon and can be disabling in terms of knee stability. The LCL connects from the lateral femoral condyle to the head of the fibula but has no direct attachment to the lateral meniscus (as does the MCL with the medial meniscus).

Most isolated LCL sprains, like MCL sprains, heal with conservative management. The typical time frame of 6 to 12 weeks may be anticipated for return to full unrestricted activity. A hinged knee brace that protects the knee from valgus stress is indicated. When associated with a multiligament injury, especially a cruciate ligament disruption and posterior lateral instability, surgical repair may be necessary to restore function.

Individuals and athletes who wish to return to competitive sports typically have ACL injuries repaired; PCL tears are treated on a case-by-case basis because many individuals can compensate for this injury without surgery. An ACL-deficient knee often results in ongoing instability (a "trick knee"), even in nonathletic individuals, and the risk for tearing the meniscus or causing other damage to the knee is high. Rehabilitation from this injury usually takes a minimum of 6 months.

Meniscal tears in the setting of a ligamentous injury are common (Figure 22-104). Some tears (bucket handle tears) can become caught in the joint, and may result in a "locked knee." Manipulative procedures to slightly widen the joint space wherein lies the lodged meniscal fragment might liberate an incarcerated fragment. Sometimes, surgery is the sole solution for this problem.

ACHILLES TENDON RUPTURE

Achilles tendon rupture occurs most commonly in the 35- to 55-year-old age group. This injury usually happens as an individual applies an eccentric (lengthening while contracting) load to the calf and Achilles tendon. The affected individual often feels as though he or she has been struck by a baseball bat at the posterior aspect of the ankle. Active plantarflexion is impossible. In the Thompson squeeze test, the injured person kneels on an elevated surface without sitting on the haunches and allows the feet to hang over the edge of the surface. Squeezing the calf does not result in involuntary plantarflexion on the injured side.

Apply a short-leg splint as a temporizing measure. The affected individual may bear weight as tolerated. This injury may be treated with or without surgery.

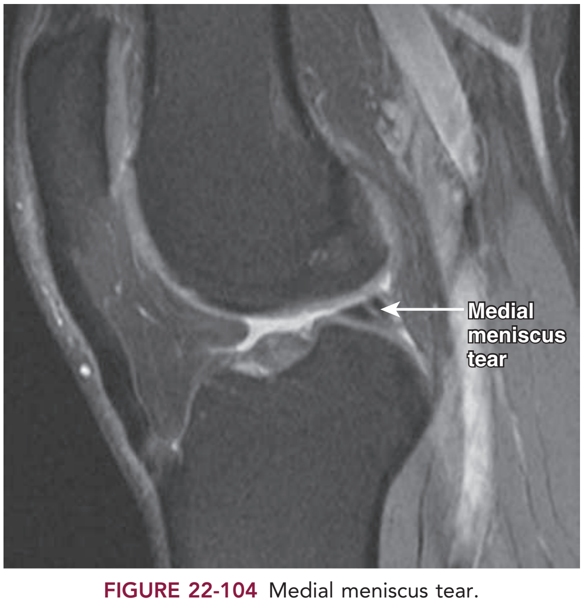


FIGURE 22-104 Medial meniscus tear.

HAMSTRING STRAIN OR TEAR

Hamstring strain or tear can occur when there is a hyperflexion mechanism applied to the hip simultaneously with a hyperextension mechanism to the leg (eccentric load). Hamstring tear or strain can also occur as an overuse injury. The best way to treat this injury is to apply ice, stretch gently, and bear weight as tolerated. Most hamstring tears heal with conservative management. If a complete tear or significant avulsion from the ischial tuberosity occurs, surgical repair may be indicated. There are no evidence-based recommendations for repair. However, in active people with more than 2 cm (0.8 inch) of retraction from the ischium, repair can result in decreased pain and improved function over time.

JOINT OR BURSAL EFFUSIONS

Joint or bursal effusions occur when there is excess synovial fluid production. Effusions may result from trauma (e.g., hemarthrosis with an ACL tear, or lipohemarthrosis with a tibial plateau fracture). Because it is rarely possible to perform aspiration under sterile conditions in the wilderness, the effusion should be treated with NSAIDs, compression dressing, and application of cold. A painful effusion without trauma in a person over the age of 40 years is more likely gout or pseudogout than infection. If there is strong suspicion that the effusion may be infected (e.g., accompanied by fever, chills, and lack of trauma), antibiotics can be administered, accompanied by prompt evacuation for aspiration.

OVERUSE SYNDROMES AND SPECIAL CONSIDERATIONS

PLANTAR FASCIITIS

Plantar fasciitis is inflammation of the fascia (tough connective tissue) on the sole of the foot. An individual with plantar fasciitis complains of insidious onset of pain at the origin of the plantar fascia, which is located at the most anterior medial aspect of the heel pad. Any activities that stretch the plantar fascia elicit pain. The pain is worst when first arising in the morning or after resting and is accentuated when the ankle and great toe are dorsiflexed (e.g., during push-off). Conservative treatment consists of (1) heel cord stretching, (2) NSAIDs, (3) taping, and (4) wearing an orthotic that cups the heel, has a soft spot under the tender area, and supports the arch. It may take several weeks for symptoms to improve, but conservative therapy is successful in 90% of cases. An ankle-foot splint worn at night may help because it holds the foot in a neutral position, keeping the plantar fascia slightly stretched. The orthosis also provides significant pain relief if used while walking.

CARPAL TUNNEL SYNDROME

Carpal tunnel syndrome (CTS) occurs when the median nerve is compressed within the carpal tunnel (Figure 22-105). Located on the palmar side of the wrist, the carpal tunnel is formed by the transverse carpal ligament volarly and the carpal bones dorsally. The flexor digitorum profundus and superficialis tendons to the second through fifth digits, long thumb flexor, and median nerve pass through this canal. Individuals with "compressive median neuropathy" (CTS) complain of pain and paresthesias along the palmar aspects of the radial digits. They also complain of

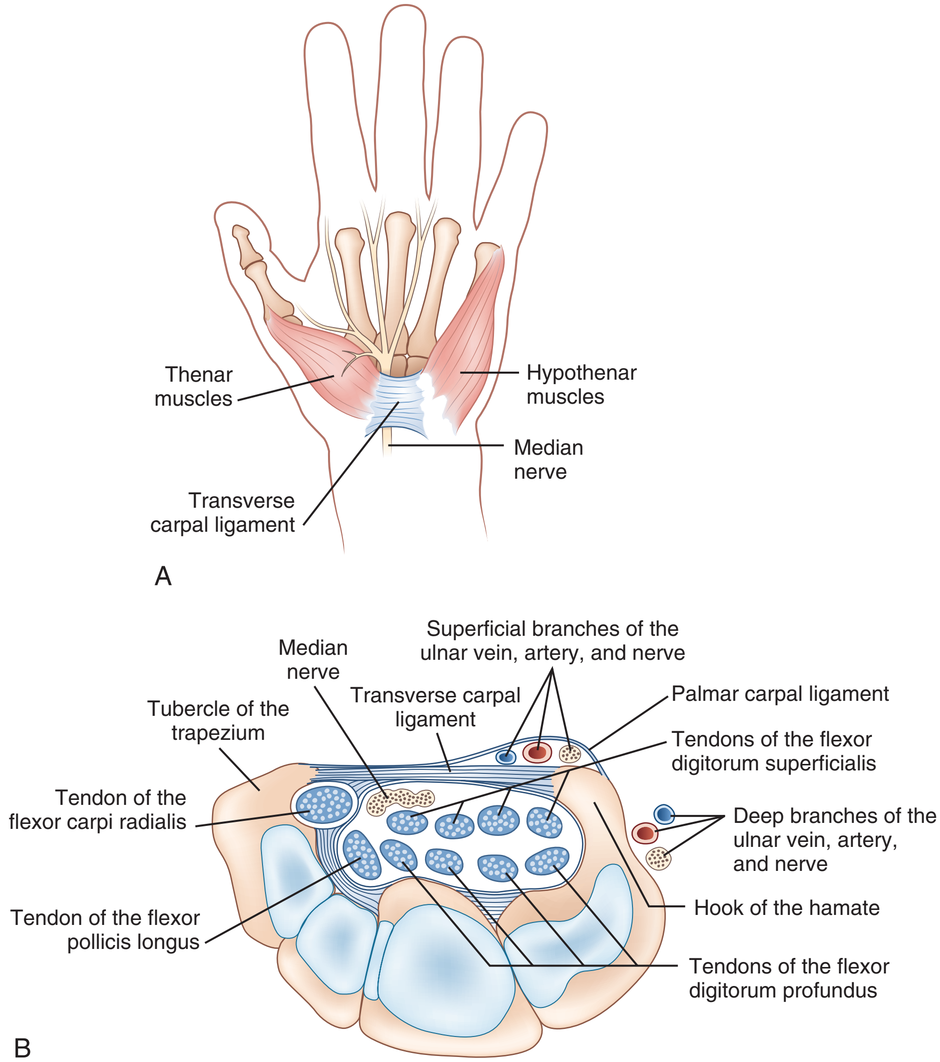


FIGURE 22-105 Anatomic basis of carpal tunnel syndrome. **A,** General view of the relationship between the median nerve and the flexor retinaculum. **B,** Cross section of the distal carpal row, showing the structures in the carpal tunnel. *(Redrawing based on an illustration by Li-Guo Liang, in Yu Hi, Chase RA, Strauch B:* Atlas of hand anatomy and clinical implications, *Philadelphia, 2004, Mosby, p 513.)*

frequently dropping objects. Symptoms are worse at night and aggravated with prolonged wrist extension or flexion. The Phalen's sign, which is numbness and tingling in the median nerve distribution after sustained wrist flexion, is suggestive of CTS. Thenar muscle atrophy is seen only in severe cases. CTS may occur during pregnancy, or it may be caused by endocrine disorders (diabetes or hypothyroidism) or acute or chronic trauma. Treatment consists of wrist splinting in slight extension, activity modification, and NSAIDs.

STRESS FRACTURES

Stress fractures can occur in individuals who suddenly increase their activity. Although tibial and metatarsal fractures are most common, any bone can sustain a stress fracture (Figure 22-106). Victims complain of pain with weight bearing, swelling, tenderness to palpation, and increased warmth at the fracture site. Treatment consists of activity reduction, protective weight bearing, and avoidance of activities that produce pain. As the pain subsides, the activity level can be increased. Resolution of symptoms may require 2 to 3 months.

BURSITIS, INFLAMMATION, AND IRRITATION

The iliotibial band travels along the lateral thigh, from its origin at the iliac crest to insertion at Gerdy's tubercle on the proximal lateral tibia. Irritation and inflammation occur along the path of the iliotibial band at the bony prominences over which it runs, proximally at the greater trochanter and distally at the lateral femoral epicondyle. Treatment for these conditions in the wilderness involves NSAIDs, ice, and, insofar as it is possible, decreased activity. Stretching can also be of benefit for these conditions, especially as a preventive measure or as treatment over the long term.

Olecranon bursitis and prepatellar bursitis can occur in the wilderness setting. If either condition arises and is painful, the antiinflammatory interventions mentioned above can be of benefit.

SPINAL DISORDERS

Back strain and pain episodes may dampen the enthusiasm of even the most dedicated outdoor enthusiast. Most often, these events represent low back strain with associated muscle spasm. These conditions often occur in the setting of heavy lifting, bending, or twisting activities. Treatment involves low-impact exercise, such as walking on a level surface, ice, and NSAIDs.

Occasionally, symptomatic intervertebral disk herniation, protrusion, or extrusion may occur. Typically this is painful and manifests with or without focal radicular symptoms. In an individual with severe, intractable pain, loss of motor strength, or loss of bowel or bladder function, evacuation may be necessary.

FIGURE 22-106 A 53-year-old woman who sustained a fibular stress fracture after a several-week hike along the Pacific Crest Trail.

FIGURE 22-108 This 56-year-old woman does not let her scoliosis slow her down. She is performing a yoga pose in the Grand Canyon.

It is important to treat patients rather than diagnostic images. Individuals with significant scoliosis, spinal angulation, spondylolysis, spondylolisthesis, or arthritis on radiographs (or other imaging studies) may still function normally. The 56-year-old woman in Figure 22-107 has significant scoliosis yet remains vigorously active in yoga and carries a full backpack down into the Grand Canyon on an annual pilgrimage (Figure 22-108).

CORTICOSTEROID INJECTIONS

Corticosteroid injections are commonly performed in the clinic setting when degenerative joint disease is present or when the pain of bursitis, tendinitis, or muscle inflammation limits activity.[16,27] A corticosteroid injection combined with an anesthetic drug can offer both diagnostic and therapeutic benefit. When injected into a joint or area of inflammation, the anesthetic should provide immediate relief of discomfort if that anatomic site is in fact that of pain generation. The antiinflammatory benefits of the corticosteroid component may not be evident for days or weeks. If concern exists about a possible joint infection, a corticosteroid should not be injected; treatment with appropriate antibiotics and surgical referral may be indicated.

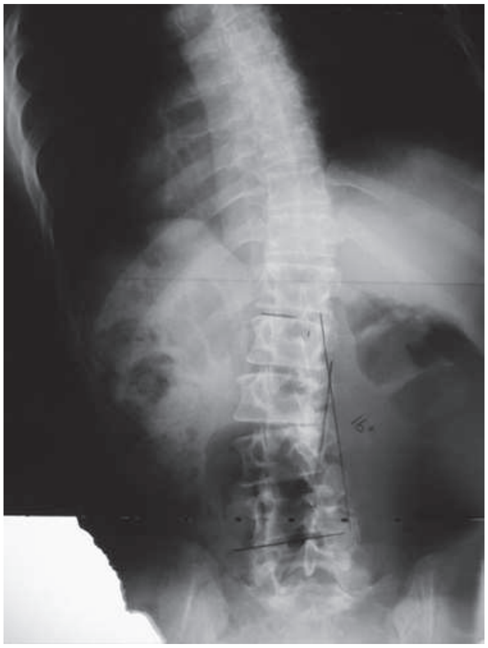


FIGURE 22-107 Lumbar spine radiograph of active individual that demonstrates significant scoliosis.

The experienced wilderness medicine practitioner can perform these procedures in an emergency or disaster setting as long as the sterile "no-touch" technique is used and the benefits of the procedure are acknowledged to outweigh the risks.

For the sterile no-touch technique, adhere to the following:

1. Cleanse the injection site, wash the hands, use sterile disposable needles and syringes, and use single-dose vials.
2. Change needles after drawing up the solution.
3. Do not touch the skin after marking and cleansing the injection site.
4. Do not guide the needle with your finger.
5. Carefully inspect any aspirated fluid for turbidity or other indication of infection.

An injectable anesthetic agent such as lidocaine may be used to numb the skin initially. Alternately, a topical spray "skin refrigerant," such as ethyl chloride, may be used. A combined solution of the anesthetic (lidocaine 1% to 2% or bupivacaine 0.25% is often used) and the corticosteroid preparation may then be injected into the affected joint. Lidocaine and bupivacaine are both amides and have a lower risk of adverse effects compared with the cocaine-derivative ester anesthetics (e.g., benzocaine) used in the past. The anesthetic solution serves as a diluent and fluid vehicle to distribute the corticosteroid. Commonly injected sites are the knee, shoulder, elbow, hip, wrist, ankle, and foot (Tables 22-1 and 22-2).

Although many infiltrations are performed into the relatively open joint space of the shoulder or knee, injecting tendon anchors or ligaments often requires a "peppering" technique to help disperse the solution throughout the structure. In this technique there is a single puncture of the skin with redirection of the needle in the subcutaneous space to achieve multiple penetrations of the tendon, ligament, or fascia. Tendon sheath injections require the caregiver to be able to insert the needle through

TABLE 22-1 Joint Injections: Suggested Average Doses and Total Volumes

Joint or Anatomic Site	Dosage (mg)*	Volume (mL)†
Shoulder: subacromial or glenohumeral	40	5
Shoulder: acromioclavicular	10	1
Elbow	20	2
Elbow: epicondyle (medial or lateral)	10	1
Wrist	20	2
Thumb	10	1
Finger	5	0.5
Hip	40	5
Hip: trochanteric bursitis	20	2
Knee	40	5-10
Ankle	20	2
Foot	20	2
Plantar fasciitis	10-20	1-2
Toe	10	1

From Saunders S, Longworth S: *Injection techniques in musculoskeletal medicine*, 4th ed, Edinburgh, 2013, Churchill Livingstone.
***Dosage (mg):** Kenalog-40 (Triamcinolone Acetonide Injectable Suspension, USP), 40 mg per 1 mL (Bristol-Meyers Squibb Company, Princeton, New Jersey, 08543).
†Volume (mg): Combined volume of corticosteroid dose and 1% lidocaine solution as anesthetic/dilutant.

the sheath overlying the tendon while gently infiltrating the space between the structures.

CORTICOSTEROID MEDICATIONS

Corticosteroid medications are categorized into three basic categories of potency and duration. The short-acting preparation is hydrocortisone acetate; the intermediate-acting preparation is methylprednisolone acetate (Depo-Medrol); and the long-acting preparations are triamcinolone acetonide (Kenalog) and triamcinolone hexacetonide (Aristospan).

RISKS AND SIDE EFFECTS OF CORTICOSTEROID INJECTIONS

Possible risks and side effects associated with corticosteroid injections may include postinjection flare, prolonged numbness, neurotoxicity, injury due to needle placement, elevation of blood glucose, infection or sepsis, bleeding or hematoma, skin depigmentation, soft tissue calcification, subcutaneous atrophy, bony osteonecrosis, or a vasovagal event causing loss of consciousness.

KNEE JOINT INJECTION

The knee may be injected with the patient either seated or in a lying position. If seated, the tibial-femoral joint space can be accessed either medially or laterally; if supine, a superior-lateral approach to the retropatellar space is commonly used. A medial approach beneath the patella may also be employed. A 10-mL syringe and 1.5-inch 22-gauge needle are used to inject 40 mg of triamcinolone acetonide (40 mg/mL) and 9 mL of 1% lidocaine in a commonly used adult dose. The caregiver should attempt to aspirate the joint prior to the injection. Inspection of the aspirated fluid should determine the advisability of a corticosteroid injection. Bloody aspirated fluid is consistent with a traumatic ligament injury (often a cruciate tear) or possible tibial plateau fracture, particularly if there is fat noted in the aspirant. Fluid with a cloudy appearance may be consistent with a rheumatologic disorder or inflammatory process such as gout. If there is evidence of purulence, a corticosteroid injection should not be performed. Hyaluronic acid injections are sometimes used for knee arthritis management but would not be an acute field intervention.

TABLE 22-2 Tendon Injections: Suggested Average Doses and Volumes

Small tendons	10 mg of steroid plus local anesthetic in a total volume of 1 mL (Example: 0.25 mL triamcinolone acetonide + 0.75 mL lidocaine)
Large tendons	20 mg of steroid plus local anesthetic in a total volume of 2 mL (Example: 0.5 mL triamcinolone acetonide + 1.5 mL lidocaine)

From Saunders S, Longworth S: *Injection techniques in musculoskeletal medicine*, 4th ed, Edinburgh, 2013, Churchill Livingstone.

SHOULDER INJECTIONS

Subacromial Joint Injection

"Impingement" symptoms in the shoulder are often due to a combination of subacromial bursitis and supraspinatus tendinitis. Degenerative fraying of the long head of the biceps tendon and labrum often accompany these changes. The most commonly performed shoulder injection to address these symptoms is directed into the subacromial space (Figure 22-109). Insertion of the needle beneath the posterior-lateral corner of the acromion usually allows direct placement into the subacromial space and bursa while remaining above the supraspinatus tendon. The injection should flow easily. If the needle is correctly placed and the diagnosis is correct, immediate "diagnostic" improvement is often noted. A 5-mL syringe and 1.5-inch 22-gauge needle are used to inject 20 mg of triamcinolone acetonide (40 mg/mL) and 4.5 mL of 1% lidocaine; this is a commonly used adult dose.

Glenohumeral Joint Injection

This injection may be performed in a patient with degenerative osteoarthritis of the glenohumeral joint, or "frozen shoulder." A posterior approach frequently allows easy access to the joint with less pain than would be caused by passing the injection through

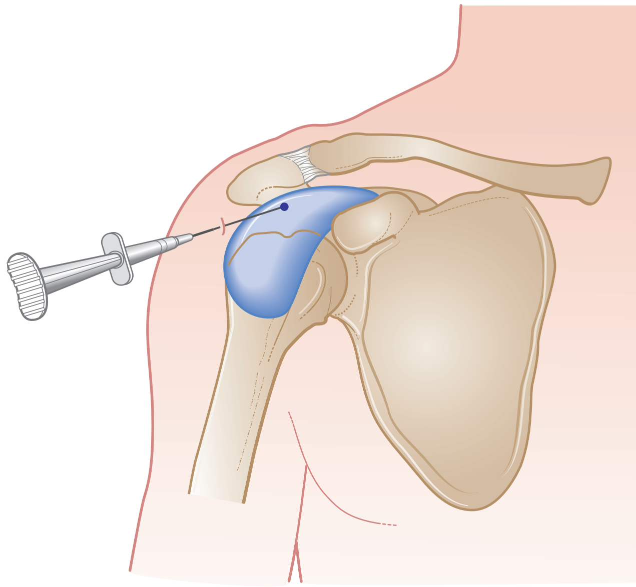


FIGURE 22-109 Injection for shoulder impingement (subacromial bursitis/supraspinatus tendinitis): The needle is advanced from the lateral or posterior-lateral approach into the subacromial space for injection of the combined solution. Ideally, both a short-term diagnostic benefit (lidocaine) and prolonged therapeutic benefit (corticosteroid) will be used. The dosage is 40 mg of triamcinolone acetonide and 5 mL of 1% lidocaine, for a total volume of 6 mL. *(From Saunders S, Longworth S, editors:* Injection techniques in musculoskeletal medicine, *4th ed, Edinburgh, 2013,* Churchill Livingstone, *p 113.)*

anterior structures. Palpation of the glenohumeral space and gentle internal and external rotation of the relaxed upper arm by an assistant help to guide needle placement. For a common adult dosage, a 5-mL syringe and 1.5-inch 22-gauge needle are used to inject 40 mg of triamcinolone acetonide (40 mg/mL) and 4 mL of 1% lidocaine.

Acromioclavicular Joint Injection

A previous acromioclavicular joint "separation" (grade 1, 2, or 3) often leads to arthritic changes and pain in the joint. The injection can be performed with the patient seated and the arm hanging over the lap to help widen the joint space. Identify the acromioclavicular joint space and insert the needle through the capsule, injecting the solution as a bolus. For a common dosage, a 1-mL syringe and 1.5-inch 25-gauge needle are used to inject 10 mg of triamcinolone acetonide (40 mg/mL) and 0.75 mL of 1% lidocaine.

Trochanteric Bursitis Injection

Trochanteric bursitis (now sometimes called greater trochanteric pain syndrome) is a relatively common problem. Patients who do not improve with conservative measures may benefit from a corticosteroid injection into the region of the trochanteric bursa (Figure 22-110). The injection should be performed at the point of maximal tenderness. With the patient lying on the unaffected side, the skin over the greater trochanter is prepped using a fenestrated drape and sterile procedure. Depending on the patient's body habitus, a spinal needle may be required to penetrate the tough iliotibial band and reach the underlying bursa. A 3-mL syringe and 1.5-inch to 3-inch 22-gauge spinal needle are used to inject 20 mg of triamcinolone acetonide (40 mg/mL) and 1.5 mL of 1% lidocaine in a common adult dose.

Olecranon Bursitis Injection

Olecranon bursitis may occur following a traumatic fall or injury to the elbow with fluid accumulation of a hemorrhagic nature. Spontaneous swelling may also occur without known antecedent injury. Infection of the olecranon bursa is a frequent concern.

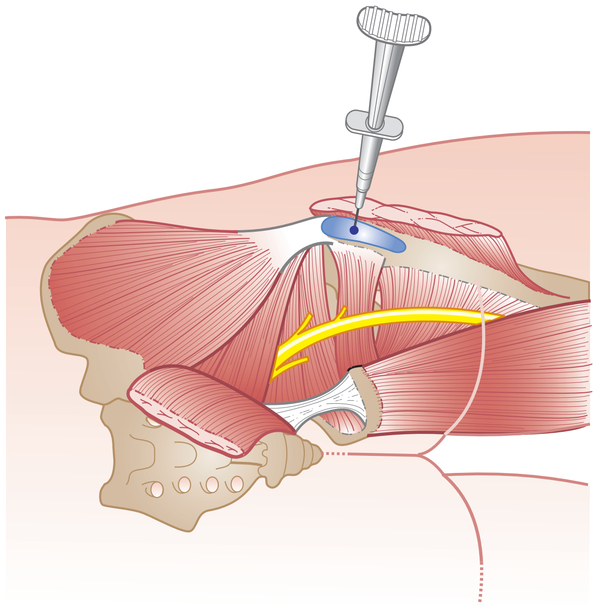


FIGURE 22-110 Injection for trochanteric bursitis: The needle is inserted over the area of maximal tenderness. It is important to penetrate the tough fascial iliotibial band (ITB) to reach the underlying trochanteric bursa; if the injection is placed external to the ITB, it is unlikely to be effective. It may be necessary to use a 3-inch 22-gauge spinal needle in large patients. The dosage is 20 mg of triamcinolone acetonide and 3 mL of 1% lidocaine, for a total volume of 3.5 mL. *(From Saunders S, Longworth S, editors:* Injection techniques in musculoskeletal medicine, *4th ed, Edinburgh, 2013,* Churchill Livingstone, *p 167.)*

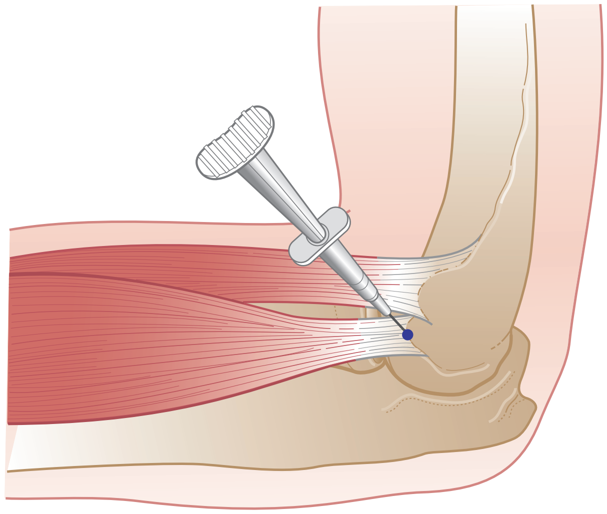


FIGURE 22-111 Injection for lateral epicondylitis (tennis elbow): The needle is inserted over the lateral epicondyle of the humerus at the origin of the extensor carpi radialis brevis (ECRB) muscle tendon. Inject using a fan-wise, peppering technique. The dosage is 10 mg of triamcinolone acetonide and 0.75 mL of 1% lidocaine, for a total volume of 1 mL. *(From Saunders S, Longworth S, editors:* Injection techniques in musculoskeletal medicine, *4th ed, Edinburgh, 2013,* Churchill Livingstone, *p 131.)*

Direct aspiration should be performed before injection to evaluate the fluid aspirant. For a common adult dosage, a 2-mL syringe and 22-gauge needle are used to inject 20 mg of triamcinolone acetonide (40 mg/mL) and 1.5 mL of 1% lidocaine.

Medial and Lateral Epicondylitis Injection

Medial (golfer's elbow) epicondylitis and lateral (tennis elbow) epicondylitis are defined as tendinopathies rather than tendinitis due to the chronic, granular histologic changes seen in the tendon matrix. This frustrating condition is often of a slowly resolving nature, and may benefit from corticosteroid injection for symptom management if other conservative modalities have failed. The injection can be performed with the arm resting on the examination table while the patient is seated or with the patient supine. The needle should be inserted at the tendinous origin of the flexor or extensor group, respectively, rather than at an area of tenderness in the flexor or extensor aponeurosis (Figure 22-111). A 1-mL syringe and 0.5-inch 25-gauge needle are used to inject 10 mg of triamcinolone acetonide (40 mg/mL) and 0.75 mL of 1% lidocaine in a commonly used adult dose.

Iliotibial Band Injection

The iliotibial band syndrome, or iliotibial band friction syndrome, can cause pain over the lateral aspect of the knee, most commonly in the region of the lateral femoral condyle or Gerdy's tubercle. The injection can be performed with the patient lying supine and should be directed to the region of greatest tenderness. Care should be taken to avoid neurovascular structures in the lateral knee, such as the peroneal nerve. A 2-mL syringe and 1-inch 23-gauge needle are used to inject 20 mg of triamcinolone acetonide (40 mg/mL) and 1.5 mL of 1% lidocaine in a common adult dose.

Pes Anserine Bursitis Injection

Overuse or trauma to the distal insertion of the medial hamstring bundle at the medial aspect of the proximal tibia may result in pes anserine bursitis or tendinitis. This common tendon is formed by the sartorius, gracilis, and semitendinosus groups. The injection is best performed with the knee in flexed position and should be directed at the area of greatest tenderness below the medial joint line. For a common dosage for adults, a 2-mL syringe and 1-inch 23-gauge needle are used to inject 20 mg of triamcinolone acetonide (40 mg/mL) and 1.5 mL of 1% lidocaine.

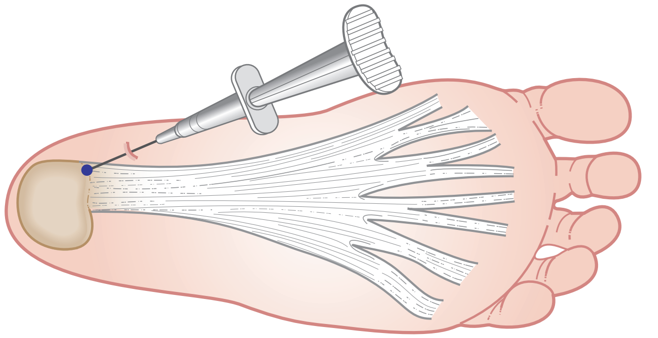


FIGURE 22-112 Injection for plantar fasciitis: The needle is inserted from the medial plantar aspect of the heel and directed to the anterior medial aspect of the calcaneus to reach the origin of the plantar fascia. The dosage is 20 mg of triamcinolone acetonide and 2 mL of 1% lidocaine, for a total volume of 2.5 mL. *(From Saunders S, Longworth S, editors:* Injection Techniques in Musculoskeletal Medicine, *4th ed, Edinburgh, 2013,* Churchill Livingstone, *p 213.)*

FIGURE 22-113 Right hip resurfacing for osteoarthritis in an active 58-year-old man. Resurfacing arthroplasty provides a surgical option for osteoarthritis treatment that requires less bone resection than do more traditional total hip arthroplasty techniques.

Prepatellar Bursitis Injection

Trauma, contusion, or repeated sheer forces to the anterior knee may result in inflammation of the prepatellar bursae. This injury may be acute or chronic. Aspiration of the bursa prior to injection is advised. It is important to avoid injecting into the distal patellar tendon. A 2- to 3-mL syringe and 1-inch 23-gauge needle are used to inject 20 mg of triamcinolone acetonide (40 mg/mL) and 1.5 mL of 1% lidocaine in a common adult dose.

Plantar Fasciitis Injection

The pain associated with this relatively common problem is often focal at the common origin of the fascia from the inferior surface of the anteromedial calcaneus. The injection is best accomplished with the patient lying prone with the foot relaxed on a pillow or other support. Angle the injection from the medial aspect of the heel to avoid a direct weight-bearing area of the undersurface of the foot (Figure 22-112). A common adult dosage uses a 1-mL syringe and 0.5-inch 25-gauge needle to inject 10 mg of triamcinolone acetonide (40 mg/mL) and 0.75 mL of 1% lidocaine.

Field Block

The term *field block* is used to indicate injection or infiltration of a local anesthetic into the anatomic area or region of injury for pain management without attempting to anesthetize a specific nerve.

Hematoma Block

A hematoma block involves diffusely infiltrating a reversible local anesthetic, such as lidocaine, into the region of a fracture hematoma to achieve pain reduction sufficient to allow manipulation in order to attain bony alignment. This can be a useful technique in a wilderness setting. Bier block, brachial plexus block, regional nerve block, or other controlled methods of parenteral anesthesia are more applicable in a hospital setting.

RETURNING TO THE WILDERNESS AFTER TOTAL JOINT REPLACEMENT

Increasing numbers of outdoor enthusiasts have had total joint replacement surgeries, primarily of the knee and hip, and have returned to their previous activities. New technologies, such as hip resurfacing, have been developed to possibly improve longevity of arthroplasty for young active individuals (Figure 22-113). Given appropriate physical therapy and rehabilitation, many individuals can regain near-normal function. Although the possibility of reinjury, prosthesis damage, accelerated prosthetic loosening, or periprosthetic fractures remains a concern, many individuals are willing to accept such risks to enjoy the pursuit of wilderness passions (Figure 22-114).

It was barely 50 years ago that Sir John Charnley implanted the first total hip in England. He would be amazed to see a 61-year-old patient who had previously suffered from advanced hip arthritis trekking in the Himalayas and climbing 6000-meter peaks after staged cementless, bilateral hip arthoplasties.[23] There were no signs of prosthesis loosening or abnormal wear of the bearing materials in the mountaineer in Figure 22-115 at age 69, 16 years after the first procedure and 8 years following the second.

Most individuals temper activities following total joint replacement. Current recommendations regarding a return to activity are variable. An experienced athlete can usually return to a sport in which he or she is skilled following total joint arthroplasty, given reasonable limits (Table 22-3). Despite such recommendations, patients continue to "push the envelope" in returning to aggressive sporting activities. Examples of highly successful returns to play after total hip or total knee replacement abound:

- Bo Jackson returned to professional baseball in 1993 after his total hip arthroplasty in 1992.

TABLE 22-3 Return to Activity After Total Knee and Total Hip Replacement*

Generally Safe	Greater Risk	Risky Activities
Swimming	Ice skating	Downhill skiing
Stationary bike/cycling	Cross-country ski skating	High-impact aerobics
Low-resistance rowing	Rollerblading	Basketball
Walking	Horseback riding	Football
Hiking with poles on even terrain	Softball	Hockey
Low-resistance lifting	Volleyball	Soccer
Canoeing	Hunting on uneven terrain	Gymnastics
Bowling	Fencing	Power lifting
Croquet	Nordic track	Rock climbing
Golf		Parachuting
Tennis: doubles		Hang gliding
Table tennis		Rodeo
Ballroom dancing		Distance running
Classic cross-country skiing		Hardball
Horseshoes		Lacrosse
Shooting		Tennis: singles
Shuffleboard		Rubgy

*There is no absolute consensus regarding return to activity after joint replacement. These suggestions are a synthesis of survey results from The Hip Society, The Knee Society, and The American Association of Hip and Knee Surgeons. Virtually all agree that it is important to limit impact loading and rotational or levering forces on the artificial joint. Failure to control these forces increases the possibility of prosthetic dislocation, biomechanical failure, or periprosthetic fracture.

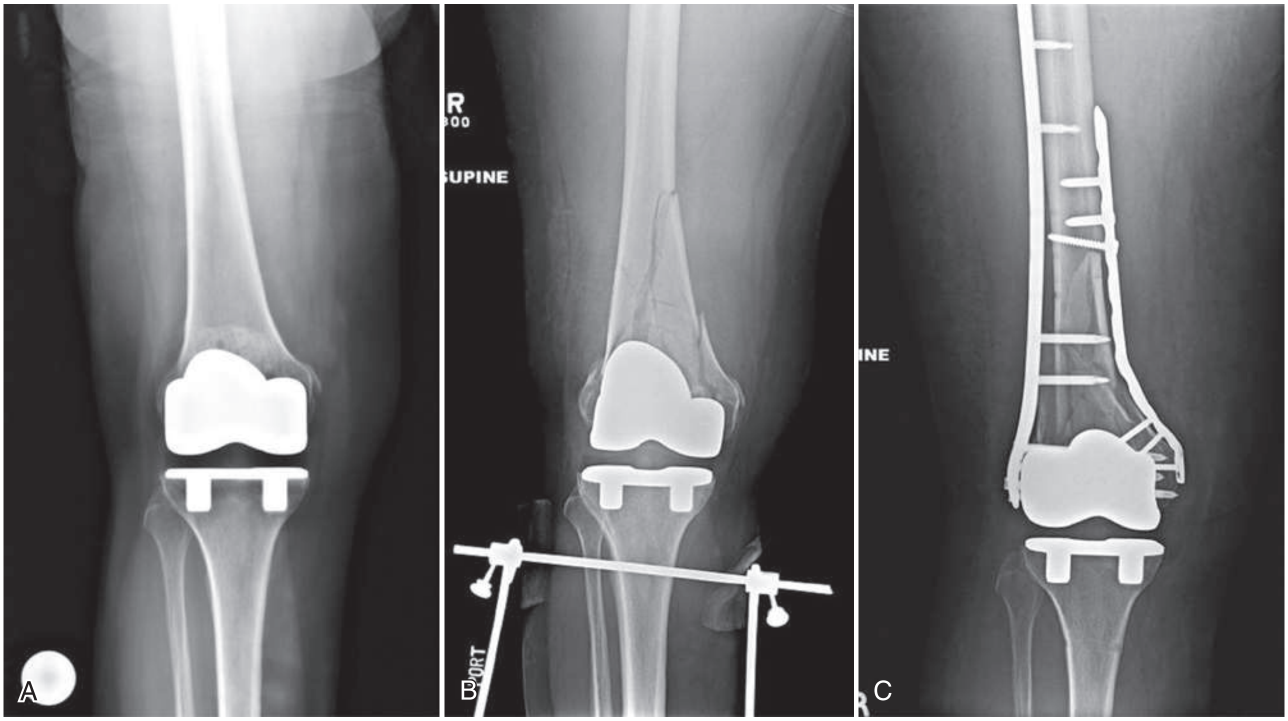


FIGURE 22-114 **A** and **B,** A 70-year-old woman with a total knee arthroplasty sustained a periprosthetic distal femoral fracture when she fell while hiking. **C,** One year after open reduction and internal fixation of her fractures, she hiked the same trail.

- Golfer George Archer had a right hip replacement in 1996 and won the Senior PGA Tour in 1998.
- Golfing great Jack Nicklaus had a total hip arthroplasty in 1999 and returned to high-level play.
- Figure skater Rudy Galindo had bilateral ceramic-on-ceramic total hip arthroplasties in 2003 and was landing triple jumps with Champions on Ice in 2004.
- A 69-year-old mountaineer, after bilateral total hip arthroplasties in 1987 and 1995, climbed two peaks over 6000 m in the Andes.
- Floyd Landis had a hip resurfacing in 2006, was riding a stationary bike 5 days after surgery, and has since returned to competitive cycling.

A cautionary and common sense approach is advised. Although one may attempt to return to a "skill" sport in which one has participated in the past, it is not recommended that one attempt to learn a "new" sport that requires advanced proprioceptive skills and/or significant impact loading, as categorized in Table 22-3. Sports and fitness regimens vary significantly with the competence, confidence, and risk tolerance of the individual. High-risk and high-impact activities may cause accelerated wear and loosening of implants that lead to the need for early revision. The necessity for revision arthroplasty has a markedly increased cost and rate of complications relative to primary joint replacement, and the functional result tends to deteriorate with each successive revision.

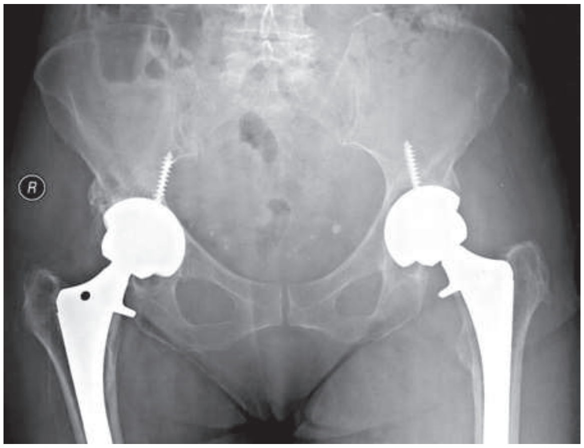


FIGURE 22-115 Bilateral total hip arthroplasties in a patient who, following her second surgery, climbed to the summit of Mt. Rainier.

Although dislocation of a normal hip is a rare event caused by high-energy trauma, hip replacements dislocate with relative ease. If this occurs, the reduction maneuver is the same as described above.

PROSTHETICS IN THE WILDERNESS

Orthotics and limb replacement devices have given individuals who have sustained amputations, whether from trauma, congenital disorder, or cancer, the chance to participate in wilderness-based adventures that in the past may have been unattainable. Computer-assisted prosthetic design now enables much better custom-fitted prostheses and therefore provides the opportunity for recipients to participate in outdoor activities with other "able-bodied" individuals, often on an equal basis. Some persons have claimed that the new prostheses, in certain instances, offer an enhanced level of performance, as in the case of the South African runner Oscar Pistorius, with his bilateral graphite-carbon "feet." In the wilderness setting, there may be significant benefits in not worrying about frostbite or getting one's foot back into a cold boot at dawn (Figure 22-116). However, additional concerns remain. These include limb swelling, skin breakdown in a limb stump, inability to change a sock liner on a regular basis, and possibility of prosthesis damage.

Intrepid mountaineers, such as Tom Whittaker, who became the first below-the-knee amputee to summit Mt. Everest in 1998, testify to the capabilities of a motivated athlete despite limb loss[32] (Figure 22-117). Whittaker founded and has worked for years with the Cooperative Wilderness Handicapped Outdoor Group (C.W. HOG). Many members of this organization suffer from spinal cord injuries, cerebral palsy, amputations, or other

FIGURE 22-116 Tom Whittaker marked his tent at Mt. Everest base camp with a spare prosthesis so that his 70-year-old father, who hiked to 18,000 feet after a total hip replacement, could find the correct tent. *(Copyright Tom Whittaker Collection.)*

neuromuscular problems. In spite of this, they have participated in diverse activities and mountaineering (Figure 22-118).

NEW TECHNOLOGIES FOR CASTING AND BRACING

The Flemish army surgeon Mathijsen first introduced muslin rubbed with calcium that formed a hard shell and provided the first plaster of Paris casts in 1852. Synthetic fiberglass became popular in the 1980s and has become the dominant material used in casting and splinting in the United States. Plaster remains desirable in some situations because it molds easily and is inexpensive. Both plaster of Paris and fiberglass are removed using a cast saw. When wet, plaster of Paris becomes sodden and heavy and loses stability. Waterproof linings, such as Gore-Tex, may allow fiberglass casts and splints to be used in wet environments. Other materials, such as Aquaplast and Orthoplast, may be softened in a hot water hydrocollator and have specific indications in appropriate patients.

FIGURE 22-117 Tom Whittaker on Aconcagua's Argentine Andes. Note carbon flex prosthesis on right lower extremity. *(Copyright Tom Whittaker Collection.)*

FIGURE 22-118 Tom Whittaker assists fellow Cooperative Wilderness Handicapped Outdoor Group (C.W. HOG) member Carl Brinker with rappelling down an 80-foot basalt cliff. *(Copyright Tom Whittaker Collection.)*

New prefabricated casting and bracing materials have evolved from ski boot technologies. These use dry heat–formable polymers laminated with closed-cell foam and antiabrasive fabrics to provide custom-fitted musculoskeletal support devices. These materials are waterproof, lighter than fiberglass, durable, and remoldable, and use adjustable closure systems. Such products offer improved patient comfort and allow early return to hiking, skiing, or water sports (Figure 22-119).

FIGURE 22-119 New dry heat–formable thermoplastic technologies, such as this Exos fracture brace, are durable, waterproof, and lightweight, allowing earlier return to outdoor activities.

FIGURE 22-120 Prompt evacuation in certain scenarios is crucial.

BOX 22-2 Indications for Emergency Evacuation

Suspected spine injury
Suspected pelvic injury
Open fracture
Suspected compartment syndrome
Hip or knee dislocation
Vascular compromise to an extremity
Laceration with tendon or nerve injury
Uncertainty of severity of injury

DECISIONS ABOUT EVACUATION

The decision to evacuate an orthopedically injured individual depends on the goals of the expedition or mission and available support. Criteria for evacuation of an injured person in a family of four spending a week hiking in the Rockies differ from those of a military campaign or group of 25 climbers in the Himalayas with physician support and a field hospital at base camp. In all cases, party leaders should have a plan for contacting evacuation support teams if a serious injury occurs (Figure 22-120).

Musculoskeletal injuries that warrant immediate evacuation to a definitive care center are listed in Box 22-2. These include any suspected cervical, thoracic, or lumbar spine injury. A victim who has a suspected pelvic injury with posterior instability, possibly significant blood loss, or injury to the sacral plexus should be emergently evacuated on a backboard. Any open fracture requires definitive debridement and care within 8 hours to prevent deep infection. Victims with suspected compartment syndromes must be evacuated on an emergency basis. Joint dislocations involving the hip or knee warrant immediate evacuation because of the associated risk for vascular injury or posttraumatic avascular necrosis of the femoral head.

Lacerations involving a tendon or nerve warrant urgent evacuation to a center where an extremity surgeon is available. In all but the most serious wilderness expeditions, arrangements should be made to evacuate the victim when the treating individuals are not reasonably certain of the nature of the injury or its appropriate management.

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

CHAPTER 23

Splints and Slings

MISHA R. KASSEL, TERRY O'CONNOR, AND ALAN GIANOTTI

Splints and slings[1] have been staples of medical care for thousands of years. For instance, orthopedic splinting was well documented in ancient Egypt more than 5000 years ago[49] (Figure 23-1).

First and foremost, splints and slings stabilize injuries by limiting movement (Box 23-1). Limiting movement minimizes pain and decreases potential further tissue damage. Splinting eases transportation from the field, minimizes blood loss, and aids in healing.[19] In general, all fractures and dislocations should be splinted before transport unless the patient's life is at immediate risk or the rescue scene is unsafe.[20] Basic splint types include rigid, soft, anatomic, and traction splints. Splint choice is based on the fracture type and available materials. In improvisational situations, splints can be made from just about any material. Examples include newspapers, pillows, umbrellas, and other supportive materials (Figure 23-2).[8]

SPINE IMMOBILIZATION

Spinal cord injuries are rare, affecting 40 to 50 individuals per million annually in the United States. These injuries may result in long-term disability.[32] The 5 million people each year who are placed in spine immobilization after traffic collisions account for most spinal cord injuries. In one wilderness study, only 3.6% of mountain trauma patients who were alive when rescued had spine injuries.[27]

Spine stabilization has traditionally been first accomplished by manual techniques and then by mechanical devices (e.g., backboards, collars, straps), which we review below. We will also review newer immobilization devices. In light of recent evidence and guidelines, the indications, risks, and benefits of spine immobilization merit review.

INDICATIONS FOR SPINE IMMOBILIZATION

The most common scenario for prehospital spine immobilization is an injury sustained during a motor vehicle collision. All-terrain vehicles, automobiles, snowmobiles, motorcycles, and other off-road vehicles are the most common causes of high-force spine trauma in the wilderness setting. Falls and other high-force mechanisms are other causes. Worrisome symptoms include spine pain or palpable tenderness, altered mental status,

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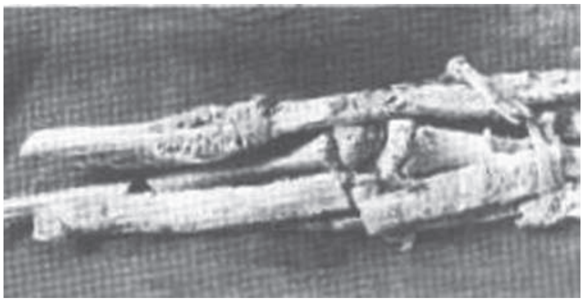

FIGURE 23-1 A fractured and splinted forearm showing signs of healing. Egyptian mummy from Dynasty V. *(From Arab S:* Medicine in ancient Egypt. http://www.arabworldbooks.com/articles8b.htm.*)*

FIGURE 23-2 Improvised cervical spine and ankle stabilization (pillow, towels, cardboard, and tape) in Port au Prince, Haiti, 2010. *(Courtesy Anil Menon, MD.)*

BOX 23-1 Principles of Splinting

Visualize the injured body part.
Continually recheck the patient's neurovascular status.
Traction is indicated if the pulse is not palpable.
Gentle traction involves less than 10 pounds of force.
Cover open wounds with sterile dressings.
Immobilize the joints above and below the injury.
Padding prevents further tissue damage.
Do not reset open or protruding fractures.
Splint the extremity in the position in which it was found.
Splint the patient before transport (if he is stable).
Ice and elevate the injury after immobilization.

Modified from Bowman W, editor: *Outdoor emergency care: comprehensive prehospital care for nonurban settings,* 4th ed, 2003, Sudbury, Massachusetts, Jones and Bartlett; and Campbell J: *Extremity trauma: international trauma life support for prehospital care providers,* 6th ed, Upper Saddle River, New Jersey, 2008, Brady.

neurologic complaints, or a head injury. Factors that may complicate a spine injury are extremes of patient age, patient alcohol or drug use, and a communication barrier between patient and caregivers. If the examination is unreliable because another injury distracts the examiner, important information about the spine injury may be missed[9] (Box 23-2).

BENEFITS OF SPINE IMMOBILIZATION

In an attempt to improve outcomes, techniques for immobilization of the patient with potential spine injury have been implemented in the prehospital setting. Spine immobilization as performed on urban trauma patients remains the standard of care. Evidence-based reviews reveal that although spine immobilization efforts are well intentioned, a definitive understanding of their effects on neurologic injury and spine stability and their adverse effects (including death) in trauma patients remains uncertain.[32]

Spine immobilization is intended to prevent worsening of an existing spinal cord injury or the creation of a spinal cord injury in the case of a ligamentous disruption. Previous reviews of the medical literature reference multiple reports of worsening neurologic deficits after patients with spinal cord injuries are moved.[9,51,52] Recent expert reviews reveal that these episodes of neurologic deterioration are more likely a result of the original injury itself and not poor prehospital care or immobilization.[45] The authors report that the most frequently referenced cases of missed spine injuries resulting in neurologic deterioration occurred after arrival in the emergency department.[6,15,54] Some data suggest that nonimmobilized patients had better neurologic outcomes than patients with similar injuries who had been immobilized.[25] Such evidence suggests that not only is secondary injury due to transport rare, but real risks to the patient due to spine immobilization warrant consideration.

RISKS OF SPINE IMMOBILIZATION

Extreme settings mandate a different interpretation of "urban" recommendations to fit the wilderness scenario. Wilderness data are limited, so prehospital spine immobilization is still considered prudent when practical. The routine use of spine immobilization without consideration of risks, however, can greatly increase the complexity of a wilderness care scenario, potentially leading to increased complications and even death for the patient and, perhaps, adverse effects for rescue personnel.

Placing a patient in spine immobilization can adversely affect breathing and airway management. The American Heart Association 2010 evidence-based guidelines state that "Routine C-spine immobilization is Class III (potentially harmful) unless clear trauma is evident in the history or exam, because it may unnecessarily delay or impede ventilations."[4] One study conducted on healthy volunteers showed that placing a patient on a backboard restricts respiration, with older patients having a greater degree of restriction.[55]

Studies have shown that C-spine collars cause increased intracranial pressure, which may be clinically significant for patients

BOX 23-2 Indications for Spine Immobilization

Spine pain or tenderness
Traumatic mechanism of injury
Altered mental status
Distracting injury
Unreliable examination (e.g., as a result of alcohol or drug use)
Neurologic complaints
Head injury
Extremes of age

Modified from Brabson T, Greenfield M: *Prehospital immobilization.* In Roberts JR, Hedges JR, editors: *Clinical procedures in emergency medicine,* 5th ed, Philadelphia, 2007, Saunders.

with head injuries.[18,29] Therefore, hard cervical collars should be removed immediately after exclusion of a C-spine injury, especially from patients with head injuries.

C-spine collars are contraindicated in patients with penetrating neck injuries, because they may interfere with management of neck wounds or even conceal wounds. Penetrating wounds to the spinal cord are rare. Cervical immobilization creates the real possibility of causing greater morbidity.[26]

Pressure ulcers are very painful complications that can result from spinal immobilization. Pressure ulcers begin forming within 30 minutes of immobilization. This is particularly troubling when one considers that the mean time a patient spends on a backboard can exceed 2 hours in an urban setting. This time is likely protracted in wilderness settings.[12]

Complications of full spine immobilization are listed in Box 23-3.

CONTRAINDICATIONS FOR SPINE IMMOBILIZATION

Strict contraindications for spine immobilization are few but include emergency evacuation from an unsafe environment. Examples of such environments, with the risk of impending danger, include areas of toxic spills, fire hazards, congested traffic, and other situations in which application of an immobilization device would delay immediate evacuation to safety. In these dangerous situations, expedited removal with manual cervical stabilization is advised.[31] When the patient is in a safe location, full spine immobilization can be applied as indicated.

GUIDELINES FOR SPINE IMMOBILIZATION

The emergency medical community has considered precautionary immobilization to be uniformly safe, conservative, and in the best interest of the patient. However, in some cases, spine immobilization may not be in the patient's best interest.

In light of this recent thinking, efforts to minimize unwarranted or potentially hazardous immobilization have begun as evidenced by development of selective immobilization guidelines. Several states and emergency medical systems (EMSs) across the nation are beginning to use protocols that decrease the number of trauma patients subjected to prehospital spine immobilization. Studies show that prehospital care providers can safely apply these spine injury assessment protocols and not miss clinically significant spine injuries.[16,40,50]

The guidelines that have been adopted by multiple prehospital systems are typically based on the Canadian C-spine rule and the National Emergency X-Radiography Utilization Study (NEXUS) low-risk criteria. Each has similar parameters, requiring that the patient be awake, alert, and conversant, and without significant distracting injury or intoxication. In addition, the guidelines further state that the physical examination should reveal no pain

BOX 23-3 Complications of Spine Immobilization

Tight straps and a rigid board may cause discomfort or distress.
Tight straps may cause vascular compromise.
An immobilized position may interfere with normal respiratory function.
Complications from emesis include aspiration.
Intracranial pressure may become elevated.
Pressure ulcers may develop.
Penetrating neck injuries may be associated with morbidity.
Loose straps may be inadequate for spine immobilization.

From Brabson T, Greenfield M, editors: Prehospital immobilization. In *Clinical procedures in emergency medicine,* 5th ed, Philadelphia, 2007, Saunders; Campbell J: *Extremity trauma: international trauma life support for prehospital care providers,* 6th ed, Upper Saddle River, NJ, 2008, Brady; Hamilton RS, Pons PT: The efficacy and comfort of full-body vacuum splints for cervical-spine immobilization, *J Emerg Med* 14:553, 1996; and Kwan I, Bunn F, Roberts I: Spinal immobilization for trauma patients, *Cochrane Database Syst Rev* (2): CD002803, 2001.

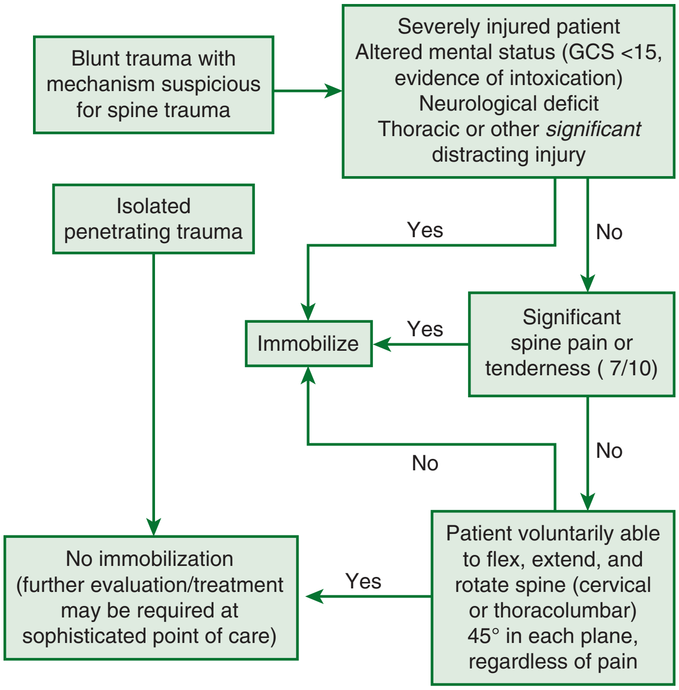

FIGURE 23-3 Wilderness Medical Society recommendations for spine clearance and immobilization in the austere environment. *(Reprinted with permission from the Wilderness Medical Society. Copyright 2014 Wilderness Medical Society).*

or tenderness to the posterior neck and back, and the neurologic examination must find normal motor and sensory function in the extremities.[28]

For the wilderness setting, a similar guideline has been recently proposed. The treatment algorithm was specifically calibrated so as to minimize the risk of exacerbating a potentially unstable spine injury weighed against the risks to rescuers and victim in the austere setting.[45] (Figure 23-3). Further research is still warranted to better classify appropriate indications, validate guidelines, and further assess the risk-benefit ratio for spine immobilization in the wilderness.

CERVICAL SPINE IMMOBILIZATION TECHNIQUE

High cervical spine (C-spine) injuries have great potential for morbidity and disability. The goals of C-spine immobilization are to minimize movement and maintain "neutral" alignment. Standard C-spine immobilization is performed with a hard collar in conjunction with a backboard, vacuum mattress, or similar device. Typically, lateral support devices are also employed. The modern standard cervical collar has five contact points and makes use of the head, C-spine, and thorax. The thorax contact points include the trapezius muscles (posterior), clavicle, and sternum (anterior). Hard collars alone do not adequately limit cervical motion. Backboards and lateral support devices are required in conjunction with a hard collar (Figures 23-4 and 23-5). Newer vacuum spine boards also serve this purpose (Figure 23-6). The

FIGURE 23-4 Standard hard cervical collars. *(Courtesy Laerdal Medical Corporation.)*

FIGURE 23-5 **A** to **C,** Different lateral support devices. **D,** Complete spine immobilization. *(Courtesy Laerdal Medical Corporation.)*

patient's neck requires manual stabilization in a neutral, in-line position until he or she is fully immobilized. Standard emergency medical services equipment includes lateral support devices (foam or plastic). In the wilderness setting, these devices can be improvised by rolling clothes, sheets, or blankets and placing them on both sides of the head while securing everything in place with tape (see Figure 23-2).[24]

C-SPINE IMMOBILIZATION DEVICE

The application of a C-spine immobilization device depends on the position in which the patient is found and the device that is available. Universal application diagrams are generally helpful with regard to in-line stabilization, neutral neck alignment, chin positioning, and collar placement. Diagrams for application of improvised C-spine collars or C-spine collars on patients who are found in sitting positions are also helpful (Figures 23-7 to 23-10).

SPECIAL CONSIDERATIONS

Special populations require accurately sized equipment. This includes people with a very long or short neck for whom a

FIGURE 23-6 Vacuum lateral support device. *(Courtesy Rick Lipke, Copyright 2014 by Conterra, Inc. All rights reserved. Used by permission.)*

FIGURE 23-7 Improvisational "horse collar." *(Courtesy Ferno-Washington, Inc.)*

standard cervical hard collar is not effective. Children who are younger than 8 years old are at risk for further injury when immobilized on a standard backboard because of a proportionately large head, which may cause increased flexion during a collision.[56] Modifications to counter this anatomic feature include raising the shoulders to the level of the head by placing a pad underneath the shoulders (Figure 23-11). This should be considered for all children who are on backboards.[42,43]

Cases of neurologic deterioration, and even death, have now been reported with the use of a cervical collar in patients with ankylosing spondylitis.[53] In these patients, a cervical collar is contraindicated.

IMPROVISATIONAL TECHNIQUES

The key ingredients to an improvisational C-spine device include maximizing stability and fit while limiting airway compromise and allowing access for mouth opening, thus limiting aspiration

FIGURE 23-8 Fashioning an improvised cervical spine collar from a SAM Splint. *(Courtesy Alan Gianotti, MD.)*

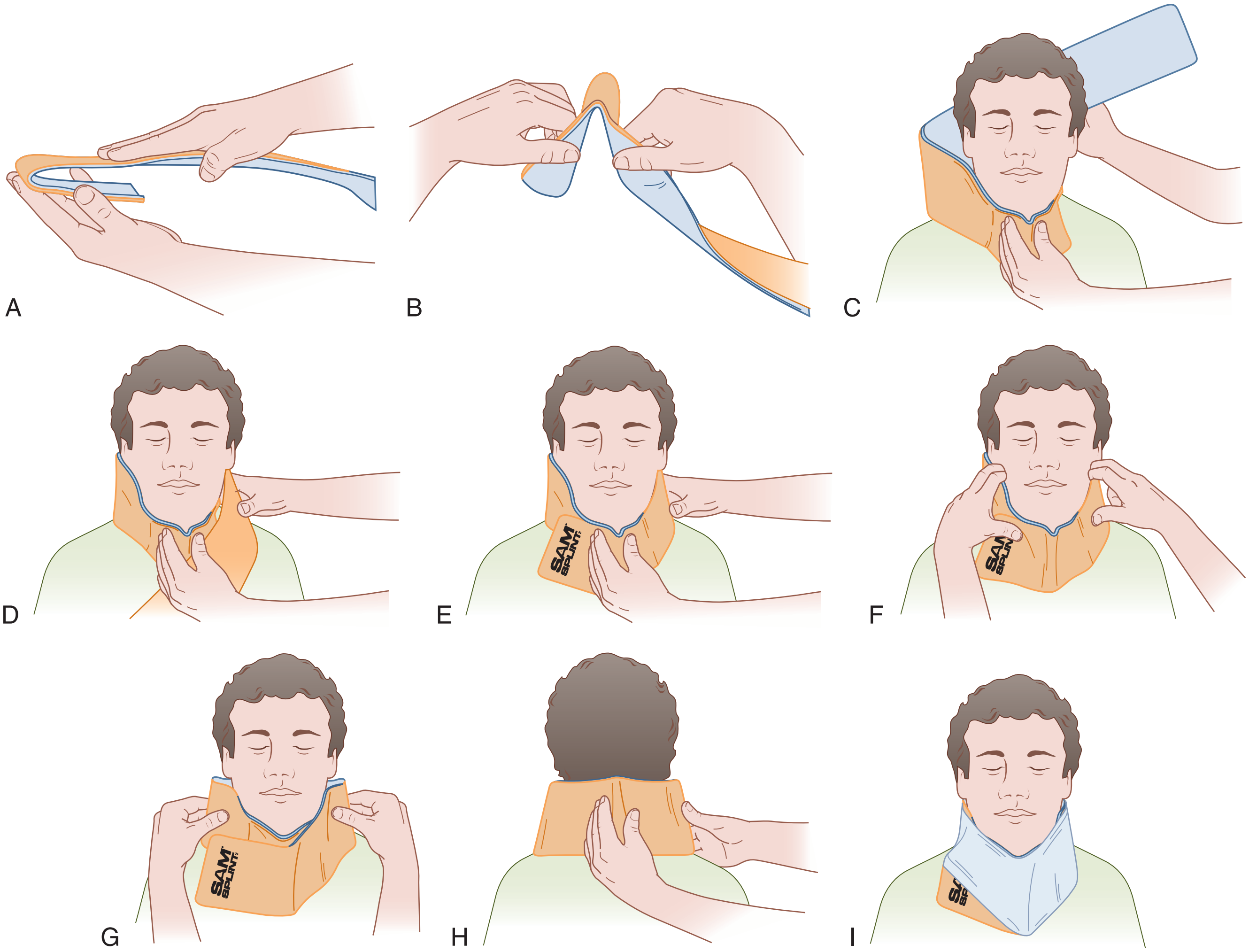

FIGURE 23-9 Improvised cervical spine collar from a SAM Splint. **A,** Fold 36-inch splint 5 inches from the end. **B,** While bracing the thumbs on either side of the fold, pull the edges to create a V-shaped chin rest. **C,** Place the chin rest below the patient's chin, and place the rest of the splint loosely around the patient's neck. **D,** Bring the end forward and down in an oblique direction until it touches the chest. **E,** While supporting the chin, bring the chest portion of the splint around the chin to create a chin post. Squeeze to deepen the chin post. **F,** Insert the index fingers on either side of the splint and pull. **G,** Squeeze to create lateral posts to ensure a snug fit. **H,** Squeeze the back of the splint to create more stability. **I,** Fold up any excess splint and secure it with wrap or tape. *(Courtesy SAM Medical Products.)*

risk.[21] A "horse collar" technique involves a towel, blanket, or other available and malleable material rolled to the desired thickness and placed underneath the patient's neck. The ends are crossed over the patient's chest and secured. As with the cervical hard collar, the patient's C-spine is maintained in a neutral position during application and for as long as possible afterward by manual in-line stabilization[2,9] (see Figure 23-7).

A structural aluminum malleable (SAM) splint can also be molded into a C-spine collar. Studies have shown it to be as effective as a Philadelphia collar, with the advantage of being small, lightweight, versatile, and portable. These characteristics are advantageous in the wilderness setting (see Figure 23-9).[38] A similar device can be fashioned by wrapping sleeping mattress padding or closed-cell foam around the support of a rolled wire splint (Figure 23-12).

THORACOLUMBAR IMMOBILIZATION

A full-length immobilization device best accomplishes immobilization of the thoracolumbar spine. In addition, a cervical collar, lateral neck stabilizers, and backboard straps are essential for full spine immobilization. If the patient is already upright, standing, or lying supine, application of full-body immobilization is straightforward, as described later in this chapter. However, with the suspected cervical injury of a seated patient, an intermediate device is required. There are many forms of this short board, such as a Kendrick Extrication Device (see Figure 23-10). Short boards are applied only after manual in-line stabilization and cervical collar placement have been performed. When the short board is in place, the patient can be safely transferred to full spine immobilization.[9]

FULL SPINE IMMOBILIZATION

From a supine (lying) position and after placement of a cervical collar, the patient is logrolled, or the slide and transfer technique is used to place the patient onto a board or vacuum splint. With the logroll technique, three people are required to transfer a patient onto a board. The first person is positioned at the head and applies in-line stabilization, the second is at chest level, and the third is at pelvis level. On the command of the person at the head, the patient is rolled onto the least-injured side. The board is slid underneath the patient while the back is evaluated for injuries. With the lift and slide technique, multiple attendants are also required. One individual maintains manual, in-line stabilization of the head and neck while the other rescuers straddle the victim in preparation for lifting the upper torso, hips, pelvis, and lower extremities. A final assistant is responsible for placement

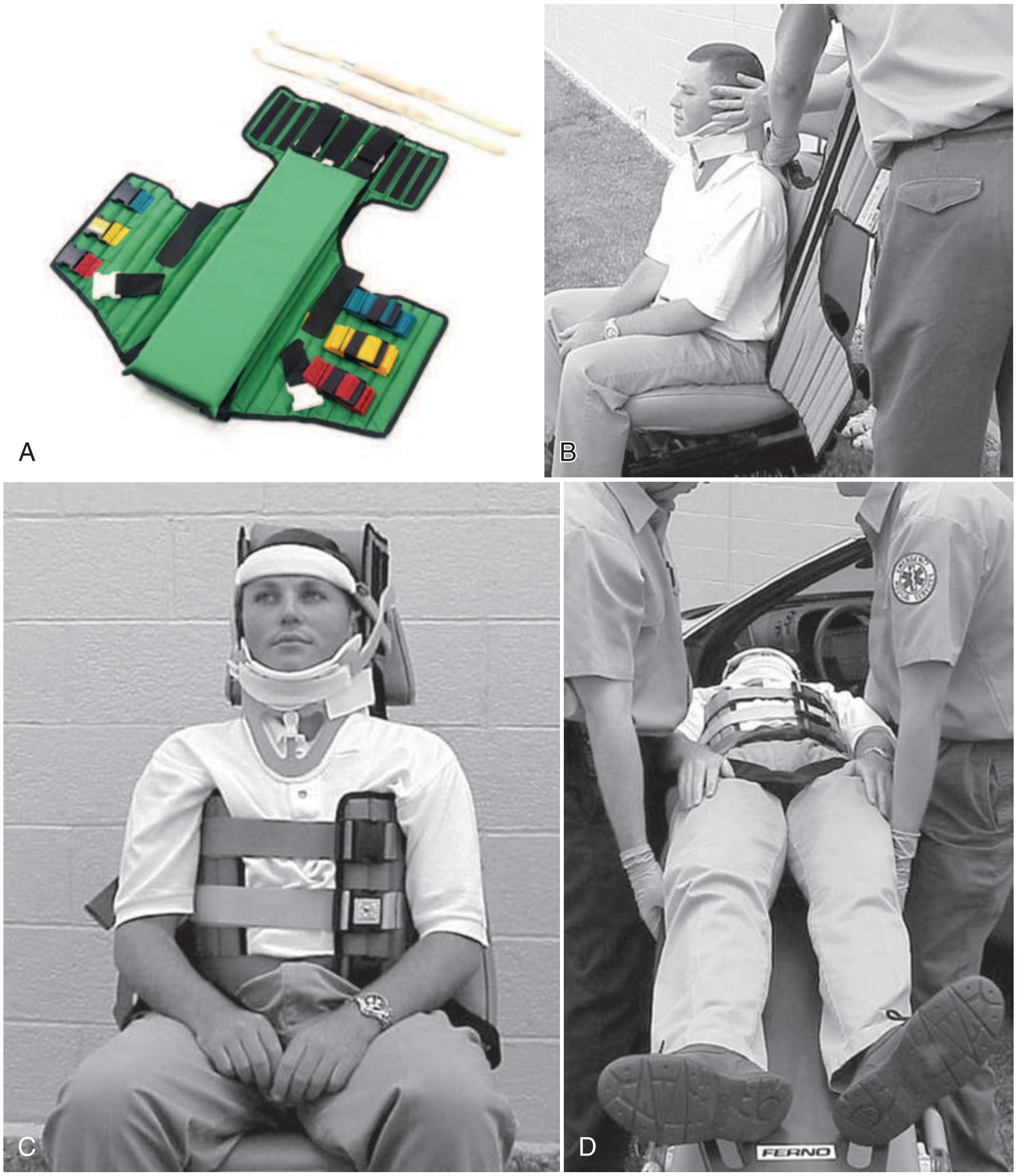

FIGURE 23-10 **A,** Kendrick Extrication Device (KED). **B,** Manual in-line stabilization of the cervical spine with the KED slid behind the patient. **C,** Applied KED with cervical collar in place. **D,** Patient transferred to long board. *(Courtesy Ferno-Washington, Inc.)*

of the spine board. When all participants are ready, the individual stabilizing the head and neck directs the others to raise the patient off the ground to enable the remaining rescuer to slide the spine board under the patient from the foot end. Body straps and lateral neck stabilizers are then placed (Figures 23-13 and 23-14).[9]

Choices for full-body splints include hard backboards, scoop stretchers, and full-body vacuum splints (Figures 23-15 to 23-18). Full-body hard backboards have been traditionally used. Unfortunately, their size and weight make them undesirable for backcountry use. Secured straps minimize spine movement during transport. These are especially important with vomiting patients, when the airway is potentially compromised and a quick change of position is required to allow for removal and drainage of emesis.[9] Hard backboards are uncomfortable. Spine pain that is induced by a backboard may be misinterpreted, and this can complicate and delay therapy.[23] Because rigid backboards can induce pain, patient agitation, pressure ulcers, and respiratory compromise, a recent position statement from EMS physicians and trauma surgeons has advocated limiting their use.[41]

Logrolling is not required with scoop stretchers, thereby minimizing spine movement (see Figure 23-16). Scoop stretchers, like other rigid devices, are otherwise compromised by the same disadvantages listed above.

Vacuum splint devices offer certain advantages over rigid hard backboards. They can be applied more quickly and are significantly more comfortable (Figure 23-19 and see also Figure 23-18). They also offer a similar degree of spine immobilization.[30] Several studies have demonstrated that a vacuum mattress provides significantly superior spine stability, increased speed of application, and markedly improved patient comfort when compared with a backboard. Vacuum mattress immobilization of the potentially injured spine is the current recommendation of the International Commission for Mountain Emergency Medicine.[19] During mountain rescue, vacuum splints are therefore the preferred device for total spine immobilization (Figure 23-20 and see also Figures 23-18 and 23-19). In circumstances in remote austere settings with limited resources where quick extrication is necessary, semirigid spine boards can be improvised (Figure 23-21).

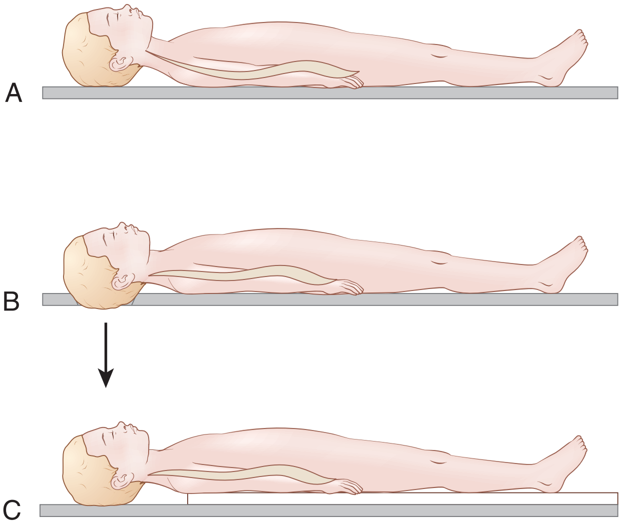

FIGURE 23-11 Backboard considerations and increased cervical flexion for children who are younger than 8 years old. **A,** A young child immobilized on a standard backboard. Note how the large head forces the neck into flexion. Backboards can be modified by an occiput cutout **(B)** or a double mattress pad **(C)** to raise the chest. The actual clinical consequences of this observation are unknown. *(Modified from Herzenberg JE, Hensinger RN, Dedrick DK, et al: Emergency transport and positioning of young children who have an injury of the cervical spine,* J Bone Joint Surg Am *71:15, 1989.)*

FIGURE 23-12 Wire splint/closed-cell foam improvised cervical collar. *(Courtesy Terry O'Connor, MD.)*

FIGURE 23-13 Logroll technique for spine immobilization. *(Courtesy Terry O'Connor, MD/Ketchum, Idaho, Fire Department.)*

FIGURE 23-14 Lift and slide technique for spine immobilization. *(Courtesy Terry O'Connor, MD/Ketchum, Idaho, Fire Department.)*

FIGURE 23-15 Standard rigid backboard. *(Courtesy Laerdal Medical Corporation.)*