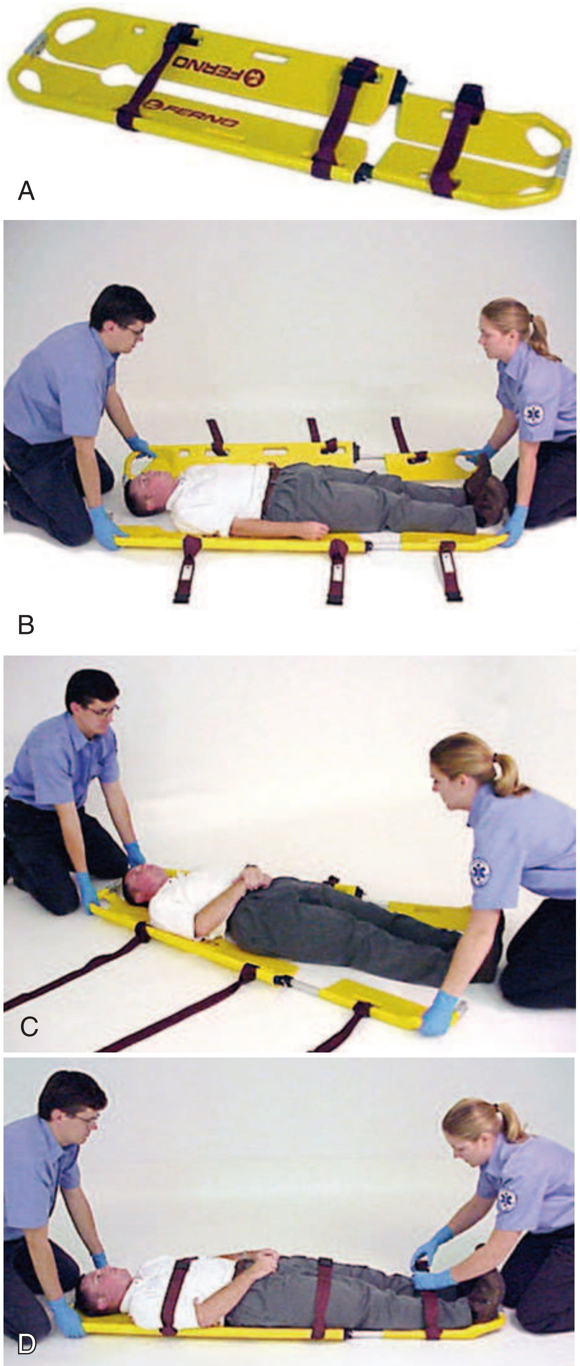


**FIGURE 23-16** **A,** Scoop stretcher. **B,** Stretcher placed beside the patient. **C,** Stretcher slid under the patient. **D,** Stretcher locked in place with straps secured. *(Courtesy Ferno-Washington, Inc.)*

# SPLINTING OF THE EXTREMITIES

## UPPER EXTREMITY SPLINTING

The most common upper extremity injury scenario is bracing from a ground-level fall. Rigid and soft splints are used to stabilize upper extremity injuries. It is always important to leave fingertips exposed to allow continuous assessment of neurovascular status.[9] Common examples of upper extremity splints include malleable, cardboard, air, vacuum, pillow, and sling and swathe splints. Specific splinting recommendations for upper extremity injuries are given in Table 23-1. When feasible, upper extremity injuries are splinted in a position of function (Table 23-2).

**FIGURE 23-17** Example of a full-body vacuum splint used for wilderness rescue. *(Courtesy Sheri Trbovich and the Weber County Sheriff Department, Utah.)*

## LOWER EXTREMITY SPLINTING

Although the principles of lower extremity splinting are similar to those of upper extremity splinting, the ramifications are not the same in terms of evacuation. Lower extremity fractures are more likely to involve weight-bearing bones and thus to require rigid splinting. Specific recommendations, including positions of function, are found in Tables 23-2 and 23-3.

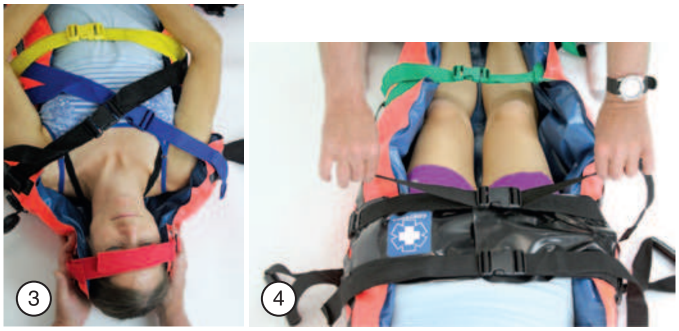
One needs look no further than Joe Simpson's 1985 epic self-rescue from the Peruvian Andes, which was described in *Touching the Void,* to appreciate the pain of an unsplinted weight-bearing fracture[48]:

> *The moment I jumped I knew I would fall…. I had lain face-down in the gravel, clenching my teeth, waiting for the pain to subside. It remained with me, burning my knee unbearably as it had never done before… I stood and fell, writhed where I fell, cried and swore, and felt sure in my heart that these were my last spastic efforts before I lay still for good.*

**FIGURE 23-18** Conterra Vacuum Spine Board. *(Courtesy Rick Lipke, Copyright 2014 by Conterra, Inc. All rights reserved. Used by permission.)*

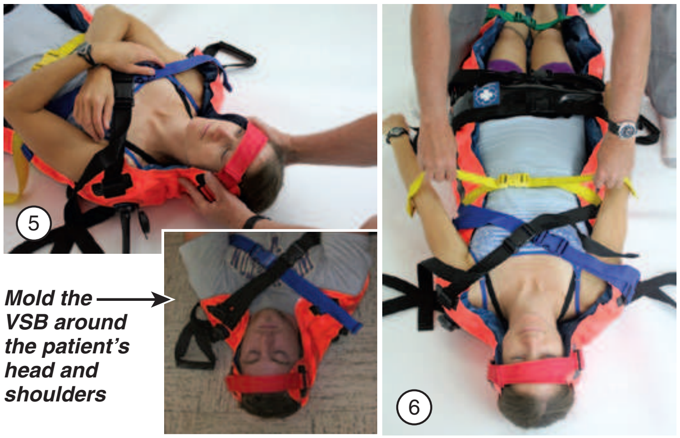

1) The top of the patient's head should be even with the top seam of the device.

2) Connect the straps in "stoplight" color order; first red, then yellow, then green. This is the proper sequence for nonrigid devices like the VSB and VSI.




3) Connect the blue and black decell straps over the shoulders and under the arms.

4) Make sure the pelvic binder is over the lower third of the pelvis and tighten.




5) Close the valve and plug in the pump (not too tight!). Mold the VSB around the patient's head and shoulders while pulling the air out of the device (you cannot overpump).

6) Retighten the straps.

- Stow the VSB with the buckles clipped together and the pump nested in the center of the device.This will ensure that it is ready for the next use.
- We recommend that the VSB and pump be stored inside its protective bag. This will ensure that the device is clean and ready for use. It will also add years to the life of the product.

FIGURE 23-19 Application instructions for vacuum spine board. *(Courtesy Rick Lipke, Conterra EMS/Rescue.)*

## TYPES OF EXTREMITY SPLINTS

### Rigid Splints

Rigid splints can be improvised from materials such as cardboard, wood, and wire. Proprietary vacuum splints and air splints are commonly used in the field. Rigid splints are attached to the extremity with a variety of fasteners, including tape, straps, gauze, and Velcro. For all splints, ample padding is essential, especially over bony surfaces and swollen tissue to minimize pressure damage and pain.[8]

Cardboard splints have the advantage of being lightweight, inexpensive, easy to apply, and radiolucent.[9] They can be premade or improvised (Figures 23-22 to 23-24 and see also

FIGURE 23-20 Example of vacuum spine board applied in high-angle rescue. *(Courtesy Andy Rich, Remote Rescue Training.)*

FIGURE 23-21 Example of improvised spine immobilization. *(Courtesy Terry O'Connor, MD.)*

**TABLE 23-1 Upper Extremity Splints**

| Splint | Indication |
|---|---|
| Figure-of-eight splint | Medial clavicular fractures |
| Sling and swathe splint | Shoulder and humerus injuries |
| Sugar-tong splint | |
| Proximal | Humeral fractures |
| Distal | Wrist and distal forearm fractures |
| Posterior arm splint | Stable elbow and forearm injuries |
| Volar splint | Wrist fractures and fractures of the second through fifth metacarpals |
| Gutter splint | Phalangeal and metacarpal fractures |
| Thumb spica splint | Scaphoid fractures, thumb dislocations and fractures, and ulnar collateral ligament injuries |
| Volar finger splint | Fractures of the distal phalanges and interphalangeal joints |

Modified from Abarbanell NR: Prehospital midthigh trauma and traction splint use: recommendations for treatment protocols, *Am J Emerg Med* 19:137, 2001; Boyd AS, Benjamin HJ, Asplund C: Splints and casts: Indications and methods, *Am Fam Physician* 80:491, 2009; Fitch MT, Nicks BA, Pariyadath M, et al: Videos in clinical medicine: basic splinting techniques, *N Engl J Med* 359:e32, 2008; Garza D, Hendey G: *Extremity trauma.* In Mahadevan S, Garmel G, editors: *An introduction to clinical emergency medicine,* Cambridge, UK, 2005, Cambridge University Press; and Chudnofsky CR, Byers SE: *Splinting techniques.* In Roberts J, Hedges J, editors: *Clinical procedures in emergency medicine,* 5th ed, Philadelphia, 2009, Saunders.

**TABLE 23-2 Splinting Guidelines: Positions of Function**

| Splint | Position |
|---|---|
| Volar wrist splint | Neutral forearm (thumb up) with the wrist in 20 degrees of flexion |
| Ulnar and radial gutter splints | Neutral forearm with the wrist in 20 degrees of extension; metacarpophalangeal joint in 50 degrees of flexion; proximal interphalangeal joint in slight flexion (e.g., 10 degrees); distal interphalangeal joint in extension |
| Thumb spica splint | Forearm neutral with the wrist in 20 degrees of extension and the thumb slightly flexed to allow for thumb–index finger opposition and alignment of the thumb and the forearm |
| Finger splint | Finger in slight flexion |
| Sugar-tong and posterior arm splints | Elbow at 90 degrees of flexion with a neutral position of the forearm and the wrist |
| Posterior leg splint | Ankle at 90 degrees |

Modified from Abarbanell NR: Prehospital midthigh trauma and traction splint use: Recommendations for treatment protocols, *Am J Emerg Med* 19(2):137, 2001; Boyd AS, Benjamin HJ, Asplund C: Splints and casts: indications and methods, *Am Fam Physician* 80:491, 2009; Fitch MT, Nicks BA, Pariyadath M, et al: Videos in clinical medicine: basic splinting techniques, *N Engl J Med* 359:e32, 2008; and Chudnofsky CR, Byers SE: *Splinting techniques.* In Roberts J, Hedges J, editors: *Clinical procedures in emergency medicine,* 5th ed, Philadelphia, 2009, WB Saunders.

**TABLE 23-3 Lower Extremity Splints**

| Splint | Indication |
|---|---|
| Knee immobilizer splint | Knee injuries |
| Posterior ankle splint | Distal tibial and fibular injuries; ankle, tarsal, and metatarsal fractures |
| Stirrup splint | Ankle fractures |
| Buddy taping | Toe fractures |
| Traction splint | Femoral fractures |

Modified from Boyd AS, Benjamin HJ, Asplund C: Splints and casts: indications and methods, *Am Fam Physician* 80:491, 2009; Fitch MT, Nicks BA, Pariyadath M, et al: Videos in clinical medicine: basic splinting techniques, *N Engl J Med* 359:e32, 2008; Garza D, Hendey G: *Extremity trauma.* In Mahadevan S, Garmel G, editors: *An introduction to clinical emergency medicine,* Cambridge, UK, 2005, Cambridge University Press; and Chudnofsky CR, Byers SE: *Splinting techniques.* In Roberts J, Hedges J, editors: *Clinical procedures in emergency medicine,* 5th ed, Philadelphia, 2009, Saunders.

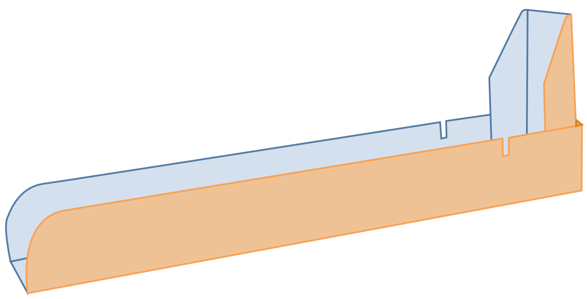


**FIGURE 23-22** Premade cardboard splint. *(Courtesy Ferno-Washington, Inc.)*

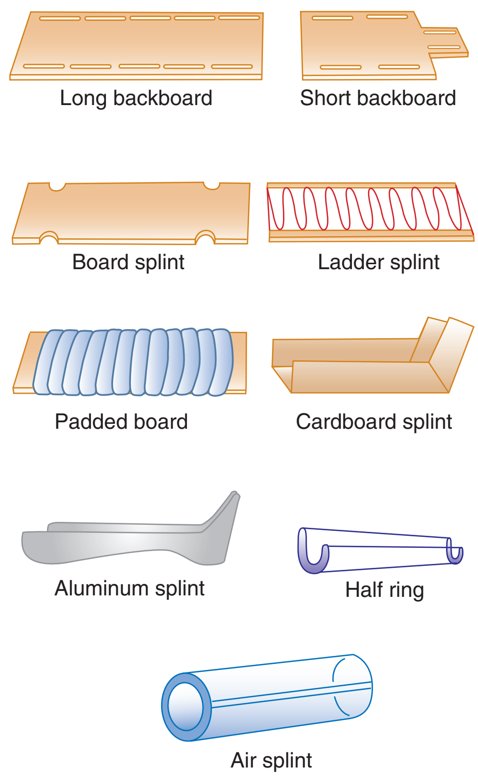



**FIGURE 23-23** A variety of splints. *(From Geiderman JM, Katz D: General principles of orthopedic injuries. In Marx J, Hockberger R, Walls R, editors:* Rosen's emergency medicine: concepts and clinical practice, *7th ed, Philadelphia, 2009, Saunders. Used with permission.)*

FIGURE 23-24 Improvising a pelvic compression device. This cardboard splint is used to treat the lower extremity. *(Courtesy Alan Gianotti, MD.)*

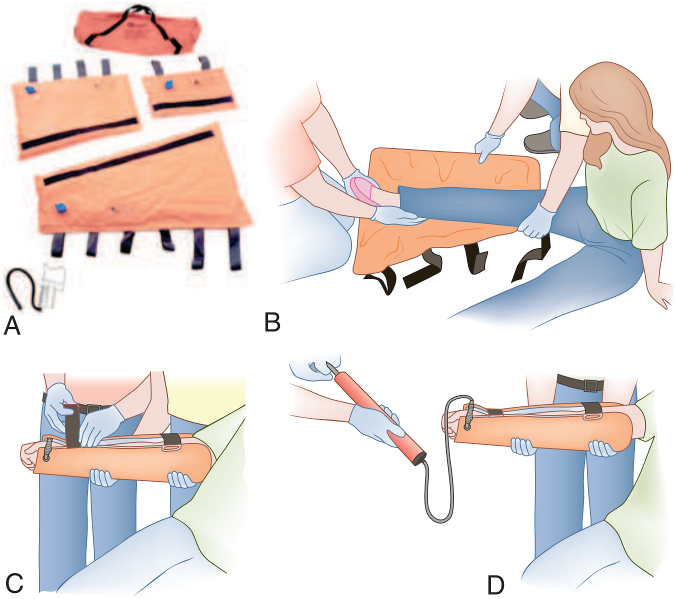



FIGURE 23-25 Vacuum splinting. **A,** A variety of vacuum splints. **B,** Stabilizing the fracture while laying the splint flat under the injured limb with the valve on the outside. **C,** Securing the splint. **D,** Removing air from splint to complete the application. *(Courtesy Ferno-Washington, Inc.)*

Figure 23-2). When improvising, it is important to cut the cardboard so that the corrugations run lengthwise to maintain the material's intrinsic strength. Splints can be individually fitted using the unaffected extremity as a model and placed on the affected extremity. They are usually secured with adhesive tape. Disadvantages include loss of integrity when wet and greater laxity as compared with other splinting options. The distorted and grossly swollen extremity is difficult to splint using this technique.[19]

Although they are initially malleable, vacuum splints are a type of rigid splint (Figure 23-25). These splints are made of many tiny plastic pellets in a closed, airtight bag. The bag is placed around the injured extremity, and air is manually extracted via a hand pump to form a rigid "mold" of the injured extremity. The extremity is left in its position of injury to minimize pain (Figure 23-26). No external force is applied, thereby maximizing circulation.[9] Unfortunately, vacuum splints are expensive, moderately bulky, affected by changes in altitude, and penetrable. In addition, any perforation renders the splint nonfunctional.[19]

A lightweight, inexpensive, and popular rigid splint is the SAM Splint. Constructed of an aluminum center that is sandwiched between thin strips of foam, this splint is also malleable and versatile.[9] It is very strong and pliable, and it can be used for nearly all extremity requirements.

Other malleable splints include ladder splints (i.e., pliable metal splints) and rolled-wire splints, both of which are readily available at most outdoor sporting goods stores[8] (Figure 23-27). Given their weight, size, reliability, versatility, and cost, malleable splints have become a popular choice for the universal wilderness medical kit.[19] They may also be fashioned with improvised padding, such as mattress padding or foam (see Figure 23-12).

## Soft Splints

A soft splint earns its name from the soft, padded material that is used to secure the injury. Soft splints include sling and swathe splints, pillow splints, and blanket-roll splints[10] (see Figure 23-2). Soft splints allow for more laxity than do rigid splints, but can be combined with rigid splints for extra stability.

Pillow splints are soft splints adapted for wrist and hand injuries. Their main advantages are ease of application and comfort.[9] As with other soft splints, they allow for more movement at the fracture site but are bulkier than other splints.

FIGURE 23-26 Upper and lower body vacuum splints used for wilderness rescue. *(Courtesy Sheri Trbovich and the Weber County Sheriff Department, Utah.)*

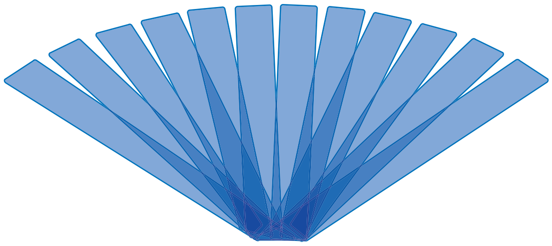


FIGURE 23-27 Pliable metal ladder splints. *(Courtesy Ferno-Washington, Inc.)*

Sling and swathe splinting can be used alone or in combination with other forms of splints. Shoulder, clavicle, upper arm, elbow, forearm, wrist, and even hand injuries are commonly stabilized with a sling and swathe. For a shoulder injury in which it is not possible to adduct the arm, a pillow (or similar material) can be used to bridge the empty space, with the sling supporting the arm and the swathe stabilizing it.[9] This technique takes advantage of the chest wall to provide the splint foundation. Distal humeral injuries necessitate a sling and swathe splint in combination with rigid splints. Sling and swathe splinting is used alone for many clavicle, shoulder, and proximal humeral injuries. Its advantages are its light weight, portability, and improvisational versatility.

Air splints are hybrid splints that are made from inflatable yet durable plastic. These splints are most often used for the elbow, knee, and ankle (Figure 23-28). They are placed around the injured extremity and inflated to the desired pressure and rigidity.[8] They have the advantages of being lightweight and portable. Variable external pressures can be used to control hemorrhage. External pressure has the potential to limit distal perfusion. Air splints should be temporarily deflated (e.g., for 5 minutes every 90 minutes) to decrease the risk for ischemic damage.[10] Air splint pressure varies with altitude and temperature. For these reasons, it is important to reevaluate neurovascular status during transport.[19]

### SAM Splints

Malleable splints, such as SAM Splints,[58] no longer fall into the category of improvised splinting. These splints are commonly found in the standard wilderness medical kit. They are lightweight, reusable, versatile, and padded, and not affected by changes in pressure or temperature. They are radiolucent to allow radiographs to be taken with the splint in place. The malleable SAM Splint is pliable in its native form, yet easily strengthened with creasing. The basic SAM Splint adaptations are depicted in Figure 23-29. In addition, the SAM Splint can be molded to form an adequate C-spine collar (see Figures 23-8 and 23-9).

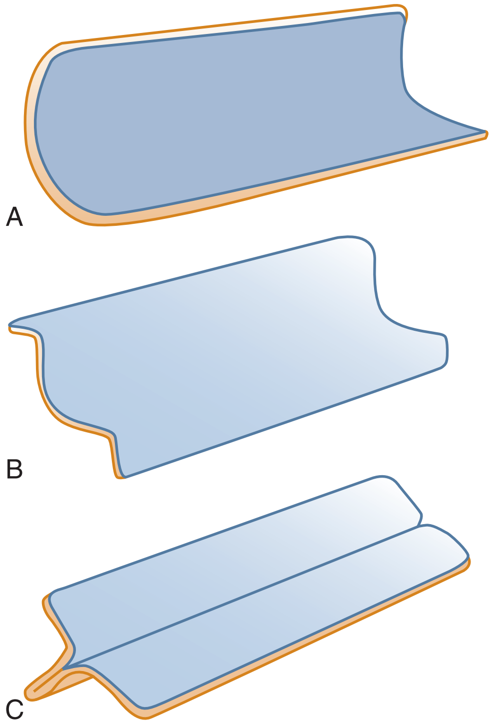



FIGURE 23-29 Basic SAM Splint adaptations. **A,** C-curve. **B,** Reverse C-curve. **C,** T-curve (maximum strength). *(Courtesy SAM Medical Products.)*

FIGURE 23-28 Lower extremity air splint used for a wilderness rescue. *(Courtesy Ed Gray.)*

### Improvised Extremity Splints

Improvised splints can be made from branches, boards, padded pack straps, or rolled-up newspapers or magazines. Anatomic splints involve an uninjured neighboring body part, primarily a digit. Slings can also be made from unused clothes.[8] In these cases, one need not pack additional materials. Improvised splints have a disadvantage in that they are less effective than commercial splinting devices.[19]

# TECHNIQUES OF SPLINTING

## PELVIC SPLINTING

Pelvic fractures are potentially life-threatening injuries.[34] Splinting is essential for pain and hemorrhage control. Pelvic fractures are often difficult to diagnose in the field but must be suspected when a high-force mechanism of injury has led to pelvic pain or an altered sensorium. A pelvic compression device should be applied.[19] Appropriate stabilization with such a splinting device slows hemorrhaging and stabilizes fracture fragments.[9] Open-book fractures (i.e., diastasis of the pubic rami with posterior pelvic disruption) create a large surface area for potential hemorrhage. Circumferential compression of the pelvis is recommended for emergency stabilization.[7] This can be accomplished by pelvic circumferential compression devices, a pneumatic antishock garment (PASG), compression devices incorporated into vacuum spine boards, or improvised techniques such as pelvic sheeting[10] (Figure 23-30; see also Figure 23-24).

Optimal pelvic stabilization is achieved by applying a sling around both greater trochanters and the symphysis pubis.[7] Pelvic circumferential devices are similar in function (Figure 23-31).

A pelvic compression device can be improvised in the wilderness. Sheets, jackets, and other long fabrics are readily available on most expeditions. The sheet or fabric is wrapped around the

FIGURE 23-30 Pelvic compression device incorporated into vacuum spine board. *(Courtesy Rick Lipke, Conterra EMS/Rescue.)*

pelvis over the greater trochanters and the symphysis pubis and pulled tight and secured to increase pressure at the wound and to decrease the potential space for hemorrhage. The PASG and the military antishock trousers, which were commonly used in the past, have generally fallen out of favor (Figure 23-32). Proponents of PASG and military antishock trousers point to the position paper of the National Association of EMS Physicians for support. The paper states that the PASG is beneficial in the setting of a ruptured abdominal aortic aneurysm and that it is potentially beneficial in many other scenarios (e.g., hypotension from pelvic fractures, gynecologic bleeding, ruptured ectopic pregnancy, severe traumatic hypotension, and uncontrolled lower extremity hemorrhage).[17] Postulated successful mechanisms for correcting hypotension include increasing peripheral vascular resistance, tamponade of local hemorrhage, and increasing blood return from the lower extremities.[33] PASG disadvantages include prolonged scene time, pressure changes with altitude (e.g., potential compartment syndrome with air travel), and interference with normal pulmonary function.[39] In addition, animal studies have demonstrated lactic acidosis after prolonged use. Rapid deflation may cause hypotension as a result of volume redistribution. Studies have not shown improvement in hospital duration, and others have shown increased mortality rates.[13] PASGs are bulky and expensive. Absolute contraindications for PASG use include diaphragmatic rupture, penetrating thoracic injury, splinted lower extremity fracture, gravid uterus, or abdominal evisceration.[33] Thus, routine use of the PASG in the field is not recommended. In the case of isolated femoral fracture, a PASG can be used, but other viable options are more readily available in the wilderness.

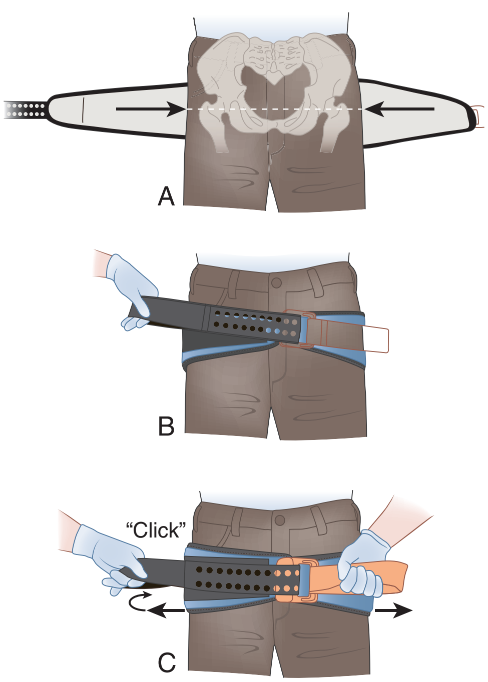



FIGURE 23-31 Application of the SAM Pelvic Sling. **A,** Remove all objects from the pockets. Place the sling under the patient's hips. **B,** Place the black strap through the buckle, and pull it completely through. **C,** Hold the orange strap with one hand and pull the black strap in the opposite direction under tension until a click is heard. Maintain tension, and place the black strap against the sling surface to secure. *(Courtesy SAM Medical Products.)*


FIGURE 23-32 Military antishock trouser/pneumatic antishock garment. *(Courtesy Common Cents EMS Supply.)*

## HIP AND FEMUR SPLINTING

Femoral fractures result from high-force trauma. These fractures can be diagnosed clinically in the appropriate wilderness setting. Deformity, swelling, and tenderness along the thigh and in the face of significant trauma are highly suggestive of a femoral fracture.[22] Femoral fractures produce significant hemorrhage; a closed femoral fracture may bleed more than 1 L into the thigh.[14] Femoral shaft fractures also have a mortality rate that ranges from 20% to 54%.[37]

A general indication for traction splint placement is any suspected femoral fracture in the nonambulatory patient. The proposed benefits of traction splints are to minimize blood loss, pain, and other adverse sequelae while achieving realignment of bone fragments.[9]

It is important to note that proposed benefits of traction beyond typical splinting are purely anecdotal. There are no definitive studies demonstrating morbidity or mortality benefits from prehospital use of traction splints.[44,59]

Contraindications to traction splint placement are fractures that involve the knee, pelvis, or ankle, or that include damage to the sciatic nerve.[37] Unfortunately, such comorbidities are common with severe wilderness injuries, which makes it impossible or dangerous to anchor the traction splint.[5] Controversy exists regarding whether a traction splint should be placed with an open femoral fracture, but this is not a strict contraindication. In general, it is argued that splinting these patients in the field increases on-scene time and endangers their well-being.[5,36]

In summary, in a patient with an isolated femoral fracture and no other apparent injuries, traction splints may be appropriate, but there is no medical evidence to show they would improve the patient's ultimate outcome. Although their use is well intentioned, the proposed benefits are theoretical. Traction splints take some time to apply properly, and in a patient with multiple injuries, that time must be weighed against using other stabilization maneuvers and moving the patient toward the place where the injuries can be definitively treated.

There are many femur traction splint devices, and all are based on the same principle: a rigid frame that anchors at the proximal pelvis and extends traction beyond the distal heel. The proximal aspect is padded against the ischial tuberosity. Traction to the fractured femur is applied with a heel strap that is anchored off of the distal frame. The thigh, knee, and leg are also secured with soft straps.[19] Traction devices that have a half-ring design (e.g., Thomas or Hare splints) can cause hip flexion of up to 30 degrees. This can cause incomplete fracture realignment unless the leg is elevated to match the angle.[9] Traction splints that do not have a posterior half-ring (e.g., Sager splints) do not compress the sciatic nerve and can be used with groin injuries. They can also be used for patients with pelvic fractures or for bilateral femoral fractures by applying a splint to each leg.[47]

Traction splint application is not always intuitive (Figures 23-33 to 23-36). Two rescuers are needed for proper placement.[8] Manual traction should be applied to reduce the fracture until the splint can be placed.[1] As with any splint placement, it is important to establish pain control, check neurovascular status both before and after splint placement, and fully explain the process to the conscious patient. After the proximal femur splint is in place, the thigh strap is fastened. The ankle harness is placed just above the malleoli and attached to the distal splint. Traction (6.8 kg [15 pounds]) is applied, and the remaining straps are applied. After the traction splint is in place, the patient should be logrolled onto a backboard to minimize fracture fragment movement.[8] Improvised traction splints in small studies have been shown to create similar pounds of traction at 30 minutes.[57] Traction splint complications result from improper strap and splint placement and include sciatic or peroneal nerve injury, pressure wounds, hemorrhage, and pain.[10,19,37,47]

Different femur traction systems can be improvised out of very little material. A double-runner system is a very straightforward technique that can be used in a wilderness setting (Figure 23-37). The patient's own boot can be used to improvise a hitch and a traction system (Figure 23-38). One more option is a Buck's traction device, which uses a foam pad and duct tape and can be better for longer transports because it distributes the force of traction over a larger area (Figure 23-39). For the proximal anchor, one can use a Cam lock/Fastex slider system and attach it to a tent pole, ski pole, or other similar device (Figures 23-40 and 23-41).

## ANKLE SPLINTING

Ankle sprains are common orthopedic injuries incurred during expeditions and the most common of all sprains.[2] There are literally hundreds of examples of available over-the-counter ankle supports, braces, and splints. These include but are not limited to leather bracing, canvas bracing, air stirrups, air bladders, air casts and air boots, plastic splints with Velcro strapping, and malleable varieties, including wire ladder splints. On the basis of the high incidence of ankle sprains, it appears prudent to have a readily available lightweight ankle splint in one's medical kit. The goal is to offer ankle support that will fit within the size constraints of the patient's hiking boot. The time-tested alternative is athletic tape. The taped sprained ankle has talofibular ligament support (for a limited duration), and tape does not add significant weight to the medical kit. All wilderness health care providers should be adept at taping ankles.

## SHOULDER DISLOCATION

Anterior shoulder dislocation is a common injury. The arm is most comfortable in an abducted position. This can be accomplished with a rolled blanket, pillow, jacket, or SAM Splint that has been fashioned into a triangle (Figure 23-42).

A shoulder spica wrap can be used for support if a shoulder dislocation has been reduced (Figure 23-43).

## HUMERUS SHAFT INJURY

Humeral shaft fracture is often treated with a sling or with a sling and swathe splint alone. For pain control, a splint is often desirable (Figure 23-44).

## ELBOW DISLOCATION

A dislocated elbow can be reduced in the field with the appropriate analgesia and experience. The dislocated elbow can also be splinted in place and the patient transported for definitive care (Figure 23-45).

## ELBOW FRACTURE

A sugar-tong splint is useful for most elbow injuries. These most commonly include supracondylar, olecranon, and radial head fractures (Figures 23-46 and 23-47).

## WRIST FRACTURE

The volar wrist splint is used for most wrist fractures, dislocations, sprains, lacerations, and other wrist injuries. A T-beam volar wrist splint, fashioned by applying a T-curve to the folded SAM Splint, can be used for greater support when traveling over rough terrain or when more support is desired (Figure 23-48).

## METATARSAL FRACTURES

Ulnar gutter splints are used for fourth and fifth metatarsal injuries and for corresponding digit injuries (Figure 23-49).

## THUMB INJURIES

A thumb spica splint is used for suspected scaphoid (navicular) fractures, thumb dislocations and fractures, and ulnar collateral ligament injuries (Figure 23-50). If splinting material is not available, the thumb should be taped until more definitive care is available (Figure 23-51).

## FINGER INJURIES

Finger splints are used for finger fractures, fingertip injuries, and lacerations (Figure 23-52).

## FEMORAL FRACTURE

A femoral traction splint can be improvised in a variety of ways with a SAM Splint. One practical wilderness example involves the use of ski poles and a SAM Splint. An improvised version of a half-ring splint is made from two ski poles, a small piece of metal, and a 91.4-cm (36-inch) SAM Splint (Figure 23-53).

## KNEE INJURIES

A knee immobilizer splint is used for knee injuries, patellar tendon injuries, dislocations, and other severe ligamentous sprains when immobilization is required (Figure 23-54).

*Text continued on p. 517*


**FIGURE 23-33** Slishman traction splint. **A,** Remove the ankle strap and end cap from the pole. Apply the ankle strap with the end cap lateral and facing up to receive the splint pole, and secure with Velcro wrap. **B,** May apply ankle wrap above the calf in the setting of lower leg injury. **C,** Rest female buckle on anterior thigh. Wrap male buckle and strap behind the thigh. Snap buckles and tighten. **D** and **E,** Release the distal pole clamp and extend the distal pole. **F,** Once at the desired length, close the distal pole clamp. **G,** Release the proximal pole clamp, pull cord to desired traction, and close the proximal pole clamp. **H,** Adjust traction as needed to minimize pain while maintaining perfusion. Attach the midleg strap to the splint for rotational stability. **I,** For patients under 110 cm (≈ 43 inches) in height and/or younger than 3 years of age, lengthen the groin strap, allowing the splint to rest closer to the hip. *(Courtesy of Rescue Essentials.)*

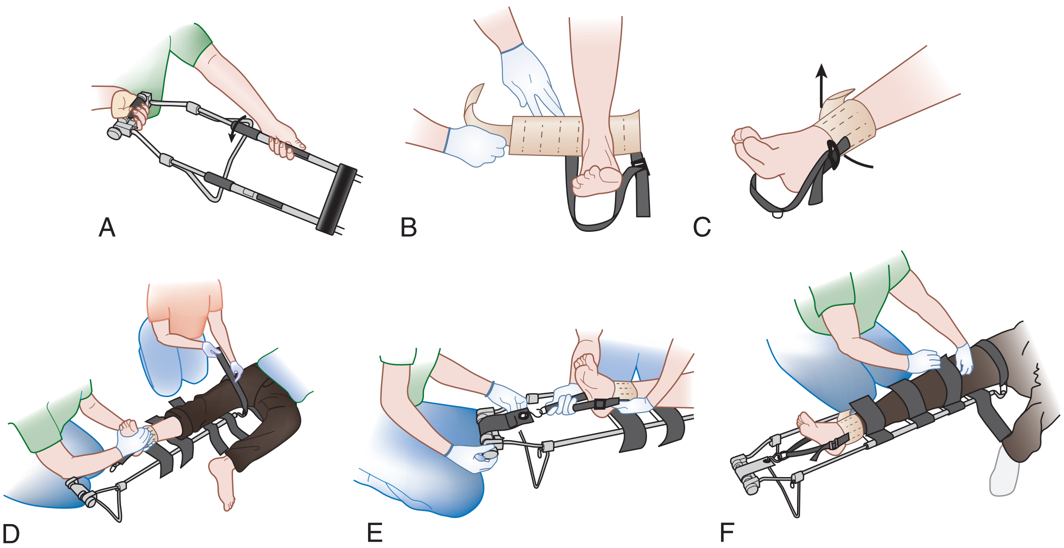
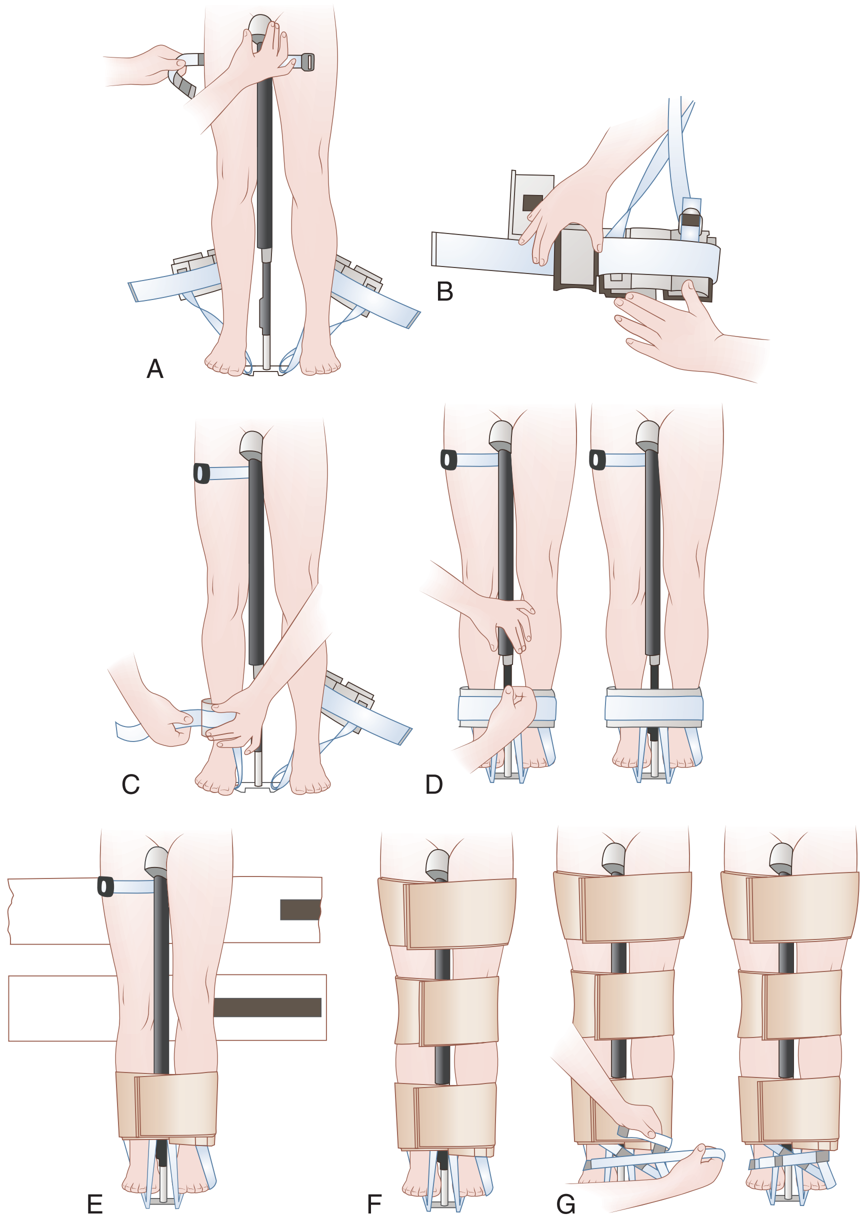



**FIGURE 23-34** Ferno traction splint. **A,** Adjust the length of the splint to fit the patient. Use the patient's uninjured leg to determine the desired length. **B,** One operator supports the injured leg and places the ankle wrap under the ankle. **C,** Center the foot, wrap the strap around the ankle, and secure it with the fastening strip. **D,** Support the leg, slide the splint under the injured leg until the pad rests against the lower pelvic bone, and fasten the hip strap. **E,** Attach the S-hook to the D-ring, and apply traction. **F,** Reposition the splint and fasten the straps. *(From Ferno-Washington, Inc. Used with permission.)*

**FIGURE 23-35** Applying the Sager traction splint. **A,** Position the splint between the patient's legs, and rest the splint cushion against the ischial tuberosity. **B,** Fold down the number of comfort cushions needed to engage the ankle above the medial and lateral malleoli. **C,** Use the ankle straps to secure the splint snugly. **D,** Pull the control tabs to tightly engage the ankle harness against the crossbar. Grab the padded shaft of the splint with one hand and the traction handle with the other, and gently extend the inner shaft to obtain the desired traction. **E,** Adjust the thigh strap at the upper thigh securely. **F,** Firmly secure the elastic leg cravats. **G,** Apply the foot strap around the feet to prevent rotation. Check the patient for sensation and pulses. *(Courtesy Minto Research and Development, Inc.)*



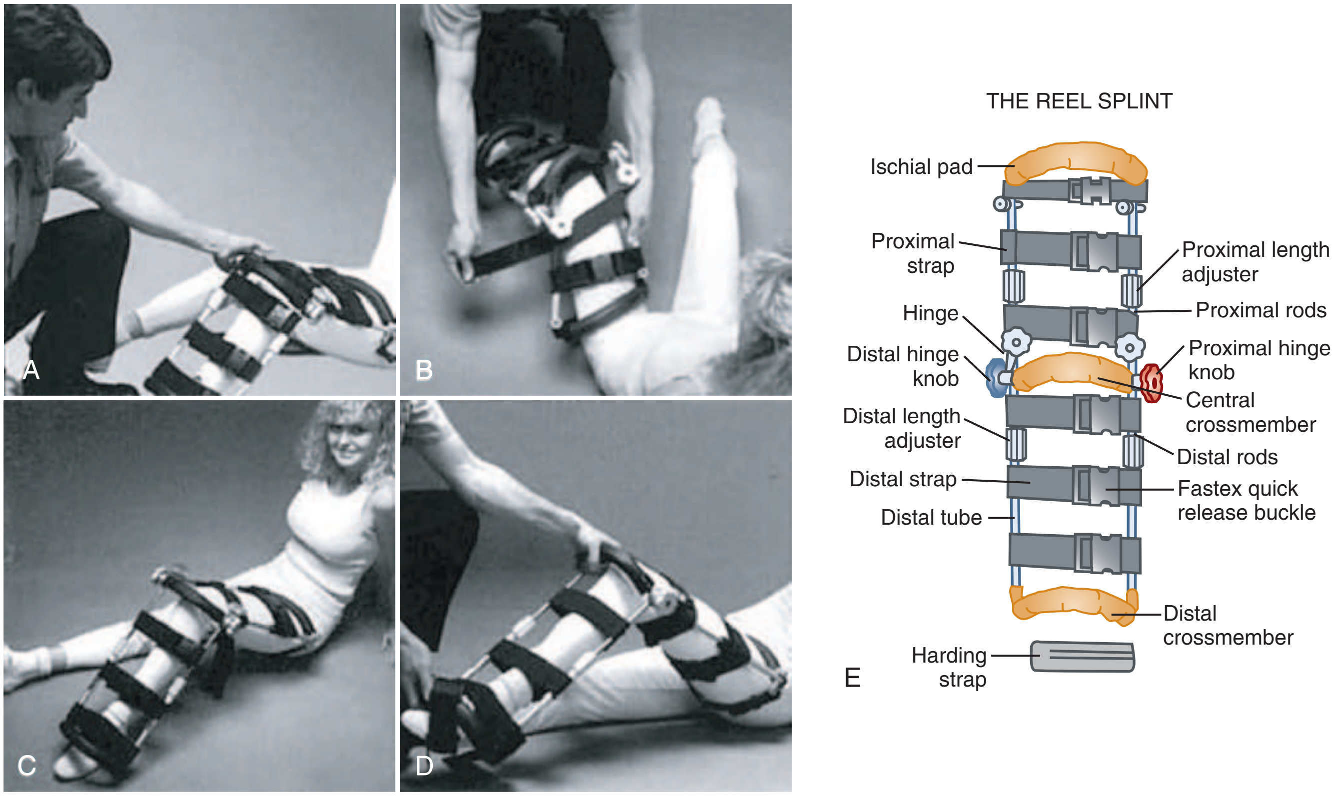



**FIGURE 23-36** Reel splint hybrid system. **A,** Adjust the splint to match the extremity's position, and place it on the limb. Fine-tune the angle adjustment for proper fit, and securely tighten both the distal and proximal hinge knobs. **B,** Apply the support strap and pull the tab securely. Loosen and adjust the proximal length adjuster. Retighten and repeat the process for the remaining adjuster. Apply the ischial strap. **C,** Loosen the distal length adjusters, extend them to the desired length, and retighten. Apply and retighten the remaining support straps. **D,** Wrap the Harding strap under the foot, and attach it to the distal crossmember. **E,** The Reel splint. *(From Reel Research and Development. Used with permission.)*

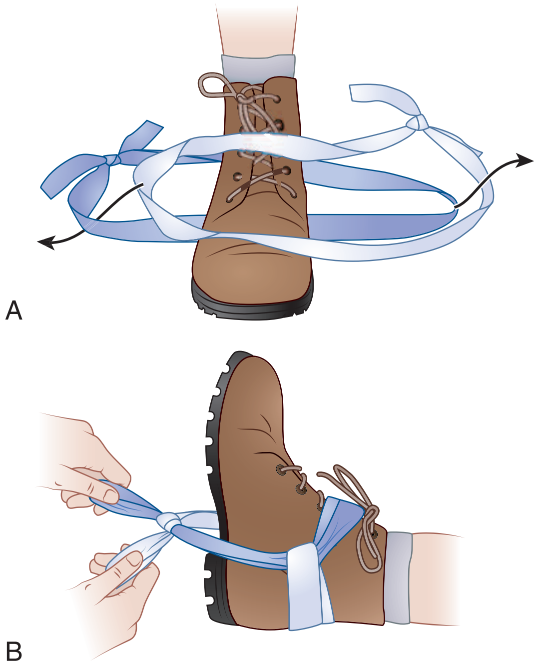



**FIGURE 23-37** Double-runner splint. Lay two short webbing loops (runners) over and under the ankle. Pass the long loop sides through the short loop on both sides and adjust.

**FIGURE 23-38** Patient's boot system. Cut two holes into the sidewalls of the boot just above the midsole, in line with the ankle joint. Thread a piece of nylon webbing or a cravat through to complete the ankle hitch. Next, cut away the toes of the boot to allow for neurovascular checks because the boot is already functionally ruined.

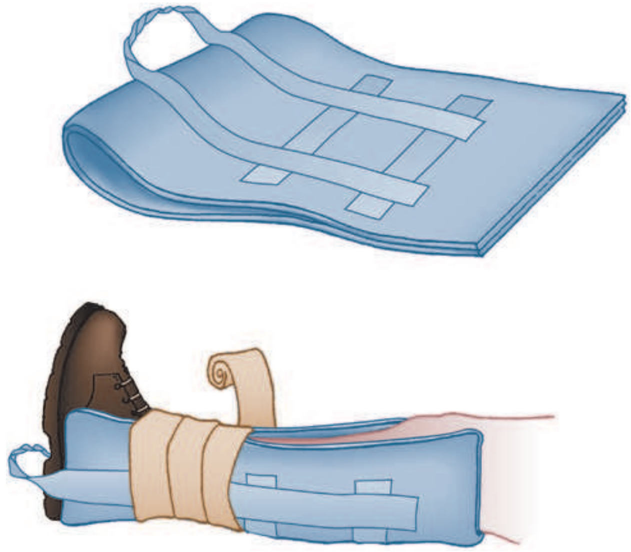


**FIGURE 23-39** Buck's traction. Improvised Buck's traction using a closed-cell foam pad. Duct tape stirrups are added to a small foam pad that is wrapped around the leg. The entire unit is wrapped with an Ace bandage.

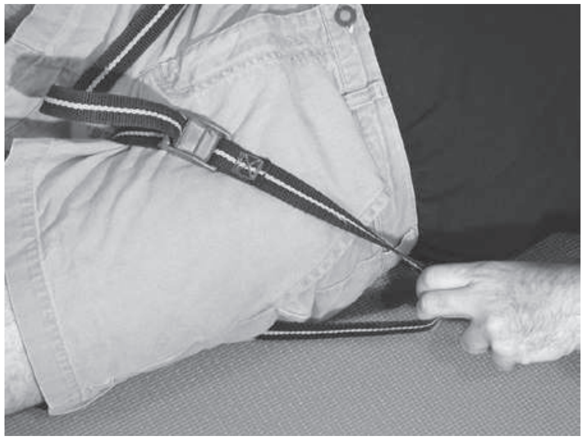


**FIGURE 23-40** Cam lock or Fastex slider. This system uses straps that have Fastex-like sliders and are often used as waist belts or to strap items to packs. Alternatively, use a Cam lock with nylon webbing. Attach the belt to the distal portion of the rigid support and then to the ankle hitch. Traction is easily applied by cinching the nylon webbing.

**FIGURE 23-41** Proximal anchor using Cam-lock belt. Ski pole is used laterally as rigid support. Duct tape is used to secure components. Pad as needed.

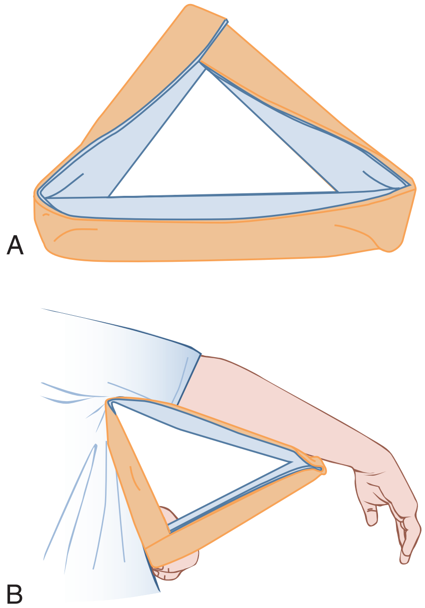



**FIGURE 23-42** Shoulder splint. **A,** Fold a 36-inch SAM Splint into three equal sections. Fold the outer sections along the longitudinal axis, and leave the middle section flat. Hook the outer ends together to make a triangle splint. **B,** Place the triangle splint under the patient's axilla to support the abducted arm. The splint can be held in place by the patient or secured with a wrap. *(Courtesy SAM Medical Products.)*

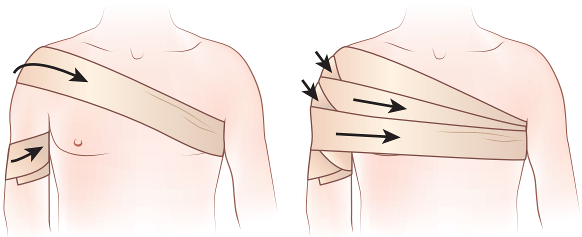


**FIGURE 23-43** Shoulder spica wrap for support after dislocation.

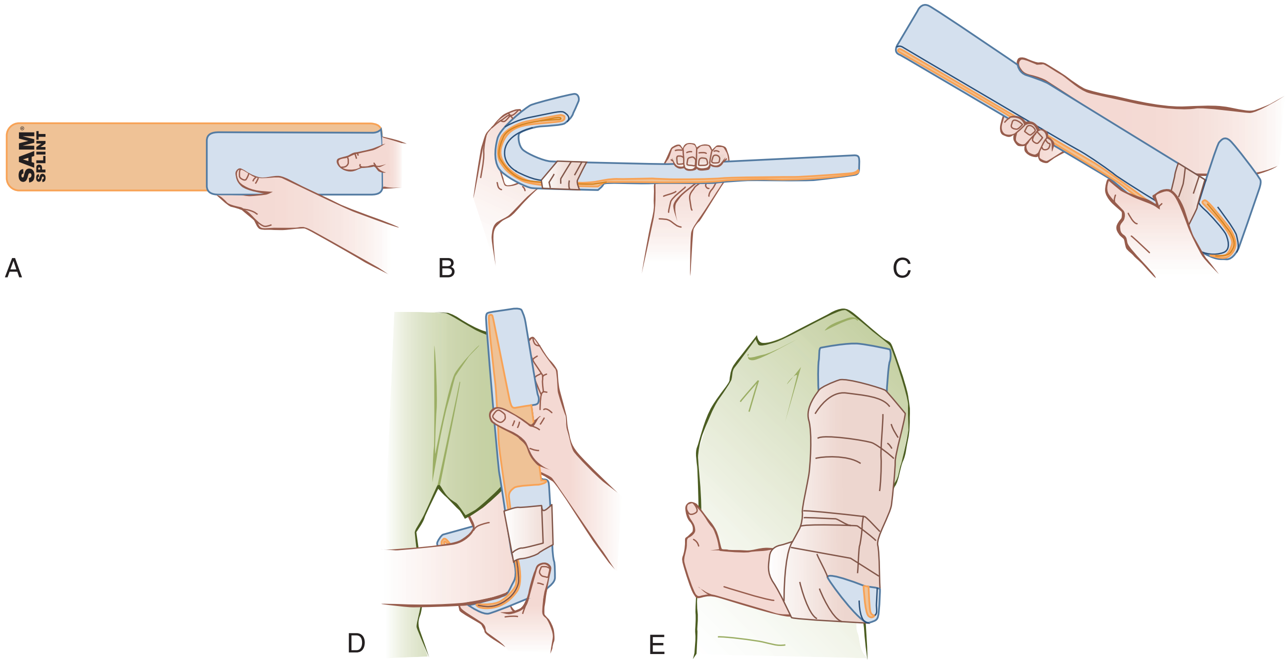



**FIGURE 23-44** Humeral shaft splint. **A,** Fold one-third of a 36-inch SAM Splint on itself. **B,** Curve the double-layer portion into a fishhook shape, and secure it with tape or wrap. **C,** Form a C-curve along the shank of the fishhook to create strength, and mold it to the arm. **D,** Apply the splint to the arm. Fold any excess splint back on itself. **E,** Secure the splint with wrap, and apply a sling and swath splint for additional support. *(Courtesy SAM Medical Products.)*

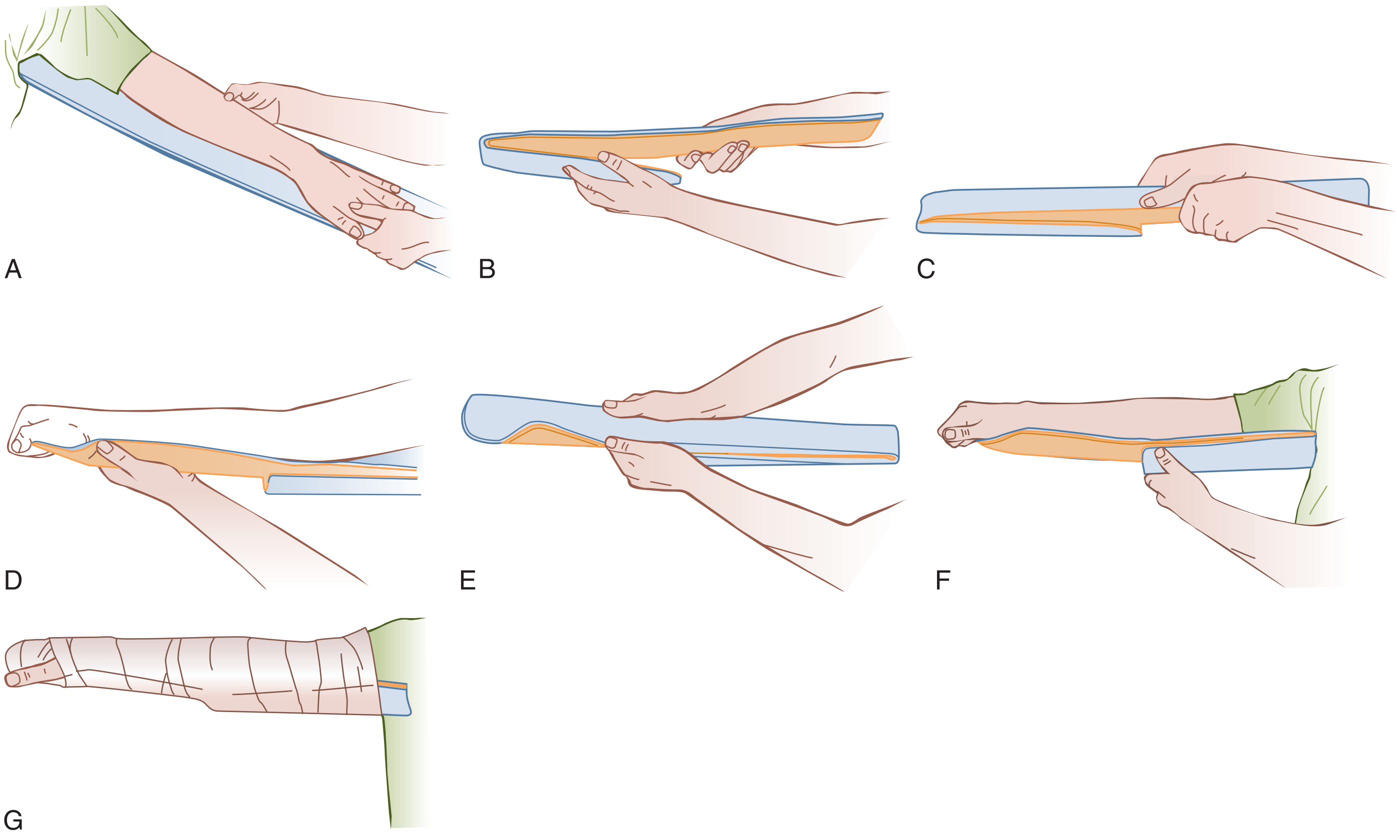



**FIGURE 23-45** Dislocated elbow splint. **A.** Use the unaffected arm as a model, and extend a 36-inch SAM Splint from under the patient's armpit to the knuckles. **B,** Fold under the portion of the splint that extends past the knuckles. **C,** Form a C-curve along the entire length of splint. **D,** Use your own arm as a template, and shape the splint. **E,** You may reverse the C-curve bends on the edges for more strength. **F** and **G,** Apply and secure the splint to the patient with wrap or tape. *(Courtesy SAM Medical Products.)*

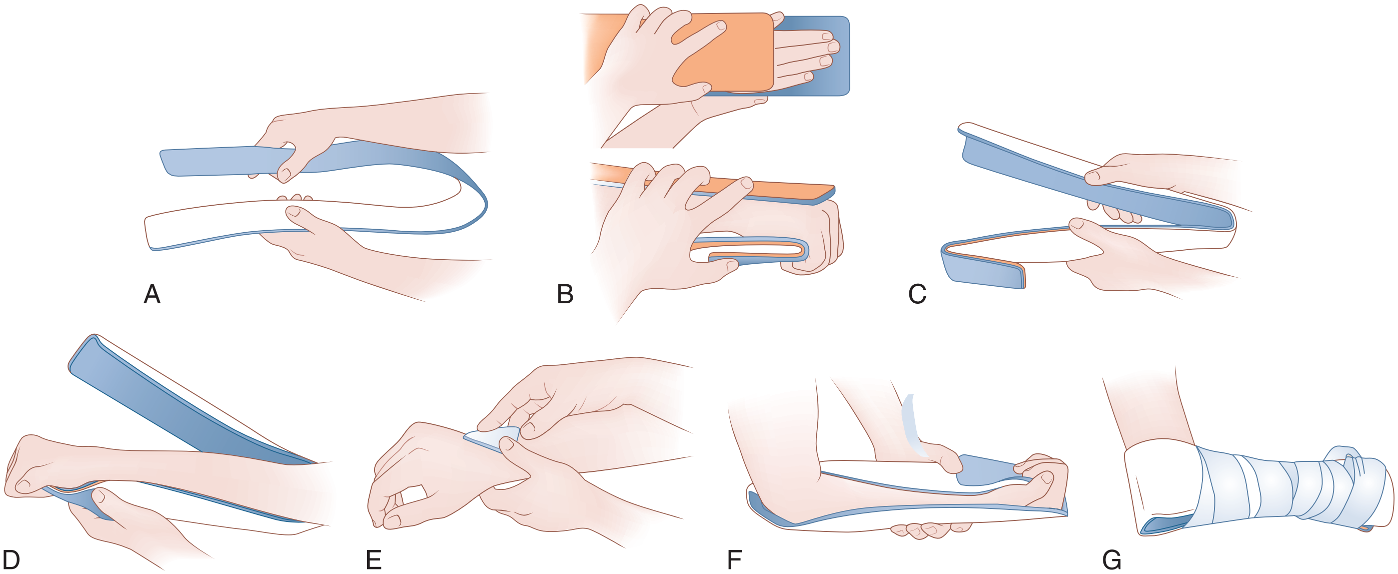
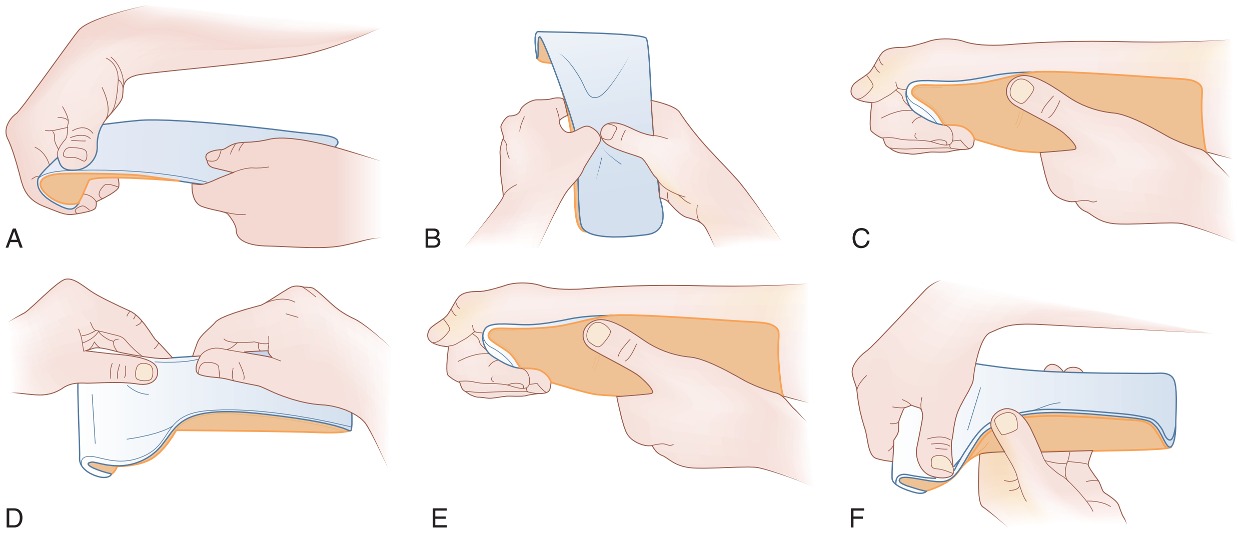



**FIGURE 23-46** Sugar-tong splint. **A,** Fold a 36-inch SAM Splint in half. **B,** To determine the proper length, fold the splint around the patient's elbow to the knuckles. **C,** Form a C-curve in each half of the splint, but no more than two-thirds of the way down each half. **D,** Shape the splint to fit, using your own arm as a template. **E,** Pad any bony prominences around the wrist and elbow. **F** and **G,** Fit and secure the splint with wrap or tape. *(Courtesy SAM Medical Products.)*

**FIGURE 23-47** Improvised sugar-tong splint with SAM Splint. *(Courtesy Terry O'Connor, MD.)*



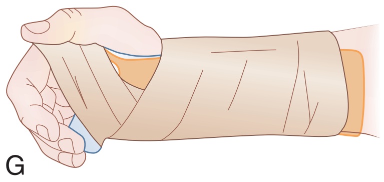




**FIGURE 23-48** Volar wrist splint. **A.** Roll the end of a 9-inch SAM Splint for children or an 18-inch splint for adults over to provide comfort for the patient's fingers. **B,** Apply a C-curve. **C,** Mold the splint into a position of function, using your own wrist as a template. **D**, Create a generous curve for the base of the thumb. **E,** Fold up the ulnar side for additional strength. **F** and **G,** Apply and secure the splint with wrap or tape. *(Courtesy SAM Medical Products.)*

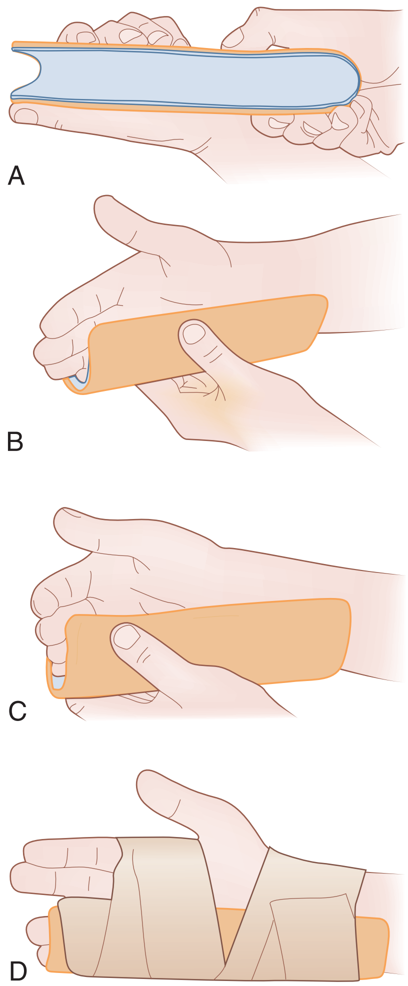



**FIGURE 23-49** Ulnar gutter splint. **A,** Fold a 9-inch SAM Splint longitudinally. **B,** Mold the splint into a desired shape, using the ulnar aspect of your own wrist and hand as a template. **C,** Apply the splint to the patient. **D,** Make fine adjustments to the splint, and secure it with wrap or tape. *(Courtesy SAM Medical Products.)*

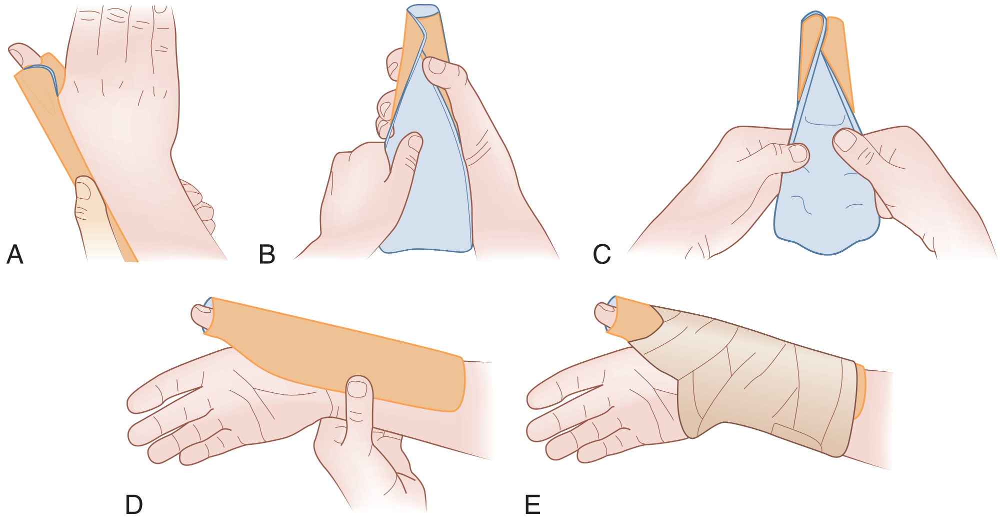



**FIGURE 23-50** Thumb spica splint. **A,** Use a 9-inch SAM Splint. **B,** Use your hand and thumb to mold the splint to create a generous curve for the thumb. **C,** Add a reverse C-curve to strengthen the splint. **D** and **E,** Apply and secure splint with tape or wrap. *(Courtesy SAM Medical Products.)*

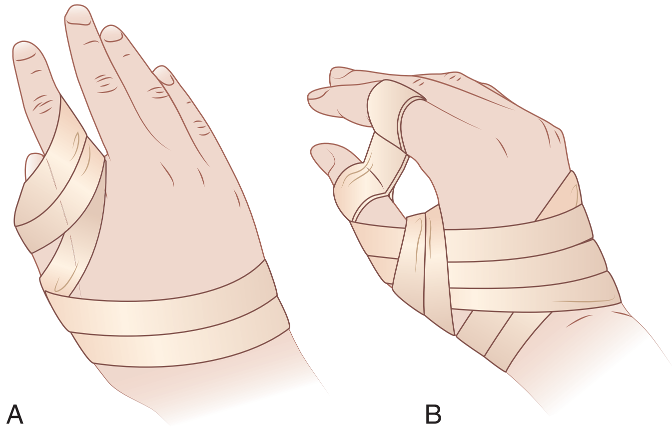



**FIGURE 23-51** Thumb immobilization taping. Taping the thumb for immobilization. **A,** The buddy-taping method. **B,** A thumb lock. If possible, padding should be placed between the thumb and forefinger.

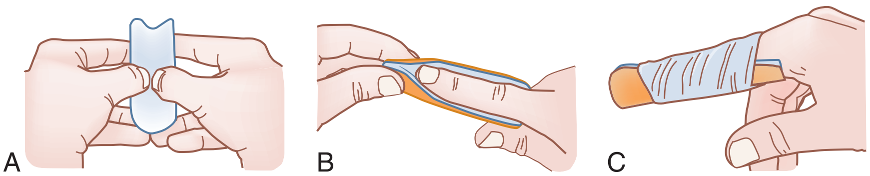



**FIGURE 23-52** Finger splint. **A,** Form a C-curve. **B,** Place the affected finger into the curved splint, and squeeze the tip to make a fingertip guard. **C,** Secure the splint with wrap or tape. *(Courtesy SAM Medical Products.)*

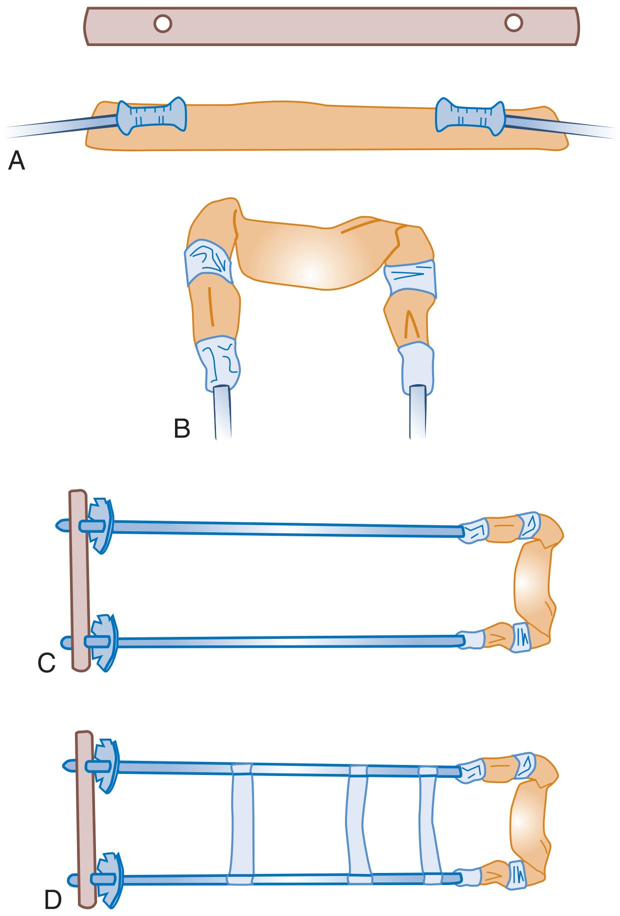



**FIGURE 23-53** Thomas half-ring femur splint. **A,** The foot support is made by cutting an 8-inch section from a ski pole. Drill or puncture two holes that are 15 cm (6 inches) apart, with the entry hole being larger. Use duct tape, cord, and safety pins to secure. Create a half-ring support by placing two ski poles, handle facing handle, on the outer thirds of a 36-inch SAM Splint. **B,** Roll the splint tightly around each handle, and secure with duct tape. Bend the splint so that the poles are now parallel and facing down. Firmly fit the pole ends through the foot support. **C** and **D,** Duct tape the thigh and calf supports, and reinforce them with cloth and elastic straps. An improvised ankle strap is required for traction. *(Courtesy SAM Medical Products.)*

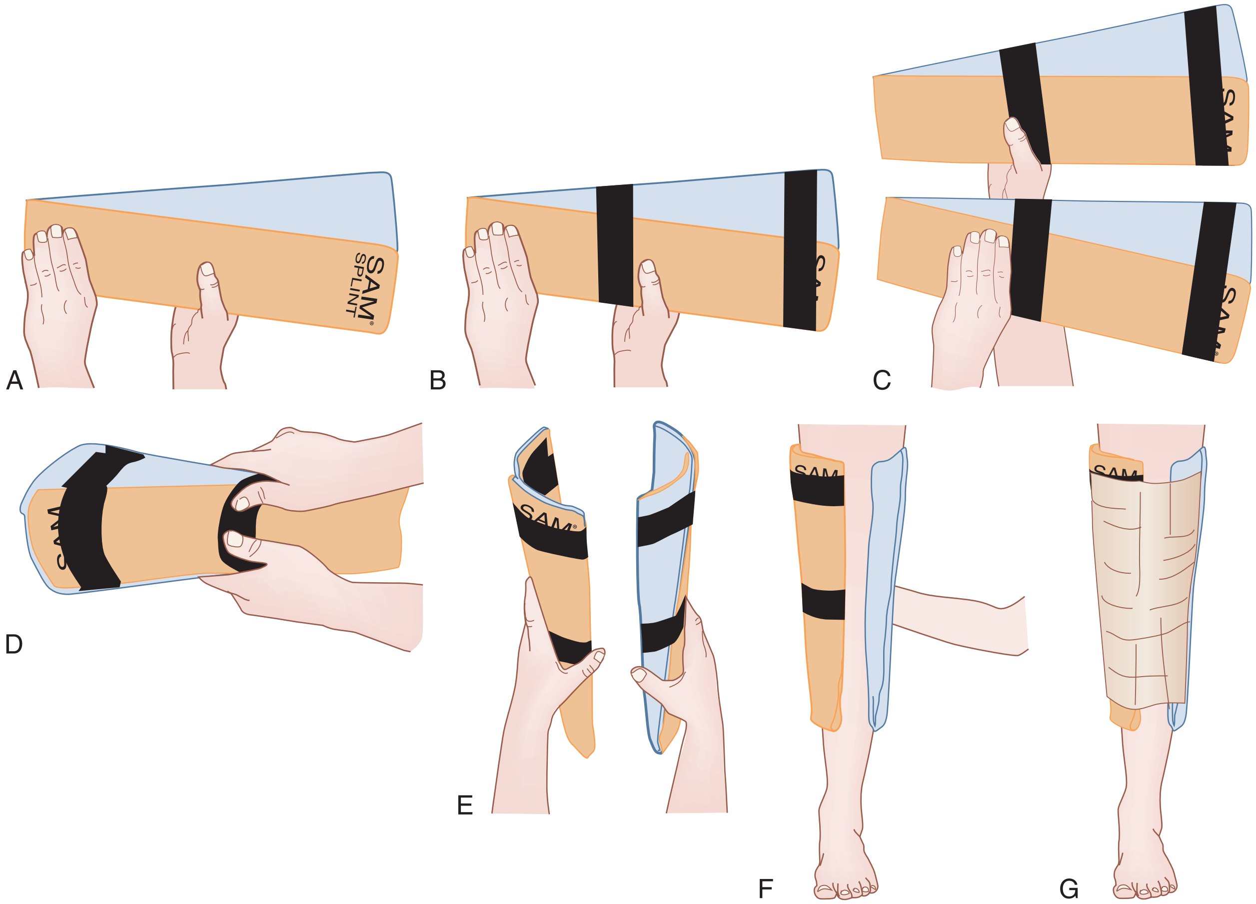



**FIGURE 23-54** Knee immobilizer splint. **A,** Fold a 36-inch SAM Splint in the center to create two equal lengths. Fan the halves so that the splint is twice as wide at one end as the other. **B,** Apply tape to the top and middle of the splint to keep the fan shape. **C,** Create a second fan-shaped splint. **D,** Form a C-curve in each splint. **E,** The C-curves should appear as shown. **F,** Place the splints on each side of the knee. **G,** Secure the splints with tape. *(Courtesy SAM Medical Products.)*

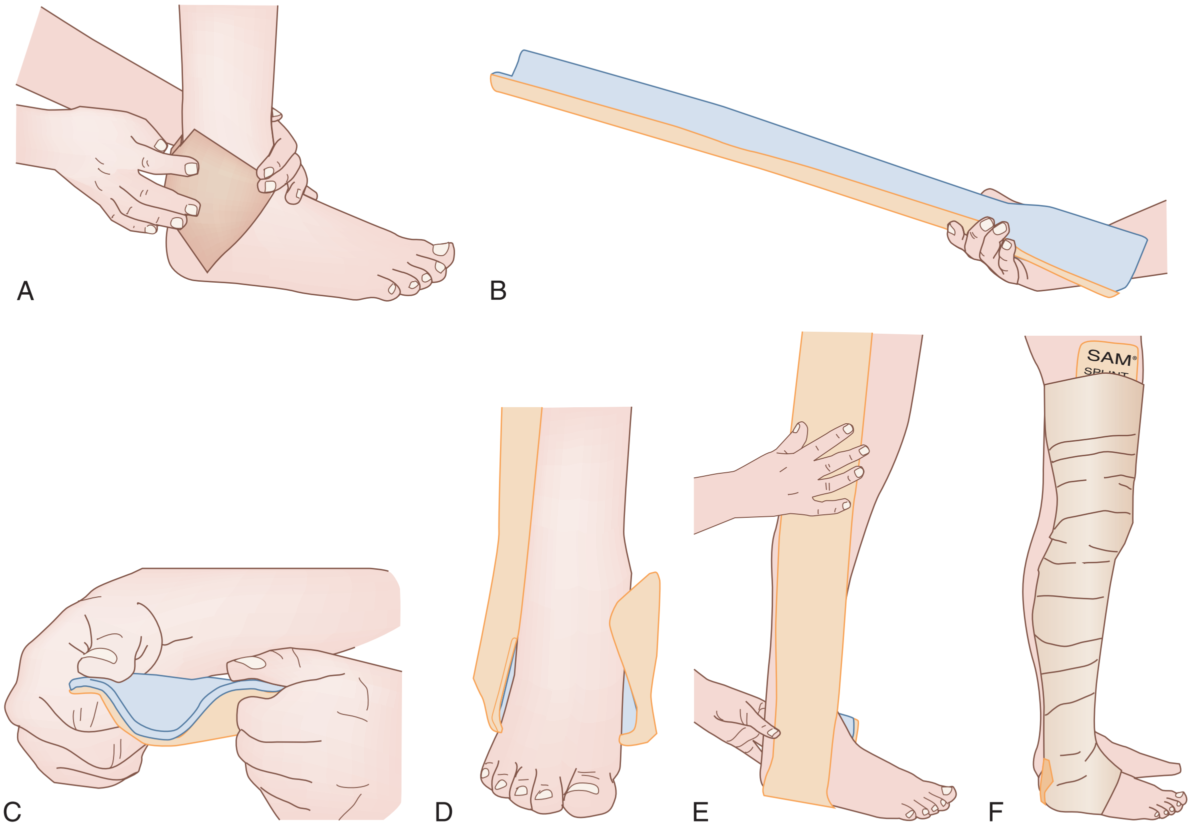



**FIGURE 23-55** Single long-leg splint. **A,** Place padding around any bony prominences on both sides of the ankle. **B,** Make a C-curve out of 30 of the SAM Splint's 36 inches, and leave the last 6 inches flat. **C,** Apply a reverse C-curve to the edges for extra strength. **D,** Place the splint against the outside of the leg, and fold the last 6 inches under the foot. **E,** Adjust the splint to fit the leg. **F,** Secure the splint with wrap or tape. (A double long-leg splint is made by repeating steps **B** to **F** so that the splints are on both sides of the leg.) *(Courtesy SAM Medical Products.)*

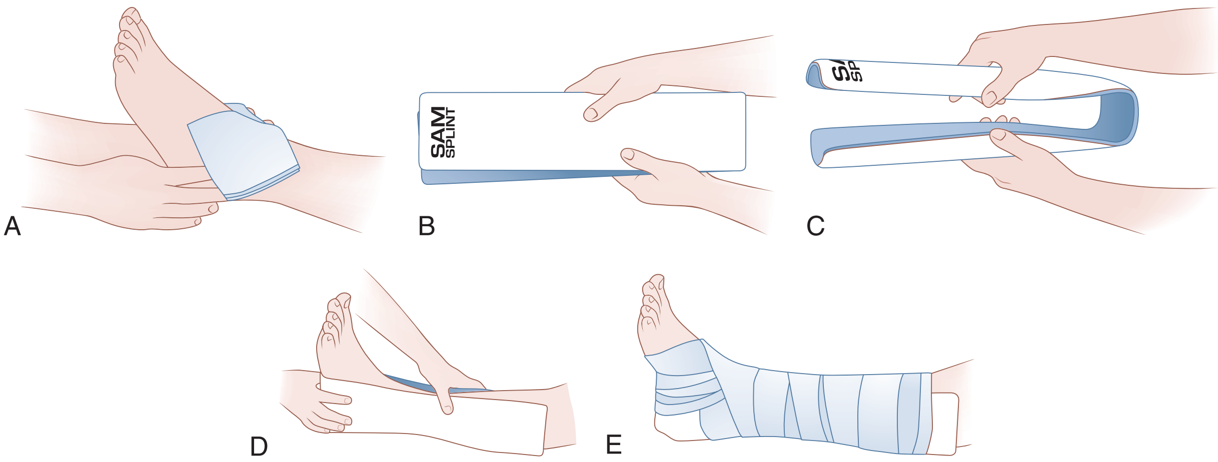



**FIGURE 23-56** Ankle stirrup splint. **A,** Pad any bony prominences. **B,** Fold a 36-inch SAM Splint in half. **C,** Apply C-curves two-thirds of the way down each half. Add reverse C-curves for strength. **D,** Fold the stirrup splint around the foot and ankle. **E,** Secure the splint with tape or wrap. *(Courtesy SAM Medical Products.)*

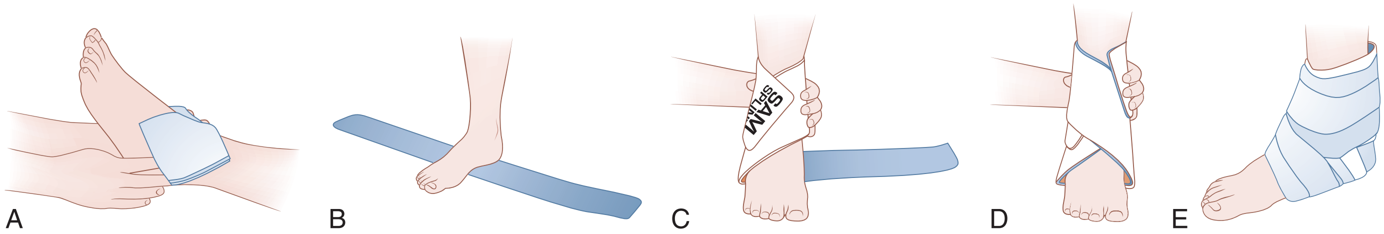



**FIGURE 23-57** Figure-of-eight splint. **A,** Pad any bony prominences. **B,** Lay a 36-inch SAM Splint flat. Put the patient's foot in the middle, with the splint just in front of the heel. **C,** Conform one side of the splint around the ankle. **D,** Repeat with the other side of the splint around the opposite side of the ankle. Crimp to fit. **E,** Secure the splint with tape or wrap. *(Courtesy SAM Medical Products.)*

## LEG FRACTURES

Long-leg splints are used for tibial and fibular fractures. Depending on the amount of stabilization needed, a single or double long-leg splint can be applied. The double long-leg splint offers more stabilization (Figure 23-55).

## ANKLE AND FOOT INJURIES

Ankle stirrup and figure-of-eight splints provide immobilization of ankle injuries. The ankle stirrup splint can also be used for fractures (Figures 23-56 and 23-57). The combination of an ankle stirrup splint and a figure-of-eight splint offers maximal support. This is done by first applying the figure-of-eight splint and then adding the ankle stirrup splint. This procedure could potentially be used for weight-bearing metatarsal fractures.[46]

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

CHAPTER 24

# Taping and Bandaging

GATES RICHARDS

Taping and bandaging are essential skills in wilderness medicine. Taping can support injured joints and soft tissues; bandaging is most often used to secure a wound dressing (Figure 24-1). Bandaging with an elastic wrap can be an alternative to taping. Over larger joints (e.g., the knee), it is often preferable.

Taping requires practice and experience, but certain simple techniques can be easily mastered. Taping is most often used for mild to moderate sprains and strains where some functional capacities (e.g., weight bearing and lifting) are maintained. Taping offers limited dynamic support but is in no way comparable to splinting, which is intended to immobilize an extremity. White athletic or "adhesive" tape used by athletic trainers in organized sports is most commonly used. Athletic tape may be applied to the skin, although adhesion may be lost if the body part is not shaved and if tape adhesive is not applied.

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FIGURE 24-1 Athletic tape *(front row)* and elastic bandages *(back row)* come in many sizes.

Some keys to successful taping include the following:

- Tape that has been exposed to the elements (cold, wetness, direct sunlight) degrades quickly. Keep medical tape inside a first aid kit to ensure viability.
- Apply tape to clean and dry skin. It may be necessary to wait until shelter is available to create an effective taping system.
- Avoid leaving any gaps in the tape (i.e., allowing any skin to be visible). These gaps lead to blisters. Avoid excessive tension on tape strips that serve to fill such gaps.
- Apply tape to follow skin contours in order to avoid wrinkles.
- Try to overlap one-half of the width of the tape with each successive strip or wrap.

Bandaging is accomplished with either elastic wraps or gauze rolls of varying widths. After a dressing is applied to a wound, appropriate bandaging allows the patient to feel confident that the dressing will remain secure during activity.

Regardless of the method used, it is important to remember that taping and bandaging, especially when circumferential, should not be so tight as to limit circulation.

# TAPING

## TYPES OF TAPE

Athletic tape is composed of fibers that are woven into strips and coated with an adhesive compound. Most commonly colored white, athletic tape is available in many colors and used in sports and first aid for support and prevention of injuries. It is available in many widths and is versatile. Its major disadvantage is the tendency to lose adhesive properties from exposure to heat and moisture, thereby resulting in loss of functional support. We describe a variety of techniques used to increase durability of athletic tape under these conditions.

Elastic tape (e.g., Elastikon) is cotton elastic cloth tape that incorporates a rubber-based adhesive. Elasticity of this tape allows greater flexibility, so it is particularly useful for large joints such as knees and shoulders.

Though backcountry travelers will often have access to other sorts of tape (e.g., duct tape or electrical tape), these products are not ideal for supporting injuries. These nonmedical tapes lack the breathability and flexibility to be useful in the medical context. Adhesives on nonmedical tape are more prone to causing skin reactions, increasing patient discomfort.

Most commercially available first aid kits are usually stocked with only one roll of either 1- or 2-inch athletic tape. The following techniques will require travelers to carry sufficient taping material to meet anticipated needs in the backcountry.

### Skin Preparation

Skin preparation increases patient comfort as well as longevity of tape adhesion. Before tape is applied directly to skin, first gently shave to remove hair that may interfere with direct contact.


FIGURE 24-2 Tincture of benzoin comes in several different forms. Pictured is a single-use applicator.

Take care to avoid creating skin abrasions when shaving. These can serve as entry sites for infection. If the area cannot be shaved in a clean and deliberate manner, avoid shaving. Cover any preexisting wound with a thin layer of gauze or a small adhesive bandage before taping.

Skin adhesives are available in aerosolized or individual applicator form. These preparations (e.g., Tuf-Skin) use benzoin (Figure 24-2) as the adhesive. Skin adhesive is applied after the skin has been shaved and after all abrasions have been dressed.

If the area is not shaved, a foam underwrap or prewrap (Figure 24-3) is used to cover body hair. Prewrap rolls are available in a 3-inch width. After application of a topical skin adhesive, prewrap is applied over the part to be taped in a simple, continuous circular wrap. Prewrap is sufficiently self-adherent and does not need to be taped.

Tape applied over bony prominences can create tension on the skin surface that causes blistering. Use heel-and-lace pads and foam pads to prevent blisters and provide additional comfort by relieving potential pressure points. Heel-and-lace pads (Figure 24-4) are prefabricated pieces of white foam that are adhered together with petroleum jelly and applied to the anterior and posterior aspects of the talus before the ankle is taped. Pads of foam can be cut to size to fit over painful areas that need to be taped (e.g., for medial tibial stress syndrome) or used for support in special cases (e.g., for patellar subluxation).

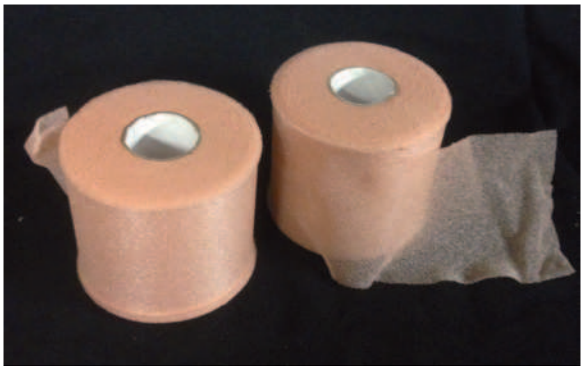


FIGURE 24-3 Prewrap or underwrap can be applied before taping to minimize skin irritation.


**FIGURE 24-4** Heel **(A)** and lace **(B)** pads can be applied to add comfort.

## ANKLE TAPING

The most common injury to the lower extremity while hiking is a sprained ankle, typically the result of inverting the ankle on an unstable surface. If the patient is able to bear weight, taping can offer support. Because most injuries occur to the lateral ligaments, taping supports the lateral surface by restricting inversion. Taping the ankle consists of anchor strips on the lower leg and foot, stirrups that run from medial to lateral underneath the calcaneus, and support from either a figure-of-eight or heel-lock technique (Figure 24-5). Heel lock requires expertise to perform, so most operators are initially more comfortable with the figure-of-eight technique.

## TOE TAPING

Taping toes that are sprained or fractured is simple and effective. This treatment involves “buddy taping” to the adjacent toe with one or two pieces of tape to provide support. A small piece of gauze, cotton, or cloth should be placed between the toes to avoid skin breakdown.

Sprain of the first metatarsophalangeal joint, known as *turf toe,* can be painful and become a chronic condition. The goal of taping for turf toe is to support and stabilize the joint (Figure 24-6).

## LOWER-LEG TAPING

Medial tibial stress syndrome, commonly called *shin splints,* can be taped for support and comfort. Tape is brought from a lateral to a medial direction. A small foam pad can be placed to cover the area of tenderness. Underwrap should be used over a foam pad to secure the pad in place (Figure 24-7).

## KNEE TAPING

Because the knee is a large joint, taping requires advanced expertise. Underwrap should not be used, because adequate traction to support the joint can only be achieved by taping directly to the skin. The patient’s knee should be shaved 6 inches above and below the joint line. Standard athletic tape should not be used, because it cannot provide sufficient support. Three-inch–wide elastic tape provides the foundation. Taping for injuries of the medial aspect of the knee is shown in Figure 24-8. For injuries of the lateral aspect of the knee, mirror the process described.

## PATELLA TAPING

Subluxation of the patella is exacerbated by the stress of walking long distances across uneven terrain. Incorporating a piece of foam into taping the knee can help to relieve symptoms. As with all taping around the knee, underwrap should not be used (Figure 24-9).

## FINGER TAPING

Injuries to fingers are common. Simple fractures and sprains can be initially treated by taping. The most common scenarios involve fingers that are hyperextended or that are “jammed.” Injuries in this scenario are often to the palmar ligaments and tendons. Patients may find it difficult to flex the finger against resistance of an examiner’s finger, or may demonstrate tenderness over the palmar aspect of the finger. Swelling is almost always present, so the precise injury may be difficult to diagnose without imaging. This presentation is also seen after reduction of a dorsal dislocation of the proximal interphalangeal joint. In these cases, it is best to splint or tape the finger in slight flexion to avoid further injury to the flexor apparatus.

Fingers are buddy taped to the adjacent finger, which serves as a splint (Figure 24-10). Second and third fingers and fourth and fifth fingers are always paired. If third and fourth fingers are paired, this makes injury to the second and fifth fingers more likely with subsequent activity.

A small piece of gauze, cotton, or cloth should be placed between fingers to avoid blistering or pressure on a tender joint. Strips of tape should be applied around the fingers but not over the joints.

Although not as common, extensor tendon injuries may occur. These typically result from hyperflexion, but may also occur with hyperextension and axial loading.[2] “Mallet finger” results from

FIGURE 24-5 Ankle taping. **A,** With ankle bent 90 degrees, apply anchors of 1.5-inch–wide tape at the lower leg and distal foot. **B,** Apply three stirrups from a medial to a lateral direction in a slight fanlike projection. **C,** Fill in any gaps with horizontal strips. **D,** Begin the figure-of-eight technique. Apply tape across the front of the ankle in a left-to-right direction. **E,** Continue taping under the foot to the opposite side, and cross back over the top of the foot. **F,** Complete by wrapping tape around the leg, and end at the anterior aspect of the ankle. **G,** Apply heel locks for both feet (omit if not familiar with this technique). Start in a lateral to medial direction, and apply tape across the front of the joint. **H,** Wrap tape around the heel (the bottom margin of the tape should be above the superior edge of the calcaneus) to form the first heel lock. **I,** Continue under the foot to the opposite side and cross back over the top of the foot. **J,** Tape is then brought back around the superior margin of the calcaneus and down and around the heel. **K,** Finish by wrapping tape around the ankle. Repeat the figure-of-eight or heel-lock technique as desired.

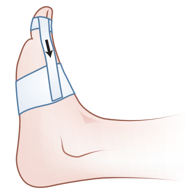
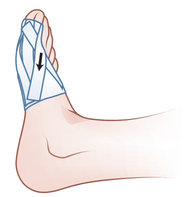
| | |
|---|---|
| 1. Apply two anchors: Place the first anchor around the IP joint of the first toe with 1-inch tape. Place the second anchor around the midfoot with $1^1/_2$-inch tape. |  |
| 2. Apply a strip of 1-inch tape from the distal to proximal anchor along the medial aspect. |  |
| 3. Continue with a strip of 1-inch tape from the lateral edge of the distal anchor along the plantar aspect of the first MTP joint to the medial aspect of the proximal anchor. |  |
| 4. Cross with a strip of 1-inch tape extending from the medial aspect of the toe to the plantar aspect of the proximal anchor. |  |
| 5. Begin dorsal strips by applying 1-inch tape from the medial aspect of the distal anchor across the dorsal aspect of the MTP joint to the proximal anchor. |  |
| 6. Cross over the previous strip by applying 1-inch tape from the lateral aspect of the distal anchor to the medial aspect of the proximal anchor. |  |
| 7. Close with 1-inch strips around the toe and $1^1/_2$-inch tape around the forefoot. |  |

**FIGURE 24-6** Toe taping.

fracturing the base of the distal phalanx, which is the site of attachment for the extensor tendon. The resulting inability to fully extend the distal phalanx results in a partially flexed finger. Injuries in which the extensor mechanism is clearly disrupted should be treated with the finger taped in full extension. A straight splint (e.g., a tongue blade or smooth stick) can be placed on the dorsal or volar surface and the finger taped to it for additional support in extension (Figure 24-11).

## THUMB TAPING

The thumb is frequently injured when forced into extreme extension or abduction (e.g., when caught in the strap of a ski pole when a person is falling). Taping can prevent reproducing the mechanism of injury, particularly when the individual is grasping an object (Figure 24-12).

## WRIST TAPING

Wrist sprain generally occurs during a fall. It can initially be difficult to distinguish from a fracture. Although splinting is usually the most desirable treatment, two basic taping approaches can be used. This choice is guided by whether the wrist was injured by hyperextension or hyperflexion. First, place anchors around the palm and distal wrist. Place support strips to prevent undesirable movements, on the palmar aspect for hyperextension injuries or dorsal aspect for hyperflexion injuries (Figure 24-13).

## ELBOW TAPING

Soft tissue injury to the elbow most commonly results from hyperextension or excessive valgus force. These ligament and tendon injuries may be significant. Taping techniques prevent reproduction of painful movements while maintaining function. Because these techniques allow for substantial joint movement, underwrap should not be used, and tape should be applied directly to the skin to allow for maximal adhesion. Taping for a hyperextension injury uses a fan of tape, similar to that used for the wrist, to prevent excessive extension (Figure 24-14).

Individuals who have suffered valgus stress injuries require reinforcement with elastic tape placed on the medial aspect of the elbow (Figure 24-15).

## SHOULDER TAPING

Taping the glenohumeral joint is rarely performed because it results in such significant restriction of movement that the patient cannot effectively function. An exception to this is to tape the

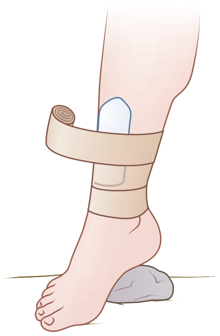
| | |
|---|---|
| 1. (Optional) Underwrap is applied over a foam pad. |  |
| 2. With the patient placing his or her heel on a rock or roll of tape, begin applying $1^1/_2$-inch tape from the superior margin of the malleoli to the calf. |  |

**FIGURE 24-7** Lower leg taping.

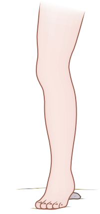
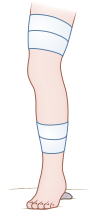
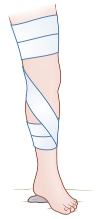
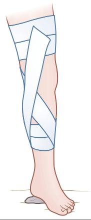
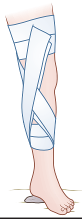
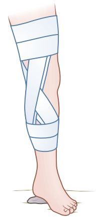
| | |
|---|---|
| 1. The patient maintains the knee in slight flexion (10-15 degrees) by placing the heel on a small stone or cap of a spray can. |  |
| 2. Apply two anchor strips of 3-inch elastic tape 6 inches above and below the joint line. |  |
| 3. Apply a strip of 3-inch elastic tape from the anterolateral aspect of the lower leg, across the knee joint and up to the posteromedial aspect of the thigh. |  |
| 4. Apply a second strip from the posterior calf to anterior thigh, forming an X. |  |
| 5. Repeat steps 3 and 4 twice. |  |
| 6. Apply two additional anchor strips of 3-inch elastic tape 6 inches above and below the joint for closure. |  |
| 7. (Optional) Wrap a 6-inch elastic bandage from mid-calf to mid-thigh to cover the tape and provide additional support. |  |

**FIGURE 24-8** Knee taping. The procedure illustrated is for medial injuries. Mirror the process for lateral injuries.

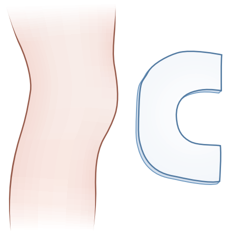
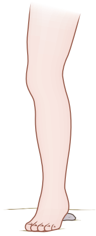
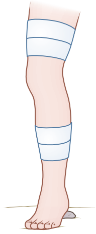
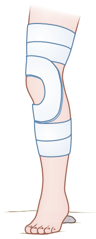
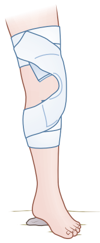
| | |
|---|---|
| 1. Cut a piece of foam into a C shape, measured to encircle one-half of the patient's patella. |  |
| 2. The patient maintains the knee in slight flexion (10-15 degrees) by placing the heel on a small stone or cap of a spray can. |  |
| 3. Apply two anchor strips of 3-inch elastic tape 4 inches above and below the patella. |  |
| 4. Apply the foam pad cut to fit the patient's patella. Elastic tape (3-inch) is applied in a manner that reproduces the curvature of the foam pad. |  |
| 5. Starting from the medial aspect of the lower leg anchors, bring the elastic tape around the lateral aspect of the patella and back to the medial aspect of the upper leg anchors. |  |
| 6. (Optional) Wrap a 6-inch elastic bandage from mid-calf to mid-thigh to cover the taping and provide additional support. |  |

**FIGURE 24-9** Patella taping.

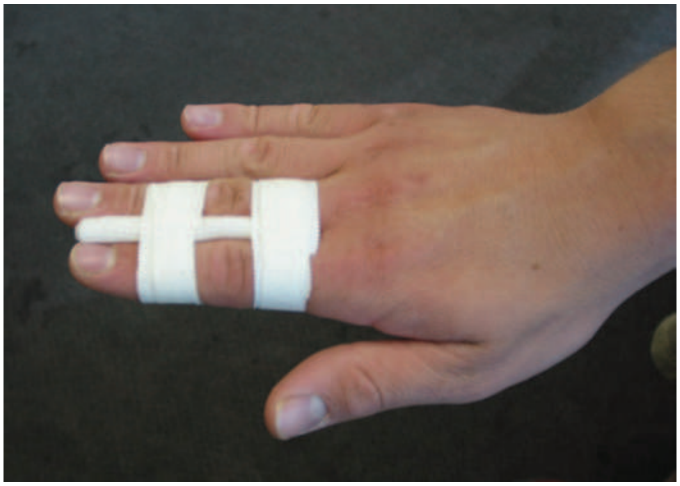


FIGURE 24-10 Buddy taping of the fingers.

acromioclavicular joint to reduce pain and maintain adequate function. Injury to the acromioclavicular joint commonly occurs when a patient falls on the lateral aspect of the shoulder. Tearing or rupturing the acromioclavicular ligament results in an "AC sprain" or "separated shoulder." For this injury, tape should be applied directly to the skin (Figure 24-16).

# BANDAGING

Bandaging may be used to wrap and support an injury or to help dress a wound. Many of the techniques described in the previous sections about taping (e.g., use of figure-of-eight patterns) are also used for bandaging.

## TYPES OF BANDAGES

The type of bandage used depends on the intended purpose. Elastic bandages (e.g., Ace wraps) come in many widths and are used to wrap injuries such as sprains and strains. These bandages generally are secured by separate or built-in clips. Of note, a double-length 6-inch–wide elastic bandage is quite useful for wrapping large joints such as the knee and the shoulder. Vet wrap (e.g., Coban) provides a self-clinging variation of elastic bandages that can be used in a similar fashion (Figure 24-17).

Bandaging wounds generally involves rolled gauze or cotton-based wraps, which secure a dressing in place (Figure 24-18). For wound care, these wraps are more desirable than are elastic bandages because they place less tension on the dressing. A triangular bandage, which is often used to create a sling, can be folded two to three times into a strap called a *cravat* (Figure 24-19). Cravat dressings are useful for applying pressure to a bleeding wound to promote hemostasis.

Whether using an elastic bandage for support or using rolled gauze or cotton bandages to secure a wound dressing, the same methods may be used. Any special techniques for wound care are described separately.

### Securing Bandages

Bandages are not adhesive and must be secured with tape or clips or by tying them to the body. When wrapping is complete, the bandage is tied off in the following way:

1. Bend the free end of the bandage backward over your fingers to create a loop. Double back around the body part, and tie the remaining free end to the loop to secure the bandage[1] (Figure 24-20).
2. Tear or cut the remaining portion of the bandage lengthwise down the middle. Double back with one of the resulting strips, and then tie off the bandage.

## ANKLE AND FOOT BANDAGING

Ankle bandaging with an elastic wrap 2 to 3 inches wide can support a sprain. Apply the bandage over a sock or directly to the skin. It is simplest to use a series of figure-of-eight wraps. A series of heel locks, described in the section on ankle taping, may also be used. In this application, anchors and stirrups are not used. When bandaging the foot, the same technique should extend to the metatarsophalangeal joint. Isolated circumferential foot bandaging often results in bandage slippage. This is less likely when the ankle is also bandaged.

## KNEE BANDAGING

A double-length 6-inch–wide elastic bandage can provide support to the knee. Have the patient place the heel on a small stone or a piece of wood to hold the knee in slight flexion (Figure 24-21A). Apply elastic wrap circumferentially from the midquadriceps to the midcalf (see Figure 24-21B). If using gauze or an elastic wrap of a smaller width to secure a dressing, a series of figure-of-eight wraps can be applied, leaving the patella exposed.

## THIGH AND GROIN BANDAGING

Quadriceps, hamstring, and hip-adductor (i.e., groin) strains can be treated with an elastic bandage in a hip spica configuration. Bandaging is modified slightly for a groin strain (Figure 24-22).

Although the quadriceps and hamstrings can be supported by wrapping only the leg with a 6-inch–wide elastic bandage, the hip spica configuration helps prevent bandage movement and provides additional support.

*Text continued on p. 528*

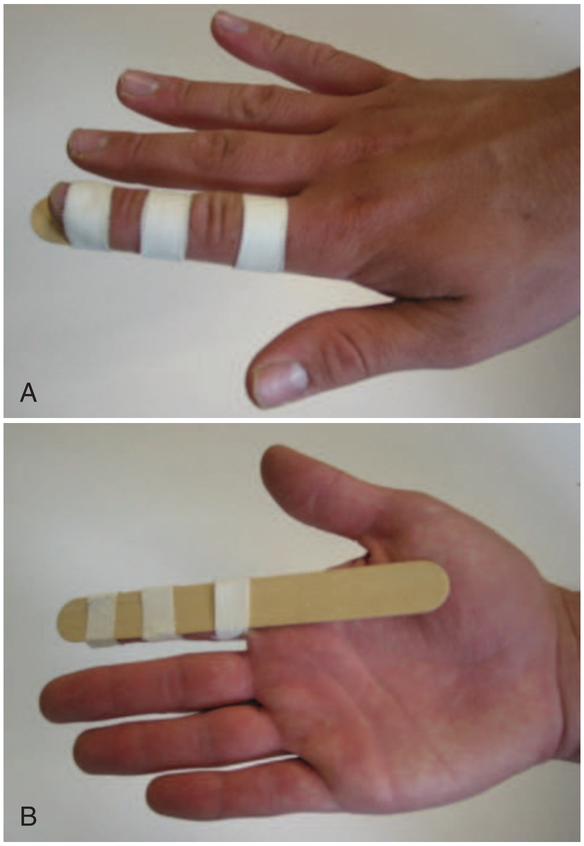



FIGURE 24-11 **A** and **B,** Extension taping of the finger with a small splint.


**FIGURE 24-12** Thumb taping. **A,** Use 1.5-inch–wide athletic tape to wrap an anchor strip around the wrist. **B,** Using 0.75-inch–wide tape, start at the volar aspect of the wrist and continue along the dorsal aspect of the thumb toward the first web space. **C,** Allow patient to crimp tape as it comes across the web space and continue around the base of thumb. **D,** Bring tape around to the volar aspect of the wrist and tape at that point. To complete a thumb spica, apply several more strips of tape in succession. To reinforce this, continue as follows. **E,** Apply an anchor strip from the volar to dorsal aspect of wrist through the first web space; note crimping. **F,** Apply a strip from the dorsal to volar aspect of the anchor strip. **G,** Apply successive strips until the wrist is reached. **H,** Add a finishing anchor strip through the first web space. **I,** Complete wrapping with an anchor strip at the wrist.

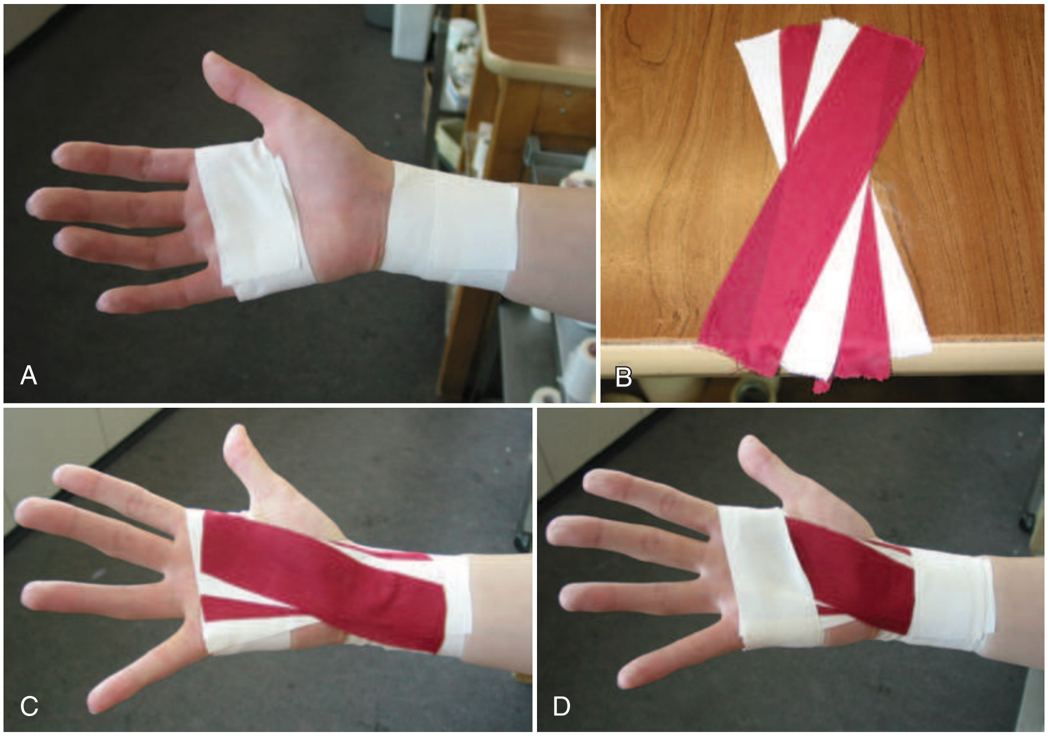



FIGURE 24-13 Wrist taping. **A,** With the hand wide open, apply one anchor across the palm of the hand and two to three anchors across the distal forearm. **B,** Measure out the distance between the two anchors, and construct a fan of four strips at varying angles on a smooth surface. **C,** For hyperextension injuries, apply these support strips to the palmar aspect; for hyperflexion injuries, apply them to the dorsal aspect. **D,** Apply another set of anchors over the support strips.

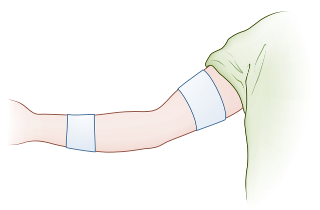
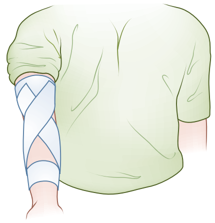
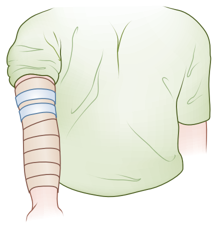
| | |
|---|---|
| 1. The arm is supinated and extended just short of where pain is experienced. Apply anchors with 3-inch elastic tape 4 inches above and below the elbow. |  |
| 2. Apply 3-inch elastic tape from distal to proximal anchors that form an X over the antecubital fossa. A total of four strips should be applied. |  |
| 3. Apply closure strips above and below the elbow over the original anchors. |  |
| 4. (Optional) Apply a 4- or 6-inch elastic bandage from distal to proximal to secure the taping. |  |

**FIGURE 24-14** Elbow taping.

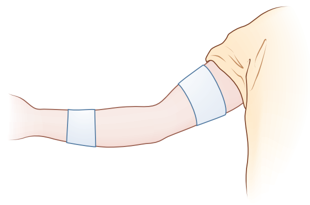
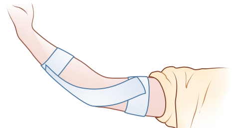
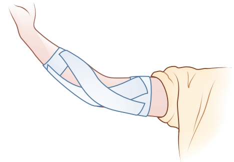
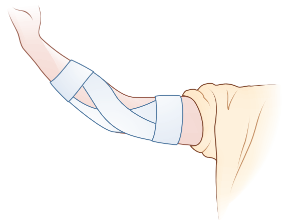
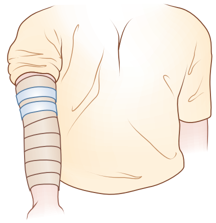
| | |
|---|---|
| 1. The arm is supinated and flexed to approximately 30 degrees. Apply anchors with 3-inch elastic tape 4 inches above and below the elbow. |  |
| 2. Apply 3-inch elastic tape that forms an X over the medial joint line.<br>The first strip begins at the posterior aspect of the proximal anchor and crosses to the anterior aspect of the distal anchor.<br>The second strip begins at the anterior aspect of the proximal anchor and crosses to the posterior aspect of the distal anchor.<br>Apply a total of four strips. |   |
| 3. Apply closure strips above and below the elbow over the original anchors. |  |
| 4. (Optional) Apply a 4- or 6-inch elastic bandage from distal to proximal to secure the taping. |  |

**FIGURE 24-15** Elbow taping for a valgus stretch injury.

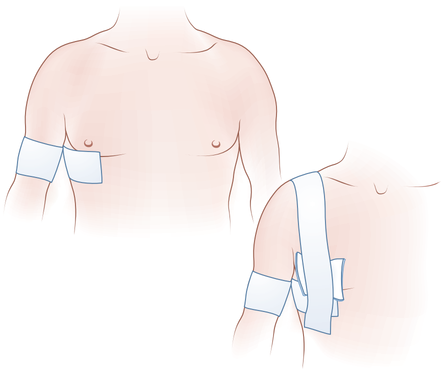
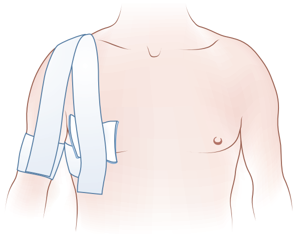
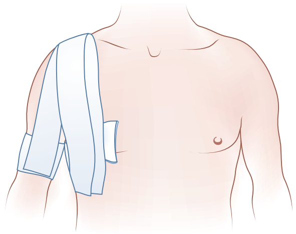
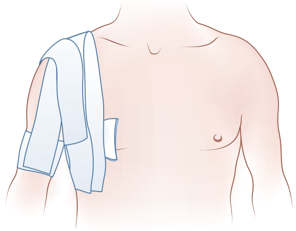
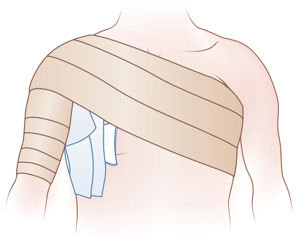
| | |
|---|---|
| 1. Apply three anchor strips with 3-inch elastic tape.<br><br>Place the first anchor around the mid-humerus.<br><br>Place the second anchor beginning inferior to the nipple anteriorly and around to the inferior tip of the scapula posteriorly.<br><br>Apply the third anchor from the anterior portion of the second anchor, over the trapezius and extending to the posterior portion of the second anchor. Note that a 3-inch gauze pad is incorporated into this anchor to protect the nipple. |  |
| 2. Apply a longitudinal strip of 3-inch elastic tape from the anterior aspect of the first anchor, over the acromioclavicular joint and ending on the posterior aspect of the third anchor. |  |
| 3. Apply the next strip overlapping two-thirds of the third anchor laterally. It should extend from posterior to anterior portions of the second anchor and cross over the acromioclavicular joint. |  |
| 4. Apply the next strip from the posterior aspect of the first anchor, over the acromioclavicular joint and ending at the anterior aspect of the third anchor. |  |
| 5. Repeat steps 2 through 4 two more times.<br><br>(Optional) Wrap a 6-inch elastic bandage in a shoulder spica for additional support. (See Bandaging section.) |  |

**FIGURE 24-16** Shoulder taping.

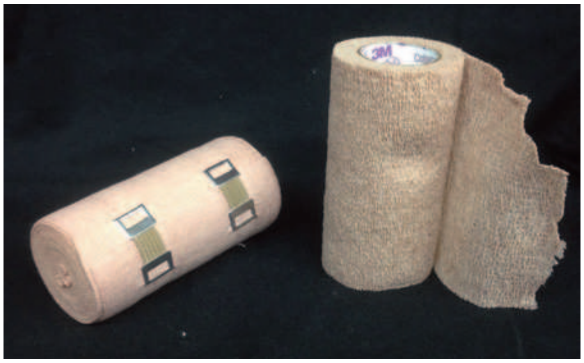


FIGURE 24-17 A standard elastic wrap *(left)* and self-clinging vet wrap *(right)*.

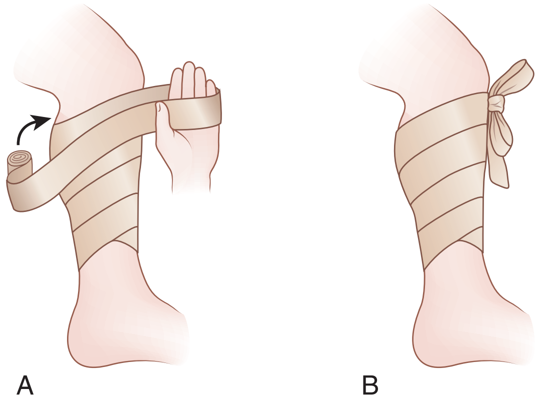



FIGURE 24-20 **A** and **B,** Securing a bandage. *(Redrawn from Donelan S: It's a wrap: wound care and bandaging,* Ski Patrol Magazine, *21(2), Winter, 2005.)*

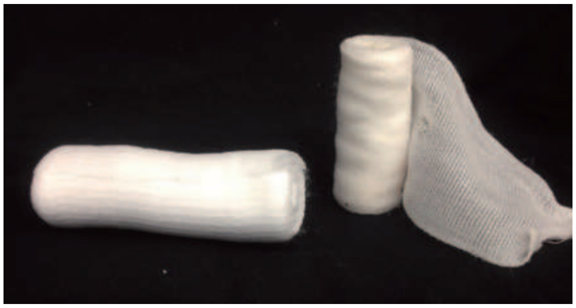


FIGURE 24-18 Gauze rolls.

## WRIST AND HAND BANDAGING

Wrist support can be supplied by using an elastic wrap 2 to 3 inches wide with a continuous wrapping technique (Figure 24-23). Using gauze, this same technique can secure a dressing to a wound on the palm of the hand. A hand cravat bandage can be used for wounds that continue to bleed despite manual pressure[1] (Figure 24-24).

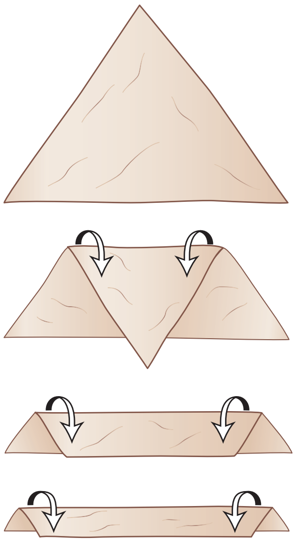


FIGURE 24-19 Making a cravat from a triangular bandage. *(Redrawn from Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

## FINGER BANDAGING

Finger wounds are generally easily treated with adhesive bandages. If wound size or continued bleeding necessitates a larger dressing, the following method may be used. Fold a 1-inch–wide piece of rolled gauze back and forth over the tip of the finger to cover and cushion the wound (Figure 24-25). Wrap the gauze around the finger until it is snug. On the last turn around the finger, pull the gauze over the top of the hand so that it extends beyond the wrist. Split this gauze tail lengthwise, and tie the ends around the wrist to secure the bandage.

## THUMB BANDAGING

Application of a bandage or dressing to the thumb usually involves a thumb spica, as described in the previous section on taping. A gauze or elastic bandage should be looped continuously rather than applied in individual strips.

## SHOULDER BANDAGING

A shoulder spica is used to support shoulder sprains, strains, and subluxations (Figure 24-26). A triangular bandage can be used to dress a shoulder wound (Figure 24-27).

## SCALP BANDAGING

Scalp wounds often require a dressing to be placed over hair, which makes adhesion very difficult. The dressing can be secured with a triangular bandage in a method that allows for considerable tension if pressure is necessary to stop any bleeding (Figure 24-28).

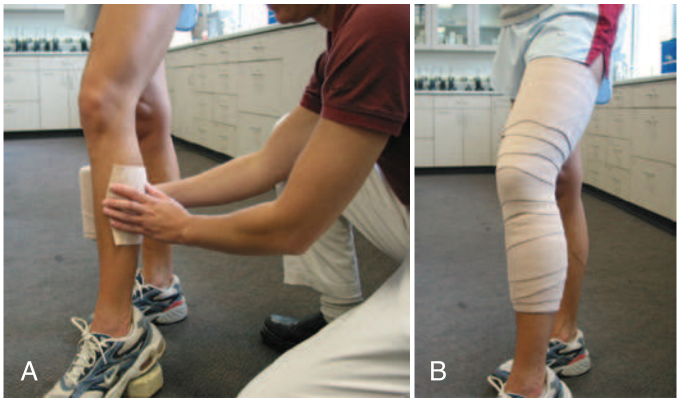



FIGURE 24-21 **A,** Knee positioned in slight flexion with a heel lift while a bandage is applied. **B,** Completed knee bandaging.

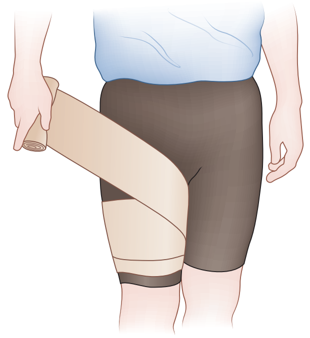
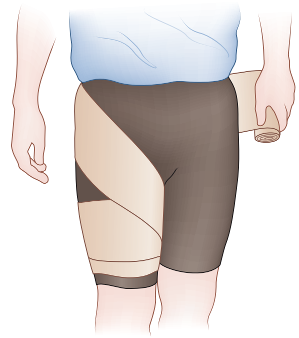
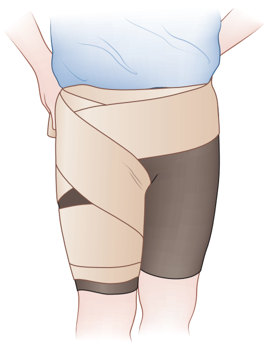
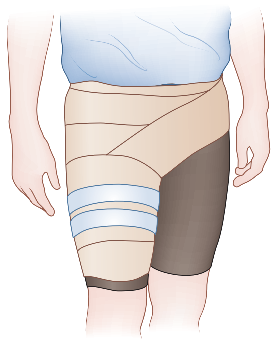
| | |
|---|---|
| 1. Wrap a double-length 6-inch elastic bandage around the mid-thigh in a medial to lateral direction and continue proximally. |  |
| 2. At the groin crease, continue up and around the waist once to help anchor the bandage. |  |
| 3. Return to the thigh to complete the figure-8.<br><br>For quadriceps and hamstring strains, concentrate on wrapping the leg, using an additional figure-8 bandage to anchor the wrap.<br><br>For groin strains, concentrate on supporting the hip adductors by alternating wrapping the leg with figure-8 wraps. |  |
| 4. Finish wrapping the leg. |  |

**FIGURE 24-22** Thigh and groin bandaging.

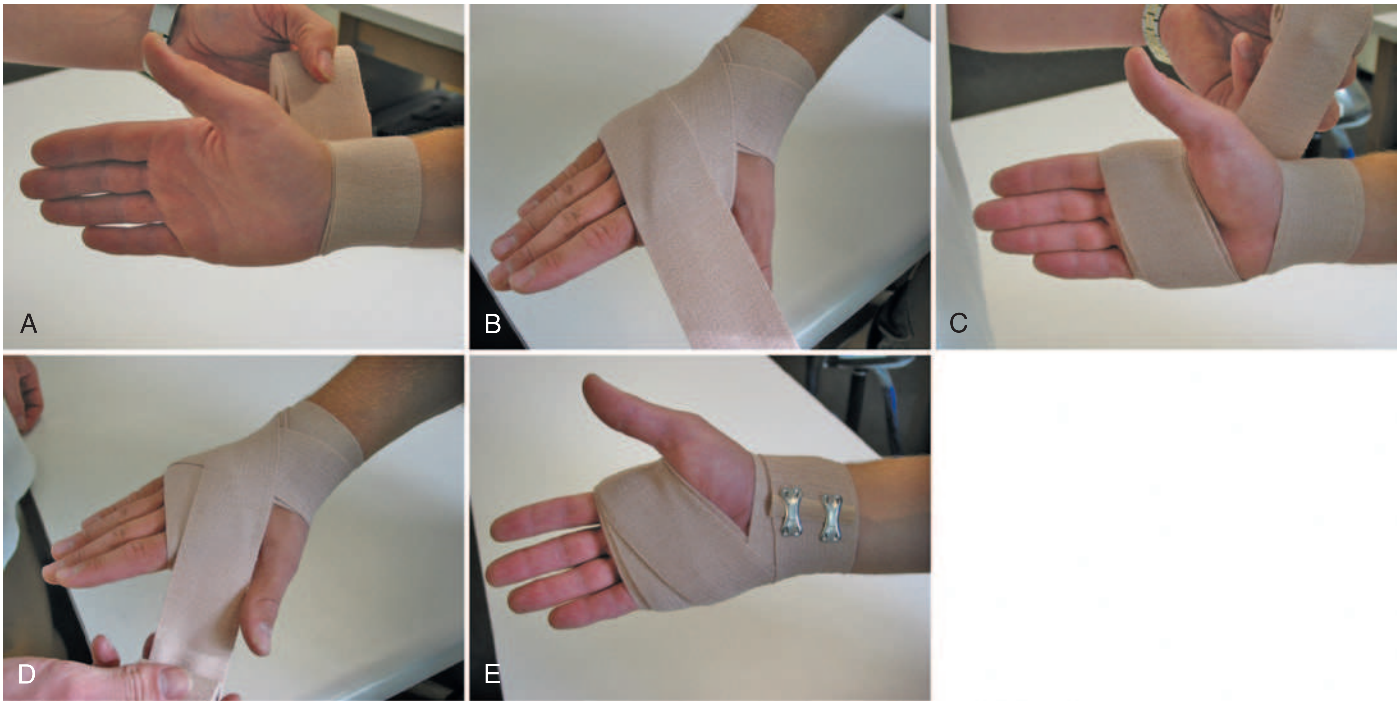



FIGURE 24-23 Wrist bandaging. **A,** Begin by encircling the wrist with the bandage two to three times. **B,** Continue bandaging across the dorsum of the hand, through the first web space, and around the base of the proximal phalanges. **C,** Continue down and across the dorsum of the hand. **D,** Circle the wrist, and bring the bandage across the dorsum of the hand to form a figure-of-eight. **E,** Repeat these steps, and make alternating figure-of-eight patterns on the dorsum of the hand. Secure the bandage at the wrist.

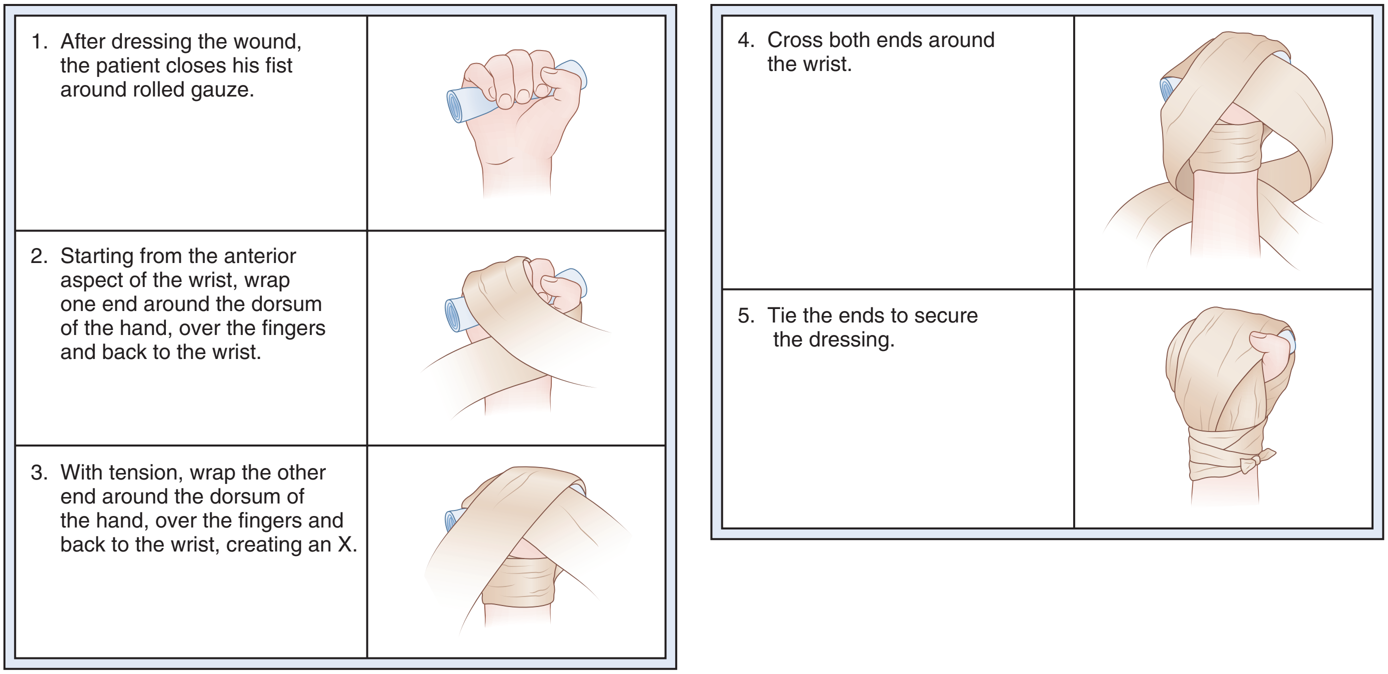



FIGURE 24-24 Hand cravat bandage. *(Redrawn from Donelan S: It's a wrap: wound care and bandaging,* Ski Patrol Magazine *21(2), Winter, 2005.)*

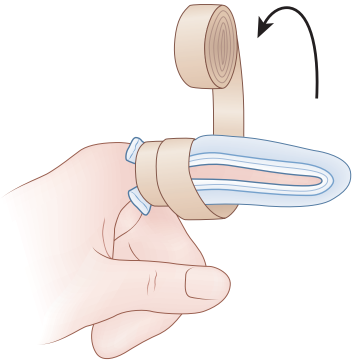


**FIGURE 24-25** To begin a finger bandage, place layers of gauze over the fingertip. *(Redrawn from Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

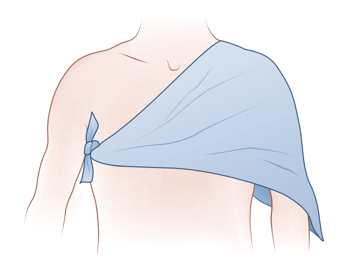
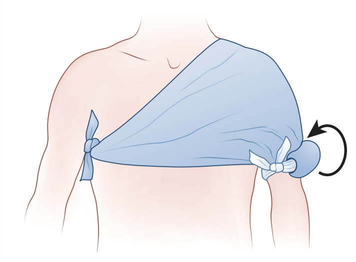
| | |
|---|---|
| 1. Lay the base of the bandage over the shoulder with the apex pointed toward the arm. Tie the two free ends just anterior to the axilla. |  |
| 2. Roll the apex up the arm to the desired point of coverage and tie off. |  |

**FIGURE 24-27** Shoulder bandaging with a triangular bandage. *(Redrawn from Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

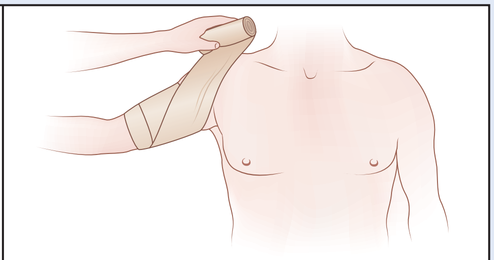
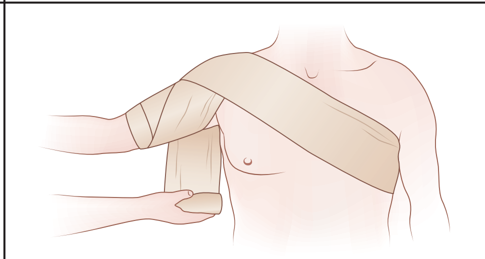
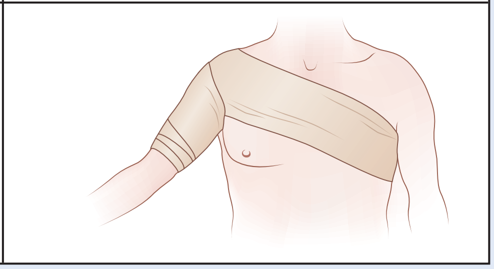
| | |
|---|---|
| 1. Begin by encircling the mid-humerus with a double-length 6-inch elastic bandage and continue proximally while wrapping. Once near the axilla, wrap over the acromioclavicular joint and around the posterior thorax. |  |
| 2. Continue under the opposite axilla, across the chest and bring down over the acromioclavicular joint and onto the upper arm. |  |
| 3. Repeat the figure-8 pattern as the length of the bandage allows and finish on the upper arm. |  |

**FIGURE 24-26** Shoulder bandaging.

1. Drape a triangular bandage just over the eyes and fold the edge 1 inch under to form a hem. Allow the apex to drop over the back of the neck.
2. Cross the free ends over the back of the head and tie in a half-knot.
3. Bring the free ends to the front of the head and tie a complete knot. At the posterior aspect of the head, tuck the apex into the half-knot.

FIGURE 24-28 Scalp bandaging. *(Redrawn from Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

1. Place the cravat over the wound at the cravat's midpoint. Wrap one end over the head and the other under the chin.
2. Cross the cravat just above ear level and wrap ends in opposite directions.
3. Tie off the ends.

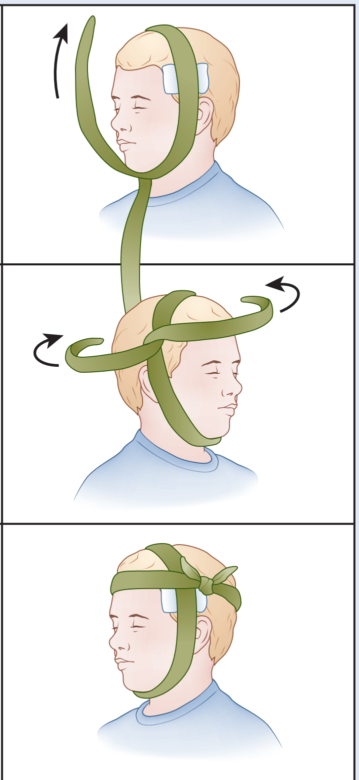


FIGURE 24-29 Ear or side of head bandaging. *(Redrawn from Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

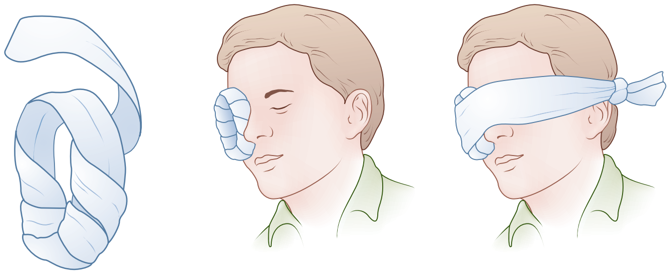


FIGURE 24-30 Bandaging for the injured eye. A cravat or cloth is rolled and wrapped to make a doughnut-shaped shield, which is fixed in place over the eye. *(Redrawn from Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

FIGURE 24-31 To hold an eye patch in place with a cravat, hang a cloth strip over the uninjured eye. Hold the patch in place with the cravat, and tie the cloth strip to lift the cravat off of the uninjured eye. *(Redrawn from Auerbach PS.* Medicine for the outdoors: the essential guide to first aid and medical emergencies, *ed 6, Philadelphia, 2016, Elsevier.)*

## EAR OR SIDE OF HEAD BANDAGING

A wound to the pinna of the ear or other location on the side of the head may require a compression dressing. If the ear is involved, gauze should be placed both anterior and posterior to the ear to provide for compression while allowing the ear to maintain its natural curvature. This helps prevent hematoma formation and necrosis of auricular cartilage. A cravat is used to secure the dressing (Figure 24-29). This method may be used for wounds anywhere along the side of the head or under the chin.

## EYE BANDAGING

To bandage an eye, place a shield over the eye socket to protect the globe, and apply a bandage over the shield. The shield may be a commercially available sterile pad, or may be cut from foam or felt, stacked gauze, or a shirt or cravat that has been fashioned into a doughnut shape (Figure 24-30). The bandage is fashioned from a cravat and a spare piece of 15-inch–wide cloth or a shirt. Spare cloth is placed over the top of the head from a posterior to anterior direction so that the anterior portion lies over the unaffected eye. A cravat is applied horizontally to hold the shield over the injured eye. To expose the uninjured eye, pull up both ends of the spare cloth and tie them at the top of the head (Figure 24-31).

# REFERENCES

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

## REFERENCES

1. Donelan S. It's a wrap: wound care and bandaging. Ski Patrol Magazine 2005;21(2).
2. Lairmore J, Engber W. Serious, often subtle, finger injuries. Phys Sports Med 1998;26:57.

CHAPTER 25

# Foot Problems and Care

GRANT S. LIPMAN AND BRIAN J. KRABAK

*The human foot is a masterpiece of engineering and a work of art.* *Leonardo da Vinci*

## BLISTERS OF THE FOOT

The American Alpine Club estimates that there are more than 100,000 climbers in the United States, who spend 1 to 2 million annual days on their feet.[23] When one combines this number with the annual estimate of 73.3 million hikers (roughly one-third of the population) and 24 million backpackers,[55] it is no surprise that friction foot blisters are the most commonly encountered problem in wilderness medicine. For some, a foot blister may be merely a nuisance; for others, it may ruin an outing, necessitate immobility, or lead to cellulitis or sepsis (Figure 25-1).[27,42]

Blistering rates in the outdoor community range from 54% of wilderness backpackers[81] to 64% of long-distance hikers on the Appalachian Trail.[4] The incidence of blisters in marathons ranges from 0.2% to 39%[44] and is as high as 76% to 100% in multistage ultramarathon runners.[41,42,69] Blisters were the most common factor adversely affecting race performance in single-stage ultramarathon finishers.[28] Foot care–related problems represent the most commonly reported injuries in both multistage ultramarathons and expedition-length adventure races, at 74%[37] and 33% to 45%, respectively.[45,80]

In the military, foot problems are recognized as among the most common training complications and preventable debilitating injuries. In 1895, the Duke of Connaught reported 824 cases of blistered feet during maneuvers in New Forest, England.[78] Forty-eight percent of cadets at the U.S. Military Academy reported blisters during a short training hike,[35] as did more than 65% of military personnel after a 10-km (6.2-mile) road march.[39] During a 12-month period of active duty in Operation Iraqi Freedom Phase 1, the incidence of foot blisters was 33%.[6] Although most blisters are considered to be of minor medical significance, they can impair concentration, decrease athletic performance, and lead to debilitating infections. A Navy recruit population was found to have an 84% incidence of cellulitis secondary to foot blisters, with an average loss of 8 full training days per case.[27] A study of more than 2000 U.S. Marine recruits showed that those with blisters were 50% more likely to experience additional training-related injuries.[8]

### PATHOPHYSIOLOGIC FINDINGS

The earliest meaning of the word *friction,* described from 1704, is "to rub; to crumble; they injure."[48] The mechanism of a friction blister injury is repetitive action of skin rubbing against another surface. As a sock or other footwear moves across the skin, the frictional force (Ff) opposes this movement. Frictional force increases with increasing external force. When external force exceeds frictional force, movement occurs at the interface. In addition to the magnitude of frictional force, the frequency of an object cycling across the skin contributes to a higher probability of blister development.[53] There is an inverse relationship between these variables: when frictional forces are higher, it takes fewer cycles to form blisters.[1,11,12,53]

The skin surface is subjected to normal forces (Fn); perpendicular forces, or "force of contact;"[36] and nonperpendicular, or tangential shear, forces (Figure 25-2). The magnitude and relationship of a frictional force are defined by the formula

$$Ff = \mu \times Fn$$

where μ is the coefficient of friction minus the ratio of shear to normal force that must be overcome to initiate movement of material relative to skin.[67] There is wide variation in the coefficient of friction between the skin and various substances (Table 25-1), and frictional properties of skin depend on inherent suppleness and hydration, as well as external factors that include temperature and humidity.[85]

Shear forces extend horizontally between skin layers (Figure 25-3), the skin and sock interface, different socks, and socks and other footwear. When forces overcome resistance, sliding occurs. Repeated sliding at a friction point causes exfoliation of the stratum corneum and erythema in and around this zone.[36,53] This is experienced as an initial sensation of heat, known as the "hot spot." Continued friction on a hot spot causes epidermal cells in the stratum spinosum to delaminate and split.[2,76] With continued rubbing, a sensation of stinging or burning occurs as a narrow pale area forms around the central reddened region. This enlarges inward.[36] The skin becomes elevated as underlying epidermis fills with fluid, and a blister is created (Figure 25-4).[76] The intact superficial cells of the stratum corneum and stratum granulosum form the blister's "roof." The separated cleft under the blister roof fills with a low-protein, electrolyte-rich transudate as a result of hydrostatic pressure.[14] The underlying basal skin layer and associated epidermal-dermal interface are usually unaffected and undamaged.

Healing of a blister occurs rapidly if one can reduce further friction and exacerbation of injury. At 6 hours, cells at the blister base increase the uptake of amino acid and nucleoside, precursors of RNA and DNA. After 24 hours, there is high mitotic activity in the wound, and at 48 hours, new stratum granulosum can be seen. By 120 hours, a new stratum corneum has been made.[20] With ongoing friction and pressure when continued ambulation and activity are unavoidable, the blister needs assistance to heal.

### BLISTER PREVENTION

A normal perpendicular force directed between the foot and insole is determined by the weight of the hiker plus any weight being carried. An increased body mass index has been found to be a significant risk factor for the number of blisters developed in multistage ultramarathons.[42] In backpackers, reducing the magnitude of normal forces that cause a friction blister can be as simple as reducing the carried load.[2] Another way to minimize force is to use a padded insole or an arch support. There are myriad available generic and custom-moldable insoles. Although an insole or orthotic does not technically reduce perpendicular forces on the feet, it helps to more evenly distribute pressure over the foot's plantar surface. Greater pressure occurs when there is a high load on a smaller surface area, causing that area of skin to be susceptible to blister formation.

Increasing or decreasing the ease with which two surfaces rub against each other can reduce blister development. If the coefficient of friction is small, the resulting frictional force will be minimized, with greater ease of sliding and reduction of shear forces and hence less blister formation. Another option is to maximize frictional forces through well-fitted footwear, resulting in little or no movement at the skin-surface interface.

**TABLE 25-1** Laboratory Product Comparison of the Coefficient of Friction Using a Custom-Made Friction Measurement Apparatus (2006)

| Product | Manufacturer | Average CoF* | Difference (%)† | Thickness (mm) | No. of Tests |
|---|---|---|---|---|---|
| Bursatek bandage | Advanced Wound Systems, Newport, OR | 0.57 | — | 6 | 3 |
| Dr. Scholl's Moleskin Plus | Schering-Plough Corp, Kenilworth, NJ | 0.69 | +21 | 31 | 3 |
| Moleskin | PPR, Inc., Brooklyn, NY | 0.94 | +64 | 26 | 3 |
| Band-Aid | Johnson & Johnson, New Brunswick, NJ | 1.01 | +77 | 22 | 3 |
| Band-Aid Plastic | Johnson & Johnson | 1.03 | +80 | 18 | 3 |
| 2nd Skin Blister Pads | Spenco Medical Corp, Waco, TX | 1.04 | +82 | 35 | 3 |
| New-Skin | Medtech, Jackson, WY | 1.05 | +84 | 9 | 4 |
| Nexcare Comfort | 3M Health Care, St Paul, MN | 1.08 | +89 | 35 | 3 |
| Dr. Scholl's Blister Treatment | Schering-Plough Corp | 1.20 | +110 | 32 | 3 |
| Blister Block (Compeed) | Johnson & Johnson | 1.37 | +139 | 40 | 3 |
| Tegaderm | 3M Health Care | 1.54 | +169 | 1.5 | 3 |

*CoF indicates coefficient of friction: 237-g normal applied load to end probe.
†Compared with the Bursatek device.
From Polliack AA, Scheinberg S: A new technology for reducing shear and friction forces on the skin: implications for blister care in the wilderness setting, *Wilderness Environ Med* 17:109-119, 2006.

## Reduction of Movement Within the Footwear System

Shoes or boots should fit properly and comfortably. Overly tight shoes can increase contact points of pressure. Shoes that are too loose allow excess movement, generating frictional forces. Narrow shoes can cause blisters on large and small toes. Loose shoes can create blisters on tips of toes from sliding and jamming into the toe box. A too shallow toe box can cause blisters from repeated contact on the toe tops. It is important to fit shoes in the evening because feet tend to swell throughout the day and therefore the size of the foot in the evening will be similar to the size with the natural swelling that occurs while one is active. Shoes and boots should be tried with the same socks and/or insoles or orthotics that will be used on trails. Size the boots to compensate for thicker socks. Allowing ample time to break in a new set of footwear before outdoor use increases flexibility in the material, thereby reducing potential high-friction areas.

**FIGURE 25-1** Aggressively spreading leg cellulitis. *(Courtesy Grant S. Lipman, MD.)*

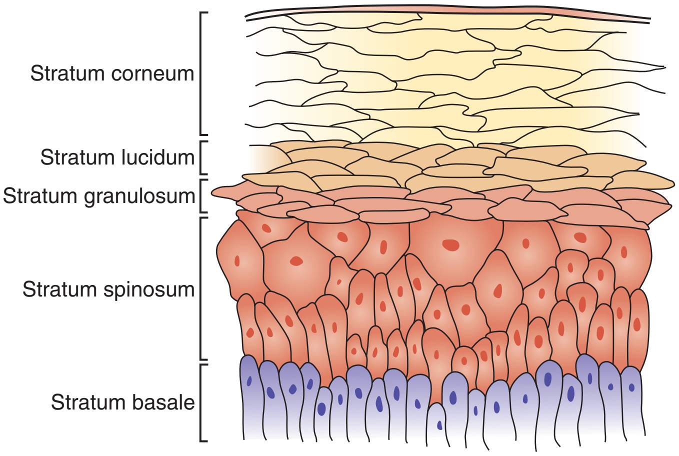



**FIGURE 25-3** Epidermal layers.

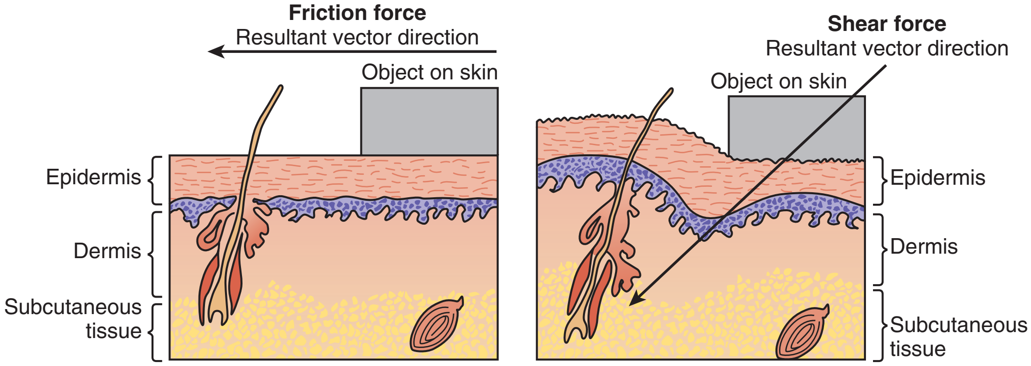



**FIGURE 25-2** Cross-sectional illustration of skin and resultant vector direction of friction force and vector direction of shear force. *(From Polliack AA, Scheinberg S: A new technology for reducing shear and friction forces on the skin: implications for blister care in the wilderness setting,* Wilderness Environ Med *17:109, 2006.)*

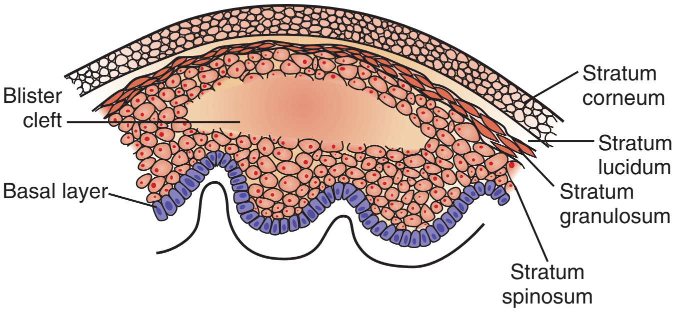



FIGURE 25-4 Longitudinal section of epidermis showing a friction blister. *(From Knapik JJ, Reynolds KL, Duplantis KL: Friction blisters: pathophysiology, prevention, and treatment,* Sports Med *20(3):136-147, 1995.)*

FIGURE 25-6 Blister-free feet after completing a 150-mile multistage ultramarathon, preceded by 2 months of prophylactic Bag Balm preparation.

### Increasing Movement Within Footwear Systems

Various combinations of layers of socks can create a nonspecific weak shear layer, exploiting coefficients of friction and minimizing friction forces against the skin itself. The goal is for friction to occur between two layers of socks, not between the skin and the socks. A smooth, thin, snug-fitting synthetic sock worn as an inner layer directly against the skin will move with the foot, whereas a thick, woven sock tends to move with footwear and cushions against shocks. Socks that have a low frictional coefficient worn close to skin have been found by computer modeling to reduce plantar shear stress. This reduction is compounded by wearing a sock that has high friction against the insole, such as a thicker woven sock.[17] This combination is used by many outdoor enthusiasts and has been found to produce the fewest blisters in military populations.[34] Thinner synthetic liner socks also assist in humidity control by retaining less moisture, and by wicking moisture and perspiration away from the skin surface.[25,26]

A longitudinal double-blind study was conducted to determine the effect of sock fiber on the frequency and size of blisters. Two different visually identical socks were tested, one with acrylic fibers and the other with 100% natural cotton fibers. Acrylic fiber socks were associated with fewer blister events and smaller blister size, compared with cotton fiber socks.[25]

### Minimizing Moisture

Repetitive rubbing on moist skin produces higher frictional forces than rubbing on very wet or dry skin.[2,53,76] Cutaneous hydration leads to an increased contact area, adhesion, and maceration, resulting in more frequent blisters (Figure 25-5). However, very wet skin has a low incidence of blister formation, likely because of the lubricating effects of water on the skin surface. Frictional forces on dry skin may exfoliate superficial cells of the stratum corneum, lubricating the feet as might graphite powder.[36]

High-technology oversocks combine waterproof materials with traditional socks to keep feet dry when they are repeatedly exposed to water. Combining Gore-Tex oversocks with wicking liner socks and foot antiperspirant reduces foot moisture. Consider adding gaiters to help eliminate mud, dirt, gravel, sand, or rocks from entering the sock-shoe system. Consistently moist skin or sweaty feet may require frequent changing of socks.

### Foot Preparation

Repeated low-intensity exposure to frictional forces results in cellular proliferation and epidermal thickening, adaptations to skin that may reduce the likelihood of developing blisters. Soft and supple feet withstand frictional stress better than do cracked, horny feet. Many podiatrists and ultraendurance athletes recommend preparing feet with a moisturizer, such as Bag Balm, petroleum jelly, or other softening agent, for months before an event (Figure 25-6). Other clinicians and athletes have the opinion that "dry is better" and take serial foot baths in povidone-iodine or tannic acid to promote epidermal proliferation and thickening.[44] Calluses should be filed down with a pumice stone or emery board to prevent them from tearing off and leaving an open wound. Blisters deep to a callus are extremely painful and difficult to drain (Figure 25-7). Toenails should be kept short and beveled downward to reduce the incidence of subungual hematomas. Before an important event or outing, consider having a professional pedicure. Having this done at least a week beforehand allows time for manipulations of the epidermis and cuticles to heal, avoiding potential bacterial entry and infection on the trail.

### Blister Prevention Compounds

Blister prevention involves decreasing shear forces on the skin. Despite extensive studies regarding the impact of shear forces

FIGURE 25-5 Moist, macerated feet. *(Courtesy Mark Ellis, MD.)*

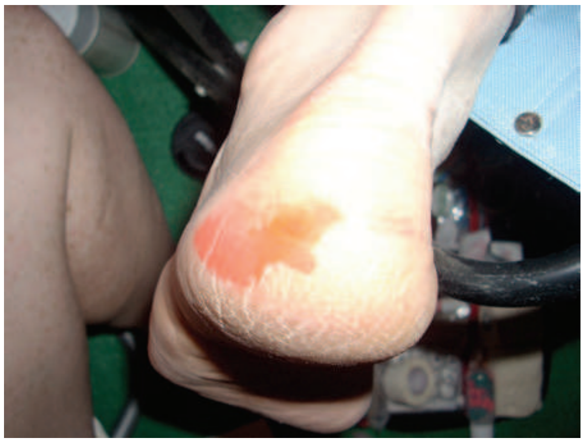


FIGURE 25-7 Subcallus blister. *(Courtesy Grant S. Lipman, MD.)*

on the development of blisters, there are few studies examining the efficacy of various modalities (e.g., powders, antiperspirants, lubricants, tapes, pads). Theoretically, each offers a distinct advantage. Lubricants, tapes, and pads are proposed to decrease friction that leads to blisters, whereas powders and antiperspirants are thought to limit perspiration and the resulting cutaneous hydration associated with activity that leads to increased blister formation. An antiperspirant works by depositing a metallic salt that dissolves at the skin surface, forming an acidic solution that hydrolyzes upon contact with more alkaline sweat, precipitating and "plugging" the acrosyringium of eccrine sweat glands.[59,60]

## Preventive Taping and Pads

A preventive barrier between footwear and any potential point of blister formation can proactively avoid a blister. Barriers are best used as preventive measures before blisters form, either at the beginning of the day or when a hot spot develops. Barriers should be adhesive so as to remain fixed despite the frictional forces, heat, or humidity present inside footwear. The concept of prevention is to have a layer over the skin so shear stresses will occur between the barrier and footwear, not between footwear and skin. The shelves of drugstores and running stores are filled with products that can be applied to areas that have historically developed blisters. These include Micropore paper tape, cloth tape, Elastikon, Kinesio tape, moleskin, Spenco Blister Pads, Blist-O-Ban, and duct tape (Table 25-2). Use of an adhesive, such as tincture of benzoin or Tuf-Skin Taping Base Spray, keeps the barrier fixed to skin. ENGO Blister Prevention Patches are smooth, fabric-film composite patches placed inside shoes or insoles. Silicone gel toecaps and sheaths reduce friction at the tips of and between toes.

Taping is a relatively easy and cost-effective method of preventing hot spots and subsequent blister injuries. Ideally, taping products should be thin and easy to apply, adhere well, and have few limited seams that could become friction points. Paper-like tape (Figure 25-8) can be easily placed over and around the toes; on the heel and plantar and dorsal aspects of the foot; or on other areas vulnerable to blisters (Figure 25-9). Due to its low cost, ease of use, and silky feel, it is the authors' first-line product for applying to a hot spot to prevent blisters. Empirically taping the entire foot has not been shown to prevent blisters and may increase the rate of blistering on toes when combined with the glove-like individually toed Injinji socks (San Diego, CA).[41] Rather, pretaping only areas where one is predisposed to develop blisters has been found to have a robust protective effect. In a multisite prospective randomized trial that analyzed 128 multistage ultramarathon runners, pretaping was found to reduce the blister incidence by 40%, with a success rate of more than 70% in both the intent-to-treat analysis and protocol-compliant groups.[42] Preventive taping with paper tape appears to be an ideal method for avoiding blisters in "at-risk" areas, with the caveat that paper tape will likely need to be reapplied after becoming moist.


**FIGURE 25-8** Paper tape. *(Courtesy 3M Corporation, St. Paul, MN.)*

**FIGURE 25-9** Paper tape prophylactically applied to prevent hot spots. *(Courtesy Mark Ellis, MD.)*

**TABLE 25-2** Foot Care Tapes and Pads

| Product | Description | Advantage |
|---|---|---|
| Blist-O-Ban | Ultrathin patented BursaMed dome reported to decrease forces along skin by deflecting forces away from skin; useful over hot spots or mild blisters | Ultrathin, easy to apply, hypoallergenic, multiday use, water resistant |
| Compeed | Sterile hypoallergenic plaster reported to protect vulnerable skin from friction damage | Easy to apply, water resistant, flexible, multiday use |
| Duct tape | Polyethylene tape with flexible shell and pressure-sensitive adhesive quality; however, not very breathable and difficult to remove; may be used over any surface | Strong, easy to apply, multiday use |
| Elastikon | Flexible tape made of a porous high-twist, cotton elastic cloth tape with a rubber-based adhesive; useful over heels and plantar surface of foot | Breathable, easy to apply to uneven surfaces |
| Leukotape | Slightly thicker tape with zinc oxide and rayon backing; may be used over any part of foot | Breathable, easy to apply |
| Micropore paper tape | Breathable pressure-sensitive adhesive tape; useful for preventive taping and underneath thicker tape; however, not well suited for wet environments | Easy to apply and remove, hypoallergenic, multiday use |
| Moleskin | A heavy cotton fabric sheared on one side with adhesive backing on the other; useful over relatively even surfaces to offset direct pressure on large blisters | Easy to apply, hypoallergenic |
| Spenco 2nd Skin | Series of products ranging from nonwoven cotton tape to a hydrogel pad designed to assist with fluid absorption and wound healing; pads are very useful for complicated blisters without any skin cover | Easy to apply, hypoallergenic, multiday use |

**FIGURE 25-10** Wrinkled duct tape that promotes blister formation.

Elastikon is a sturdy, wide tape that may be used over the plantar and dorsal surfaces of feet and heels. Because this tape has a rough surface like athletic cloth tape, it should not be used on the toes, because it may induce blisters on adjacent toes. Duct tape is used with variable success in areas such as the heel. However, there are innate qualities that make duct tape suboptimal for blister prevention. It is nonporous, leading to increased moisture retention and maceration of skin beneath the tape; it wrinkles easily, causing pressure points (Figure 25-10); and the adhesive backing sticks too well, so that when the tape is removed, the epidermis may also be removed. Detailed taping techniques are discussed in the blister treatment section of this chapter.

Like taping, pads (which are a combination of an adhesive dressing with a central thicker composite pad) are relatively easy to apply to prevent or treat developing blisters, particularly over smooth surfaces such as the Achilles or metatarsal area. However, pads are usually bulkier than tape, making them more difficult to apply on uneven surfaces or in small areas, such as between toes. Improper application can lead to excessive friction around the product and epidermal injury. Pads are much more expensive than tape and take up more space in a pack, limiting their use on multiday trips where weight and space may be at a premium. Compeed, a product made popular by British athletes, is notorious for its strong adhesive (Figure 25-11); this becomes apparent when layers of epidermis may be removed along with the bandage (Figure 25-12).

The adhesive bandage Blist-O-Ban has been prospectively studied affixed at individualized blister-prone sites (e.g., the heel or metatarsal head). The product appears to decrease the incidence of new blisters in treated feet compared with untreated feet and adheres well in humid conditions. These studies did not

**FIGURE 25-11** Removing a Compeed bandage placed over a blister, showing strong adhesive qualities. *(Courtesy Grant S. Lipman, MD.)*

**FIGURE 25-12** Torn epidermis resulting from Compeed bandage removal. *(Courtesy Grant S. Lipman, MD.)*

address blister formation in the intertriginous spaces, which can be difficult to treat with abrasive or bulky dressings.[62,71]

Moleskin is a product that has been a fixture in hikers' first-aid kits for generations (Box 25-1). The technique for using Moleskin is to affix a doughnut-shaped patch around a hot spot or blister, securing the material with irritated epidermis in the opening, so that friction will act on the perimeter of felt-like material rather than on the hot spot. Although large or open heel blisters may benefit from being surrounded by Moleskin or Molefoam (Figure 25-13), we do not recommend this family of products for treatment or prevention of hot spots or blisters. Anecdotally, it has a high failure rate and is difficult to anchor, and the volume of product in a well-fitted shoe box may cause a "contrecoup" blister on toes or even under Moleskin itself because of its high coefficient of friction.[57]

### Antiperspirants and Powders

Antiperspirants and powders (Table 25-3) have been proposed as preventive measures to decrease moisture at the foot-sock interface. Study findings are inconsistent with regard to foot perspiration and blister prevention. A small, prospective, nonblinded study assessed the effectiveness of two different aluminum-based antiperspirants in reducing sweat accumulation and preventing blisters. Each subject applied antiperspirant and completed a 1-hour treadmill march in a warm environment. Overall, subjects experienced a decrease in foot-sweat accumulation of more than 50% and a nonsignificant trend toward fewer blisters; however, there was an increased incidence of irritant dermatitis.[18] A randomized study of 23 healthy males examined the impact of antiperspirants with emollients by applying a 20% aluminum-based antiperspirant with an emollient additive, an emollient alone, or nothing for 4 days before ambulating on a treadmill for 4 hours in a warm environment while carrying a load. All groups experienced a similar incidence of blisters and sweat accumulation with no reported skin irritation.[63] The largest of these antiperspirant studies was a double-blind trial of 667 U.S. military cadets randomized to either a 20% aluminum-based antiperspirant or a

**BOX 25-1** Personal Foot Care Kit

- Safety pins
- Alcohol swabs or squares
- Benzoin swabs or squares
- Spenco 2nd Skin burn pads (in resealable bag)
- Lubricant
- Paper tape
- 10-cm (4-inch) Elastikon roll
- Small roll of duct tape
- Small scissors
- 18-gauge needle

FIGURE 25-13 Moleskin donut. *(Courtesy Paul Langer, DPM.)*



placebo for 5 days before a short hike. For compliant subjects who used the preparation for at least 3 nights, the incidence of blister formation was 21% in the antiperspirant group versus 48% in the placebo group. The results were tempered by a 57% incidence of skin irritation in the antiperspirant group, compared with 6% for the placebo group.[35] The gained benefit in blister prevention from an antiperspirant may not be worth the risk of irritation and should not be considered first-line blister prophylaxis. Antiperspirants are most likely helpful for people who suffer from excessively sweaty feet (hyperhidrosis). If the decision is made to use an antiperspirant, a trial should be attempted at least a week before the planned outing to avoid having skin irritation during the outing.

A variety of powders are designed to help with foot odor and perspiration. These powders are typically composed of an astringent to assist with itching and an inorganic compound (talc, sodium bicarbonate) to assist with wetness. Despite widespread marketing of these compounds, there is no published scientific evidence to suggest that they prevent foot blisters.[5] In addition, powders may increase the risk for blisters because of their tendency to clump with perspiration. Despite anecdotal support for their use, powders are likely best used to dry feet in the evening rather than used on the trail.

### Lubricants

Lubricants prevent blister formation by decreasing friction at the foot-contact material interface. Traditional lubricants, such as petrolatum, are greasy and attract grit particles that irritate and may increase friction and blister production (Table 25-4). Lubricating agents that have a subjective "greasiness" leave skin with a higher coefficient of friction than do those with a sensation of "slipperiness."[52] Advanced lubricants use silicone and petrolatum mixtures that have a silky feel and work by altering the smoothness and moisture content of skin. Several studies have shown there is an initial decrease in the coefficient of friction after applying lubricants, but within an hour it returns to baseline, with a subsequent increase in friction of 35% over baseline over the next 4 to 6 hours (Figure 25-14).[12,52] These studies suggest that with prolonged exercise, use of lubricants might contribute to blister formation, so they should be reapplied frequently.

A rat model found that skin cream appeared to reduce the surface roughness while increasing hydrophilic properties of skin. In addition, there was an inverse increase in the coefficient of friction for cream-treated skin with decreasing cream thickness.[77] Future clinical studies are needed to assess whether newer-generation lubricants or creams prevent blisters, need reapplication at certain intervals, or actually contribute to blister formation.

## BLISTER TREATMENT

Treating a blister as soon as possible improves the outcome, reduces pain, and minimizes complications from subsequent tissue damage or infection. An initial sensation of warmth from a hot spot is a blister warning sign. Prompt attention and rapid treatment at this point can stop the abrasive process, preventing blister formation. Options for hot spot treatment include the blister-preventive taping/lubricating measures mentioned earlier.

Proper blister care is not complicated but may be time intensive, depending on the extent of damage. Individuals should become familiar with techniques before facing a blister predicament. The authors' medical experiences with multistage ultramarathons have shown that implementation of mandatory personal foot care kits for competitors and an expectation of self-care takes a huge burden off the medical team (Box 25-2). The goals of blister treatment are to optimize comfort for continued activity, prevent infection, assist with epidermal recovery, and prevent further blister enlargement when inactivity is not an option.

### General Taping Rules

Tape used for blister prevention or treatment should be applied as smoothly as possible. The ideal tape acts like a second layer of skin so that any rubbing occurs directly on the tape, not the underlying skin. Folds or wrinkles in tape should be avoided

**TABLE 25-3** Foot Antiperspirants and Powders

| Product | Description | Advantages | Ingredients |
|---|---|---|---|
| Neat Feat Cool Foot Spray | Antiperspirant foot spray designed to eliminate odor, prevent irritation, and cool feet | Spray makes application extremely easy | Menthol, alcohol |
| Dr. Scholl's Foot Powder | Powder used to control foot odor, cool and soothe irritated skin, absorb wetness | It absorbs moisture, controls foot odor and odor-causing bacteria | "Special cooling product" |
| Gold Bond Powder | Medicated body powder used to prevent skin irritation and relieve itching | It absorbs moisture, controls foot odor and odor-causing bacteria, provides itch relief, and cools and soothes irritated skin | Zinc oxide and menthol |
| Odor-Eaters Foot Powder | Powder combining special ingredients with baking soda to control odor and protect against wetness | Odor and wetness protection | Unique combination of odor-destroying ingredients and baking soda |

**TABLE 25-4** Foot Care Lubricants

| Product | Description | Advantages | Application | Ingredients |
|---|---|---|---|---|
| Body Glide | Hypoallergenic, non–petroleum-based moisturizer that helps prevent friction, rubbing from footwear, and blister formation | Nongreasy, nonfragrant, sweat and water resistant | It is packaged as an applicator (i.e., deodorant stick), which can make it slightly awkward for application to the foot | Allantoin 0.5; Aloe-barba-densis *(Aloe vera)* leaf extract, C18-36 acid triglycerides, caprylic/capric triglycerides, tocopheryl acetate, tribehenin |
| Sportslick | Skin gel containing antifungal and antibacterial ingredients | Prevents blisters, chafing, and chapping of skin in dry and wet environments | Nongreasy; sweat and water resistant | Tolnaftate 1%, triclosan, silicone, petrolatum, aloe, vitamin E, soybean oil, and oil fragrance |
| SportShield | Silicon-based liquid roll-on or towelette used to minimize friction that causes blisters, chafing, and irritation | Nongreasy; water resistant, odorless | Relatively easy to apply to any body part, depending upon product used | Dimethicone, aloe vera extract, vitamin E |
| Vaseline | Petroleum-based product used to minimize friction that causes blisters, chafing, and irritation | Water resistant, odorless | Easy to apply to any body part; however, the product is greasy | 100% pure petroleum jelly |

because they cause areas of high pressure and friction. Cut tape corners to round them and avoid "dog-ears" that tend to roll off under a sock. Tape should be cut long enough to extend well beyond the blister border and any blister pads underneath the tape. Avoid circumferential wrapping of feet that may lead to venous congestion and swelling.

Before taping, ensure that there is no dirt or grit on the skin and the skin is as dry as possible, which will enhance tape adhesion. Consider an adhesive, such as benzoin, to ensure firm attachment of the applied dressing. Extra care must be given to securing the tape, possibly using duct tape or extra tape as an anchor at high-friction areas. As a general rule, avoid removing blister tape unless it is peeling off or there is unacceptable discomfort at the tape site. Some clinicians advocate removing tape during multistage events.[83] However, leaving tape on as long as possible during repetitive activity minimizes the risk of "deroofing" the blister. When tape is to be removed (ideally after activity is finished and feet will not be subjected to further abuse), soaking bandages before removal will loosen the adhesive and minimize chances of deroofing intact blisters.

### Basic Blister Treatment

Blister pain is due to pressure on incompressible fluid between skin layers. As abrasion and pressure build, there is further pain and separation of skin layers and increasing potential for blister rupture, leaving exposed raw and sensitive skin. The best protection for a blister is its own "roof," so efforts should be taken to maintain this natural skin protection.

The best method for treating a symptomatic blister is to drain the fluid. The seminal prospective treatment trial found that multiple blister drainages in the first 24 hours led to the quickest healing rate versus no drainage (75% versus 16%).[13] Small friction blisters that are not causing significant discomfort can be left intact. If the blister is punctured with a needle and drained, it will often refill within a few hours. If a large hole is made that allows continuous fluid drainage, there is the risk for losing

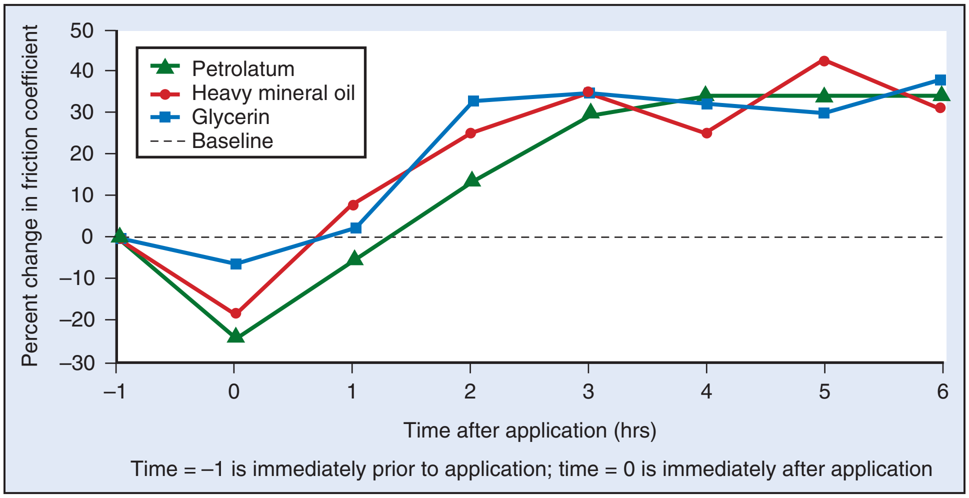



**FIGURE 25-14** Effect of lubricant cosmetic ingredient on skin friction coefficient. *(From Sivamani RK, Goodman J, Gitis NV, Maibach HI: Coefficient of friction: tribological studies in man: an overview,* Skin Res Technol *9:227-234, 2003.)*

## BOX 25-2 Expedition Foot Care Kit

**Foot Care Materials**

Alcohol swabs or towelettes
Micropore paper tape, 2.5 cm (1 inch)
Micropore paper tape, 5 cm (2 inch)
Paper towels or gauze for draining blister fluid
Elastikon tape, 5 cm (2 inch)
Elastikon tape, 10 cm (4 inch)
Tuf-Skin Taping Base Spray or benzoin swabs or towelettes
Adhesive felt
Spenco 2nd Skin 2.5-cm (1-inch) squares
Spenco 2nd Skin 7.5-cm (3-inch) squares
Athletic tape
Lubricant
Duct tape

**Instruments**

Tissue scissors
Bandage scissors
Nail file
Sterile No. 15 blades
18-gauge hypodermic needles
25-gauge hypodermic needles 3.2 cm (1.25 inch)
Syringes
Safety pins

**Miscellaneous**

Ankle or SAM Splints
Isopropyl alcohol liquid in bottle
Povidone-iodine sticks
Povidone-iodine liquid in bottle
Antibiotic or antiseptic cream
Antiinflammatory cream
Nonsterile latex-free gloves
Chemical ice packs
Antiseptic hand-washing cleanser
Washbasin for cleaning feet
Garbage bags
Sharps container
Cephalexin, 500-mg pills
Amoxicillin-clavulanic acid, 875-mg pills
Levofloxacin, 750-mg pills
Ceftriaxone, 1-g ampules
Lidocaine 1%
18-gauge and 20-gauge intravenous catheters plus starter kit and tubing

integrity of the blister and having the roof tear off, leaving a large damaged area. The authors' recommendation is to use a safety pin or similar-sized needle.

Prepare the blister skin and safety pin with an alcohol pad. Puncture the blister with the prepared pin at a distal point. This will allow natural foot pressure to continually squeeze out fluid. If more drainage is required, use several small holes rather than one large hole, limiting the risk for deroofing the blister. Gently blot out the expressed fluid (Figures 25-15 and 25-16). Cover the now-flattened blister with paper tape cut to overlap the blister edge (Figure 25-17). This very important step protects the blister roof from avulsion when the overlying tape is removed. Cover the paper tape with benzoin adhesive and allow it to become tacky. As a final layer, apply shaped adhesive tape such as Elastikon over the paper-taped blister (Figure 25-18). Rounding the corners of the overlying adhesive tape will prevent it from peeling off. Blisters that recur under intact tape can be drained through the tape with a prepared safety pin.

### Open Blister Treatment

Because the blister is partially open, carefully unroof the remaining blister (Figure 25-19), completely trimming off the dead skin. Devitalized skin is insensate and is not painful to remove. Open blisters may appear like a raw wound or ulcer (Figure 25-20). Place a piece of a Spenco 2nd Skin pad over the exposed blister base, extending slightly beyond the external margins (Figure 25-21). The hydrocolloid Spenco pads absorb moisture and promote collagen production and healing while providing cooling relief and padding. Finish by covering with paper tape (Figure 25-22), a benzoin adhesive layer, and then shaped Elastikon tape or tape product of choice (as with basic blister treatment) (Figure 25-23).

**FIGURE 25-15** Intact blister. *(Courtesy Grant S. Lipman, MD.)*

**FIGURE 25-16** Expressing fluid from a toe blister. *(Courtesy Grant S. Lipman, MD.)*

### Toe Blisters

Only paper tape should be used on toe blisters because tape with a rough texture can cause irritation, abrasion, and blisters

**FIGURE 25-17** Paper tape covering of drained blister. *(Courtesy Grant S. Lipman, MD.)*

**FIGURE 25-18** Elastikon tape layer over paper-taped blister. The elastic tape allows smooth application and contours to the foot. Note rounded corners to prevent peeling. *(Courtesy Grant S. Lipman, MD.)*

**FIGURE 25-19** Removal of the torn roof of an open blister. *(Courtesy Grant S. Lipman, MD.)*

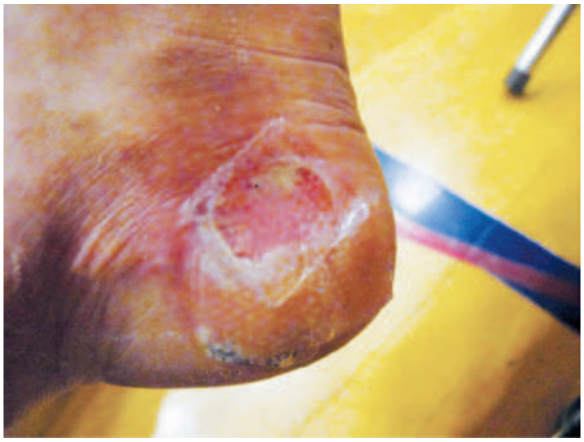


**FIGURE 25-21** Spenco 2nd Skin cut to size, slightly overlapping open blister circumference. *(Courtesy Grant S. Lipman, MD.)*

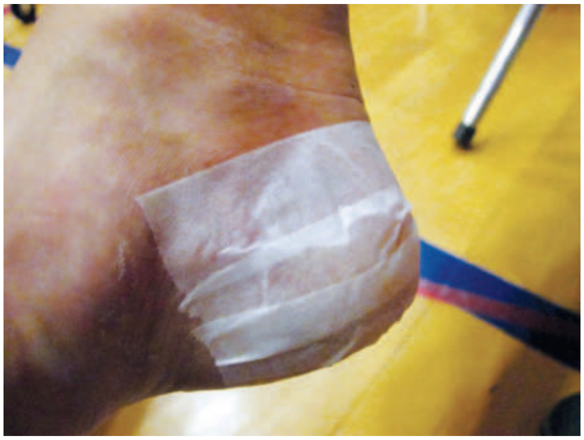


**FIGURE 25-22** Paper tape over Spenco 2nd Skin that is covering an open blister. *(Courtesy Grant S. Lipman, MD.)*

on neighboring toes. Drain a clean blister with a prepared safety pin. If a blister is at the end of a toe (Figure 25-24), apply a piece of paper tape longitudinally, covering the distal phalanx from the dorsum to the plantar aspect (Figure 25-25). A second strip of paper tape is used as an anchor, encircling the toe circumferentially (Figure 25-26). If there is an isolated blister in the web space, applying the circumferential wrap should be sufficient. Care should be taken not to overlap the tape multiple times, not to constrict the digit, and to leave the tape end on the dorsum of the foot to avoid irritating neighboring toes. Pinch the tape closed, and trim any dog-ears or wrinkles.

### Heel Blisters

Heel blisters are notorious for their size and potential for pain and disability (Figure 25-27). The authors have seen exasperated people cut out the heel of a shoe to remove the instigating point

**FIGURE 25-20** Large open heel blister. *(Courtesy Grant S. Lipman, MD.)*

**FIGURE 25-23** Elastikon-wrapped blister. *(Courtesy Grant S. Lipman, MD.)*

FIGURE 25-24 Toe blister. *(Courtesy Grant S. Lipman, MD.)*

FIGURE 25-25 Longitudinal strip of paper tape over a toe. This technique can be used for treatment of toe blisters or prophylactic pretaping. *(Courtesy Grant S. Lipman, MD.)*

of friction. A "heel cup" is useful for providing a large surface area over a blister while providing a large anchoring surface to compensate for shear stresses. A large, 10-cm (4-inch) piece of Elastikon is cut to cover the calcaneus, with corners that are rounded off. A horizontal incision is cut almost completely through the tape, leaving an anchoring piece in the middle like a sideways H (Figure 25-28). The upper portion is wrapped around the upper heel (Figure 25-29), and the lower "wings" are wrapped over the plantar heel and up over the ends of the upper portion, anchoring them down (Figure 25-30). A strip of anchoring tape can be placed perpendicular to the Achilles tendon to prevent bandage slippage and further abrasion (Figures 25-31 and 25-32).

FIGURE 25-26 Circumferential strip of paper tape over a toe. This technique can be used for treatment of toe blisters or prophylactic pretaping. *(Courtesy Grant S. Lipman, MD.)*

FIGURE 25-27 Large open heel blister. *(Courtesy Grant S. Lipman, MD.)*

### Ball-of-Foot Blisters

Blisters on the ball of the foot may be very painful because this is a large weight-bearing surface (Figure 25-33). These blisters are often difficult to manage. Taping across the ball and up the sides of the foot is an option, but because tape is running perpendicular to the mechanical movement of the foot in the shoe, it has a tendency to pull off. The authors prefer a method we have named "desert origami." The blister is drained and treated using either the open or closed method described earlier. Figure 25-34 shows a dumbbell- or butterfly-shaped cutout of Elastikon tape with a thin connector piece. This has three important

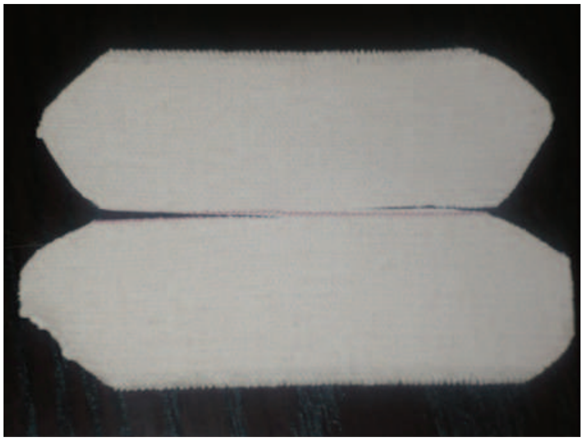


FIGURE 25-28 A 10-cm (4-inch) piece of Elastikon tape is prepared for heel cup application; tape is cut longitudinally with a central connected piece. Note rounded edges to minimize peeling off. *(Courtesy Grant S. Lipman, MD.)*

FIGURE 25-29 Wrapping the wings of a heel cup up under the malleoli helps stabilize the bandage inside footwear. *(Courtesy Ashlie Emmett.)*

FIGURE 25-30 A completed heel cup covering a heel blister. *(Courtesy DJ Kennedy, MD.)*

functions: (1) The tape has a large surface area for covering and protecting the blister; (2) it has a large surface area that can be anchored on the dorsum of the foot; and (3) the thin strip of material connecting the two halves of tape passes between the toes' web space, causing minimal irritation and avoiding further web-space blisters. In some cases, a piece of Elastikon tape may be used over the instep to secure everything (Figure 25-35).

### Subungual Hematomas

A subungual hematoma is a collection of blood that develops underneath the nail bed. Increasing pressure in an enclosed

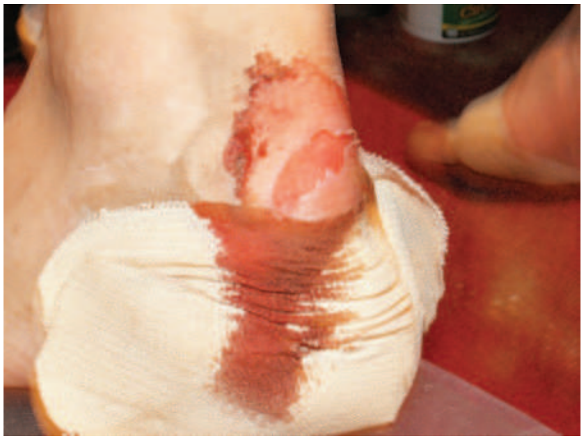


FIGURE 25-31 Abraded heel cup and skin. *(Courtesy Grant S. Lipman, MD.)*

FIGURE 25-32 Top border of a heel cup stabilized with a perpendicular piece of Elastikon tape. *(Courtesy Grant S. Lipman, MD.)*

FIGURE 25-33 Ball-of-foot blister. *(Courtesy Grant S. Lipman, MD.)*

FIGURE 25-34 Blister origami. *(Courtesy Grant S. Lipman, MD.)*

FIGURE 25-35 Ball-of-foot blister treated with blister origami and stabilized with a perpendicular piece of Elastikon tape. *(Courtesy Mark Ellis, MD.)*

FIGURE 25-37 Moderate downward pressure applied to a rotating 18-gauge hypodermic needle drills a hole and releases blood under a toenail. *(Courtesy Brandee Waite, MD.)*



space makes this very painful. It is common to acquire a subungual hematoma on downhill hikes or runs when toes are repetitively jammed into the toe box. A toenail that has been beveled downward at a 45-degree angle seems to direct pressure upward rather than back into the toe matrix. Some people find silicone toe caps useful to prevent these injuries. Other athletes have gone so far as to have all their nails removed prophylactically. Subungual hematomas are easily treated. An 18-gauge hypodermic needle is placed perpendicular to the proximal nail bed over the area of greatest fullness (Figure 25-36). With gentle downward pressure, hold the needle between the thumb and first finger (Figure 25-37). Twirl the needle back and forth as it easily drills into and through the nail, releasing the hematoma (Figure 25-38). The release of blood under pressure through the 18-gauge hole may be dramatic, causing it to squirt, so use appropriate universal precautions. If a needle is not available, it may be possible to improvise by heating the tip of a partially uncoiled metal paperclip (while holding the other end with a pliers, such as is found on a multiuse tool) to a temperature sufficient to allow it to penetrate the nail. This requires pressing on the nail, which will commonly be painful. If only partial penetration is obtained, it may be necessary for the paperclip to be reheated one or more times. If a portable self-powered cautery device is in the first aid kit, it may be used for this purpose as well. If the nail is penetrated, a squirt of blood will occur and the patient will likely briskly pull back the hand, so as noted above, use appropriate universal precautions.

## Advanced Blister Care Treatments

In the needle-and-thread technique (Figure 25-39), a needle and thread are cleaned with alcohol and passed through the blister. The thread acts as a wick to continuously drain fluid and quickly dry the blister. Although this method seems to work well, it is only cautiously mentioned, because any route for fluid out of a blister is a potential entry point for bacteria.

Chemical blister treatments have variable rates of success but consistently high levels of procedural pain. One method to seal a blister's roof uses benzoin. After the blister has been drained, benzoin or a "liquid bandage" is directly injected into the blister cavity and pressure is applied to the roof of the blister. This seals or "glues" the blister together. A similar technique has been attempted (cutting off the blister roof, blotting away the blister fluid, and gluing the blister's roof down) in a prospective study using 2-octylcyanoacrylate (tissue glue). There was no

FIGURE 25-36 A subungual hematoma pending drainage with an 18-gauge hypodermic needle. *(Courtesy Brandee Waite, MD.)*

FIGURE 25-38 The drained subungual hematoma. *(Courtesy Brandee Waite, MD.)*

FIGURE 25-39 Needle-and-thread blister technique. *(Courtesy Brian Krabak, MD.)*


FIGURE 25-40 Mercurochrome brand antiseptic. *(Courtesy Grant S. Lipman, MD.)*

significant difference in the intervention or control groups in mean blister size or time of return to normal activity; however, the 2-octylcyanoacrylate arm was associated with significant procedural discomfort.[39]

A particularly uncomfortable technique made popular by the *Marathon des Sables* is the application of merbromin (Figure 25-40) to a manually deroofed blister. This mercury salt compound effectively dries out the blister base, allowing further activity on a now callus-like epidermis (Figure 25-41). Of note, this product was moved from the "generally recognized as safe" into the "untested" classification by the U.S. Food and Drug Administration in 1998 over concerns about mercury toxicity,[84] effectively stopping its U.S. distribution. It is widely available internationally.

### Blood-Filled Blisters

Blood-filled blisters indicate injury to the dermal plexus (Figure 25-42). This serves as a potential route for bacteria to enter the wound and bloodstream, which can lead to cellulitis or sepsis. Blood blisters should be left intact unless they are large, fluctuant, and at risk for spontaneous rupture. To drain a blood blister, use a povidone-iodine preparation and clean gloves and instruments following previously described techniques. Recheck blister sites frequently for redness, streaking, or purulent drainage (Figure 25-43); any sign of infection should be treated promptly with a systemic antibiotic.

### Infected Blisters

A blister containing murky or hazy fluid or pus may be infected. It should be deroofed and irrigated with povidone-iodine (Figure 25-44); an antiseptic or antibiotic ointment is then applied to the cavity before it is covered using the "open blister" technique. This intact blister roof is often very sensitive. An infected blister surrounded by tender, warm, and red skin or accompanied by lymphangitic streaking may represent cellulitis. It should be opened and managed as described above, with the addition of a systemic antibiotic. If the patient shows signs of worsening local infection or systemic symptoms, such as chills, fevers, nausea, or weakness, definitive care should be sought as soon as possible.

### Subcallus Blisters

Blisters deep to a callus should not be drained. These are difficult to access, yield little blister fluid, and quickly refill after drainage. In addition, drainage procedures can introduce deep space infection. Although these blisters are painful, there is no better treatment option than taping as for a basic blister and allowing the fluid to be reabsorbed. These painful and difficult-to-manage blisters emphasize why it is beneficial to minimize callouses with a pumice stone or emery board before an outing.

FIGURE 25-41 Mercurochrome applied to large open heel blister with resulting red staining and desiccated skin. *(Courtesy Grant S. Lipman, MD.)*

**FIGURE 25-42** Large fluctuant blood blister. *(Courtesy DJ Kennedy, MD.)*

**FIGURE 25-43** Infected open heel blister with surrounding erythema and edema. *(Courtesy Grant S. Lipman, MD.)*

**FIGURE 25-44** Infected blister with surrounding erythema opened and covered with povidone-iodine. *(Courtesy Grant S. Lipman, MD.)*

# COMMON FOOT AND ANKLE INJURIES

Wilderness medicine providers should be prepared to evaluate and treat common foot and ankle injuries.

## LIGAMENT INJURIES

Most ligament injuries involve the ankle joint. Ankle sprains represent 14% to 21% of sports injuries.[15] A sprain typically involves the lateral ankle complex (85%), compared with the medial complex or syndesmosis.[21] The distal fibula extends more inferiorly than does the tibia, contributing to lateral ankle instability. The lateral ankle ligaments (anterior talofibular ligament [ATFL], calcaneofibular ligament [CFL], and posterior talofibular ligament [PTFL]) are small compared with the thicker medial deltoid ligament. The syndesmotic ligament includes an interosseous membrane connecting the distal tibia, fibula, ATFL, and PTFL.

The typical mechanism of ankle injury involves inversion and plantar foot flexion, resulting in a torn lateral ligament. Most lateral ankle sprains involve the ATFL, but they include the CFL up to 50% of the time. The PTFL is involved in fewer than 10% of lateral ankle injuries.[15] Patients often describe a "popping" sensation when twisting an ankle, often on an uneven surface. Pain and swelling are noted immediately on the lateral aspect of the ankle, with difficulty in bearing weight. Palpation reveals tenderness involving the lateral ligament complex, but it should not include the posterior edge of the tip of the lateral or medial malleolus, navicular, calcaneus, or base of the fifth metatarsal bone. Tenderness in these other areas and inability to bear weight suggest a more severe injury, such as a fracture.[38,73] Ligamentous instability of the ATFL should be assessed with the anterior drawer test (the foot is plantarflexed 30 degrees, and the calcaneus is cupped and moved anteriorly while the distal tibia is stabilized) and of the CFL with the talar tilt test (the foot is at 0 degrees of plantarflexion, and the calcaneus is cupped and inverted while the distal tibia is stabilized). Any increased excursion of the joint compared with the opposite side is considered a positive test and suggestive of a ligament tear.

Medial ankle sprains are much less common than are lateral sprains, but are more severe. The typical mechanism of injury involves excessive external rotation leading to a torn deltoid ligament and possible proximal fibula fracture. Patients describe exquisite pain on the medial aspect of the ankle and possibly over the proximal fibula due to concurrent fracture. Pain usually causes inability to bear weight. Palpation reveals marked tenderness involving the medial ankle at the distal tibia and proximal fibula if there is a concurrent fracture. Eversion stress of the ankle joint (foot plantarflexed and everted) produces pain and may reveal instability compared with the noninjured ankle.

Like medial ankle sprains, syndesmotic, or "high-ankle," sprains are less common but more severe. The mechanism of injury involves excessive external rotation and dorsiflexion of the ankle joint, leading to a torn syndesmosis.[58] Individuals describe pain between the distal tibia and fibula with inability to bear weight. Palpation reveals tenderness along the distal tibia-fibula joint. The external rotation stress test (foot is externally rotated while held at 0 degrees of plantarflexion) and squeeze test (squeezing the midshaft tibia and fibula) reproduce pain in the distal tibia-fibula joint.

Once an ankle sprain is suspected, treatment focuses on pain control and joint stabilization. It is not necessary to "grade" the ankle sprain, although appreciating the severity of injury may alter treatment recommendations in a wilderness setting. Swelling may be minimized through use of a cold compress made of chemical ice packs or snow, or immersion into cold river water. Pain medication should be considered. Ideally, the wilderness provider will have an ankle brace, elastic wrap, tape (athletic tape or Coban), or splinting device (e.g., SAM Splint) to provide support for the injured ankle.[46] Appropriately sized sticks placed on either side of the ankle joint may work as splints if no other method is available. When the patient is not ambulating, the limb should be elevated to limit swelling. Weight bearing should be avoided as much as possible, which may be challenging in the wilderness. Evacuation may be necessary if a severe injury or fracture is suspected and the patient is unable to ambulate. A proper rehabilitation program focusing on proprioceptive and strength training will help prevent future injures.[9]

## SOFT TISSUE INJURIES

Many soft tissue injuries to the foot and ankle involve tendon injuries (described below) that occur from excessive overuse and/or improperly fitting shoes. Individuals who are poorly conditioned, insufficiently prepared, or overtrained are at risk for injury.[70] Injury often occurs because of tendon sheath inflammation or tendon degeneration over time. Fortunately, unless there is subsequent tendon tear, these injuries can be treated conservatively in the wilderness, as described with ligamentous injuries. Further treatment includes nonsteroidal antiinflammatory drugs and possibly physical therapy that should focus on biomechanical deficits that contributed to the injury, including inflexibility or strength issues.

### Achilles Tendinopathy

Achilles tendinopathy may range from mild tendinitis to complete rupture of the tendon necessitating surgical repair. An estimated 6.5% to 18% of runners experience Achilles tendon injury.[66] Injury is often due to excessive loading of the tendon with rapid deceleration or acceleration, such as walking up or down a steep hill. Contributing factors may include inappropriate footwear (stiff support around the ankle), hyperpronation, fluoroquinolone use, and obesity.[82] Pain and swelling occur around the distal tendon, approximately 2 to 6 cm (0.8 to 2.4 inches) above its insertion into the calcaneus. If there is complete rupture, individuals describe a "popping" sensation and inability to take a step; they may note an obvious defect in the tendon. Palpation of the tendon reveals tenderness, swelling, or a defect in cases of rupture. A positive Thompson test (lack of ankle plantarflexion with compression of the gastrocnemius complex) suggests complete rupture of the Achilles tendon.

Treatment depends on the severity of injury. In mild tendinopathies and incomplete tears, ice and nonsteroidal antiinflammatories help manage the symptoms.[66] A heel cup or use of a layered felt pad or Moleskin under the heel may help decrease plantarflexion at the ankle, resulting in less stress to the tendon. However, chronic use of heel cups could lead to tendon shortening and further pain. Frequent rest breaks from activity and Achilles tendon stretching may help manage symptoms. If a complete tendon rupture is suspected, the ankle joint should be immobilized in plantarflexion and evaluated as soon as possible by an orthopedic surgeon. Long-term treatment should focus on eccentric (strengthening while lengthening a muscle) exercises, which have been shown to be very helpful.[51]

### Plantar Fasciitis

The plantar fascia stretches along the bottom of the foot from the heel bone toward the toes, with some fibers close to the skin. It provides support and helps maintain dynamic alignment of the foot and leg while a person is walking and running. Overuse and repetitive microtrauma cause inflammation and degeneration of the fibers. When this tissue becomes painful and stiff, it is described as plantar fasciitis. Risk factors include obesity, heel spurs, poor strength and flexibility, and prolonged standing.[64] In athletes, especially runners, there is increased risk with flat feet, high-arched feet, limited ankle flexibility (from tight Achilles tendons), incorrect running shoe fit, inadequate warm-up, and excessive training (especially with sudden increases in distance).

Persons with plantar fasciitis describe sharp pain on the plantar aspect of the foot. It is worse when beginning to walk after sitting or lying down, especially first thing in the morning. Symptoms often get worse at the beginning of a workout but improve with activity. Worsening heel pain with continued ambulation could be indicative of an underlying calcaneus stress fracture. On examination, there is usually a discrete tender area over the medial part of the heel bone. Discomfort can extend over the length of the fibers to the toes. There should not be tenderness involving the calcaneus away from the plantar fascial insertion. Limited big toe extension is often seen with plantar fascial tightness.

Treatment of plantar fasciitis is not emergent. The condition should improve with conservative treatment.[79] In the acute setting, management addresses both symptoms and mechanical factors. Initial therapy includes protection with activity modification. Ice massage, especially after activity or at the end of the day, may be helpful. Antiinflammatory medications may be used briefly (1 to 2 weeks). Arch support with taping and/or use of heel cups may be helpful in some patients. Some individuals respond to night splints, which assist in maintaining a stretch to the plantar fascia while sleeping. Use of custom orthotics may be helpful for some patients. Recalcitrant symptoms may require other interventions, including the use of physical therapy and, rarely, surgery (plantar fascial release).

## BONE INJURIES

The reader is referred to Chapter 22 for a complete discussion regarding diagnosis and treatment of fractures. This section focuses on two common injuries involving feet, stress fractures of the metatarsal bones and sesamoiditis. Both of these diagnoses contribute to metatarsal pain, or metatarsalgia.

### Stress Fractures

Stress fractures are common in athletes and soldiers. They occur when excessive repetitive stress is placed on normal bone, or normal stress is placed on abnormal bone.[7] Studies have found a 5% to 35% incidence of foot stress fractures, depending on the specific population and anatomic location.[33,54] Stress fractures most often involve the metatarsal foot region (march fracture) but may involve the calcaneus or talus. Metatarsal stress fractures most commonly involve the second metatarsal, followed by the third and first metatarsals. Various extrinsic and intrinsic factors contribute to stress fractures. Extrinsic factors include excessive training, incorrect footwear, and new footwear. Intrinsic factors include pes planus,[61] pes cavus, excessive forefoot varus, a tight Achilles tendon, and weak hip muscles.

Individuals with stress fractures report a variety of symptoms, depending on the location of injury. They first describe diffuse pain in the region of the fracture that localizes to a specific area over time. Pain is worsened with continued weight-bearing activity and relieved by rest. On physical examination, localized bone pain on palpation corresponding to the symptomatic region suggests a stress fracture. Swelling may be noted over the dorsum of the foot for metatarsal stress fractures or around the ankle for talus or calcaneus stress fractures. Inspection should reveal normal anatomic alignment of foot and ankle structures. Thorough neuromuscular examination should be performed to rule out other injuries.

Treatment in the wilderness setting should focus on specific symptoms in relation to the suspected fractured area. Medication, ice, and elevation help with pain and swelling. Some individuals may be able to tolerate continued ambulation with metatarsal stress fractures if pain is not too severe. Individuals with severe metatarsal, talus, and/or calcaneus pain may not be able to bear weight; they should be placed in a posterior splint for protection and evacuated to a hospital for x-rays, depending on the severity of symptoms. Fortunately, metatarsal stress fractures resolve over 4 to 6 weeks with rest. Calcaneus and talus stress fractures take longer to heal. A proper treatment program focuses on correcting biomechanical factors that caused injury, training errors, and nutritional deficiencies.

### Sesamoiditis

Sesamoiditis involves injury to the sesamoid bones under the first metatarsal head. Although the term suggests inflammation, the injury is most likely a stress fracture of the sesamoid bones. Pain is localized to the plantar surface of the first metatarsal; it continues with weight bearing and improves with rest. On physical examination, there is swelling of the first metatarsal region and pain with palpation that may move slightly with extension and flexion of the great toe. Treatment focuses on decreasing pressure to the sesamoid region, including the use of doughnut-shaped padding to relieve pressure to the sesamoid, and decreased weight bearing.

### Orthotics

Foot orthoses are commonly used to manage various lower extremity injuries. Despite widespread use, there are conflicting data regarding their efficacy and potential use in preventing blister formation or injury. Theories that have been proposed about how orthoses help prevent lower extremity injuries focus on kinematics, shock attenuation, and neuromotor control. In the kinematic model,[47] abnormal pronation at the subtalar joint coupled with abnormal tibial rotation leads to lower extremity injuries. In the shock attenuation model,[50] excessive impact forces on the lower extremity contribute to injury. The neuromotor control model[7,47,50] suggests that inappropriate muscle activity and fatigue contribute to injury. A recent metaanalysis of orthotics found a significant amount of variability in study design and how patients responded to their use.[47] Patients who had orthoses, even when they were not custom made, had greater rear-foot and tibial motion control compared with controls without orthoses. Patients with custom-molded orthoses had a bigger decrease in the loading rate and impact forces on the lower extremities compared with controls without orthoses. Orthoses appear to increase the activation of lower extremity muscles, including the tibialis anterior, peroneus longus, medial gastrocnemius, and thigh muscles. It is not clear whether these changes can prevent future lower extremity injuries.

Several studies have found that use of running shoes and orthoses may actually contribute to lower extremity injuries. Analysis of gait patterns and forces in the lower extremity of barefoot and shoed runners[32,40,49] suggests that barefoot runners strike with the midfoot and forefoot, compared with shoed runners, who strike with the heel.[19,40] As a result, barefoot runners have lesser impact forces,[32,40] lesser contact times, better transfer of energy to rotational energy, and more natural motion of the lower extremity. In addition, proponents of barefoot running suggest that immobilizing feet through use of shoes or orthoses leads to deconditioning and atrophy of lower extremity muscles, contributing to injury.

Whether or not an individual should use orthotics depends on several factors. For persons without injury, orthoses are probably not needed. More importantly, an appropriate training schedule to slowly stress bones, muscles, ligaments, and skin of the lower extremities will help prevent injuries. Further research is needed to identify the optimal shoes for preventing injury. For individuals with recurrent or prolonged injuries, correction of flexibility and strength deficits and a revised training schedule should help treat injuries. Addition of orthotics may help treat specific injuries, depending on the lower extremity biomechanical or neuromuscular control issues.

### Bunions

A bunion, or hallux valgus deformity, manifests as abnormal foot alignment, typically involving the first metatarsal phalangeal joint. A bunionette, or tailor's bunion, involves the fifth metatarsal phalangeal joint. Some experts hypothesize that there is a genetic predisposition to bunions.[31,56] Bunions slowly develop over time, leading to alignment changes in the foot, including a valgus deformity, widening of the forefoot, and pes planus. Eventually, the metatarsal phalangeal joint develops degenerative arthritis.

Bunions are painful when hiking or running because of altered foot biomechanics. Blisters may form over the bunion. Ideally, preventive strategies such as appropriately fitting shoes with a wide toe box and orthotics may help avoid symptoms.[31] Preventive treatment of bunion skin with strategies for blister care mentioned earlier may be helpful. Treatment is focused on alleviating symptoms through rest, ice, blister care, and decreased weight bearing.

## TINEA PEDIS

Tinea pedis, or athlete's foot, is a fungal infection. It usually occurs in web spaces between toes but may occur along the plantar surface or instep of feet. There is an increased prevalence of tinea pedis in athletes compared with the general population.[22] Reported prevalence rates vary by sport, with a preponderance in runners (22% to 31%) and soccer players (61%).[10] *Trichophyton rubrum* and *T. mentagrophytes* cause most cases; less common causes include *Epidermophyton floccosum* and *Candida*. Factors unique to athletes include excessive sweating, water exposure, occlusive athletic footwear, and skin trauma. Typical symptoms include pain, itching, and burning pain with red, dry, or cracking skin with scaling. Feet may develop erythematous plaques, fissures, vesicles, or bullae. Superinfection with bacteria may cause skin to appear shiny, taut, and red with increasingly severe pain.

Prevention and aggressive treatment are crucial to managing tinea pedis. Preventive strategies include keeping feet dry by using synthetic socks (rather than cotton), changing socks often, wearing well-ventilated shoes, and dusting over-the-counter antifungal powders into shoes. Treatment options include antifungal ointments or powders, such as azoles, tolnaftate, or allylamines, for 4 weeks. Nonadherence to a 4-week treatment course leads to recurrence. For more refractory cases, oral drug therapy, such as itraconazole, fluconazole, or terbinafine, may be necessary.

## PLANTAR WARTS

A plantar wart (verruca plantaris) is a benign epithelial tumor caused by human papillomavirus on the plantar surface (sole) of feet and toes (Figure 25-45). This highly contagious virus can survive several months without a host. Skin that is moist, cracked, or with an open blister is most susceptible to infection. Avoiding direct skin-to-skin contact with a wart minimizes the chances of transmission. The lesion appears as a flesh-colored, white, brown, or gray area, is usually hard and granulated, and can have a spongy cauliflower-like appearance. The wart may have punctate bleeding when irritated. Plantar warts can be differentiated from calluses or corns by recognizing the skin striations that persist around plantar warts, rather than continuing through them. This is because the skin's DNA is altered by the virus. After infection, it may take several weeks or months for a wart to become visible, because pressure on the foot causes layers of hardened epithelium to form over the deep infection.

Plantar warts are self-limited and resolve on average within 15 weeks.[24] Irritation and pain exacerbated by physical activity drive many to seek treatment. Although no single therapy provides complete remission, treatment may decrease the duration and reduce transmission.[24] Treatment of warts in the field is limited to providing symptomatic relief by padding the surrounding area with a doughnut cut out of Moleskin or Molefoam to minimize direct pressure. Salicylic acid therapy is considered first-line medical treatment[3]; if used while a person is active, the area should be covered with duct tape (occlusion therapy). Debridement of the area is discouraged because it may lead to

FIGURE 25-45 Verruca plantaris (plantar warts) on the sole of the foot. *(From Bacelieri R, Johnson SM: Cutaneous warts: an evidence-based approach to therapy,* Am Fam Physician *72(4):647-652, 2005.)*

superinfection or autoinoculation of surrounding skin. If a plantar wart remains bothersome, referral to a podiatrist for further evaluation and treatment is recommended.

## HYPERHIDROSIS

Hyperhidrosis is sweating in excess of what is needed for thermoregulation.[30] It usually occurs in a focal distribution, affecting the axillae, palms, and/or soles. The cause is unknown (idiopathic) in most cases, but sometimes is attributed to sympathetic overactivity or rarely to an underlying pathologic state. Generalized sweating other than in focal areas suggests a secondary hyperhidrosis that may represent underlying disease and should be investigated by a physician. The onset of idiopathic hyperhidrosis usually occurs in adolescence. Sweating is usually exacerbated by heat or emotional stimuli, and has physiologic consequences because continuously wet feet predispose to maceration, blisters, and infection.

The mainstay of treatment is frequent changing into dry socks and application of topical antiperspirant. Most over-the-counter antiperspirants contain small concentrations of metal salts that may be successful in alleviating mild symptoms. Prescription-strength antiperspirants are available; unfortunately, effectiveness is often limited by resulting skin irritation. To minimize irritation, a prescription-strength antiperspirant should be applied to dry skin between sweating episodes. Some clinicians recommend applying it in the evening (when hyperhidrosis is at a minimum) and washing it off in the morning.[75] Some advocate applying baking soda in the morning to neutralize any remaining noxious compound.[68]

Iontophoresis is a treatment that temporarily blocks sweat glands by delivering low-voltage direct current to intact skin. Feet act as a conductor between positively and negatively charged buckets of water; minerals in the water (released by current) are thought to affect sweat ducts. This technology involving both hands and feet is available for home use. Several small clinical trials have shown a success rate of up to 85%,[16,29,74] but iontophoresis has been described as mildly painful and is a time-consuming process of repeated treatment over several weeks.

More invasive options for treating severe plantar hyperhidrosis include surgery (lumbar sympathectomy) and botulinum toxin injection. Botulinum toxin blocks release of neuronal acetylcholine, and several small trials studying palmar hyperhidrosis have demonstrated successful outcomes.[43,72] Lumbar sympathectomy is a relatively new procedure reserved for severe and refractory cases of plantar hyperhidrosis. Sympathectomy has a success rate of 90%; some initially concerning adverse effects such as hypotension, male infertility, and sexual dysfunction have not been validated.[65]

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

# CHAPTER 26
# Hunting and Fishing Injuries

EDWARD J. OTTEN

*Even as Nimrod the mighty hunter before the Lord. Genesis 10:9*

Hunting is a popular pastime in the United States, and injuries are quite common. The instruments used to kill game are inherently dangerous, and hunters often place themselves in dangerous situations, such as tree stands, to improve their success. Understanding wound ballistics, types of firearms, arrows, and traps can aid clinicians in caring for the various wounds produced by these instruments. Fishing has specific injuries as a result of hooks and spears, and clinicians should know various techniques for their removal.

## HUNTING INJURIES

Anthropologists have many theories concerning the origins and importance of hunting in the evolution of the human species. The physical attributes of bipedal locomotion, binocular vision, and an opposable thumb all make humans more efficient hunters. Whether these exist because humans have an innate compulsion to hunt or whether humans are hunters because of these traits is debatable. There is no debate, however, that the social evolution of humans, human acquisition of language and use of tools, and domestication of animals are directly related to more efficient hunting. In a survival situation, and in some ways with regard to evolution, hunter-gatherer animals have a distinct advantage over strictly vegetarian animals because of the relative food value of meat over plants. Hunters tend to be males. Approximately three-fourths of all calories in modern hunter-gatherer groups are derived from plants, and this portion of the food is usually supplied by the women in the group. Even in Inuit tribes where plants make up little of the diet, women do most of the fishing while the men hunt.

Hominids were at a disadvantage, even in groups, when hunting large animals or driving off other predators from their kills until they began using stones, long bones, and sticks to enhance their relatively weak teeth and claws. Implements for hunting and skinning animals were the earliest tools found by anthropologists. Human cultural evolution followed closely the technologic changes in weapons, although sports, business, and war had replaced the need for hunting in most cultures, even by the time Nimrod walked the earth. Bows and arrows, slings, spears, nets, harpoons, traps, and firearms were designed to extend the reach and increase the lethality of the human hand. Unfortunately, humans discovered that they could kill each other with these weapons. Since the discovery of gunpowder, the development of weapons technology has surpassed all other forms of human endeavor, including medicine and transportation.[5,8,16]

Only a few cultures still depend on hunting as their primary food-gathering method. Examples are the Mbuti tribe of the Ituri Forest in Zaire, the Andaman Islanders in the Bay of Bengal, and the Inuit. Many cultures use hunting to supplement agriculture, plant gathering, or raising livestock. Most hunting in the United

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States is done for sport or pleasure, although in some areas of the country, hunting and trapping are still the primary sources of income for a few people.

## HUNTING IN THE UNITED STATES

The total number of hunters and trappers is unknown. Some participate illegally and are not licensed. A report from the U.S. Fish and Wildlife Service in 2013 stated that 36 million individuals purchased hunting licenses, tags, permits, and stamps at a cost to consumers of $790 million. An additional $260 million in taxes combines to total $1 billion dollars for wildlife conservation. Hunters spent another $67 billion on guns, ammunition, and other equipment; travel; and lodging. Although hunting seasons are regulated and relatively short, hunters spent 16 million visitor-days in the national forests and 220 million days total. Fishing numbers for 2011 show 46 million anglers with fees of $1.45 billion for conservation, $15 billion in taxes paid, and overall $115 billion in expenditures.[71,72]

The North American Association of Hunter Safety Coordinators, a division of the New York State Office of Wildlife Management, reported 860 fatal hunting injuries in the United States during the 4-year period between 1983 and 1986, with a total of 6992 injuries from firearms.[54] Interestingly, 34% of the total injuries and 89% of the handgun injuries were self-inflicted. Shotguns accounted for 106 of the fatalities and 906 of the total injuries, and rifles accounted for 79 fatalities and 465 injuries. The New York State Department of Environmental Conservation reported that the average number of hunting injuries decreased from an average of 137 per year in the decade of the 1960s to only 48 in 2001 and 37 in 2002.[10] They credit the institution of hunter safety programs in 1960. In 2001, Colorado reported 9 injuries and 1 death per 500,000 licensed hunters.[13] Michigan reported 2 deaths per 2,665,952 hunters in 2003, giving hunting one of the lowest injury and fatality rates of any recreational activity.[71] According to the National Safety Council, unintentional firearm fatalities decreased nationwide from 1441 in 1991 to 606 in 2011, a decrease of 58%. Fatalities for persons under 14 years of age decreased from 236 to 62, a decrease of 74% from 1990 to 2010. Data in 2011 from the National Sporting Goods Association estimated one injury for every 1810 bowling participants, 97 softball participants, 677 mountain bikers, 120 snowboarders, and 2400 hunters. The U.S. Department of Transportation estimated that 16,500 annual injuries were caused by deer-vehicle collisions.

The type of hunting influences the rate of injury. Smith and colleagues[64] reviewed 1345 hunting injuries in Pennsylvania from 1987 to 1999. They showed that turkey hunters had the highest rate of injury (7.5 per 100,000 hunters) and grouse hunters the lowest (1.9 per 100,000 hunters). This was attributed to turkey hunters not wearing orange hunter clothing. Deer hunters had the highest case-fatality ratio at 10.3%, and pheasant hunters the lowest at 1.3%. This higher fatality rate was largely because most deer-hunting injuries were due to wounds caused by rifle bullets. They also noted that younger hunters suffered the highest rate of injuries, and the largest percentage of incidents occurred on opening day.

Hunting-related shootings represent a very small portion of the total number of accidental firearm deaths in the United States. In Colorado, from 1997 to 2005, there were four deaths during hunting, all attributed to cardiac causes, and none in hunters from firearms, falls, or penetrating injuries. The most common traumatic injuries were lacerations; 75% of lacerations were from knife injuries during field dressing of animals. Of 131 unintentional firearm deaths in California from 1977 to 1983, only 8 were the result of hunting accidents.[12,13,36,52,54,59,64,71,72]

Hunting injury data may be inaccurate for a number of reasons. Many minor nonfatal injuries likely go unreported, and most states do not differentiate accidental firearm hunting deaths from deaths that occur during any other activity. Also, automobile and all-terrain vehicle accidents that occur while hunting or gunshot wounds inflicted while "cleaning a gun" at home may be classified as hunting or nonhunting injuries.

## TYPES OF INJURIES ENCOUNTERED

Most injuries to hunters are the same types of injuries seen in backpackers, anglers, and climbers. Frostbite, sprains, burns, and fractures occur with the same frequency in hunters as in others who visit wilderness areas. Prolonged extraction times may increase the risks of hypothermia, wound infection, dehydration, missed medications, and other time-dependent secondary complications.

Injuries that are unique to hunters are those caused by their weapons. Most hunting is done with firearms. Shotguns and rifles are more commonly used, although handguns are increasing in popularity. Use of bows and crossbows in hunting is also increasing because hunters using these weapons frequently are permitted an extended hunting season that does not overlap with periods for rifle and shotgun hunting. Hunters who use bows and crossbows pose far less danger to people in the hunting area at long range compared with those using rifles and shotguns. Bow hunting requires more skill, use of camouflage, and stealth because of the short effective ranges of arrows and bolts. These factors place bow hunters at greater risk for being mistaken for a game animal at long ranges, which is why rifle and shotgun seasons rarely run concurrently with bow-hunting activity.

Other weapons used for hunting are less likely to be encountered. For example, spears, harpoons, and nets are used by some hunters in the Arctic, Australia, and Africa. Spear injuries from gas-powered spearguns or rubber band–powered Hawaiian slings have been associated with fatal injuries, especially when occurring in ocean or lake environments where secondary drowning or shark attack may be an additional hazard. Harpoon and fishing spearheads may separate from the shaft and, depending on the force used, may penetrate the skull or a body cavity. Slingshots are rubber band–powered devices that use the energy in a stretched piece of rubber to hurl a projectile, often a small rock or ball bearing, at 61 to 91 m/sec (200 to 300 feet/sec). Although this is considered a low-velocity and thus low-energy projectile, injuries to the head and face, especially the eyes, have been reported.

Blowguns, although mainly used by aboriginal hunters, have become popular with some recreational hunters of birds and small game. The blowgun varies in length, and a variety of darts can be projected 6 to 15 m (19.7 to 49.2 feet) by the exhaled breath. The darts have low energy and do not penetrate very deeply. Modern blowguns rarely cause serious injury unless striking the eye or possibly a blood vessel. To effectively kill small game, the darts generally must carry an immobilizing or poisonous toxin. Darts used by some tribes contain toxins derived from both animal and plant sources. These toxins can cause paralysis and death in humans who have been punctured by the dart either accidently during transport or purposefully during tribal war. Animal toxins are primarily neuromuscular toxins and many have been developed for medical use. South American tribes have used *Dendrobates* frog toxins, which are steroidal alkaloid compounds known as batrachotoxins and homobatrachotoxins. These toxins act at voltage-gated sodium channels and cause irreversible depolarization of nerves and muscles. Several other toxins, including gephyrotoxin, pumiliotoxins, histrionicotoxins, and epibatidine, have been isolated from poison dart frogs. The last toxin is the most potent nicotinic agonist known and is a powerful nonopiate analgesic. Interestingly, these frogs lose their ability to produce toxins in captivity, leading to the finding that the frog's diet of *Melyridae* beetles actually is the source of the toxins. Plant-derived toxins include strychnine, curare, and a number of cardiac glycosides from Africa, South America, and Asia, where dart and arrow poisons are still used by indigenous people. All of these toxins, especially the cardenolides from the *Maquira, Naucleopsis,* and other Moraceae species, have been studied for possible medicinal value.[58,62]

Veterinarians commonly use air-powered darts fired from rifles or blowguns to subdue large animals. These darts contain pharmacoactive agents, such as succinylcholine, phencyclidine, ketamine, and xylazine, in concentrations great enough to bring down an elephant, lion, or rhinoceros. The darts are 3-mL plastic syringes with 16-gauge needles delivered using a 1.8-m (5.9-foot) blowgun or rifle. Accidental human injection can be rapidly fatal if a reversing agent or advanced life support is not available. Homemade blowguns are frequently used for sport and usually consist of a needle or pin attached to a wooden shaft and a cotton ball or piece of yarn for a feather. Although these darts do not contain any toxins, they are still capable of causing injuries, especially to the eye. There have been reported cases of aspiration of darts.[27,31,73]

Trap injuries may be included in the definition of hunting injuries. Most traps are designed to catch and hold small game. Injuries usually occur when a trapper prematurely triggers a spring-loaded trap. Crush injuries and puncture wounds to the hands are most common. Hikers occasionally tread on unmarked traps, and domestic animals, such as dogs, are accidentally caught in poachers' traps. Another problem with traps occurs when an animal (wild or domestic) is caught in a trap and attacks while being released.

Many knife lacerations occur when hunters clean game. Lack of familiarity with the process or techniques for field dressing and cleaning game is the likely cause. Failing to wear protective gloves; using the wrong type of knife; working with bloody, slippery material; and having cold hands all contribute to accidents.

## Tree Stand Injuries

A frequent preventable cause of serious injury and death among hunters is not associated with firearms at all. It is the tree stand injury. Tree stands are small platforms designed to hold hunters high above the ground so they can more easily spot and kill large game while remaining undetected. Whether homemade or of commercial design, the platforms generally are small, portable devices that the hunter attaches to the trunk of a tree near game trails or water holes. The stands may have attached ropes or ladders for access, or the hunter may free-climb the tree for placement of the stand or fasten small climbing steps on the tree (Figures 26-1 and 26-2). Hunters may fall asleep on the platforms

FIGURE 26-1 The wrong way to use a tree stand. This hunter is not wearing a safety harness, is drinking alcohol, and is pulling his firearm into the tree stand with the muzzle pointing upward.

FIGURE 26-2 A commercially produced tree stand can be used to climb the tree and obviates the need for a ladder or steps, which are the cause of many falls.

and fall off or fall while climbing up or down trees. At least one-half of these injuries could be prevented if all hunters wore tree stand safety harnesses (Figure 26-3). Although most of the injuries are similar to those seen with any type of fall, occasionally a hunter drops a firearm, which discharges, or falls on an arrow or rifle, causing an additional weapons injury. Over 10 years, injuries of this type in Georgia accounted for 36% of reported hunting injuries and 20% of hunting fatalities.[9] A study from the University of Rochester, New York, looked at tree stand injuries from 1996 to 2001.[48] The authors noted that 51 injuries occurred, all in men, with a mean age of 42. Alcohol was present in 10% of patients and 2 of 3 deaths. Spinal fractures were the most common injuries (51%), followed by extremity (41%), head (24%), and lung (22%) injuries. Only two patients had been using a safety belt (4%). Sixteen spinal cord injuries were reported between 1987 and 1999 in Oklahoma; the mean height of fall was 16 feet, and 18% were related to alcohol ingestion. Ninety percent resulted in paraplegia/paraparesis, and 12.5% were fatal. Loder[42] looked at National Injury Electronic Surveillance System data from 100 U.S. hospital emergency departments during the period of 2004 to 2012. There were 57,820 hunting stand injuries, and no fatalities. Fractures were the most common injuries, and alcohol use was 0.6% Crockett and associates[15] reported data from two level 1 trauma centers in Ohio from 1998 to 2007. There were 60 tree stand injuries that included 4 permanent neurologic deficits and 1 fatality.[11,20,48,63,66,70]

## Arrow Injuries

Modern arrows are usually made from aluminum, graphite, or fiberglass, although many beginners still use inexpensive wooden arrows. A number of types of arrowhead are in use, such as field points and target points, but most injuries are due to specially designed hunting arrowheads called broadheads. These razor-sharp metal points come in a variety of sizes and shapes and are

FIGURE 26-3 The correct way to bring a firearm or quiver into the tree stand, with the muzzle or arrowheads pointing down and the hunter wearing a safety harness at all times.

designed to kill game by lacerating tissue and blood vessels, causing bleeding and shock. Unlike hunting firearms projectiles, which are designed to kill quickly through massive tissue damage and rapid incapacitating hemorrhage, arrows usually kill more slowly, with less tissue damage (Figure 26-4).[22,23,25] Arrows are propelled by a conventional bow, which may be straight, recurved, or compound, or by a crossbow. Crossbow projectiles may be called arrows or *bolts* and generally are shorter and heavier than arrows fired from a bow. The force used to propel the arrow is usually measured in *draw weight,* which is the number of foot-pounds necessary to draw a 71.1-cm (28-inch) arrow to its full length. The higher the pound draw, the more powerful the bow and the deeper the penetration achieved by the same type of arrow.

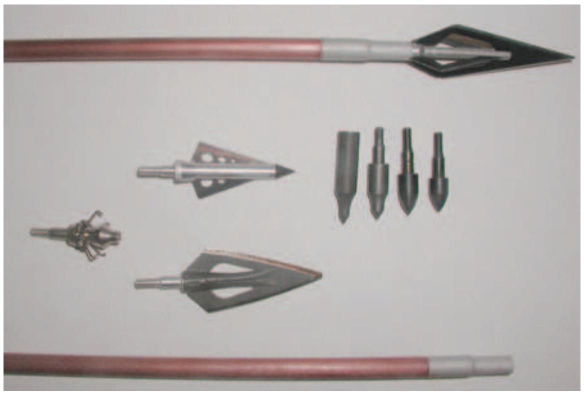

FIGURE 26-4 Types of arrows. *Top,* Aluminum shaft arrow with hunting broadhead. *Middle left to right,* Small game blunt hunting head with spring claws to prevent arrow loss from burrowing into the ground, two types of hunting broadheads, four field points of varying weights. *Bottom,* Fiberglass shaft for interchangeable heads.

Arrows have a much shorter range than do bullets, and arrows must be more accurately placed to kill the animal quickly; therefore, most shots taken are under 50 m (164 feet). Because brush and tree branches can easily deflect an arrow, most shots are taken with a clear field of view. For these reasons, bow hunters rarely mistakenly shoot another hunter they presumed was a game animal. Most arrow injuries occur when hunters fire illegally at night in heavy brush and are not sure of their target. Another common injury occurs when a hunter runs after a wounded animal and falls on an arrow that was to be used for a second shot or falls out of a tree stand onto an arrow. A loaded crossbow is similar to a loaded gun. Hunters have been accidentally shot when dropping the weapon or snagging the trigger on a branch or fence. Hunting arrowheads are quite sharp; self-inflicted injuries may occur when a hunter is sharpening the blades of the broadhead or returning an arrow to the quiver.

## Injuries From Firearms

**Nonpowder Firearms.** Although the word *firearms* technically defines guns that fire projectiles by ignition and burning of a propellant, similar designs referred to as "nonpowder" firearms using springs, compressed air, or compressed gas cartridges are in widespread use among sport hunters and children and will be considered as firearms in practical use.

Whereas traditional firearms discharge a projectile by the contained expanding gases generated in the gun barrel by modern fast-burning powders or old-fashioned black powder, nonpowder firearms use a spring, compressed air, or carbon dioxide cartridge to accelerate the projectile out of the barrel. Although air guns are quite accurate at short distances and can develop muzzle velocities in excess of 365.8 m/sec (1200 feet/sec), the small lightweight projectiles usually cannot penetrate skin at distances greater than 100 m (328 feet). Nonpowder firearms are commonly used by children, who cannot legally obtain or use other types of firearms. Uninformed parents buy them as toys, erroneously believing them to be harmless by design. Without supervision and proper training in gun safety, severe injury and death can result. The wounds they cause can be lethal, especially from high-powered air rifles, which can send out pointed projectiles at sufficiently high velocities to penetrate the skull and body cavities. In a recent technical report, Laraque and colleagues estimated that 21,840 injuries had occurred during the year 2000 from nonpowder firearms, with a 4% hospitalization rate. There were 39 related deaths between 1990 and 2000. Care must be taken not to trivialize these injuries, especially in the pediatric patient, where softer, thinner bone may lead to deep penetration by even lightweight projectiles.[34,37,38,44,53,69] Less-than-lethal rounds are used by police and military to subdue individuals without causing serious injury. These rounds may be rubber, wooden, synthetic sponge, or soft wax. Although designed to disperse a crowd or incapacitate a person until he or she can be subdued, they can cause significant injury. This usually occurs when the person is struck in the head or in some cases the abdomen or thorax. These rounds are not designed for hunting but may be encountered if used by the uninitiated. Rounds, such as airsoft, are used in many police and military training facilities to add realism to the training scenario. These rounds may cause eye injuries if safety precautions are not used.[21,33] Paintball guns, although not designed or generally used for hunting, are commonly used in outdoor activities that mimic tactical games. Most injuries occur in children who are not wearing eye protection, but there are also reported cases of vascular injuries. Paintballs are 14-mm (0.6-inch) gelatin capsules that are filled with water-soluble paint of various colors. Because of their small size, they can evade the bony orbital protection of the eye. Paintballs propelled by carbon dioxide can travel over 91.4 m/sec (300 feet/sec). At this velocity, the globe, cornea, and retina can be disrupted with a

FIGURE 26-5 American Society for Testing and Materials–approved helmet designed for paintball activities with integral eye, face, and ear protection.

direct hit. The American Society for Testing and Materials has standards for eye protection for paintball sports. These include a helmet with integral eye, face, and ear protection (Figure 26-5). Unfortunately, many children either do not wear the recommended protection or remove it during play because of fogging or discomfort.[14,24,30,32,41]

**Powder Firearms.** In older style weapons *(black powder weapons),* gunpowder is loaded directly into the barrel. In modern weapons, gunpowder is contained in a cartridge.

Black powder weapons use a centuries-old slow-burning propellant that is ignited with a spark from flint striking steel or a percussion cap. The firearms are usually single shot and loaded from the muzzle by pouring a measured amount of black powder down the barrel and then inserting the projectile and tamping it down onto the powder charge. When ignited, the propellant is converted to a gas that expands and pushes the projectile out of the barrel of the weapon. With modern design and manufacturing techniques, these weapons are sufficiently accurate to hunt large game, such as deer and elk. The injuries from black powder weapons are similar to those from modern weapons and are discussed later. The same precautions should be used when hunting with or shooting any type of firearm, whether the propellant is air or gunpowder.[1,55]

The term *cartridge* is used to refer to the intact, unfired assembly of projectile and propellant loaded into the gun for firing. Rifle and pistol cartridges consist of a metal case that contains the gunpowder propellant and into which the bullet is seated and held by compressing the case around the bullet base at the time of manufacture. The base of the case contains a small metal primer filled with a small amount of high explosive that serves to ignite the fast-burning propellant when it is struck by the firing pin of the gun. The primer is in the center of the base of the case (*center-fire* ammunition) in all cartridges except in small-caliber .22 cartridges, where it is incorporated into the entire circumference of the cartridge base rim (known as *rimfire* ammunition). Rifle and pistol cartridges generally contain a single bullet, although some may be loaded with very small shot to increase the probability of hitting small objects at short distances. Shotgun cartridges consist of a center-fire metal base combined with a paper or plastic shell in the form of a closed-end tube. Within this tube is placed the propellant and then the projectile(s), along with associated plastic, cotton, or paper materials collectively referred to as *wadding* (Figure 26-6).

Shotgun projectiles consist of shot ranging in size from 1 to 10 mm (0.04 to 0.4 inch) (Figure 26-7) or a single solid projectile known as a *slug*. Shot pellets used to be made of lead. Because of high lead levels in ducks and geese that ingested spent shot while feeding, lead shot for bird hunting was banned in 1991. Approved shot may be made of steel, tin, or various mixtures of tin, bismuth, and up to 15% iron. Steel shot can be identified on radiographs because it retains a perfect round shape, whereas lead and tin shot deforms inside the barrel during firing, resulting in nonspherical shapes. Determining the shot type can help clinicians decide about the safety and usefulness of magnetic resonance imaging scans in the setting of steel projectiles, or the risk for lead toxicity.

The wadding is commonly a single plastic cup with a thickened expandable base designed to contain the shot and serve as a seal inside the barrel to contain the expanding gases behind the shot cup for maximal muzzle velocity. Slugs also have a type of wadding known as a *sabot,* which surrounds the slug inside the barrel of the shotgun. In all cases, the wadding is fired from the gun and immediately peels away from the slug or shot. Wadding is commonly found inside close-range wound channels but generally is not involved in wounds at firing distances of more than 5 to 7 m (16 to 23 feet).

Besides the wadding and projectile(s), hot gas and unburned powder also exit the muzzle. In cases of close-proximity wounds, usually under 1.1 m (3.5 feet), powder stippling may appear on clothing or skin. The presence of powder stippling or wadding in a wound may have important forensic applications and should always be noted. With contact wounds, where the muzzle is pressed into the skin at the time of firing, escaping hot gases may enter the wound channel and expand inside the victim, causing burns, organ damage, burst skin, and/or a stellate laceration around the point of entrance. Figures 26-8 to 26-10 show examples of gunshot wounds.

Hundreds of types of cartridges are available for firearms. They may be factory loaded or hand loaded, which adds the variables of propellant amount and type. Rifle and pistol cartridges are initially classified according to caliber, or diameter, of the bullet. For example, .22-caliber means the diameter of the bullet is 0.22 inch (5.6 mm); .45-caliber is 0.45 inch (11.4 mm); and so forth. The caliber may be expressed in metric measurement; for example, a 9-mm bullet is 9 mm in diameter, which is 0.35 inch. However, bullet diameter alone is insufficient to name a cartridge, because bullet length can vary, as do cartridge length and width. The U.S. Army M-16 service rifle fires a .22-caliber bullet weighing 4 g (62 grains) at 945 m/sec (3100 feet/sec) initial velocity. The common .22 rimfire rifle used by generations of young shooters fires a .22-caliber bullet weighing 2.6 g (40 grains) at 335.3 m/sec (1100 feet/sec) initial velocity. Obviously the wounding potential of these two projectiles is vastly different. Nomenclature for a particular cartridge is made more specific by including a measurement of cartridge length, name of the inventor or inventing company, amount of powder in the case, length of the entire cartridge, or the year the cartridge was invented. For instance, the M-16 round is generally referred to as a 5.56 mm

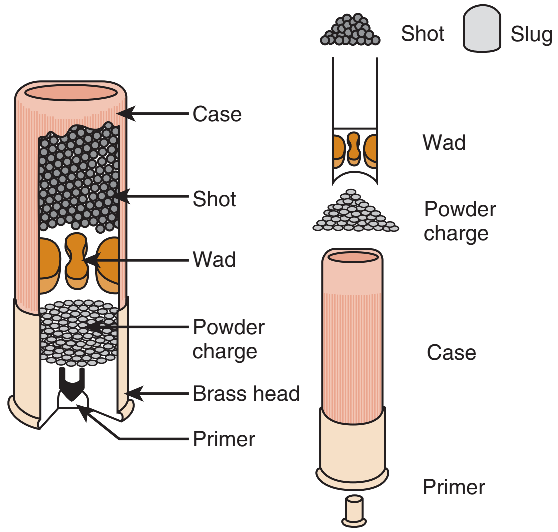


FIGURE 26-6 Cutaway diagram of shotgun shell.

| Lead shot sizes: | 12 | 9 | $8^1/_2$ | 8 | $7^1/_2$ | 6 | 5 | 4 | 2 | BB |
|---|---|---|---|---|---|---|---|---|---|---|
| Pellet diameter (inches) | .05 | .080 | .085 | .090 | .095 | .110 | .120 | .130 | .150 | .180 |
| (mm) | 1.27 | 2.30 | 2.16 | 2.29 | 2.41 | 2.79 | 3.05 | 3.30 | 3.81 | 4.57 |

| Buckshot sizes: | No. 4 | No. 3 | No. 2 | No. 1 | No. 0 | No. 00 | No. 000 |
|---|---|---|---|---|---|---|---|
| Pellet diameter (inches) | .24 | .25 | .27 | .30 | .32 | .33 | .36 |
| (mm) | 6.10 | 6.35 | 6.86 | 7.62 | 8.13 | 8.38 | 9.14 |

| Steel shot sizes: | 6 | 5 | 4 | 3 | 2 | 1 | Air Rifle | BB | BBB | T | F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pellet diameter (inches) | .11 | .12 | .13 | .14 | .15 | .16 | .177 | .18 | .19 | .20 | .22 |
| (mm) | 2.79 | 3.05 | 3.30 | 3.56 | 3.81 | 4.06 | 4.49 | 4.57 | 4.83 | 5.08 | 5.59 |

Note: the size of shot, whether lead or steel, is based on American Standard shot sizes. Thus, a steel No. 4 pellet and a lead No. 4 pellet are both .13 inches (3.3 mm) in diameter.

**FIGURE 26-7** Standard shot size number and letter system (with corresponding metric measurements) of hunting shotgun shell projectiles. The smaller the shot size, the more pellets loaded in a single shotgun shell. Larger pellets are heavier, lose less velocity per unit of flight time, and penetrate more deeply than do smaller pellets. *(From* Shotgunworld.com. *Used with permission.)*

(metric) or a .223 cartridge (English system of measurement), with the third digit differentiating it from the common low-power .22 rimfire cartridge. Other common hunting cartridge names illustrating these variations are .45/70 (70 grains of powder), .30-06 (adopted in 1906), and .35 Whelen (the man who developed the round).

*Magnum* refers more to the type and amount of powder than to the size of the bullet used. Magnum cartridges are designed to give hunters the ability to successfully hunt large game with pistols by improving terminal ballistic performance of the bullet.

Figure 26-11 shows some examples of different bullets. Shotgun terminology is a little less complicated, based on the number of lead balls, the diameter of the barrel, and how many lead balls it takes to make a pound. For example, a 12-gauge shotgun has a barrel that is the same diameter as a lead ball that weighs 0.08 lb (37.6 g); a 20-gauge, 0.05 lb (22.7 g). The higher the gauge number, the smaller the barrel and the smaller the projectile. The only exception is the .410 shotgun, which is caliber .410, or 0.410 inch (1 cm) in diameter. Figure 26-12 shows some examples of shotgun rounds and the shot and wadding within them.

**FIGURE 26-8** Gunshot wound to the face and mandible showing extensive bone and soft tissue injury. Patient was initially able to protect his airway, but later required endotracheal intubation because of edema and bleeding.

**FIGURE 26-9** Shotgun wound to the upper arm. Initially the wound looked benign. Both entrance and exit can be seen.

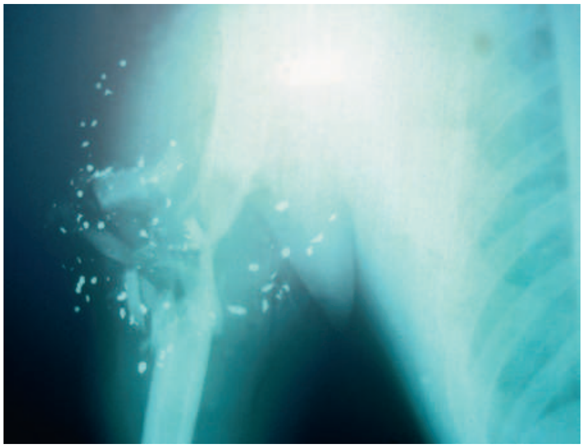

**FIGURE 26-10** Radiograph of the same shotgun wound to the upper arm as seen in Figure 26-9. Extensive bone and soft tissue injury, as well as vascular and nerve damage, can be seen.

**FIGURE 26-11** Examples of hunting bullets. *Left to right,* .50-caliber black powder lead bullet, .22-caliber long rifle lead bullet, .22-magnum caliber copper jacketed bullet, .44-magnum semijacketed hollow-point bullet, .44-magnum shotshell, .223-caliber (5.56-mm) full metal jacket bullet, .30/30-caliber soft point flat nose bullet, .30-06-caliber round nose soft point bullet, and .270-caliber pointed soft nose bullet.

The type and severity of wounds inflicted by a firearm depend on several factors. The factor most often quoted, but least important, is the amount of energy the bullet (projectile) has when leaving the firearm. The kinetic energy formula, $E_k = \frac{1}{2}MV^2$, can be applied to any moving object and can be used to calculate the muzzle energy for a particular type of firearm. Energy increases much more as a function of the velocity of the bullet than as a function of the mass. For this reason, most firearms are classified according to muzzle velocity. The higher the velocity of the bullet, the greater the energy and the greater the potential for injury. Firearms with muzzle velocities greater than 762 m/sec (2500 feet/sec) are considered high velocity, 457.2 to 762 m/sec (1500 to 2500 feet/sec) are medium velocity, and less than 457.2 m/sec (1500 feet/sec) are low velocity (Table 26-1).

**FIGURE 26-12** Examples of shotgun rounds. *Left to right,* 12-gauge slug round, empty 12-gauge plastic round, plastic 12-gauge wadding, and No. 6 shotgun pellets.

**TABLE 26-1** Comparison of Bullet Caliber, Weight, Velocity, and Muzzle Energy

| Caliber | Weight in Grams (Grains) | Muzzle Velocity | | Muzzle Energy in Foot-Pounds |
|---|---|---|---|---|
| | | feet/sec | m/sec | |
| .22 | 2.6 (40) | 1080 | 329 | 90 |
| .223 | 3.6 (55) | 3250 | 991 | 1280 |
| .44 magnum | 11.7 (180) | 1600 | 488 | 1045 |
| .30/60 | 9.7 (150) | 2750 | 838 | 2500 |

Bullets cause damage to tissue by crushing. The energy of a bullet may be transmitted to the tissue in part or in total depending on the surface area the bullet presents to the tissue. Bullets that yaw, expand, or fragment present more surface area than do bullets that stay in one axis and maintain one shape. By international agreement codified in the articles of the Hague Convention IV of 1907, military bullets are not to be designed in a manner to produce "superfluous" wounding effects by features that would encourage the bullets to flatten or expand on impact with tissue. They are typically completely encased in a copper jacket to prevent deformation of the soft lead core. Such rounds generally pass through an individual, leaving a permanent wound tract similar in diameter to that of the bullet. The ammunition is designed to wound a soldier and put him or her out of combat, but not to kill the soldier. In contrast, hunting ammunition is designed to expand on impact up to two or three times its diameter, resulting in a much larger wound channel, greater tissue damage, and rapid incapacitation and death (Figure 26-13). This feature of planned deformation also promotes retention of the bullet within the target and reduces the risk for injury to unseen

**FIGURE 26-13** The .30-caliber Nosler 180-g AccuBond Polymer Tip bullet fired into calibrated 10% ordnance gelatin is typical of the .30-caliber hunting bullets used for .30-06, .308, .300 Win Mag, and other cartridges. This photo shows this bullet fired from a .308 rifle with a 45.8 cm- (18-inch) long barrel. Muzzle velocity was 762 m/sec (2499 feet/sec). Penetration depth exceeded 50.8 cm (20 inches). Temporary cavity maximum width was 11.4 cm (4.7 inches) at a depth between 7.1 cm (2.8 inches) and 22.1 cm (8.7 inches). Diameter of the recovered bullet at the front surface was 1.4 cm (0.6 inches). Weight of the recovered bullet was 149.5 g (5.3 oz); 17% of the bullet turned into fragments. Terminal performance of this type is suitable for all medium to heavy game encountered in the lower 48 U.S. states, including moose, elk, black bear, pigs, and deer. Ten-cent coin (dime) is shown for comparison. *(Courtesy Gary K. Roberts, DDS.)*

individuals downrange from the game animal. In fact, many states require the use of expanding ammunition for hunting large game. This may increase the wound severity of hunting injuries compared with military and criminal shootings.

In addition to direct tissue destruction by the deforming bullet, fragmentation may occur when a bullet strikes bone and sends bone and bullet fragments in several directions. These secondary missiles cause injuries within the body similar to those from bullet fragments and may even exit the body to injure bystanders. A second injury mechanism of terminal ballistic bullet behavior is *temporary cavitation,* which occurs at all velocities to some degree but becomes a significant wounding mechanism factor only at high velocities. The temporary cavity is created by radial dispersion of tissue by the bullet surface as a result of acceleration of tissue away from its path. A *permanent cavity* occurs when a bullet or fragment crushes tissue. In high-velocity bullet wounds, the temporary cavity may be many times larger than the permanent cavity. This wave is well tolerated by most elastic tissue, such as muscle, bowel, and lung; however, inelastic tissues, such as liver or brain, do not tolerate it and may be severely damaged by the temporary cavity.

Bullet motion in flight is described by *rotation, yaw,* and *pitch*. The rifle grooves cut into the inside of the barrel cause the bullet to spin around its long axis, just like a football thrown in a tight spiral. *Yaw* and *pitch* describe bullet motion left or right, or up and down relative to the long axis of the bullet. In wound ballistics, yaw is used to describe both axes of motion. A rifle bullet will usually yaw after striking any object outside the body, such as a tree branch, belt, or clothing, and when striking skin and other tissue within the body. Yaw can result in complete end-over-end rotation of the bullet within tissue, causing the bullet to increase the area that is crushed as the entire side profile of the bullet passes through the tissue. Bullets with round ends, for example the .45 automatic Colt pistol bullet or round musket balls, routinely do not yaw, and produce wound channels equal to their caliber or expanded caliber. Yaw causes maximum damage at 90 degrees of rotation, when the entire side profile of the bullet crushes tissue. This factor, combined with any bullet expansion, can cause the exiting bullet to produce a much larger wound than when it entered.

To allow laboratory comparison of projectile designs and to study the effect of velocity and expansion, experimental *wounding profiles* have been described using ballistic gelatin, which accurately simulates human muscle tissue. These wounding profiles show the various aspects of potential ballistic injury, including cavitation, yaw, and fragmentation (Figures 26-14 and 26-15).[19] The total effect of high energy, fragmentation, expansion, yaw, and temporary cavity formation results in tissue injury. Although the kinetic energy formula yields the total energy available to cause injury, the physical behavior of the projectile(s) and the transited tissues are the actual determinants of the complete injury pattern. The type of tissue struck is the most important factor. As can be seen from Table 26-1, the .22-caliber long rifle rimfire bullet has a low mass and velocity and thus a low muzzle energy, yet more fatalities have occurred from this round than from any other. It is very inexpensive, can be fired from a number of rifles and handguns, is commonly used to hunt game, and is not thought of as particularly dangerous by inexperienced hunters. For these reasons, more people are shot by this cartridge than by any other single bullet type. The bullet is highly lethal when striking the brain, heart, or a major blood vessel.[1,17-19,40,67] Rubber or plastic bullets, although generally not used for hunting, may be encountered. These bullets travel at about 61 m/sec (200 feet/sec) and will not usually penetrate skin, although at short ranges (under 15.2 m [50 feet]) can cause fractures, eye trauma, and other blunt injuries.[45]

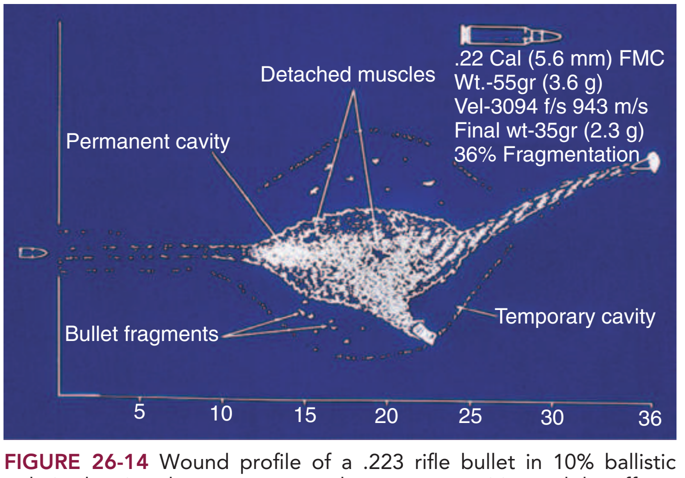


**FIGURE 26-14** Wound profile of a .223 rifle bullet in 10% ballistic gelatin showing the permanent and temporary cavities and the effects of tumbling and fragmentation.

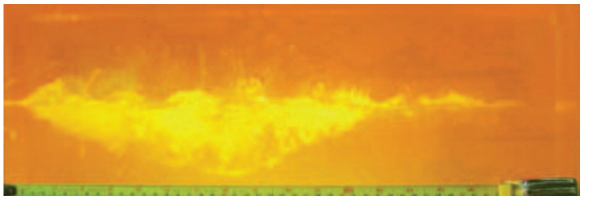

**FIGURE 26-15** The path of a test bullet through ballistic gelatin suggests the amount of tissue damage that a hunting bullet can do inside the human body, even if entrance and exit wounds are small. The data for this bullet are given with Figure 26-13. *(Courtesy Gary K. Roberts, DDS.)*

Other rare problems associated with firearms are explosions that occur within the firearm itself. These can cause burns or fragment types of injuries. When firearms are loaded with excessive amounts of powder or when the wrong powder is used in reloading bullets, the resulting detonation may cause the frame or cylinder of the firearm to explode. The burning powder or fragments of metal can cause injuries to the shooter. These injuries usually occur to the face and hands; penetrating eye injuries are also common. Obstruction of the barrel of the firearm by snow, mud, or other foreign material may cause a similar explosion.

### Trap Injuries

Traps are designed either to kill animals or to capture them alive and uninjured. The latter type poses no risk to humans unless they should happen upon a trap and attempt to free the animal or otherwise approach the trap. The trapped animal often will bite or claw anyone within range. Leghold traps designed to kill or injure an animal may occasionally cause problems for unwary hikers or campers. These traps have a spring-loaded jaw that closes when triggered by something touching the trigger plate, usually involving only 0.5 to 1 kg (1 to 2 lb) of pressure. Most injuries involve the foot, but any area of the body that can fit between the jaws potentially can be injured. The jaws can be released by compressing the spring controlling the jaws (Figure 26-16). Very large traps used to trap poachers or to catch large animals, such as tigers or bears, cannot easily be released without help. These traps may also be attached to large weights, such as logs or concrete blocks, to prevent escape. Fortunately, most of these large traps are now collector's items and not used in the field.

Many injuries occur when the person setting the trap inadvertently causes the trap to spring before it is set in the ground. This often causes hand and finger injuries, especially with amateur trappers unfamiliar with the type of trap (Figure 26-17). Unconventional traps, such as snares, deadfalls, and pit traps, may rarely be encountered, but the mechanisms and types of injuries are quite variable. Trap guns are illegal in most areas of the world; injuries are similar to gunshot wounds.

## TREATMENT OF HUNTING INJURIES

Treatment of hunting injuries involves standard principles and priorities of trauma care. Airway, breathing, circulation, bleeding


**FIGURE 26-16** **A,** A leghold trap set. **B** and **C,** A leghold trap sprung. **D** and **E,** To release a trap that has been sprung, stand on each end of the trap and compress the spring.

**FIGURE 26-17** Spring traps must be set carefully to avoid injury to the person setting the trap.

control, immobilization of the spine and fractured extremities, wound care, and stabilization of the victim for transport should be performed in an expedient manner. Hemorrhage control using a tourniquet for extremity injuries or hemostatic gauze for nonextremity injuries may be necessary. The victim should always be disarmed to prevent accidental injury to the rescuer or further injury to the victim. Removing the firearm or arrow from the vicinity of patient care is usually sufficient, but ideally the firearm should be made safe by removal of the ammunition and opening the firing chamber. Arrows should be placed in a quiver, or the points may be wrapped in cloth to prevent injury.

Management of common traumatic injuries and illnesses, such as hypothermia and mountain sickness, is no different than normal except for one important point: always disarm the victim. A victim with a charged weapon and a head injury or change in mental status for any reason presents immediate danger to a well-meaning rescuer. If the person attempting to offer aid to an injured hunter is not familiar with weapons, it is usually best to move the weapon several feet from the victim and point it in a direction where accidental discharge will do the least harm.

## Arrow Injuries

Lacerations from razor-sharp hunting points are not unusual and can be treated like any similar laceration. The wound should be irrigated, foreign material removed, and the laceration closed primarily. Victims pierced by an arrow should be stabilized, and the arrow should be left in place during transport, if possible. Attempts to remove the arrow by pulling it out or pushing it through the wound may cause significantly more injury and should be avoided. It is acceptable to cut off the shaft of the arrow and leave 8 to 10 cm (3 to 4 inches) protruding from the wound to make transport easier if this can be accomplished with a minimum of arrow movement. A large pair of paramedic-type shears can usually cut through an arrow shaft if it is stabilized during cutting. The portion of the arrow that remains in the wound should be fixed with gauze pads or cloth and tape. A similar approach should be used for spears and knives. The victim should be transferred as quickly as possible to an operating room, where the arrow can be removed under controlled conditions. Radiographs are helpful to identify associated anatomic structures before removal is attempted in the operating room (Figure 26-18).

## Gunshot Wounds

**Myths About Gunshot Wounds.** Many myths associated with the management of gunshot wounds should be repudiated.

*Myth 1:* The size or caliber of the bullet can be determined by the size of the wound. In truth, skin is quite elastic and has high tensile strength. Although a knife or arrow can cut the skin, a blunt bullet must crush the tissue by stretching. This stretching occurs until the bullet passes through and then retracts, causing the wound in the skin to be smaller than the caliber of the bullet.

*Myth 2:* The size of the wound determines whether it is an exit or entrance wound. Actually, the bullet usually tumbles or yaws after striking the skin and soft tissue; if the bullet exits while still tumbling, the exit wound may be larger than the entrance wound. This commonly occurs when a missile strikes an arm or leg where the bullet is in midtumble at 90 degrees when exiting. Often the bullet fragments and only a small portion of the bullet exit, making the exit wound much smaller than the entrance wound. In addition, pieces of bone or tooth may exit, causing an odd-size wound.

*Myth 3:* The path of the bullet can be determined by connecting the entrance and exit wounds. This myth may lead to inappropriate intervention in gunshot wounds. For example, a gunshot wound victim had two wounds about 15 cm (5.9 inches) apart on his upper thigh, and they were initially thought to be entrance and exit wounds. The patient developed abdominal pain, and on chest radiograph it was noted that there were two bullets in the left chest. Subsequent surgical intervention revealed injury to the colon, spleen, bowel, stomach, diaphragm, lungs, and subclavian vessels. So, what appeared to be entrance and exit wounds were actually two gunshot wounds sustained while the patient was lying supine.

FIGURE 26-18 Arrow wound to the left side of the neck near the mandible. The shape of the wound resembles the blades of the broadhead as shown in Figure 26-4.

The outcome of most gunshot and blast wounds depends primarily on the body part that has been injured and secondarily on the environment in which the injury occurred and the quality and timeliness of medical intervention. Although knowing the type of weapon and the physics of ballistics and blast can help predict the extent of physical damage, there is no substitute for attention to detail when examining the patient.

**Emergency Department Care.** Emergency department care of the gunshot wound victim includes securing the airway, placing two intravenous lines in unaffected extremities, performing cardiac monitoring, and providing oxygen therapy. The patient with a neck wound and expanding hematoma should be endotracheally intubated as soon as possible. If endotracheal intubation is not possible, a needle cricothyrotomy followed by a surgical cricothyrotomy should be performed. Relief of tension pneumothorax with a needle or tube thoracostomy or occlusion of a sucking chest wound should be done immediately. Any external bleeding should be controlled by tourniquet or direct pressure. In a wilderness situation, a tourniquet may be necessary to control significant bleeding.

A radiograph should be obtained of the involved area, and where there is a presumed entrance wound without an exit wound, multiple radiographic studies may be needed to find the location of the bullet. On rare occasion, bullets have been observed to embolize from the chest area via the aorta to the lower extremity arteries or to the heart via the vena cava. A type and crossmatch and basic trauma laboratory tests should be performed. Tetanus toxoid and immunoglobulin should be administered as indicated by the victim's history. Any patient in hemorrhagic shock and less than 3 hours since the injury should receive tranexamic acid. This may be given in the prehospital environment and is used by field medics in the military. The dose is 1 g in 100 mL of Ringer's lactate over 10 minutes. This 1-g dose may repeated as an infusion over 8 hours.[49]

Broad-spectrum antibiotics should be administered to cover the wide range of pathogens associated with gunshot wounds, especially with complex wounds to the abdomen and extremities. Antibiotics should be given as soon as possible after injury and may be given in the prehospital setting. The bacterial components of gunshot and blast injury wounds are quite complex. There are a number of environmental pathogens, including soil and water bacteria, such as *Clostridium, Aeromonas, Staphylococcus, Streptococcus, Bacteroides,* and *Bacillus*. These bacteria and associated bacteria on the victim's clothing and skin account for the majority of infections in soft tissue. Wounds penetrating the abdomen increase the presence of *Pseudomonas, Proteus, Escherichia coli,* and other coliforms. Systemic antibiotics should be started as soon as possible and continued for at least 24 hours. Because there is no specific antibiotic that will cover all organisms, the antibiotic should be selected on the basis of the probable type of infection. Cellulitis and necrotizing soft tissue infections can be treated with ceftriaxone plus metronidazole plus gentamicin. Intraabdominal infections can be treated with the same regimen or cefotetan, and ampicillin-sulbactam can be substituted for ceftriaxone, clindamycin for metronidazole, and ciprofloxacin for gentamicin. There is no substitute for drainage of abscesses and empyemas, excision of devitalized tissue, and removal of foreign debris. Topical antibiotics have not been shown to be useful. Surgical debridement and systemic antibiotics are the mainstays of prevention and treatment of wound infection.

Victims in shock should be taken to the operating room immediately to control bleeding. If this is not possible, type O–negative or type-specific blood, plasma, platelets, and tranexamic acid should be transfused. Damage control resuscitation and permissive hypotension as described by Holcomb and others have been shown to be optimal in treating battlefield casualties. The ratio of plasma to red blood cells to platelets at 1 : 1 : 1 is recommended. In some cases, a "massive transfusion" protocol should be instituted. Freeze-dried plasma, synthetic hemoglobin, and other blood substitutes are on the horizon and may one day be recommended for use in the field for treating hemorrhagic shock. Autotransfusion, when available, can be an ideal way to replace lost blood in the victim in shock. Starch or other blood substitutes may raise the blood pressure temporarily, but large amounts of crystalloid fluids may cause increased bleeding. Hypotensive resuscitation, which allows the patient to remain relatively hypotensive as long as organ perfusion is adequate, may be the best intervention if an operating room is not readily available. A systolic blood pressure of 80 mm Hg may not be "normal," but it may be sufficient for a supine patient. Increasing the blood pressure to 110 mm Hg may seem "normal," but it may also cause rebleeding and irreversible shock. Hypotensive resuscitation should be the standard unless the patient loses his or her pulse or level of consciousness. At that time, blood products are the fluids of choice, followed by a starch such as hetastarch (Hextend). Both animal and human studies have shown that hetastarch is superior to crystalloid in maintaining perfusion; therefore, it is recommended by the Committee on Tactical Combat Casualty Care. Level of consciousness and return of pulse should be the clinical goals. Once bleeding is controlled, fluid resuscitation based on physiologic criteria, such as blood pressure, hematocrit, oxygenation, and acid-base status, can be used. Hypothermia, hypotension, and acidosis are the three main causes of coagulopathy in the trauma patient and should be avoided. The patient should be monitored using thromboelastography, which can help guide administration of blood products. Military antishock trousers or pneumatic antishock garments have not been shown to be beneficial in the treatment of shock secondary to penetrating trauma. Emergency thoracotomy is indicated for victims who have lost vital signs shortly before reaching the emergency department or while in the emergency department. Injuries to the heart or great vessels can be occluded with Foley catheter balloons, pericardial tamponade can be relieved, and the aorta can be cross-clamped. Hypothermia is commonly unrecognized in the trauma victim and may lead to coagulopathy, cardiac arrhythmias, or electrolyte disturbances. Rectal temperatures should be obtained and only warmed fluids and blood given to the victim.[2,4,7,26,28,29,35,74]

Wounds from high-velocity bullets are similar to other types of wounds, and standard rules of debridement should be followed. Wide debridement of normal-appearing tissue is unnecessary and should not be done. In general, victims of gunshot wounds should be evacuated quickly and stabilized if possible. Most victims (80%) of gunshot wounds to the chest who survive the first 30 minutes can be treated with a thoracostomy tube and observation.[35] The amount of blood that is drained from the thoracostomy tube determines whether operative intervention is necessary. Draining more than 1500 mL of blood immediately or more than 200 mL/hr for over 4 hours is an indication for thoracotomy. Signs of pericardial tamponade are an indication for immediate pericardiocentesis and operative repair. All gunshot wounds to the abdomen should be explored in the operating room. These include all penetrating injuries below the nipples and above the symphysis pubis.

Radiographs should be used to identify bullets, bullet fragments, and bony injuries. Extremity wounds can be treated conservatively unless signs of vascular injury are present. Signs of arterial injury include pulsatile bleeding, expanding hematoma, absent pulses, presence of a thrill or bruit, or an ischemic limb. Experience in combat has shown that vascular injuries do best when identified and treated immediately. A tourniquet may be needed to control vascular bleeding; if left in place for less than 6 hours, a tourniquet will not likely lead to injury to the limb. Obviously, major bony injuries and nerve injuries eventually need operative therapy, but immediate intervention is rarely necessary. Most important, the underlying injury cannot be determined by examination of the external wound.

Vascular injuries may not be identified during the initial examination; therefore, noninvasive, portable Doppler ultrasound studies can be extremely valuable in the emergency department. Contrast angiography should be performed on any victim with a suspected vascular injury. The removal of the bullet or bullet fragment is not necessary unless the bullet is intravascular, intraarticular, or in contact with nervous tissue, such as the spinal cord or a peripheral nerve. MRI/MRA can be used if indicated and there is minimal iron in the bullet. Most bullets contain lead and copper, but some have a steel core or jacket. Bullets found during exploratory laparotomy or wound debridement should be removed, but it is unnecessary to explore soft tissue, such as muscle or fat, solely to remove a bullet. Shotgun pellets that have minimal penetration can be removed from the skin with a forceps. Plastic or cloth wadding found in superficial shotgun wounds should be removed. Shotgun blasts may produce large soft tissue defects that need extensive debridement and either skin grafting or surgical flap rotation to maximize coverage. Patients with powder burns should have as much of the powder residue removed as possible with a brush under local anesthesia. The powder will tattoo the skin if it is not removed, and the deep burns may need dermabrasion or surgical debridement[46,74] (Figure 26-19).

Retained lead bullets and shotgun pellets for the most part are not hazardous; however, when they are within joint spaces or the gastrointestinal tract, significant amounts of lead can be absorbed and toxicity can occur. Infection of gunshot wounds is common, especially with large tissue injuries, injuries to the bowel, and wounds that are highly contaminated with clothing or other debris. Despite myths to the contrary, bullets are not sterile. Certainly, clothing, skin, and other substances that the bullet may acquire during flight are not sterile. Forensic studies have shown that skin flora, such as *Staphylococcus*, *Streptococcus*, *Mycobacterium*, and other organisms, may be incorporated into the bullet path.[3,57,65]

## PREVENTION OF HUNTING INJURIES

Most state fish and wildlife agencies have recognized that hunters are at risk for injuries and have tried to develop programs to

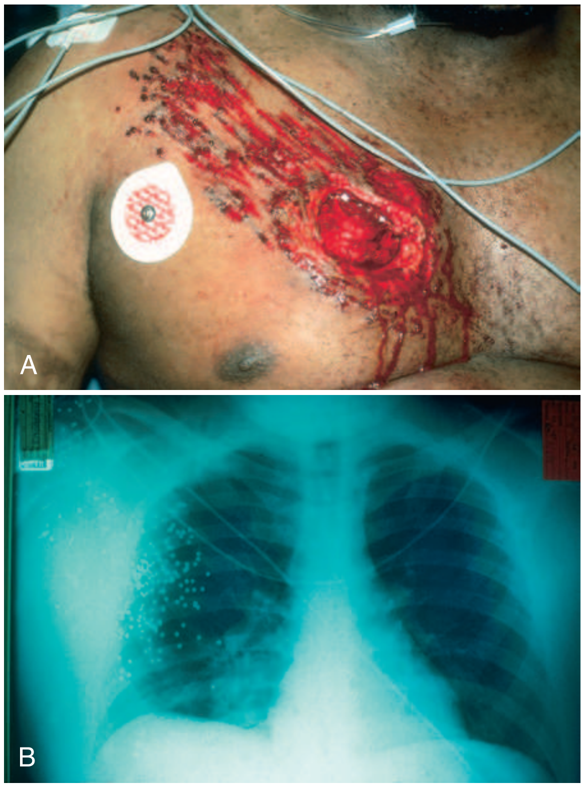


**FIGURE 26-19** **A,** Close-range 12-gauge shotgun wound to the right side of the upper chest. The large central wound was caused by the plastic wadding, and the pellets have struck at an angle toward the shoulder. The patient was turning to the right when shot. The external appearance of the wound indicates a massive injury to the chest. **B,** Chest radiograph of the patient in **A.** No pellets have penetrated the chest, and there was no pneumothorax, pulmonary contusion, or vascular injury. The injury was totally superficial, and the patient was admitted for observation and local wound care.

**FIGURE 26-20** Hunter wearing bright-orange clothing, which is essential to distinguish a human from the background and avoid an accidental shooting. Many accidental shootings have occurred when one hunter's movement was mistaken by another hunter for the movement of an animal.



minimize complications and deaths. National organizations such as the Boy Scouts of America and the National Rifle Association have been teaching firearm and hunting safety for decades. The Hunter Education Association and the International Hunter Education Association have attempted to identify high-risk groups and situations by collecting data on both fatal and nonfatal hunting-related injuries. Hunter safety programs approved by the association are available in every state, and all states except Alaska, Massachusetts, and South Carolina require the course before issuing a license to hunt. These courses are roughly 12 hours long and cover hunter responsibility, firearms and ammunition, bow hunting, personal safety, game care, and wildlife identification. They stress respect for the wilderness and a rational approach to game management. All hunters, potential hunters, and persons going into hunting areas should take one of these courses. Approximately 650,000 hunters complete a hunter safety course annually. Since the first course was given in Kentucky in 1946, more than 18 million hunters have been certified.

Most injuries could probably be prevented by following a few simple rules. Nonhunters should be aware of hunting seasons and designated hunting areas and wear international orange clothing while in hunting areas (Figure 26-20). Hunters should always be sure of their target before shooting, use safety harnesses in tree stands, and use appropriate technique and tools for cleaning game. Tree stands should be well constructed. Hunters should never consume alcohol or mind-altering drugs that might interfere with their judgment. Eye protection in the form of safety glasses should be worn while hunting or target shooting to prevent injuries from ricocheting fragments and shotgun pellets. High-frequency hearing loss is common in hunters because of the loud report of the firearm. Although earplugs and headsets can protect the hunter, they are impractical for most hunting and are used mainly for target shooting. Some hunters use a single earplug for the ear closest to the muzzle of the firearm. This protects the ear most likely to be injured but still allows the hunter to hear approaching game and other hunters. Bow hunters should always use wrist and finger protection to prevent injuries from the arrow fletching and the bowstring. All arrows should be carried in a quiver until ready for use. The broadhead arrow should always be pointed away from the hunter. These few steps would probably eliminate most hunting injuries.[55]

## FISHING INJURIES

Sport fishing is associated with a large number of relatively minor injuries compared with hunting. The usual problems associated with outdoor recreation are common among fishermen: sunburn, frostbite, hypothermia, near drowning, sprains, fractures, motion sickness, and heat illness. Lacerations are relatively more common because of the use of knives to cut bait and fishing lines and to clean fish. These lacerations are often contaminated with a variety of marine and freshwater pathogens that may increase the incidence of wound infection. Thorough debridement of the wound and copious irrigation with sterile saline solution are the best initial methods to prevent infection. If sterile saline in not available, then the cleanest water available should be used. Chlorhexidine scrub incorporated into a brush makes an excellent wilderness cleansing device.

### FISHHOOK INJURIES

Fishhooks are designed to penetrate the skin of fish easily and to hold fast while the fish is played and landed. To perform this dual role, they are extremely sharp at the tip, have a barb just proximal to the tip, and are curved so that the more force applied to the hook, the deeper it penetrates. Fishhooks may be single or in clusters of two, three, or four to increase the chance of catching the fish. Some state fishing laws limit the number of hooks allowed on a single line when fishing for certain game fish, to make fishing more sporting. The greater the number of hooks on a lure or line, the greater the chance of catching a fisherman. The most common fishhook punctures occur when fish are removed from hooks. The combination of sharp hook, slippery fish, and inexperienced fisherman leads to puncture wounds or embedded fishhooks. Many fishermen use commercial fishhook removers or large Kelly forceps to remove hooks. Some fishing guides simply cut the hook with a side-cutting pliers; they believe the remaining segment of hook will eventually oxidize in the fish and disintegrate. A person may step on a fishhook with a bare foot, or a backcast may catch the skin of the angler or another person.

Fishhooks can penetrate skin, muscle, and bone, and they may pierce the eye or the penis. Care must be taken in removing a fishhook so that further damage to underlying structures is avoided. The first step is to remove the portion of the hook that is embedded from any attached lines, fish, bait, or lures. This is best done with a sharp side-cutting pliers. A bolt cutter may be needed for large, hardened hooks, as are used in shark or swordfish fishing. Treble hooks, with three separate hooks attached at a single eye, are designed to improve the chance of catching a fish going after live or artificial bait (Figure 26-21). They are also used in "snagging" fish, in which the line with one or more treble hooks is pulled through the water in an attempt to snag a fish on any part of its body. They may be found on many types of

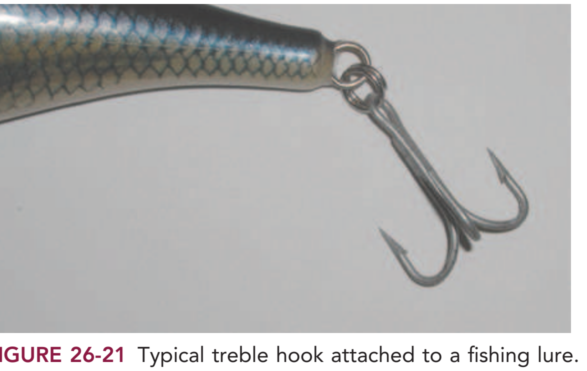

**FIGURE 26-21** Typical treble hook attached to a fishing lure.

**FIGURE 26-22** Examples of types of fishing lures with various arrangements of hooks.

**FIGURE 26-24** Cutting off the body of a fishing lure before applying an eye shield.

fishing lures, some with three or more treble hooks on a single lure (Figure 26-22). When this type of hook is embedded, often more than one of the hooks is involved. Cutting the embedded hooks off the lure or the treble hook will prevent further injury before removal. Most fishermen carry a multitool or needle-nose pliers for removing hooks and lures from fish. These same tools can be used in the field to remove or stabilize embedded hooks.

A number of techniques are used for removing embedded fishhooks, but all involve a certain amount of movement of the hook, which causes increased pain. A local anesthetic should be infiltrated around the puncture site to minimize pain and movement of the patient. The following method can be used if the hook is not deeply embedded (Figure 26-23, *E*). Pressure is applied along the curve of the hook while the hook is pulled with a snapping motion away from the point. Because the barb is on the inside of the curve of the hook, this enlarges the entrance hole enough to allow the barb and point to pass through. Sometimes a string looped through the curve of the hook facilitates the process. If the hook is deeply embedded, pressure can be applied along the curve of the hook to advance it further into the tissue until the point and barb penetrate the skin at another place on the surface, and then the barb can be cut off and the remainder (shaft) of the hook backed out (see Figure 26-23, *A* to *D*).

Most fishhook injuries are not significant. However, penetrating eye injuries can lead to loss of vision in one or both eyes. These types of injuries can occur when the angler has snagged the fishing lure on a rock or other object and, in order to attempt to free the lure, gives a pull that displaces the lure and strikes the angler in the eye. This can also occur when attempting to land a fish, when the lure pulls out of the fish's mouth and strikes the angler in the eye. Many anglers also hook other anglers stationed behind them in a boat or on shore with the backcast. Fishhooks embedded in the eye should be left in place; the eye covered with a noncompressing metal patch, goggles, glasses, or cup; and the victim referred to an ophthalmologist for further care. Local anesthetic can be used to anesthetize the eye before applying the protection. If possible, the body of the fishing lure should be separated from the hook if it can be done without causing further harm. A wire cutter or multipurpose tool can be used for this (Figure 26-24). A plastic cup can be cut to size, or safety glasses or goggles can be used as an expedient eye shield. A pressure patch should not be applied, because this may lead to more serious injury. The cup, glasses, or goggles should be taped in place to prevent the victim from touching the eye and to prevent displacement during evacuation. It is not necessary to patch both eyes (Figures 26-25 to 26-27). All persons with penetrating eye injuries should be given oral antibiotics as soon as possible to prevent vision-threatening endophthalmitis. Rarely hooks become embedded in bone or cartilage; this victim must be taken to the operating room to have the hook removed via a surgical incision.

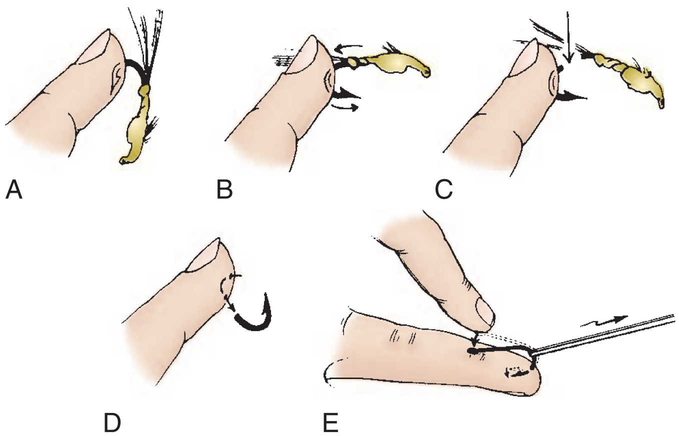


**FIGURE 26-23** **A** to **D,** Removal of a fishhook that has deeply penetrated a fingertip. **E,** "Press-and-yank" method of fishhook removal.

**FIGURE 26-25** Improvised eye shield using a plastic cup cut to fit over the eye without touching it.

**FIGURE 26-26** Improvised eye shield using a pair of glasses.

**FIGURE 26-27** Improvised eye shield using a pair of goggles.

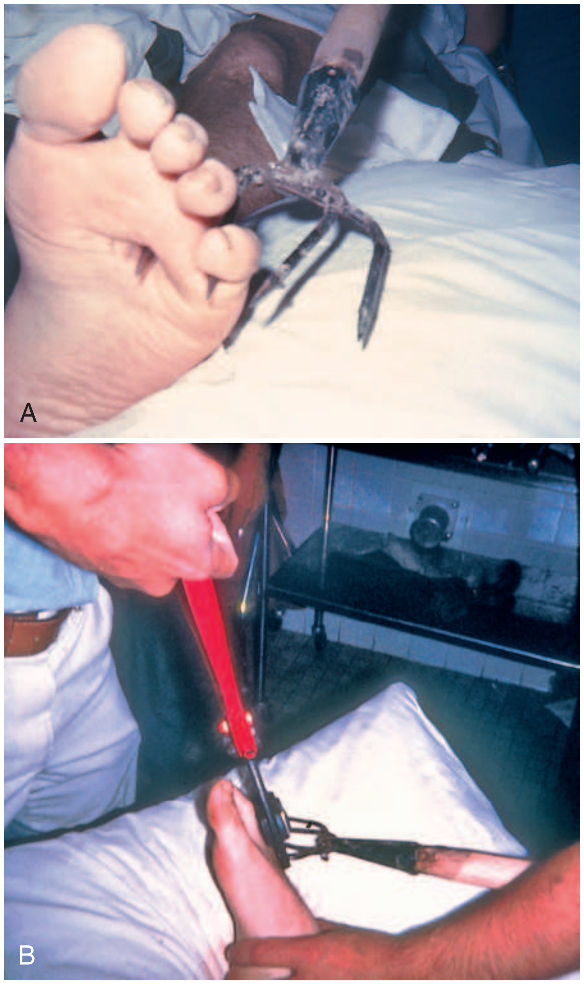


**FIGURE 26-28** **A,** Male patient with a multipronged fishing spear through the foot. He said he saw something move, and he speared it. **B,** Same patient with the spear being cut off in the emergency department with a bolt cutter. The patient was taken to the operating room to have the remainder of the spear removed.

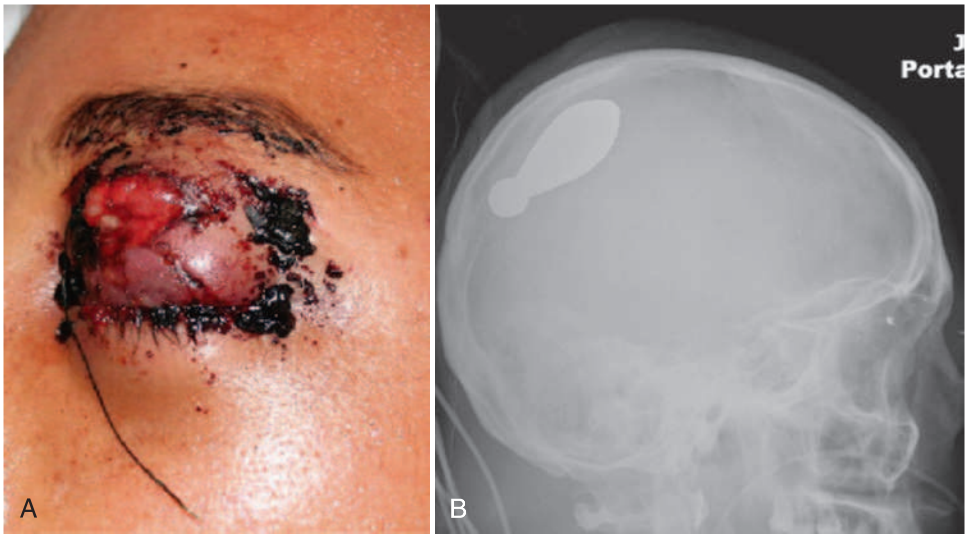


**FIGURE 26-29** Intracranial fishing line sinker, **A,** Eye sinker wound. **B,** Skull sinker radiograph. *(From Seitelman E, Premo J, Cardoza S, et al: Young man with fishing injury: Intracranial fishing line sinker,* Ann Emerg Med *54:854, 2009.)*

## FISHING SPEAR INJURIES

Fishing spears, like fishhooks, are designed to penetrate and hold fish. They may be jabbed, thrown, or propelled by rubber straps or carbon dioxide cartridges. The more force used to propel the spear, the deeper the penetration into tissue. Although arrows are designed to cause bleeding and bullets to cause crushing, fishing spears are designed to hold the fish until it drowns or is otherwise dispatched. Spears may penetrate the human chest or abdominal cavity, skull, or any other anatomic area. Some bleeding may occur, especially if major blood vessels are struck. The victim should be removed from the water as soon as possible and immediate attention given to airway, breathing, and bleeding control. The spear should be stabilized in place, and the victim immediately transported to a medical facility. Penetrating neck and chest injuries may require endotracheal intubation and tube thoracostomy. If a spear is embedded in the victim's cheek and interferes with his or her airway, cutting the spear off with a bolt cutter and removing it through the mouth is permitted. Spears in all other locations should be left in place, although they may be cut off to facilitate transportation or improve the victim's comfort (Figure 26-28).[50]

## OTHER FISHING INJURIES

Although spears and hooks cause the majority of penetrating injuries, fishing weights or sinkers can also be hazardous. Fishing sinkers are usually composed of lead and range in size from a few grams to 85 to 113 g (3 to 4 oz). When propelled by the action of a rod, they may act as projectiles with quite a bit of kinetic energy. Ancient hunters and warriors used lead and stone projectiles propelled by slings to hunt game or in battle to inflict serious injuries. The energy stored in a 2.1-m (7-foot) fiberglass fishing rod is potentially more than that delivered by a standard sling, so it is not surprising that an injury such as the one shown in Figure 26-29 is possible.

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CHAPTER 27

# Tactical Medicine

LAWRENCE E. HEISKELL, BOHDAN T. OLESNICKY, AND SYDNEY J. VAIL

Tactical medicine is both routine care and emergency care provided to victims of illness or injury related to law enforcement or military operations, often in a hostile environment.[52] Many law enforcement agencies now have tactical medical teams composed of physicians and prehospital care providers. The U.S. military, law enforcement agencies, emergency medical services (EMSs), and prehospital communities commonly use the term *tactical medicine*. In the past, the term *tactical emergency medical support (TEMS)* has been used. In addition, the U.S. military coined the phrase *combat casualty care* (see Chapter 28).

The field of tactical medicine, a subspecialty of emergency medicine, has grown rapidly. In the past 25 years, hundreds of publications addressing tactical medicine issues have been written worldwide. Tactical medicine education programs have trained tens of thousands of emergency medical technicians (EMTs), paramedics, and physicians who have responded to the call to provide on-scene emergency medical care to members of the law enforcement community[48] (Figure 27-1). Tactical medicine is similar for both military and civilian providers; techniques, strategies, protocols, and equipment have few differences. Although routine medical care and performance enhancement (e.g., conditioning, nutrition, and rest) are important for both civilian and military tactical teams, they are especially important for the military provider. A civilian operation typically lasts hours to days. (The Waco and Ruby Ridge incidents were exceptions and more in keeping with a military-style length of engagement.) Military medical providers often serve long deployments (days to months) that require significant attention to preventive medicine. Prevention and treatment of other sources of poor health (e.g., disease and nonbattle injury) are as important as tactical medical care (Table 27-1).

Tactical medicine is critical for modern military operations. Hospital corpsmen, or combat medics, are deployed on the front lines with warfighters to provide basic medical care. This care is often provided under fire and in harsh environments (e.g., jungle, desert, ocean, high mountains, and other austere conditions). Leaders have recognized the need to extend ever higher levels of care closer to the battle area. During Operation Iraqi Freedom, shock trauma platoons, composed of emergency physicians and support staff, were sent to the front lines to provide advanced resuscitative support. These units could be fully operational and caring for patients in less than 30 minutes. Mobile surgical teams and forward resuscitative surgical teams developed technology to establish trauma surgical teams within minutes of the location of a combat casualty. These teams have evolved to become fully mobile and able to set up or dismantle in 30 minutes. They use tent shelters or shelters of opportunity to perform operations and provide lifesaving damage-control surgery to multiple patients under extreme wartime conditions. During civilian law enforcement tactical operations, medics can be deployed within seconds to care for an injured officer (Figure 27-2).

Tactical medics are trained to resuscitate, treat, and transport patients in extreme hot or cold temperatures over rough terrain and in hostile territory while protecting patients from further injury. Critically injured patients can be pharmacologically paralyzed and intubated, while wounds are still open and efforts are made to prevent hypothermia, dehydration, and coagulopathy (Figure 27-3).

Tactical medicine anticipates and reacts to changes in combat strategy. This translates directly to law enforcement. During Operation Iraqi Freedom, the most serious injury patterns were primarily high-velocity penetrating wounds, mostly gunshot wounds (Figure 27-4 and Table 27-2).[27] As the war continued in Iraq, improvised explosive devices (IEDs) became the insurgents' weapon of choice.[75] Such weapons produce significantly more trauma (i.e., shrapnel, blast, and thermal injuries). IEDs have required changes in tactics, vehicles, and protective body armor because injury patterns have changed to include more devastating extremity and head-and-neck wounds than torso wounds

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**FIGURE 27-1** Law enforcement tactical medic prepares to intubate an unresponsive officer. *(Courtesy International School of Tactical Medicine.)*

(Figure 27-5).[26] IED blast patterns cause shrapnel to angle up under traditional body armor and through arm openings. This has promoted development of armor that better helps protect the torso.

Civilians may also sustain penetrating injuries during tactical operations (Figure 27-6). Terrorist attacks of September 11, 2001, and mass shootings (e.g., Columbine High School shootings in 1999) have increased American awareness of local threats of terrorism and violence. This has diminished resistance to medical providers being closely involved in law enforcement special operations. Today, hundreds of fire and EMS agencies provide tactical emergency medical support to federal, state, and local law enforcement special operations teams.

Law enforcement special operations, often referred to as SWAT (special weapons and tactics) teams, are intended to deal with a wide range of high-risk criminal problems and threats.[65] These include, but are not limited to, hostage rescues, terrorist acts, barricaded suspects, violent and suicidal suspects, take-over bank robberies, high-risk warrant services, and active shooter situations. Tactical medics must train and prepare for these types of difficult situations[16,41,42,] (Figure 27-7A).

Patient advocacy, with priorities of ensuring the best possible quality of care and patient confidentiality, can be at cross-purposes with a law enforcement officer trying to gather important facts in an investigation to ensure public safety and justice. Tactical medicine providers must respect both patient rights and mission goals. During tactical operations, medics must be constantly aware of the need to preserve evidence within the environment (see Figure 27-7B).

**TABLE 27-1** Nonbattle Conditions Encountered by Tactical Medical Personnel (Spring 2003)*

| Primary ICD-9 Disease Category | *n* | % of Total |
|---|---|---|
| Digestive | 44 | 17.4 |
| Symptoms ill defined | 38 | 15.0 |
| Mental disorders | 29 | 11.5 |
| Musculoskeletal | 29 | 11.5 |
| Genitourinary | 21 | 8.3 |
| Nervous system sense organs | 17 | 6.7 |
| Skin | 15 | 5.9 |
| Supplemental | 15 | 5.9 |
| Infectious and parasitic | 10 | 4.0 |
| Circulatory | 10 | 4.0 |
| Endocrine, nutritional | 8 | 3.2 |
| Neoplasms | 6 | 2.4 |
| Respiratory | 5 | 2.0 |
| Pregnancy | 3 | 1.2 |
| Congenital | 3 | 1.2 |
| Total | 253 | 100.0 |

*Navy/Marines Operation Iraqi Freedom from March 21 to May 15, 2003.
ICD, International Classification of Diseases.

**FIGURE 27-2** Tactical medics evaluate an injured tactical team member. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*


**FIGURE 27-3** Injured tactical officer being extracted from the hot zone. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

**FIGURE 27-4** A high-velocity gunshot wound to the right arm. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

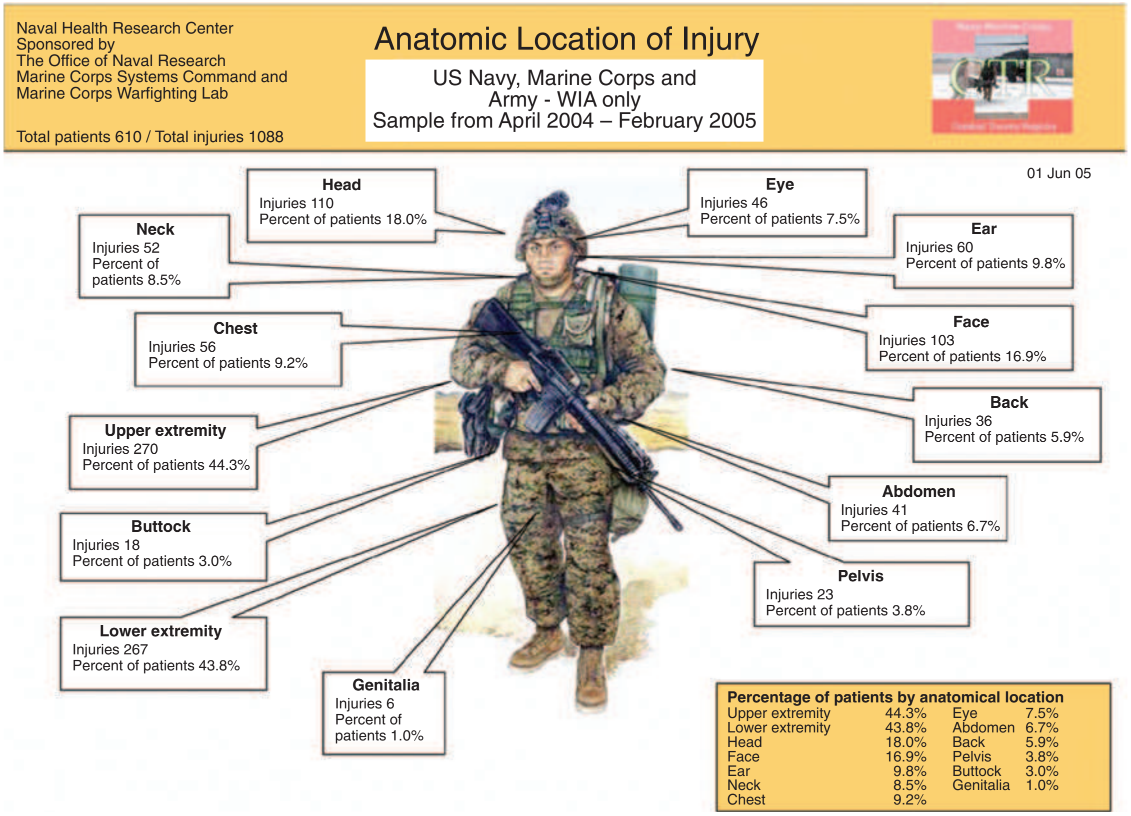


**FIGURE 27-5** Anatomic location of injury (wounded in action [WIA] only). *(Courtesy Naval Health Research Center.)*

SWAT teams are found in most midsize and larger law enforcement departments throughout the United States. In some areas, small departments have banded together to form multijurisdictional or regional SWAT teams.[14] Incidents under harsh environmental conditions, including wilderness situations, require tactical field medical support. Tactical medicine has grown into a multifaceted specialty.

## HISTORY OF TACTICAL MEDICINE

Much of civilian SWAT team training and tactics is based on military special operations experience. Military teams have their origins in the U.S. Office of Strategic Services and British Special Air Service during World War II. Some of the earliest military special operations teams incorporated tactical medical components.

German *Fallschirmjäger* (paratrooper) units incorporated a well-organized medical support team with physicians. Dr. Heinrich Neumann jumped with his unit during the invasion of Crete in 1942.[34] During the Normandy invasion in 1944, at Pegasus Bridge on the Orne River, the British, led by Major R.J. Howard, landed with medical support, accompanied by a physician, Captain J. Vaughan of the Royal Army Medical Corps.[2] The U.S. Armed Forces also incorporated physicians in their assault. Dr. Robert Franco and Dr. Daniel B. McIlvoy both parachuted into Sicily with the 82nd Airborne Division in April 1943, and jumped into Normandy in June 1944.[23]

The Army Special Forces (77th Special Forces Group) was formed in the 1950s. As U.S. Special Operations teams evolved, other specialized teams (e.g., DELTA, the U.S. elite counterterrorist force) were formed.[33] Each of these special operations units

**TABLE 27-2** Battle Conditions Encountered by Tactical Medical Personnel (Spring 2003)*

| Mechanism of Injury | n | % of Total |
|---|---|---|
| Gunshot wound | 76 | 24.1 |
| Shrapnel/fragmentation wound | 65 | 20.6 |
| Rocket-propelled grenade (handheld antitank grenade launcher/grenade) wound | 39 | 12.4 |
| Motor vehicle accident injury | 28 | 8.9 |
| Fall injury | 17 | 5.4 |
| Explosion injury | 16 | 5.1 |
| Unknown/not recorded | 16 | 5.1 |
| Land mine injury | 14 | 4.4 |
| Mechanical/machinery injury | 13 | 4.1 |
| Blast injury | 11 | 3.5 |
| Other injury | 10 | 3.2 |
| Multiple injuries (not otherwise specified) | 4 | 1.3 |
| Blunt force injury | 3 | 1.0 |
| Debris injury | 3 | 1.0 |
| Total injuries | 315 | 100.0 |

*Navy/Marines Operation Iraqi Freedom from March 21 to May 15, 2003; wounded in action.

**FIGURE 27-6** Suspect sustained a self-inflicted gunshot wound to the chest moments before a dynamic entry. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*


**FIGURE 27-7** **A,** Tactical medics train for active shooter situations under low light conditions. **B,** Crime scene: recognition and preservation of evidence are critical components of tactical medicine training and education. *(Courtesy International School of Tactical Medicine.)*

has a plan for tactical medical support. Increasing awareness of terrorism in the 1970s led to formation of other special operations groups worldwide. After the 1972 tragedy at the Olympic Village in Munich, Germany established a special unit within their border police known as GSG9 (Grenzschutzgruppe-9).[94] In 1974, France formed Groupe d'Intervention de la Gendarmerie Nationale. Many other countries have since developed similar units.

Medical providers in the combat environment were traditionally taught to apply principles of traditional hospital-based advanced trauma life support (ATLS). Although this training was instrumental in decreasing complications and deaths in trauma victims in noncombat scenarios, it provided inadequate care for patients and combatant team members in battle. Numerous reviews have noted inadequacies of this approach to battlefield medical care.[6,8,12,97]

Ninety percent of battle deaths occur in the field before any medical intervention. In 1984, a landmark review of wounds and deaths in battle noted that 31% of battlefield deaths resulted from penetrating head injury, 25% from surgically uncorrectable torso trauma, 10% from potentially correctable torso trauma, 9% from exsanguinating extremity wounds, 7% from mutilating blast trauma, 5% from tension pneumothorax, 1% from airway obstruction, and 12% from various wounds (sepsis and shock off the battlefield) (Figure 27-8).[7,69] Potentially preventable battlefield causes of death include bleeding to death from extremity wounds, tension pneumothorax, and airway obstruction.[51]

These statistics are also found in today's military conflicts and in most tactical medical scenarios. These preventable causes of death are inadequately addressed by application of basic advanced life support precepts of airway, breathing, and circulation (ABC) in battlefield and tactical situations. In 1993, led by the Naval Special Warfare Command, a multiagency working group (the Committee on Tactical Combat Casualty Care), which included special operations physicians, medics, corpsmen, and operators, began a 2-year study of this issue. This led to the guidelines entitled *Tactical Combat Casualty Care in Special Operations*.[12] The committee meets regularly and reviews new equipment, practices, and current operations to see what lessons can be learned and revises guidelines as appropriate. The guidelines, which evolved from the special operations community, are currently being evaluated and implemented in most combatant units of the U.S. military and of many other countries.[11]

The Committee for Tactical Emergency Casualty Care (C-TECC) was formed in 2011 and is made up of a broad range of interagency operational and academic leaders. It includes experts in high-threat medicine, emergency medical services, and police, fire, and military special operations. C-TECC maintains and updates TECC guidelines, incorporates new information and technology, and reflects the best evidence-based medicine principles. C-TECC remains an independent civilian entity, but maintains a close relationship with the Committee in Tactical Combat Casualty Care (TCCC) for guidance and support.

U.S. civilian SWAT teams evolved from high-profile criminal acts that resulted in possibly preventable losses of human life. The seminal incident involved a sniper in 1966 at the University of Texas at Austin, who killed 16 people and wounded 31 others.[66] Local law enforcement agencies were ill equipped to deal with the threat, hampered by inadequate weaponry, and not trained to respond in optimal fashion. After this incident, many law enforcement agencies began to develop specially trained and equipped tactical units to respond rapidly to these public safety threats.[28] The Los Angeles Police Department and the Los Angeles County Sheriff's Department were among the first law enforcement agencies in the United States to organize and develop full-time tactical units specifically trained to handle high-risk incidents.

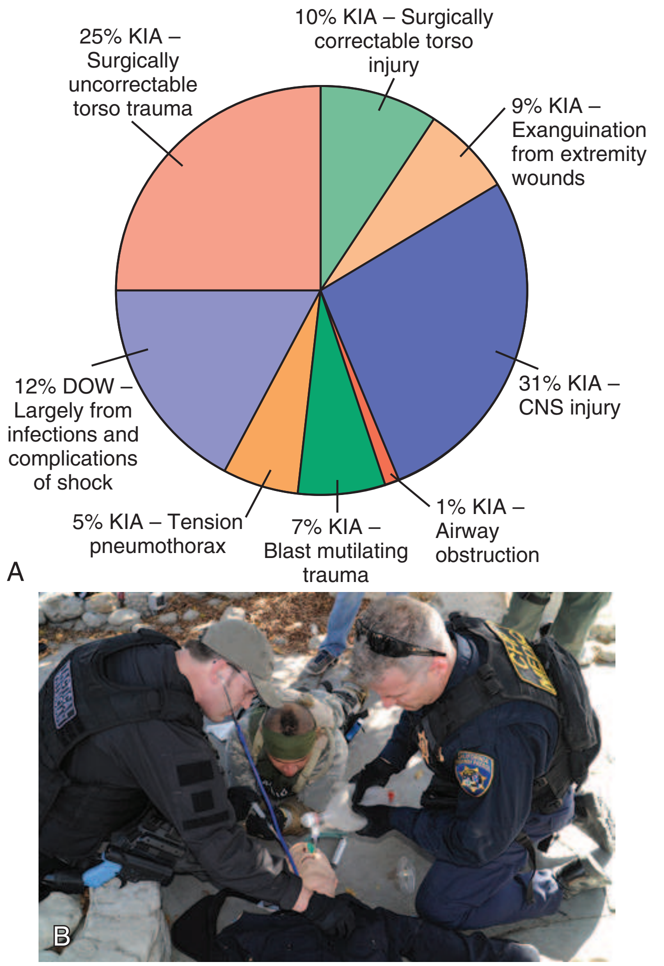


**FIGURE 27-8** **A,** How people die in ground combat. **B,** Tactical medics establish an airway during a training exercise. CNS, central nervous system; DOW, died of wounds; KIA, killed in action. *(Courtesy International School of Tactical Medicine;* ***A,*** *courtesy Colonel Ron Bellamy;* ***B,*** *courtesy Lawrence E. Heiskell, MD.)*

Before 1989, great diversity existed in how emergency medical care was provided during law enforcement tactical operations. Most law enforcement agencies relied on regular civilian EMS providers staged at a safe location removed from the area of operation, or they simply dialed 9-1-1. Although this took advantage of an established prehospital care system, care for injured officers could be significantly delayed.[96]

Other agencies trained full-time SWAT officers as EMTs or paramedics. This concept of getting medical care "close to the fight" was also realized in the Gulf War. The U.S. military put this new concept in place during Operation Iraqi Freedom. Information obtained from interviews with military emergency physicians who served in Iraq has suggested the new model of battlefield care has succeeded.

## SHARED PRINCIPLES OF MILITARY TACTICAL COMBAT CASUALTY CARE AND CIVILIAN TACTICAL MEDICINE

TCCC varies from ATLS in several distinct ways, most critically in that the victim and medical provider are not in a safe environment. In addition, medical care of the victim may not be the highest priority, and the team may be operating in the open under extreme environmental conditions, hours from higher levels of care.

The premise of TCCC is to do the right things at the right times. Underlying this basic statement is the suggestion that good hospital-based medicine is often not good battlefield medicine,[11] as logically follows from these three statements:

1. Good medicine can be bad tactics.
2. Bad tactics can get everyone killed.
3. Bad tactics can cause the mission to fail.

The ultimate goals of TCCC are the following:

1. Treat the casualty.
2. Prevent additional casualties.
3. Complete the mission.

TCCC is divided into three main stages of care:[11] care under fire, tactical field care, and combat casualty evacuation care. These are defined in the following paragraphs.

### CARE UNDER FIRE

Sometimes care is rendered by a medic or corpsman at the scene of the injury while hostile fire is still a danger. Medical equipment is limited to what the individual operator or the corpsman or medic can carry in the medical pack. The most effective medical care during this stage of TCCC is fire superiority, that is, winning the battle, or at least keeping enemy heads down and reducing hostile incoming fire. The medical provider (and the wounded soldier, if able) must work to suppress hostile fire and eliminate the threat as directed by the mission commander, and, if possible, to protect the injured fighter from further harm.

For many reasons, this is undoubtedly the most difficult phase of TCCC. Traditional providers trained to be a "medic first" may find it hard to direct attention to the threat and not respond to the casualty. This phase usually occurs in the most exposed environment where the provider cannot use normal assessment tools. For example, during nighttime hours, the provider cannot use a light, because it could draw fire. Auscultation for lung sounds with a stethoscope in an explosion-rocked firefight is useless. In earlier conflicts, it was noted that many medics who responded to aid casualties did not suppress gunfire and were wounded or killed, and that a significant number of the victims that they were trying to rescue were already dead. Medic priorities during this phase of care therefore are as follows:[11]

1. Return fire and take cover.
2. Direct the casualty to remain engaged as a combatant if appropriate.
3. Direct the casualty to move to cover and apply self-aid if able.
4. Try to keep the casualty from sustaining additional wounds.
5. Extract casualties from burning vehicles or buildings, and move them to places of relative safety. Do what is necessary to stop the burning process.


FIGURE 27-9 A police tactical medic applies a SOFT-T tourniquet during a tactical medical training simulation. *(Courtesy International School of Tactical Medicine and Tactical Medical Solutions, Inc., Lawrence E. Heiskell, MD.)*

6. Airway management is generally best deferred until the tactical field care phase.
7. Stop life-threatening external hemorrhage if tactically feasible:
   - Direct the casualty to control hemorrhage by self-aid if able.
   - Use a TCCC-recommended tourniquet for hemorrhage that is anatomically amenable to tourniquet application.
   - Apply the tourniquet proximal to the bleeding site over the uniform; then tighten it and move the casualty and medic to protective cover.

Airway and breathing problems are not addressed during this phase. The key action is to stop exsanguinating hemorrhage. A tourniquet is the primary means to stop bleeding on an extremity. A tourniquet can be applied and left in place by the injured operator or medic, who can then return fire in support of the team. If the location of the wound is not amenable to placing a tourniquet, apply direct pressure and a hemostatic dressing (Figures 27-9 to 27-12).

As soon as possible, move the casualty to a safer location and institute the next phase of TCCC. Techniques for movement are dictated by the tactical situation (e.g., vehicles, buddy lifts, or dragging). Another departure from traditional ATLS teaching is that cervical spine protection is not routinely provided in this phase of care. Studies of penetrating neck injuries in Vietnam demonstrated that only 1.4% of patients with penetrating injuries would have benefited from cervical spine immobilization.[4]

FIGURE 27-10 Tactical medic applies the SWAT-T tourniquet to an injured team member. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*


**FIGURE 27-11** SWAT-T Tourniquet being used for a thigh injury. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

## TACTICAL FIELD CARE

Consult the most current revision of the TCCC and C-TECC guidelines (c-tecc.org/guidelines).

The tactical field care phase consists of care rendered once the medic and casualty are no longer under effective hostile fire. It also applies to situations in which an injury has occurred on a mission where there has been no hostile fire. Available medical equipment is still limited to that carried into the field by mission personnel. Time before evacuation to a medical treatment facility may vary considerably.

In this phase, the medic has a short time to evaluate and treat the wounded. The medic assesses injuries, performs medical care as able (equipment is still limited to what was carried onto the battlefield), and informs the mission commander of the findings. The mission commander determines what action (e.g., evacuate, abort, continue) will be taken. This again may be a major departure from nontactical medical care, in that the medical provider is not the ultimate authority on patient disposition. The mission commander decides how much time is taken to care for the casualty in any phase of the operation, if and when medevac will occur, and what assets will be allocated from the primary mission toward care of the injured.


**FIGURE 27-12** Emergency bandage applied to the leg. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

*Step 1:* During this phase, the provider must assume not only that hostile fire may occur at any time but also that any injured team member with altered mental status may become a threat. The provider must therefore disarm the team member, an action that is resisted by most warfighters who have become casualties.

*Step 2:* Address airway compromise. Airway actions are usually rendered as follows: If the victim is unconscious without obstruction, use a nasopharyngeal airway (better tolerated and less likely to become dislodged with movement than is an oropharyngeal airway)[1] and place the victim in rescue position. If airway obstruction is present and cannot be alleviated with these maneuvers, the next recommended treatment is to move directly to a surgical cricothyrotomy. Endotracheal intubation is not recommended at this level of care for several reasons: (1) It requires the medic to carry onto the battlefield equipment that has no other purpose; (2) the medic must practice regularly to maintain his or her skills; (3) success rates under austere conditions are believed to be significantly less than those achieved in a controlled or semicontrolled setting; and (4) the laryngoscope light may compromise team safety on the field.[79,91,92] Emergency cricothyrotomy is the best option in this phase of TCCC. Because of distorted anatomy, it is the best way to protect the airway of a patient with maxillofacial wounds. Blood and tissue in the airway may preclude cord visualization and make endotracheal intubation difficult or impossible.[11,87]

*Step 3:* Treat breathing difficulties. Any severe progressive respiratory distress is assumed to be due to a tension pneumothorax (the second leading cause of preventable battlefield deaths). One cannot wait for the classic signs of diminished breath sounds, hyperresonance, and tracheal deviation to make this diagnosis, because these signs are unreliable at best and often impossible to ascertain on the battlefield.[72] Faced with victims in increasing respiratory distress and with unilateral penetrating chest trauma, the medic will perform a needle thoracostomy on the side of injury. This is the definitive procedure in this phase. A chest tube is not usually needed because it is difficult to perform on the battlefield and would further complicate patient care, transportation, and mission completion.[11]

*Step 4:* Readdress bleeding. The medic rapidly locates uncontrolled hemorrhage and any wounds that are in the vicinity of a tourniquet(s). If possible, a hemostatic dressing is placed. The tourniquet may be discontinued if the wound and tactical scenario permit. Even if the bleeding appears controlled, further "rough" evacuation may necessitate keeping a tourniquet in place to prevent rebleeding. Each action the medic takes is designed to save life with minimal additional care by the medic. For example, a medic who is holding pressure on a bleeding wound cannot return fire, take care of other casualties, or perform other procedures on this patient. The patient is not optimally prepared for transportation, which may consist of being thrown over someone's back and carried out. Thus, a tourniquet that would be a last-ditch effort in a noncombat environment becomes the method of choice in the tactical combat situation. Each operator in the field carries and knows how to use at least one tourniquet that can be self-applied. This allows the operator to self-administer lifesaving bleeding control and then continue with the fight until treatment by the medic is possible.

*Step 5:* The medic should determine whether an intravenous (IV) line or a saline lock is beneficial. Advantages include IV access for fluid resuscitation and antibiotics. Disadvantages include a probable delay in transportation, additional equipment required, increased likelihood of equipment failure (bulky apparatus can become dislodged or tangled during evacuation), and difficulty in placing an IV line under austere tactical conditions. If an IV line is deemed necessary but cannot be expeditiously placed, use the intraosseous route. Several devices can be used to achieve this, including large-bore hypodermic needles, traditional intraosseous needles, and devices such as the FAST1 Intraosseous Infusion System and BIG (Bone Injection Gun), which quickly and accurately place the needle in the sternum or another appropriate location.

*Step 6:* Determine whether fluid resuscitation is required. In general, if the patient is not in shock (the best indicators of shock in the field are altered mental status in the absence of head injury, and weak or absent pulses), then no IV fluids are necessary. If the patient is conscious, oral rehydration is permissible and preferred in many tactical scenarios. If the patient is in shock and a significant blood transfusion is anticipated, administer tranexamic acid 1 g in 100 mL normal saline or lactated Ringer's solution (as soon as possible but not later than 3 hours after the initial injury) and Hextend (6% hetastarch, balanced electrolytes, a lactate buffer, and physiologic levels of glucose) as a 500-mL bolus.[63] Reassess after 30 minutes. If the victim is still in shock, administer another 500 mL bolus of Hextend. Typically, no more than 1000 mL of Hextend is given. Determine further efforts at resuscitation based on the tactical scenario. If the patient has a traumatic brain injury and is unconscious and pulseless, give fluid resuscitation to attempt to restore pulses. This protocol maximizes patient survival and limits the amount of equipment carried onto the battlefield.

*Step 7:* Inspect and dress known wounds. Locate and appropriately treat wounds already identified but not yet treated because of tactical considerations. Perform a quick but thorough head-to-toe assessment for additional wounds. This is analogous to the secondary survey of ATLS, with a couple of notable exceptions. First, the patient is not fully exposed. This is because the patient may have to be moved quickly if the tactical situation changes and because the patient must be kept warm and protected from further injury for a much longer time than in a hospital setting. The medic often does this examination by feel to avoid using white light, to keep the victim's body armor as intact as possible, and to avoid removal of protective clothing that may be required during evacuation.

*Step 8:* Assess for pain control. Administer analgesia in this phase of care with the following considerations. If the victim is able to fight, nonnarcotic preparations are used. These do not affect mental status, and they allow the victim to remain armed and responsive. If the victim is unable to fight, morphine and promethazine, IV or intramuscular (IM), are given as needed.

*Step 9:* If not already done, splint fractures and recheck the neurovascular status.

*Step 10:* Consider early administration of antibiotics for open combat wounds. This significantly reduces the rate of infection.[13] Oral medication is preferred if the patient is conscious. A broad-spectrum antibiotic should be selected that is active against gram-positive and gram-negative microbes, aerobes, anaerobes, and freshwater and saltwater pathogens (when applicable).

If the victim is unable to take oral medication or has significant abdominal trauma, IV or IM antibiotics are used. Appropriate antibiotics may include moxifloxacin 400 mg orally once a day, cefotetan 2 g intravenously (a slow push over 3 to 5 minutes) or intramuscularly every 12 hours. Ertapenem can also be used in a dose of 1 g intravenously or intramuscularly once a day.

*Step 11:* Continue to communicate with the victim. Give encouragement, explain the care given, and provide updates on the tactical scenario if appropriate.

Traumatic cardiac arrest is treated on the battlefield just as it is in the civilian setting. If the victim is pulseless, apneic, and has no sign of life, resuscitation is not attempted. After these measures, or if medical evacuation is now available, enter the last phase of TCCC, which is combat casualty evacuation care.

### COMBAT CASUALTY EVACUATION CARE

Render this phase of care once the casualty (and usually the rest of the mission personnel) has been picked up (e.g., by aircraft, land vehicle, or boat). Additional medical personnel and prestaged equipment should be available for casualty management. Management plans are consistent with the tactical field care phase, with the addition of more equipment and, likely, higher levels of medical providers. This phase is most similar to ATLS, although it may occur within a moving conveyance and is still somewhat limited by available equipment and the tactical scenario. Basic medical plans for combat casualty evacuation care are:

*Airway management:* The procedure is the same as for tactical field care, with the addition of a laryngeal mask airway/King airway/endotracheal intubation for definitive airway management before cricothyrotomy if the operators are trained and the patient can be endotracheally intubated (e.g., has no midface injuries). Spinal immobilization is still not deemed necessary for casualties with penetrating trauma.

*Breathing:* The initial considerations are the same as those for tactical field care. Place a chest tube if needle thoracostomy has produced no improvement in breathing, or if long transport is anticipated. Most combat casualties do not require oxygen, but it may be of benefit in the following situations: low oxygen saturation by pulse oximetry, injuries associated with impaired oxygenation, unconscious patient, and traumatic brain injury (maintain oxygen saturation > 90%). Treat sucking chest wounds with petroleum gauze applied during expiration. Cover with tape or a field dressing and place the victim in the sitting position. Monitor for development of a tension pneumothorax. Chest seals are ideal for quickly securing chest tubes and for sucking chest wounds.

*Bleeding:* The procedure is the same as for tactical field care.

*IV line:* The procedure is the same as for tactical field care.

*Fluid resuscitation:* The procedure is the same as for tactical field care, with blood and/or lactated Ringer's solution if available.

*Monitoring, wound care, reinspection for additional wounds, analgesia, reassessment of fractures, antibiotics:* These steps are the same as those for tactical field care.

A main precept of TCCC is to move medical care from being the sole responsibility of the combat medic to involve each operator and level of leadership. Each fighter carries a tourniquet that can be self-placed. Each fighter is trained in basic combat lifesaving skills to minimize the effects of wounds (within defined limits) so that fire can be returned until the medic can arrive and perform appropriate advanced medical care. Each leader, from the squad level up, is trained to evaluate medical concerns as an integral part of the mission objective and can decide when to abort, continue, or alter the mission based on medical issues.

## PRINCIPLES OF CIVILIAN TACTICAL MEDICINE

Tactical environments present unique challenges to law enforcement officers and for personnel providing EMS medical support. Tactical medical care providers must understand and consider law enforcement tactics and mission-specific objectives in order to effectively plan for and provide medical support (Figure 27-13).[50] Most comprehensive law enforcement tactical medicine programs require medical providers to attend some formal law enforcement training. Before deployment, further training in


FIGURE 27-13 Tactical medic and team leader discuss an operational preplan for medical threat assessment during a tactical medical training evolution. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

**FIGURE 27-14** At the International School of Tactical Medicine, law enforcement tactical medics train for treating a tactical officer with massive blood loss during a training exercise. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

SWAT school will most likely also be required to familiarize tactical medics with basic and advanced tactics. This extensive training may result in reserve police officer status for the medical provider. The operator then takes on a truly hybrid role of medical provider and law enforcement provider.

Traditional EMS doctrine maintains that rescuer and scene safety are first priorities, and that patient care is a secondary concern.[74] Tactical operations require that law enforcement officers and tactical medical personnel operate in unsecured environments with significant potential for violence and injury (Figure 27-14).[70] Tactical scenes are rarely safe from the civilian standpoint. Tactical medical personnel are trained to conduct concise and limited medical evaluations and interventions in potentially threatening areas.[80]

What sets tactical EMS apart from standard EMS is the ability to render immediate care in an environment that may not be completely secured from threats (Figure 27-15). When a SWAT team relies on traditional EMSs to provide medical care and an individual is acutely injured during the mission, the EMS unit must either wait until the patient is brought out to the safe (cold) zone (Figure 27-16) or wait for the entire scene to be secured by law enforcement before the patient is evaluated and moved. The Columbine School shooting illustrated how certain victims will die if medical aid is not rendered in a timely manner. When a tactical medical unit is present, care can generally be rendered swiftly. When the injuries involve acute airway issues or life-threatening hemorrhage, lives may be saved by faster access to care.


**FIGURE 27-15** Tactical medics perform advanced airway management in a tactical training exercise. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

Tactical EMS differs from conventional EMS. Tactical EMS may have less medical equipment at hand, operates in adverse or austere environments (e.g., where there is a need to maintain light or sound discipline), and performs patient assessment from

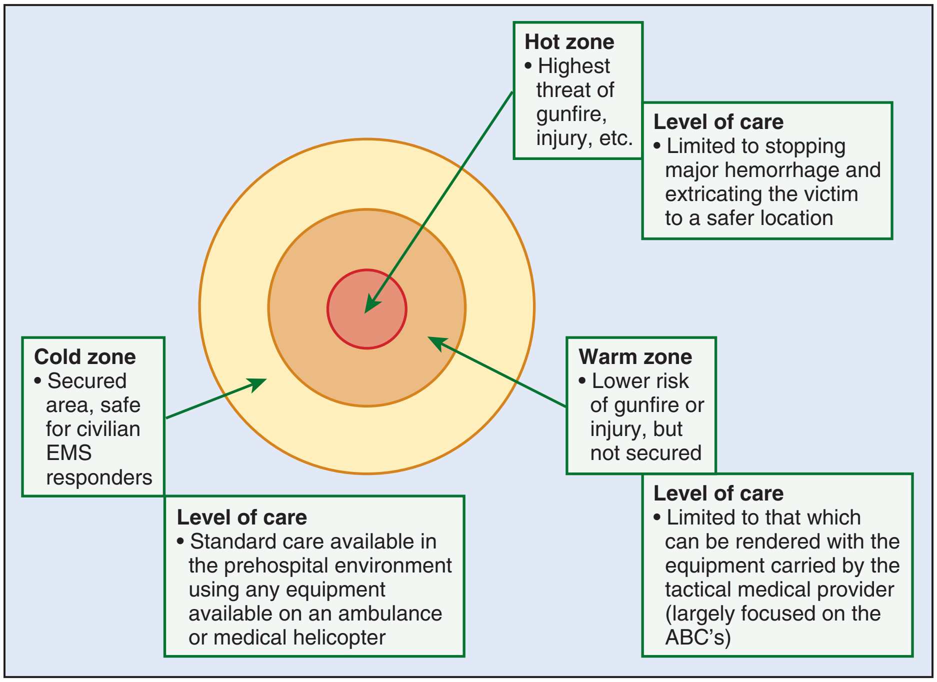


**FIGURE 27-16** Zones-of-care concept of tactical emergency medical services. ABC, airway, breathing, and circulation; EMS, emergency medical services. *(Courtesy International School of Tactical Medicine, Bohdan T. Olesnicky, MD.)*

remote locations.[85] "Medicine across the barricade" involves remote evaluation and management of patients, as when a hostage has become ill or injured and the provider attempts to assist the victim by using the eyes, ears, and hands of someone closer to the situation.[32] Tactical medical providers must use skills like those of an EMS dispatcher handling an emergency over the radio. Standard EMS medical care performed in specific clinical scenarios may require a different approach when the same situation is encountered under tactical conditions.[31]

Tactical medicine can be provided by EMTs, paramedics, registered nurses, midlevel providers (physician assistants, nurse practitioners), or physicians who serve on law enforcement tactical teams.[45] Midlevel providers and physicians traditionally have training in advanced surgical and medical procedures beyond what is normally allowed for traditional EMS personnel.[20]

The primary goal of tactical medicine is to assist a tactical team in accomplishing its mission. This is achieved through a comprehensive program outlined first by the California Commission on Peace Officer Standards and Training (POST) and California Emergency Medical Services Authority (EMSA). State Regulation 1084 established operational programs and standardized training recommendations for tactical medicine programs in California. This produced the first tactical medicine standardized training and operations recommendations by a state regulatory body. Its seven elements are medical oversight, medical contingency planning, operational support, quality improvement, team health management, training and education, and medical equipment acquisition and maintenance. In addition to operational components, tactical medicine programs must include other elements (e.g., team health management to keep the tactical team members healthy before, during, and after special operations).[18,57] A full tactical medicine program encompasses preventive and acute medical and dental care. For some teams, it may include canine support veterinary care.[47] Ready access to such care has a positive effect on team morale (Figure 27-17).


**FIGURE 27-17** California tactical medicine diagram.

Providers should create formal medical threat assessments for each training and operational deployment that takes into account environmental conditions (heat, cold, wind), low-light conditions (Figure 27-18A),[39,40] operator fatigue (and possible need for


**FIGURE 27-18** **A,** Tactical medic trainees for low-light situations. **B,** Tactical medic trainees discuss their operation plan with an instructor at the International School of Tactical Medicine. **C,** Tactical medic trainees apply a tourniquet to an injured officer who is suffering from massive blood loss. **D,** Tactical medics must prepare for the unexpected, including evaluating and treating pediatric patients injured during tactical operations. *(Courtesy International School of Tactical Medicine.)*

rotating operators), nutritional issues,[19] plant and animal threats, and a plan for extrication and transport of patients.[10] For operations, medical plans should include medical intelligence, geographic location, weather, and details on group members (names, ages, medical history and backgrounds, preexisting medical conditions)[17] (see Figure 27-18B). Determine evacuation routes and means (ground, air, or water as options) to ensure timely transport to appropriate medical facilities. Establish landing zone coordinates before the mission starts. Consider day and night landing zone requirements, as indicated by time of day.

In addition to having a role as responders for major emergencies, SWAT teams and their tactical medical teams are important community resources in planning for a community response. In conjunction with local medical control, EMS, and public health officials, tactical medical operators should create plans for future threats before resources are needed.[15,98]

Terrorists and organized criminals have the capability to produce or access chemical and biologic agents.[36] Explosive devices are used worldwide. Domestic preparedness and proper training for blast injuries are essential.[24,29,35,71,93]

Any terrorist incident is a large crime scene. The scene is initially unsecured. Additional threats (e.g., bombers, gunmen, or secondary devices) may present themselves. In a terrorist incident, tactical medics are trained to simultaneously take care of a patient, not disturb evidence, and provide security.

It is helpful to have more than one provider as part of a tactical team, particularly in the event of serious injuries or multiple casualties (e.g., in a school shooting or an act of community violence).[44,58] Team medical personnel can decrease an agency's liability exposure with adequate documentation (e.g., written, photographic) of injuries.[62] With multiple providers, a caregiver can accompany an ill or wounded patient to the hospital. This provider can act as a source of valuable history and as a patient advocate. This provides significant reassurance to the entire tactical team.[38,43,67]

## TEAM HEALTH MANAGEMENT

Tactical medical providers ensure that team members are healthy and optimally fit for duty.[46] Medical officers are responsible for team physical fitness, diet, exercise, sleep, stress management, and preventive medicine. The tactical unit can be viewed as elite "occupational athletes."

Strength training for many tactical operators may consist of traditional bodybuilding exercises. Like professional athletes, tactical operators need a broad-based program of training and physical conditioning tailored to the specific actions they will perform.

The team's medical officer should stress regular physical conditioning. A comprehensive plan of proper nutrition and exercise must be established and maintained. This should include a balance of aerobic and anaerobic exercises and stretching. Cardiovascular fitness workouts (e.g., running, cycling, or swimming) are excellent for the tactical team. Full-body or resistance circuit weight training is excellent for strength training, but it must be a total body workout. Training some parts of the body but ignoring others can lead to costly injuries and a lower level of fitness.[88]

Flexibility training is frequently ignored, but it is one of the best ways to prevent injuries in the field. Regular stretching or yoga has been long recognized as beneficial in athletic physical conditioning. A well-executed physical conditioning program keeps teams at peak effectiveness and reduces the potential for injuries.

Stress the importance of a sound diet. In response to increasing obesity, the U.S. Food and Drug Administration (FDA) and other researchers have looked at randomized clinical trials studying risks and benefits of various diets.[9,22,25,68,78,95] Based on these studies, the FDA revised the food pyramid to include five food groups (grains, vegetables, fruits, milk, and meat and beans) and allow for variations depending on age, gender, and level of physical activity. Fats, sugars, sodium, and total caloric intake are restricted. The FDA has an interactive website for the new food pyramid at foodpyramid.com. The perfect dietary program for the tactical operator is not yet known, but fast foods and simple sugars should be reduced or eliminated from the tactical operator's diet. Smart nutrition and physical training are key to achieving the fitness level expected for a SWAT operator.

Preventive medicine should be stressed with regular physical examinations, weight loss programs, and treatment. Smoking cessation, alcohol and drug counseling, and stress management are the responsibilities of every team medical officer.

## OPERATIONAL CASUALTY CARE

Lessons from military medical operations help civilian law enforcement medical providers identify equipment, recognize injury patterns, and initiate appropriate treatments during SWAT operations. Traditional resuscitation goals (i.e., the ABCs) may be difficult to achieve in a hostile environment. The priority of extrication to a place where appropriate medical care can be provided may be unfamiliar to EMSs. Hemorrhage control is paramount. Saving as much of the victim's own blood as possible has more value than replacing the blood volume with IV fluid. Tourniquets are a first-line treatment modality in tactical medical support, whereas they may be seen as a last resort in routine EMSs support (see Figure 27-18C).

Tactical medical personnel are aware that tactics come first, followed by appropriate medical care. When the two entities are blurred or reversed, a poor outcome is more likely. Each tactical medical provider must be knowledgeable in the tactics of his or her team and trained to the satisfaction of the team leader in order to not jeopardize a team's mission or increase the chances of an injury being mistreated. Medical providers must constantly reassess as much of the dynamic component of an operation as possible. Contingency planning and the ability to adapt to the fluid nature of these situations are required to be successful as a member of the SWAT team (see Figure 27-18D).

The public safety agency responsible for a tactical medicine operational program should conduct a needs assessment to determine the level of emergency care required by a SWAT team to support its mission and operations. The operational program must consider the need for medical oversight and coordination with the local EMS agency; medical direction; use of EMTs, paramedics, and other advanced life support personnel; and minimum training and equipment standards. The agency should develop policies and procedures for medical support during tactical operations.

Approved tactical medicine training programs that provide initial and continuing training should adhere to the minimum standards and guidelines established by the California POST and EMSA. These guidelines describe minimum core competencies as well as written and skills testing needed to achieve California POST and EMSA standards. Approved guidelines are available at the POST website at lib.post.ca.gov/Publications/Tactical Medicine.pdf.

## TACTICAL MEDICAL EQUIPMENT

Tactical EMS medical equipment comes from other areas of emergency medicine and law enforcement and is combined into field-expedient, multifunction toolkits. A modular approach may be most helpful (Figure 27-19A). Gear differs depending on the roles of providers and the tactical unit.[30] Basic equipment for the operator includes essential items. Typically an operator has a duty uniform (i.e., battle dress uniform).[90] The uniform may undergo appropriate modifications depending on weather conditions. Use a system of layers that can be easily adjusted to changing weather conditions. Use wicking underlayers with waterproof and breathable outer layers as needed. Additionally, a Nomex balaclava and gloves are worn on many entries to protect from exposure to pyrotechnic devices.

Because gunfire may be encountered, ballistic protection (i.e., body armor) is needed. For the tactical medical provider, level II is the bare minimum if the body armor is concealed under a shirt or uniform, but levels III-A to IV are better (Table 27-3 and see Figure 27-19B). These levels of protection have a good balance between the ability to stop a bullet and the ability to


FIGURE 27-19 **A,** Blackhawk Products Group special operations medical backpack in use by tactical medics. **B,** Tactical heavy body armor ballistic vest worn for law enforcement tactical operations. **C,** Communication with the entry team is critical for the tactical medic. This medic is equipped with headset, microphone, and encrypted radio. He is also staged behind the SWAT armored vehicle for hard cover. *(**B** courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD; **C** courtesy International School of Tactical Medicine.)*

absorb blunt trauma. Many tactical operators combine body armor with ballistic plates made of metal or ceramic, which stop high-velocity rifle bullets. Body armor is chosen by the agency from an array of types and styles. Some tactical medical providers also carry a Kevlar blanket or ballistic shield that can be used to cover a patient in harm's way or can be used as a mobile source of cover to provide care or extract a downed victim. These blankets, although effective, are extremely heavy and bulky. Despite the best ballistic protection, limbs are susceptible to ballistic trauma. As a result, uniforms with integrated tourniquets have become available. This simplifies the application of lifesaving tourniquets because they are already in place.

The weight and bulk of all nonmedical tactical equipment hinder the ability to carry large amounts of additional material. Medics must decide how much can be carried and in what way (i.e., by hand, backpack, or a load-bearing vest). Medics must be able to effectively carry equipment and operate in a tactical situation without hindering the team. Create two sets of medical equipment. One set, for immediate care, is typically worn in a small backpack or load-bearing vest. The second set, used for more extensive treatment, multiple casualties, and prolonged transports, is carried in a larger backpack or duffel bag in the support vehicle.[55]

## COMMUNICATION

Communication between team members and tactical medical providers outside the area of the operation is essential. Radios with microphones and headsets are standard for most tactical units. Radios should be set to secure channels. Some communications may even be encrypted. Simple communication during the operation between members may involve standard or specialized sign language (see Figure 27-19C).

## ENTRY AND BREACHING TOOLS

Specialized entry tools are used to gain access to barricaded subjects or closed doors. Typical items, familiar to firefighters and EMS personnel, include pry bars, battering rams, sledgehammers, hooks on chains or rope, stop blocks, and Halligan tools (Figure 27-20). Ladders may be needed to gain access. Trained explosive experts may use explosive devices to gain entry to an area.

## WEAPONS SYSTEMS

Whether a team medic should be armed (either as a sworn law enforcement officer or an armed civilian) has been a subject of much debate. Regardless, providers must be familiar with the unit's weapons systems encountered in tactical operations. A provider acting as a sworn officer has a primary role as a tactical member of the unit, and a secondary role as a medical provider.[73,76] Even a provider who is first a medical officer should be armed for self-defense. An armed officer who has become disoriented may become a danger to the team. Providers would need to take charge of all of the officer's weapons and render them safe. Providers may have to defend a downed officer using the officer's weapon.

Tactical medicine providers should be familiar with every handgun, shotgun, rifle, submachine gun, assault rifle, and smoke

FIGURE 27-20 Special tools and equipment are used to gain rapid entry by SWAT teams. *(Courtesy International School of Tactical Medicine.)*

**TABLE 27-3** U.S. Department of Justice Rating of Body Armor

| | Test Variables | | | | Performance Requirements | | |
|---|---|---|---|---|---|---|---|
| Armor Type | Test Round | Test Ammunition | Nominal Bullet Mass | Minimum Required Bullet Velocity | Required Fair Hits per Armor Part at 0° Angle of Incidence | Maximum Depth of Deformation | Required Fair Hits per Armor Part at 30° Angle of Incidence |
| I | 1 | 38 Special RN Lead | 10.2 g 158 gr | 259 m/sec (850 feet/sec) | 4 | 44 mm (1.73 inches) | 2 |
| | 2 | 22 LRHV Lead | 2.6 g 40 gr | 320 m/sec (1050 feet/sec) | 4 | 44 mm (1.73 inches) | 2 |
| II-A | 1 | 357 Magnum JSP | 10.2 g 158 gr | 381 m/sec (1250 feet/sec) | 4 | 44 mm (1.73 inches) | 2 |
| | 2 | 9 mm FMJ | 8.0 g 124 gr | 332 m/sec (1090 feet/sec) | 4 | 44 mm (1.73 inches) | 2 |
| II | 1 | 357 Magnum JSP | 10.2 g 158 gr | 425 m/sec (1395 feet/sec) | 4 | 44 mm (1.73 inches) | 2 |
| | 2 | 9 mm FMJ | 8.0 g 124 gr | 358 m/sec (1175 feet/sec) | 4 | 44 mm (1.73 inches) | 2 |
| III-A | 1 | 44 Magnum Lead SWC Gas Checked | 15.55 g 240 gr | 426 m/sec (1400 feet/sec) | 4 | 44 mm (1.73 inches) | 2 |
| | 2 | 9mm FMJ | 8.0 g 124 gr | 426 m/sec (1400 feet/sec) | 4 | 44 mm (1.73 inches) | 2 |
| III | — | 7.62 mm (308 Winchester) FMJ | 9.7 g 150 gr | 838 m/sec (2750 feet/sec) | 6 | 44 mm (1.73 inches) | 0 |
| IV | — | 30–06 AP | 10.8 g 166 gr | 868 m/sec (2850 feet/sec) | 1 | 44 mm (1.73 inches) | 0 |
| Special requirement | — | * | * | * | * | 44 mm (1.73 inches) | * |

*See section 2.2.7 of reference.
g, grams; gr, grains.
From U.S. Department of Justice National Institute of Justice: Ballistic resistance of police body armor, *NIJ Standard* 0101.03; 5.2.1, April 1987.

or chemical agent gun used by the team. All tactical team members, whether providers or not, should be able to use and render safe any weapon carried by a team member.[86] Providers should not be exempt from this requirement (Figures 27-21 and 27-22).

Weapons systems use a variety of ammunition. Typically there is a duty handgun, which shoots low-velocity handgun ammunition. This same ammunition may be used by a submachine gun (e.g., Heckler and Koch [HK] MP5, UMP 40, or UMP 45). Handgun and submachine gun cartridges should be matched to avoid placing ammunition of the wrong caliber into the wrong weapon, which could cause a catastrophic malfunction in a crisis situation. Law enforcement and military weapons (e.g., Colt M4) fire .223-caliber high-velocity cartridges. The provider may be exposed to shotgun ammunition, typically 12-gauge shells filled with 00 (pronounced "double-ought") buckshot. The team sniper deploys with a bolt action .308 high-velocity rifle. The flight characteristics and ballistics of shotgun, rifle, and handgun ammunition vary depending on the weight, shape, and velocity of the ammunition (Figure 27-23). The provider should be familiar with the characteristics of gunshot wounds in order to treat field wounds appropriately.

In addition to traditional ammunition, the provider may be faced with distraction devices, chemical munitions, and less lethal munitions. Chemical munitions deliver a chemical agent (e.g., tear gas or a derivative of pepper spray) to disorient or incapacitate an intended target to facilitate capture or surrender without loss of life. Less lethal munitions (e.g., low-velocity projectiles of wood, hard rubber, foam rubber, plastic, or beanbags) are used to incapacitate and facilitate capture. Although these agents are less lethal, they commonly cause injuries serious enough to cause pain and usually make an assailant stop aggressive action on contact. They typically cause limited blunt trauma but may penetrate into body cavities.


**FIGURE 27-21** Law enforcement tactical medics receive training with the Glock 17, 9 mm pistol **(A)** and Colt M4 Police Carbine **(B)**. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

**FIGURE 27-22** Tactical medics receive familiarization with the 40-mm less-lethal munitions launcher. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

Tasers are another example of less lethal devices. A Taser delivers an electrical charge below the level that causes cardiac arrhythmias to incapacitate the attacker. Victims experience intense diffuse muscular contraction and loss of control. The injury patterns are typically a result of the subsequent fall to the ground. Medical clearance of a victim should include an electrocardiogram, local wound care, removal of the electrodes from the skin, and update of tetanus immunization as needed (Figure 27-24).

Explosive breeching techniques and distraction devices are often deployed during tactical operations. Small explosives used to gain entry into an area can create injuries.[64] Hand-thrown distraction devices are used to deliberately disorient a suspect and divert attention toward the device and away from the entry team. These devices typically have a nonexploding canister and a small explosive charge. The device is activated and thrown much like a military hand grenade. It creates a brilliant flash of light (6 to 8 million candlepower) and a thunderous noise (≈ 175 decibels). This is accomplished by venting explosive gases through multiple holes in the canister. Physical effects of distraction devices and explosive entries include major and minor burns, smoke-induced bronchospasm, vestibular dysfunction, transient visual disorientation, and emotional upset and anxiety. In typical use, distraction devices have not been reported to cause eardrum rupture. Explosive breaching is the role of the team's explosives expert. As part of the medical threat assessment (see below), the medic should consult about types of explosives planned and blast forces that may be encountered (Figure 27-25).

## VISION

Covert operations and low-light situations dictate use of visual adjuncts. Binoculars, tactical mirrors, spotlights, periscopes,

**FIGURE 27-23** Comparison of different common ammunition sizes. *Left to right:* .50 caliber BMG (Browning Machine Gun), 12-gauge shell (shotgun), .308 (rifle), .223/ 5.56 mm (used in AR-15, M-16 rifles), .357 (pistol), 9 mm Parabellum hollow point (pistol), .22 LR hollow point, and pen for size comparison. *(Courtesy N. Stuart Harris, MD.)*

**FIGURE 27-24** Tasered suspect. The darts are intact in the left lower back area. *(Courtesy International School of Tactical Medicine.)*

strobe lights, chemical lights, and headlamps are often deployed in a low-light tactical environment (Figure 27-26). Because light may give away one's position and alert a hostile opponent to the team's position, proper training and discipline are required for use of these devices in tactical environments. Electronic night vision equipment that operates outside of the range of visible light is also extensively used.

## MEDICAL THREAT ASSESSMENT

Any mission planning must include a medical threat assessment (MTA). The SWAT commander uses information from many sources to create a tactical plan before execution of a mission, including available personnel, building layouts, street layouts, necessary support equipment, nature of the mission, available weaponry, and various sources of intelligence.[61]

An MTA is an important component of the intelligence the commander needs to properly execute the mission. It is the responsibility of the tactical medic to provide the commander with a concise and accurate medical briefing. MTA forms should

**FIGURE 27-25** Tactical team training for explosive breeching. *(Courtesy International School of Tactical Medicine.)*

**TABLE 27-4 Sample Form to Provide Operational Information**

| | | | | | | |
|---|---|---|---|---|---|---|
| Location | | | | | | |
| Type of operation | Hostage# | Suspect# | Warrant# | Protection# | Open terrain search# | Terrorist# |
| Other teams | Tactical | EMS/medics | K9 | Patrol | Detective | FBI/other |

be used on every mission to ensure systematic planning despite unique scenarios.

Tactical medical teams and MTAs are key factors in responding to large-scale terrorist events (e.g., the Columbine School shootings and the school hostage crisis in Beslan, Russia).[82] Other teams (e.g., the U.S. Marshals Service Judicial Protection Training Program) rely heavily on a team's internal capacity for medical care.[83]

A complete threat assessment should include:

Location of the operation, with a brief description of mission goals and other teams involved, with their needs and resources (Table 27-4).

Locations of all surrounding hospitals and medical care facilities (e.g., designated burn and trauma centers), with telephone numbers to facilitate communication. Local EMS numbers should be listed.

Helicopter flight plan. Before the mission, establish that a helicopter is available and there is an acceptable landing zone for day or night conditions. This should include the exact Global Positioning System coordinates of the landing zone. Clear all obstructions and debris before the mission (Table 27-5 and Figure 27-27).

Weather. Evaluate temperature, rain, wind, humidity, wet bulb temperature ($T_W$), and windchill. Record sunrise and sunset times. $T_W$ is the lowest temperature to which air can be cooled by water evaporation at a constant pressure. It reflects the ability to shed heat through sweating in a hot environment. $T_W$ is used to determine fluid requirements and need for work-rest cycles. The weather-related components of the MTA are used to determine the appropriate uniforms and shelter required to prevent overheating or hypothermia (Table 27-6). Record water sources before the mission as part of the MTA.

Plant and animal threats. Toxic plant exposures (e.g., poison ivy and poison oak) are common to snipers. Snakebites are common to team members working with police dogs. Record anticipated animal threats, along with telephone numbers for the police veterinarian, animal control, and poison control. Include sources of antivenom (Table 27-7).

**TABLE 27-5 Sample Form for Helicopter Information**

| | | | |
|---|---|---|---|
| Helicopter | Obstructions? | Landing Zone coordinates | |
| | Landing zone cleared before mission start? | | |
| Landing zone | Address: | Latitude | Longitude |

## FORMS AND DOCUMENTATION

Keep medical records for the team and for anyone treated or evaluated as a TEMS patient, and store these records for a minimum of 10 years. Records have proved to be indispensable as defense documents in several antipolice liability lawsuits. Medical records provide proof that appropriate medical care was given.

FIGURE 27-26 A SureFire LED illumination tool being used for medical work in low-light tactical situations. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*


FIGURE 27-27 Air ambulance helicopter preparing for tactical casualty evacuation. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

**TABLE 27-6 Sample Form for Weather-Related Information**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp high | Wet bulb temp °C (°F) | <15.6 (60) | 15.6-25.6 (60-78) | 25.6-27.8 (78-82) | 27.8-29.4 (82-85) | 29.4-31.1 (85-88) | 31.1-32.2 (88-90) | >32.2(90) | | Sunrise: | am |
| Temp low | $H_2O$ qt/hr | 0.5 | 0.5 | 0.5 | 0.5-1.0 | 1.0 | 1.0-1.5 | 2.0 | | Sunset: | pm |
| Rain % | Rest min/hr | 0 | 0 | 0 | 10 | 15 | 30 | 40 | | Night ops: | |
| Wind: mph | Cold casualties | Y/N | | | | | | | Work cycles | Duration: | |
| | Heat casualties | Y/N | | | | | | | Yes/No | | |
| Humidity % | Uniform adjustments | Y/N | | | | | | | Shelter: Y/N | Location: | |

**TABLE 27-7 Animal and Plant Threats**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Animal Threats** | | | | | | | |
| Yes/No | Animals present? | Yes/No | Police dog? | Yes/No | # | | |
| | Types of animals | Number: | Do you anticipate wild animals? | | | Yes/No | What type? |
| | Poisonous snake exposure: | | Veterinarian's address: | | | | Vet phone: |
| | Yes/No | | | | | | |
| | Animal Control: | Poison Control: | | | | | |
| | 973-470-2242 | 800-222-1222 | | | | | |
| **Plant Threats** | | | | | | | |
| Yes/No | Exposure to poisonous plants likely? | | Yes | Type | | | |
| | | | | | | No | |
| | Tecnu or Ivy Block available? | | | | | Yes | |
| | | | | | | No | |
| | Uniform adjustments needed? | | | | | Yes | Recommendations: |
| | | | | | | No | |

## MEDICAL PERSONAL PROTECTIVE EQUIPMENT

Employ standard precautions against infectious diseases. Medical personal protective equipment includes masks, eye protection, gloves, and gowns. Providers should carry personal protective gear in a readily accessible location. Some tactical medics don surgical gloves underneath their shooting gloves before an operation so they will be ready if the need arises. Although not sterile, they provide protection from blood and body fluid–borne pathogens. In remote locations, surgical treatment may be provided before transport to a tertiary care center.

## PERSONAL SUPPLY MODULE

To reduce equipment carried by the medic and help team members help themselves, each member of the tactical unit should carry a personal supply module (self-help kit) with medical supplies (Figure 27-28). Personal supply modules allow each team member to provide self-help or aid another member so that the medic may not have to be summoned until the scene is more secure. The modules should be vacuum sealed and contain supplies for basic trauma care and IV access (Table 27-8). Vacuum sealing reduces bulk, increases durability, and protects kit contents from the elements. Medical providers should carry a casualty response kit. This kit should be small, lightweight, and contain components necessary to treat gunshot wounds, hemorrhage, tension pneumothorax, sucking chest wounds, eye injuries, burns, and lacerations. The drop-leg configuration is often used by tactical medics because it is readily accessible (Figure 27-29).

**TABLE 27-8 Sample Contents of Personal Supply Module**

| | |
|---|---|
| Trauma dressing | Bandages, such as the Israeli bandage, can be easily self-administered by the victim on most extremity wounds |
| IV start kit | 100 mL IV fluid, an alcohol wipe, tourniquet, IV catheter (3), IV tubing, tape, flush and saline lock |
| Minor dressings | Adhesive bandages should be carried by all team members |
| Saline bullets | Foreign bodies in the eyes are very common on entries, and a bottle of eye drops (saline bullets) may allow an operator to continue on a mission |
| Medicines | *Pain:* acetaminophen, ibuprofen, narcotic analgesics<br>*Antibiotics:* ciprofloxacin, metronidazole, cephalexin |
| Other wound items | Surgical staples or liquid tissue adhesive |

IV, intravenous.

## BASIC MEDICAL MODULE

In addition to a personal supply module, team medics should carry a basic medical module. Because every team member in a tactical unit should have at least basic EMT certification, a basic medical module can be used by any team member to provide initial care to a victim. The module should have basic splinting and dressing materials (Table 27-9).

Include basic airway tools (e.g., nasal airways and pocket mask). A bag-valve-mask or a more compact alternative is advisable in the tactical environment. A simple bag-valve-mask alternative device (BVMAD) can be constructed out of respiratory supplies from a one-way valve, flexible tubing, and a mouthpiece (Figure 27-30).[5] This is the preferred ventilatory device in the tactical environment, because it allows a rescuer to provide ventilation without unnecessary bulk. If the tubing is long enough, the person providing ventilation can work hands-free if

**TABLE 27-9 Sample Contents of Basic Medical Module**

| | |
|---|---|
| Splints | Two SAM splints |
| Airway | Pocket mask, bag-valve-mask or bag-valve-mask alternative device, oral and nasal airways |
| Litter | Fold-up stretcher |
| Wound care | Various trauma dressings |
| Other | Elastic (Ace) wraps and cravats |

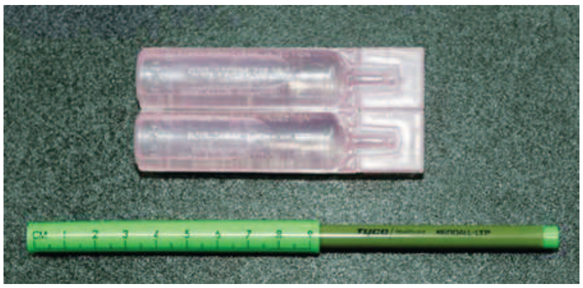

**FIGURE 27-28** Saline bullets remove the most common injury: foreign bodies in the eyes. Personal medical kit typically carried by SWAT officers. *(Courtesy International School of Tactical Medicine, Bohdan T. Olesnicky, MD.)*

**FIGURE 27-29** Casualty response kit for tactical medics. It can be carried on the belt or MOLLE (modular lightweight load–carrying equipment) system or in the drop-leg configuration. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

the patient is intubated. The additional length frees the rescuer's hands to carry the patient, perform other medical tasks, or even defend the patient with a weapon.

Oxygen is rarely useful in the immediate tactical environment, so oxygen cylinders are left in the support vehicle with a regular bag-valve-mask and retrieved when necessary. An automated external defibrillator should be carried in the support vehicle.[3] A small collapsible litter for extrication of a downed person should be a part of every basic medical module.

## INTERMEDIATE MEDICAL MODULE

An intermediate medical module is intended for use by paramedics and registered nurses. Unlike the basic medical module, it contains equipment and supplies suitable for advanced life support. Under standing orders from a team physician, advanced life support providers may provide advanced cardiac life support to a victim. An intermediate medical module is much more extensive than a basic medical module. It contains medications, IV tubing, IV fluids, an endotracheal tube, a King airway, a laryngoscope, a light wand, and, if protocol allows, a cricothyrotomy kit (Table 27-10 and Figure 27-31). These tools allow definitive airway management before transport, which, when used with a BVMAD, permits hands-free ventilation and patient extrication by one or two team members. Proficiency with the airway toolkit is of high priority.

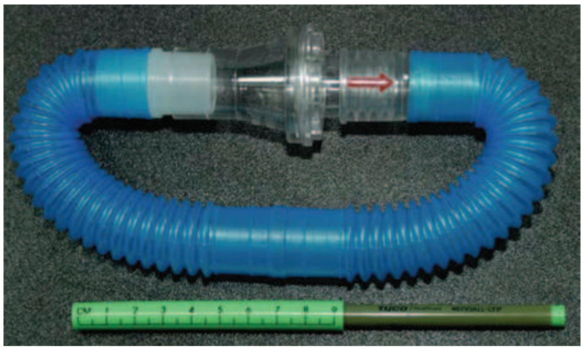

**FIGURE 27-30** Bag-valve-mask alternative device (BVMAD) as it is stored, with the mouthpiece *(red arrow)* over the exhaust port. *(Courtesy International School of Tactical Medicine, Bohdan T. Olesnicky, MD.)*

### Advanced Medical Module

The advanced medical module is intended for independent practitioners (e.g., nurse practitioners, physician assistants, and physicians). These practitioners can perform advanced lifesaving surgical procedures and medical interventions. Unless medically necessary, never delay transport to definitive care. If advanced care in the field is indicated, an independent practitioner with an advanced medical module can provide it.

## MAJOR TRAUMA MODULE

Lengthy surgical interventions in the field are not advised and have extremely poor prognoses. Rapid transport to a trauma

**TABLE 27-10** Sample Contents of Intermediate Medical Module

| | |
|---|---|
| Airway | Endotracheal tubes, laryngoscope, stylette, bougie, bag-valve-mask alternative device |
| Medications | Intravenous set-up and tubing, pain medication, rapid sequence intubation medications, antibiotics |

FIGURE 27-31 A well-stocked and functional tactical intermediate medical module airway kit, containing a laryngoscope, a bag-valve-mask alternative device, oral airways, bougie, stylette, endotracheal tubes, tape, and surgical airway kit. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

center is the rule, but some field surgical procedures may be of benefit: laceration repair to stop bleeding or facilitate evacuation, cricothyrotomy, and chest tube insertion. These types of procedures can be performed using essential equipment found in a vacuum-sealed minor-surgery tray (Figure 27-32), one component of the major trauma module for advanced providers (Table 27-11).

Direct pressure with a sterile dressing is the initial approach to hemorrhage control. Pressure point compression and tourniquets are useful adjuncts to control bleeding, so tourniquets should be included in the major trauma module. Carry a set of combine dressings, gauze, petrolatum gauze, and Israeli dressings. Use of hemostatic dressings in trauma kits is not yet well studied and remains a subject of debate.[56,81]

**TABLE 27-11** Sample Contents of Major Trauma Module

| | |
|---|---|
| Israeli dressing | May be self-administered by the patient with one hand; combines an elastic wrap, combine dressing, and tourniquet in one device |
| Combine dressings | To control heavy bleeding or cover eviscerated bowel and open fractures |
| Gauze pads | Multiple uses |
| Antibiotic packs | Preprepared medication packs for major trauma, containing pain medication and antibiotics |
| Tourniquet | Several excellent devices are available for tactical use |
| Wound closures | Sutures, staples, and wound adhesives |
| Minor-surgery tray | For performing surgical procedures that cannot wait for extrication or transport |
| Elastic wraps | Strains, sprains, and fractures are common |
| Splinting material | SAM Splint or a short sealed roll of fiberglass casting material. Bullet wounds frequently fracture long bones |
| IV fluids | For infusion of medication and management of shock as needed. Also used for wound irrigation and eye irrigation. Several IV start kits should also be on hand |
| Supplies | Gloves, tape, trauma shears, tweezers, adhesive bandages, roll gauze, cravats, nasal airways, 60-mL syringes, headlamp |
| Other | Duct tape, biohazard bags, medical record sheets, and trauma tags for multiple casualties |

IV, intravenous.

## SUPPORT VEHICLE MODULE

Keep additional supplies and equipment in the support vehicle module. Keep consumable items in the support vehicle module so that other modules can be restocked from it (Table 27-12). The support vehicle module contains equipment such as oxygen cylinders, an automated external defibrillator, airway adjunct devices, fiberoptic scopes, nebulizers, surgical trays, chest tubes, cervical collars, backboards, peroxide, povidone-iodine, liter bags of crystalloid IV fluid, replacement filters for gas masks, and fiberglass splinting material.

Field care is limited only by provider training and equipment that can be transported. Items carried by advanced providers include:

Central IV line
Cricothyrotomy/tracheotomy set
Retrograde intubation set
Laryngeal mask airway

FIGURE 27-32 A vacuum-sealed minor surgery tray. Many procedures in the tactical environment can be accomplished with a minimum of equipment. *(Courtesy International School of Tactical Medicine, Bohdan T. Olesnicky, MD.)*

**TABLE 27-12** Sample Contents of Support Vehicle Module

| | |
|---|---|
| Biohazard container | Disposal container for used sharps and medical waste |
| Saline eye flush | Foreign bodies in the eyes are common on entries |
| Elastic wraps | Strains, sprains, and fractures are common |
| Splinting material | Fairly bulky and difficult to carry in the medical pack. Cervical collars are frequently kept here and may be retrieved when needed |
| Intravenous (IV) fluids | For prolonged transport or massive hemorrhage, more IV fluid should be kept in the module and not carried on entries. Multiple IV start packs for use when necessary |
| Ice packs | Ice packs are commonly used, because ice is not always available in the field. If the location has a freezer, bags should be kept to use existing ice |
| Wound dressings | Additional adhesive bandages, Israeli dressings, combine dressings, abdominal pads, and burn dressings |
| Advanced airway tools | Difficult-airway tools may be needed in the cold zone before transport to secure a definitive airway |
| Spare uniforms | If decontamination is needed, the victim will need to be reclothed in a clean, dry uniform, particularly in cold or wet environments |
| Oxygen cylinders | Best left in the support vehicle because of their weight |
| Bag-valve-mask | Replaces the bag-valve-mask alternative device when hooked up to oxygen in the cold zone |
| Automated external defibrillator | Proved to save lives but is too bulky to carry on entry |

Chest tube set
Fiberoptic intubation set
Blood products or blood substitutes

### Chemical, Biologic, Radiologic, or Nuclear Specialty Modules

Depending on the role of the tactical unit, chemical, biologic, radiologic, or nuclear (CBRN) threats may be encountered. These incidents require tactical emergency medical care because they involve large crime scenes with casualties. Individuals trained in tactical emergency medicine are much more familiar with evidence collection and preservation. They usually already have the necessary security clearance to enter such an area. Until the scene is cleared, the tactical physician may be the only person who can provide medical care to victims. Chemical and biologic environments are specialized depending on the agent released. Civilian and military protective gear and respirators or supplied air sources may need to be worn. Operating in CBRN protective gear requires extensive training in addition to regular tactical training. Antibiotic prophylaxis with ciprofloxacin, as well as agent detection equipment, may be carried by the medic. Biologic and chemical diagnostic kits and meters are available but costly.

Radiologic incidents may involve dispersal of a radiologic agent with conventional explosives (i.e., a dirty bomb). Nuclear detonations (e.g., a nuclear bomb) refer to splitting of a radioisotope with resultant massive energy release. Geiger counters are available for radiologic and nuclear situations. These situations require a great deal of additional training but are not beyond the realm of tactical emergency medicine.

Hazardous material (hazmat) situations are frequently seen in civilian law enforcement raids on clandestine drug laboratories. Level A, B, or C protective suits with gas masks or supplied air may be required in these situations as well. Hazmat and CBRN situations are highly specialized in their nature and require extensive training, beyond the scope of this text.

## THE TACTICAL MISSION

Each mission has a number of phases:[50,89]

- Warning order (issued when a tactical team is first requested; establishes the situation and chain of command)
- Gathering of intelligence
- Building of intelligence (includes location and surrounding areas, avenues of approach, escape routes, and rally points, as well as natural and man-made obstacles, fields of fire, opportunities for cover and concealment)
- Suspect or hostage intelligence (as detailed as possible)
- Medical threat assessment (complete)
- Operation order
- Briefing phase
- Detailed planning
- Detailed briefing
- Equipment selection
- Move to staging
- Execution phase
- Entry
- Secondary search
- Transfer to arrest team and investigation team
- End of mission
- Debriefing phase
- All persons, weapons, equipment, injuries, shots fired, and ammunition must be accounted for.
- Any problems must be discussed.
- Medical personnel should have the opportunity to discuss the mission from their perspective.

In general, a tactical mission follows this order, although it may differ somewhat between agencies and missions. Proper handling of each point is required for a mission to flow seamlessly. Without proper intelligence, a mission becomes more hazardous.

## RESERVE PROGRAMS

The methods in which a tactical medical team is used by a law enforcement agency can differ widely, especially between the U.S. East and West Coasts. For example, in the western United States (e.g., California, Arizona, Nevada, Washington, Utah, and Oregon), there are many reserve programs in the police and sheriff's departments.[59] In these programs, the tactical medical provider has additional, formal law enforcement training (e.g., POST program in California). This program allows the provider to be a sworn peace officer (i.e., carry firearms and have powers of arrest), increases integration within the department, and may mitigate issues of civil liability. On the East Coast, reserve opportunities are less common, and medical providers typically serve as auxiliary units borrowed from traditional fire and EMS agencies. Liability issues and expenses in this type of relationship are often resolved via a written memorandum of understanding between participating agencies.[77]

Select appropriate providers through interviews, psychological testing, background investigations, and physical fitness testing. As with other members of the team, tactical team leaders should use a careful approach to select medical providers.[54]

## UNIFORMS AND PERSONAL PROTECTIVE GEAR

Standard law enforcement tactical operators carry between 40 and 60 lb of equipment. For longer missions, gear is heavier. Operators need to be in excellent physical condition. Mission commanders must proactively manage nutrition, hydration, and exertion levels.

Anecdotes report that the U.S. military has seen a significant decrease in truncal injuries because body armor has improved. Medical personnel noted that insurgent combatants in Operation Iraqi Freedom changed their IEDs to target the head, neck, and extremities. Body armor is being developed to protect against higher-energy weapons, protect extremities, and be sufficiently lightweight and flexible to allow fieldwork.

Protective clothing is not removed in the field. The medic must work under and around it. Vigilance is required to check all body areas for hidden wounds. This is clearly more difficult in the field, potentially in the dark, with sound and light restrictions, and with clothing in place, than when the patient is undressed in the emergency department.

Medics carry standard combat and medical equipment. Stethoscopes are often omitted for practical reasons (e.g., earpieces do not fit under helmets, tactical environments are not conducive to auscultation, and body armor limits access to patients). Advanced medical gear is usually found on the medevac vehicle, or farther to the rear where it is safe enough to remove protective equipment and further evaluate and treat the patient.

## EDUCATION AND TRAINING PROGRAMS

Many training programs provide continuing medical education credits. Courses focus on core issues of tactical medicine. A unique aspect of tactical medicine is application of advanced life support in an austere environment. Traditional approaches to providing EMS are often not feasible in tactical environments.[84]

Cost-effective tactical medicine training and education are available and should be afforded to all involved medical personnel, including prehospital care providers and physicians. All team medical personnel should be trained to the highest level possible. Training provides emergency medical personnel with an understanding of tactical procedures and an appreciation for why some routine prehospital care techniques may not be appropriate in the tactical environment.[49,53]

Tactical medicine training should be as realistic as possible with live teaching scenarios in full tactical gear (Figure 27-33). This allows the medical providers to more fully understand unique aspects of law enforcement tactical operations, roles and responsibilities of each team member, and approaches to integration with EMSs. Graduates of such training programs are better prepared to effectively perform as safe tactical medical providers (Figure 27-34).[60]

FIGURE 27-33 Tactical officer provides security for a law enforcement tactical medical team during a training exercise. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

The International School of Tactical Medicine (tacticalmedicine.com) is based in Rancho Mirage, California. This school offers a comprehensive 2-week, 80-hour program. Training and educational courses are designed for law enforcement agencies and military special operations teams to enhance provision of medical care in austere tactical environments. The program is approved by POST, EMSA, and the U.S. Department of Homeland Security. The curriculum for each course can be seen in Tables 27-13 and 27-14.

## FUTURE OF TACTICAL MEDICINE

Tactical medicine will continue to grow as a medical discipline. Emergency medicine and wilderness medicine are the ideal specialties to collaborate on its development. Emergency and wilderness medicine physicians should have an understanding of tactical medicine, because they may well have the opportunity to treat a victim of violence associated with a tactical law enforcement action.[21,37]

Research is needed to study unique aspects of tactical medicine, including injury prevention during operations, methods to ensure optimal mental and physical preparedness for tactical operators, and evaluation of various standard EMS therapies for their feasibility and efficacy in tactical scenarios.

Law enforcement professionals and the military contribute to public safety. Tactical medics, by providing medical care under operative conditions, ensure that someone is there to care for them if they are injured in the course of doing their duty.

FIGURE 27-34 Tactical medics must be able to provide medical support for a variety of injuries during tactical operations. *(Courtesy International School of Tactical Medicine, Lawrence E. Heiskell, MD.)*

**TABLE 27-13 Sample Curriculum for Basic Tactical Medicine Training**

| | |
|---|---|
| Day 1 | Administration and introduction<br>Introduction to tactical medicine<br>Tactical medical equipment<br>Tactical equipment<br>Team concepts and planning<br>Slow and deliberate team movement |
| Day 2 | Introduction to tactical pistol<br>Medical aspects of chemical agents and distraction devices<br>Forced entry techniques<br>Dynamic clearing techniques |
| Day 3 | Operational casualty care<br>Wound ballistics<br>Hemostatic techniques and dressings<br>Team health management<br>Medical aspects of clandestine drug labs<br>Tactical medical scenarios |
| Day 4 | Introduction to MP5 submachine gun<br>Special operations aeromedical evacuation<br>Medical management of K-9 emergencies<br>Disguised weapons and street survival<br>Medical threat assessment |
| Day 5 | Written examination<br>Safety briefing<br>Tactical medical scenarios |

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**TABLE 27-14 Sample Curriculum for Advanced Tactical Medicine Training**

| | |
|---|---|
| Day 1 | Administration and introduction<br>Pediatric trauma management<br>Trauma anesthesia<br>Building clearing techniques review<br>Tactical medical scenarios |
| Day 2 | Range advanced pistol—MP5<br>Advanced airway management<br>Advanced airway management skills stations<br>Environmental injuries |
| Day 3 | WMD biological weapons part 1<br>WMD biological weapons part 2<br>Medical issues of less-lethal weapons<br>Low-light tactics and team movement<br>Tactical medical scenarios |
| Day 4 | Pistol-MP5 field courses<br>Explosive entry demonstrations<br>Medical management of blast injuries<br>WMD chemical weapons<br>WMD nuclear and radiation injuries |
| Day 5 | Written examination<br>Safety briefing<br>Tactical medical scenarios |

WMD, weapons of mass destruction.
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***Complete references used in this text are available online at expertconsult.inkling.com.***

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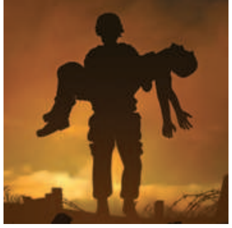

CHAPTER 28

# Combat and Casualty Care

CRAIG GOOLSBY AND DANIEL G. CONWAY

> If I am called to the battlefield, give me the courage to conserve our fighting forces by providing medical care to all who are in need … —*Excerpt, Combat Medic Prayer, Author unknown*

Whether responding to a shooting in an American inner city or treating injured soldiers on a hillside in Afghanistan, prehospital medical providers find themselves in complex environments with unique geographies, cultures, and adversaries. Resources will be constrained or desperate and armed conflict a real threat. The military's recent experiences, acquired during more than a decade of sustained conflict, are changing civilian medicine. As examples, many emergency medical services units now routinely carry tourniquets, and hospitals have altered their massive transfusion protocols. This chapter explores key combat casualty care topics, such as hemorrhage control, treatment of blast injuries, and phases of care that are now essential knowledge for wilderness providers in austere environments. We are grateful for the hard work and sacrifice of military medical providers who have advanced the science and practice of combat casualty care.

## BACKGROUND

The ancient Greek word for healer is *iatros,* meaning "remover of arrows." During ancient times, significant injuries generally could not be survived. As medical practice has improved, both on and off the battlefield, mortality rates for combat casualties have steadily decreased. Advancements, such as the formation of an ambulance corps during the American Civil War, giving antibiotics and blood replacement to casualties during World War II, and routinely using air assets for casualty evacuation during the Korean War,[21] improved mortality rates. During the Vietnam conflict and Operation Desert Storm, the overall mortality rates for wounded casualties were 24% and 25%, respectively. Most recently, the U.S. military has seen a survivability rate of more than 90% for all casualties during the conflicts in Iraq and Afghanistan.[4]

## BATTLEFIELD MEDICINE VERSUS STANDARD CIVILIAN PREHOSPITAL CARE

Battlefield medicine differs from standard prehospital medicine and conventional advanced trauma life support (ATLS) in a number of ways. It is important to note that these guidelines, designed for trauma care in fixed hospitals in noncombat zones, do not always translate well to the battlefield.[12] In a hostile practice environment, extreme austerity, limited resources, and the need to continue the military mission despite injuries or fatalities emphasize the differences between combat and civilian practice. The military has developed and implemented a set of guidelines for tactical combat casualty care (TCCC) that maximizes an injured patient's chances of survival and recovery in these conditions.[38,44] Many of the lessons learned on the battlefield, some of which contradict ATLS care, are directly translatable to wilderness medicine practitioners.

TCCC is divided into three phases of care. The first phase is care under fire. Care under fire occurs at the point of injury, when a casualty's location is still under effective hostile fire. In this phase, medical care is extremely limited and the directions to providers are clear. Medics should return fire and take cover. In the next steps, providers should direct casualties to care for themselves by returning fire, taking cover, and providing self-care if possible. The only specific medical actions during care under fire are to apply tourniquets for exsanguinating extremity hemorrhage and to remove casualties from burning vehicles and stop ongoing burning. The essential elements of this phase of care are prevention of additional casualties, especially medical providers trying to treat the initial casualty, and rapid movement to a safer location. Further management, including airway intervention, is deferred until the next phase of care.[38,44]

Tactical field care, which is the next phase of TCCC, encompasses the bulk of combat medical care provided in a military prehospital setting and is most similar to the care wilderness medical providers are likely to experience. Tactical field care occurs once the casualty and treating provider are no longer under effective hostile fire. Military providers use the pneumonic XABC, or a similar one, to remember the paramount importance of first treating exsanguinating hemorrhage. Table 28-1 summarizes the steps of tactical field care.

Although the TCCC guidelines serve as a standardized approach to tactical field care, initiating patient movement to definitive care should be accomplished as soon as is practical, usually in conjunction with the tactical field care phase of TCCC. In the military, this is accomplished by requesting a medical evacuation from an outlying medical transport unit via a "9-line": providing nine vital pieces of information to the rescue crew prior to its dispatch (Table 28-2).

Beginning the evacuation process is an important consideration for all practitioners during the tactical field care phase, but actual evacuation will not occur until the next and final phase of TCCC, the tactical evacuation (TACEVAC) phase. TACEVAC is a newer term that encompasses the concepts of both casualty evacuation (CASEVAC) and medical evacuation (MEDEVAC). CASEVAC is casualty movement via nonmedical platforms (as in the back of a vehicle or aircraft with extra room), and MEDEVAC is casualty movement via dedicated medical platforms (such as "dust-off" air ambulances). The TCCC guidelines during TACEVAC are largely similar to those during tactical field care but reflect the different resources available to paramedics transporting the wounded, as well as different concerns raised by traveling at altitude.[44] Military operations include TACEVAC planning to ensure transport of wounded casualties from the point of injury to definitive care.

## THE BASICS OF MILITARY MEDICINE

### JOINT THEATER TRAUMA SYSTEM AND REGISTRY

The military has developed an effective trauma system to handle large numbers of casualties in a combat environment. This system, known as the Joint Theater Trauma System (JTTS), has similarities to its civilian counterparts. The JTTS acquires data, critically reviews records, develops medical policy and practice guidelines, and performs ongoing evaluation of medical resource and staff utilization.[45]

The Joint Theater Trauma Registry (JTTR), a key component of the JTTS, was implemented in 2004. This registry aggregates information about casualties' demographics and injuries as injured soldiers move through the JTTS. The JTTR also tracks unique evacuation and transportation encounters, protective gear use, and specific mechanisms of injuries, such as blasts. This

| Priority | Medical Assessments and Interventions |
|---|---|
| 1 | Stop exsanguinating extremity hemorrhage |
| | Use approved medical tourniquet |
| 2 | Airway management |
| | Position |
| | Nasopharyngeal airway |
| | Surgical airway |
| 3 | Breathing |
| | Treat tension pneumothorax with needle decompression |
| | Apply occlusive dressing for open pneumothorax |
| | Supplemental oxygen |
| 4 | Circulation (bleeding) |
| | Reassess for unrecognized hemorrhage |
| | Use Combat Gauze for compressible hemorrhage not suitable for a tourniquet |
| | Apply junctional tourniquet to any appropriate site with bleeding |
| | Reassess, check pulses, mark tourniquet times on casualty |
| 5 | Establish intravenous or intraosseous access |
| 6 | Tranexamic acid |
| | Administer to any patient likely to need large blood transfusion |
| | Start as soon as possible |
| 7 | Consider fluid resuscitation |
| 8 | Prevent hypothermia |
| 9 | Eye trauma (penetrating) |
| | Rapid visual acuity testing |
| | Rigid eye shield |
| | Antibiotics for penetrating wounds |
| 10 | Use pulse oximeter |
| 11 | Inspect and dress wounds |
| 12 | Provide analgesia |
| 13 | Splint fractures |
| 14 | Provide antibiotics for all open combat wounds |
| 15 | Burn resuscitation and treatment |
| | Vigilant airway management |
| | Dress with dry sterile dressings |
| | Fluid resuscitation per USAISR Rule of Ten for > 20% total body surface area |
| | Analgesia |
| 16 | Reassuring communication with casualty |
| 17 | No cardiopulmonary resuscitation for blast or penetrating trauma casualties without signs of life (after performing bilateral needle decompressions for patients with torso trauma) |
| 18 | Document care |

**TABLE 28-1** Summary of TCCC Guidelines for Tactical Field Care

information is used to improve clinical practice guidelines, protective measures, medical and nonmedical training, and best practices for patient care from prehospital resuscitation through damage control surgery and rehabilitative care.[45]

Although JTTR data have directly improved clinical outcomes for combat casualties, the information obtained at the point of injury and initial evacuation process tends to be less complete than that later collected at fixed facilities.[33] The military is actively exploring solutions to this critical data gap. It has experimented with the Battlefield Medical Information System (Tactical, or BMIST), an electronic data collection system. Although the system is relatively light in weight at 11.1 to 14.1 oz, medics may view it as excess weight in an aid bag weighing 40 to 60 pounds. As a fail-safe method, a TCCC card or form DA 7656 is carried in the soldier's individual first-aid kit (IFAK). If a soldier is injured, this card is completed by treating medical personnel and moves with the soldier throughout the evacuation process. The information is later entered into the electronic medical record.

## MILITARY MEDICAL ECHELONS OF CARE

The military model of delivering health care on the battlefield is unique. It ranges from self-aid and "buddy" care at the point of injury to robustly equipped combat support and theater hospitals. The North Atlantic Treaty Organization (NATO) currently defines the echelons of care as a range from a role-1 facility to a role-4 facility.[16,32] At each point of care, the levels of surgical and holding capability increase, as do the chances of survival for those wounded on the battlefield.[41]

*Role-1 Care:* This medical care is attached to small units. It is capable of first aid, triage, and immediate life-saving measures.[23] Examples of role-1 facilities include a physician- or physician assistant–led battalion aid station in the Army or a two-physician shock trauma platoon in the Marine Corps or Navy. Role-1 care is often the first advanced medical care received by a casualty. Prior to "medical" assets arriving at the point of injury, the injured casualty or his fellow soldiers usually initiate life-saving self-aid or buddy care. This initial care from nonmedical personnel can have a tremendous impact on a casualty's chance for survival. Once a medic arrives, more advanced point-of-injury care can be rendered. The medic can decide to evacuate the casualty to a higher echelon of care. A medical evacuation is initiated via ground or air, using the 9-line MEDEVAC request. The casualty may be transported to the battalion aid station or shock trauma platoon from the battlefield. Role-1 medical personnel have the ability to triage patients, provide initial resuscitative care, and continue the medical evacuation process to higher echelons of care. If the injuries or illnesses are minor, treatment is provided on site and soldiers are returned to the battlefield; if injuries are more complex, casualties are evacuated to higher echelons of care. This decision is based on the security of the current situation on the ground (including weather, enemy positions, and evacuation vehicle/aircraft availability), distance relative to the "fight," and the nature of the injuries. Frequently, severely injured casualties will bypass role-1 facilities and proceed from the point of injury to a role-2 or role-3 facility.

*Role-2 Care:* Role-2 facilities, such as an area support medical battalion or an Air Force expeditionary medical support system, expand role-1 care with additional services such as limited dental, laboratory, optometry, preventive medicine, health service logistics, mental health, and patient-holding capabilities. In remote locations, role-2 facilities are often combined with a forward surgical team. The intent of augmenting a role-2 facility with a forward surgical team is to provide initial damage control surgery. An Army forward surgical team has an orthopedic surgeon, two to three general surgeons, two anesthetists, and critical care nurses.

*Role-3 Care:* Role-3 facilities are robust operations with surgical subspecialty care, advanced diagnostic and treatment options, and holding capability. Although role-3 facilities do not have all

**TABLE 28-2** 9-Line MEDEVAC Request

| Line | Item |
|---|---|
| 1 | Location of pick-up site |
| 2 | Frequency and call sign of requestor |
| 3 | Number of patients by precedence (urgent, priority, routine) |
| 4 | Special equipment needed |
| 5 | Number of patients by type (litter and ambulatory) |
| 6 | Security at pick-up site (wartime) |
| | Number and type of wounded, injured, ill (peacetime) |
| 7 | Method of marking pick-up site |
| 8 | Patient nationality and status |
| 9 | Nuclear, biologic, chemical contamination (wartime) |
| | Terrain description; features around landing site (peacetime) |

FIGURE 28-1 A deployed Army combat support hospital. *(From US Department of Defense.)*

the capabilities of a U.S. civilian level 1 trauma center, they are the closest combat approximation. Examples include Air Force theater hospitals, Navy hospital ships, and Army combat support hospitals (CSH [pronounced "cash"]). Each facility houses operating rooms, intensive care units, and patient wards (Figure 28-1). These facilities are modular and can contract or expand to meet changing needs. Role-3 facilities may have hundreds of beds. Casualties can undergo surgical procedures, recover from illnesses and injuries, and receive acute rehabilitation or extended medical treatment.

*Role-4 Care:* Role-4 facilities are found in the continental United States and other developed countries worldwide. These facilities are modern tertiary care hospitals and provide definitive care for injured and ill casualties evacuated from any military operation. In conjunction with the Department of Veterans Affairs and nonmilitary (civilian) hospitals, the Department of Defense and National Disaster Medical System is tasked with coordinating expansion of these role-4 facilities to receive an influx of casualties during a national disaster.[17]

## SCOPES OF PRACTICE FOR MILITARY MEDICAL PERSONNEL

The availability and range of medical personnel vary with the particular operational situation and military needs. The military maintains providers with many levels of skill sets. Examples include combat lifesaver, medic/corpsman, independent duty corpsman/medical technician, special operations medic, combat flight paramedic, nurse, physician assistant, nurse practitioner, and physician.

Combat lifesavers are first responders whose primary military occupational specialty may be that of an infantryman, aviator, or other military nonmedical specialty. After securing their area of combat operations, the combat lifesaver's role is to offer an extra set of skilled hands for the combat medic. In addition to basic first aid, they are able to provide such skills as inserting nasopharyngeal airways, applying tourniquets, and performing needle chest decompression for breathing difficulty after a penetrating chest wound.[18]

In addition to the combat lifesaving skills discussed above, the combat medic possesses additional medical skills to include airway adjuncts such as the Combitube, King LT airway device, and surgical cricothyrotomy. The combat medic has the ability to place an intravenous (IV) or intraosseous (IO) line and is trained to manage shock, resuscitative care, and prevention of hypothermia. In extenuating circumstances, in which a casualty cannot be evacuated rapidly to a higher level of care, the combat medic may administer blood products and place nasogastric tubes and urinary catheters. Special operations medics possess more advanced skills, similar to those of a civilian paramedic, with the ability to perform invasive trauma skills as needed in certain circumstances.

## MEDICAL EQUIPMENT UNIQUE TO THE MILITARY

Personal protective equipment and medical kits carried by troops have helped increase survival rates on the modern battlefield. The military developed and reconfigured IFAKs based upon the wounds seen during the Iraq and Afghanistan conflicts. Every deploying soldier carries an IFAK. It contains essential items to treat the major causes of preventable combat death: hemorrhage, airway compromise, and tension pneumothorax. The IFAK contains a combat application tourniquet (CAT, NSN#: 6515-01-521-7976), kaolin-impregnated gauze (QuikClot Combat Gauze, NSN#: 6510-01-562-3325), a 15.2-cm (6-inch) compression bandage (Israeli Pressure Dressing, NSN#: 6510-01-492-2275), nasopharyngeal airway, and 8.9-cm (3.5-inch) 14-gauge IV catheter for needle decompression.

Vehicles deployed with troops in a combat environment carry a warrior aid and litter kit (WALK, NSN#: 6545-01-587-1199). The WALK can also be carried via shoulder straps to the point of injury (Figure 28-2). The additional equipment increases a unit's capabilities to provide self-aid and buddy aid to treat multiple casualties. Furthermore, it provides soldiers with the ability to evacuate a nonambulatory casualty (folding litter) and increases survivability during attacks on dispersed operations, as when there are improvised explosive device (IED) and rocket-propelled grenade attacks on a convoy.

# BLAST INJURIES

Blast injuries are a unique type of injury not commonly encountered outside of combat. Military medical practitioners have used their extensive experience with IEDs (Figure 28-3) during the wars in Iraq and Afghanistan to advance the evaluation and management of blast injuries. Blast injuries frequently involve multiple mechanisms of injury that can cause complex and technically challenging polytrauma.

Blast injuries are classified into five different categories: primary, secondary, tertiary, quaternary, and quinary.[46] An absolutely essential element in managing blast injury victims is thorough examination to seek out injuries. Unlike penetrating or blunt injuries encountered in civilian settings, blast injuries are rarely isolated to a particular region of the body. The five different types of blast effects may cause different types of injuries to the same part of the body. For example, a patient may have both primary and secondary blast injuries to a lung, each requiring a different treatment approach. Liberal advanced imaging will likely be required in patients with severe blast injuries (Figure 28-4).

## PRIMARY BLAST INJURY

Primary blast injuries are injuries caused by effects of an overpressurization force, or blast wave, on the body's surface. Primary blast effects cause the greatest damage at air-tissue interfaces in the body. The most commonly encountered primary blast injuries are tympanic membrane ruptures, lung injuries (blast lung), traumatic brain injuries (TBIs), and/or hollow viscus injuries. Tympanic membrane rupture is the most common primary blast

WALK 6545–01–532–4962

FIGURE 28-2 Warrior aid and litter kit (WALK). *(From Army Medical Department Center and School: Briefing on Combat Equipment, 2007.)*


FIGURE 28-3 Improvised explosive devices found in Iraq. *(From US Department of Defense.)*

injury, because it occurs at the lowest overpressure relative to that required for other injuries. Tympanic membrane rupture can be relatively easy to find on physical examination. When a tympanic membrane rupture is discovered, medical providers should have a higher level of suspicion for additional injuries. Blast lung injuries are typically found at initial presentation, but their onset can be delayed for up to 48 hours after the initial event. Blast lung is caused by diffuse alveolar hemorrhage from the overpressure. It is commonly seen in conjunction with skull fractures, total body surface area (TBSA) burns greater than 10%, and/or penetrating trauma to the head or torso.[13] A provider should have a high level of suspicion for blast lung injury when dyspnea, cough, chest pain, or hemoptysis is present after an explosion. Blast lung is the most common fatal injury among initial survivors.[1] There are no well-validated treatment techniques, but supportive care similar to that provided for severe pulmonary contusions (high-flow oxygen, early airway management, and avoidance of barotrauma) should be initiated. Hollow viscus injuries can be extremely difficult to diagnose at first presentation. They should be considered in anyone presenting with abdominal pain, nausea, vomiting, hematemesis, rectal pain, testicular pain, or unexplained hypotension following a blast. Unfortunately, clinical signs may be subtle, so hollow viscus injuries are often not diagnosed until advanced stages of sepsis become apparent.

A number of factors affect the severity of primary blast injuries. Treating providers should consider the peak and duration of the overpressure (higher pressures for longer duration are worse), how rapidly the pressure changed over time (rapid changes are worse), the medium (underwater blasts are more serious due to the limited compressibility of water compared with air), the victim's distance from the blast, and focusing (confined structures or areas within which the blast occurred are worse). These factors help shape a picture of the likely severity of injuries (Figure 28-5).

## SECONDARY BLAST INJURY

Secondary blast injuries are sustained from debris, projectiles, and shrapnel propelled by the explosion. They are commonly seen as multiple penetrating injuries. The projectiles are bomb fragments, surrounding materials (e.g., metal from military vehicles, or pebbles from the ground), or objects (e.g., screws, ball bearings) intentionally added to a device to increase the blast's lethality. Secondary blast injuries pose a particular threat to exposed portions of the body, particularly the eyes, head, and extremities. Diagnosis and management vary depending upon the affected body part and associate injuries. An important consideration when assessing secondary injuries is cavitation. Due to extremely rapid velocities of penetrating fragments, very small objects can cause extensive wounds. As these fragments penetrate the body, cavitation effects can cause massive tissue displacement and disruption (Figure 28-6). Surface wounds that appear trivial may mask devastating internal damage.

## TERTIARY BLAST INJURY

Tertiary blast injuries occur as the victim is physically thrown by the blast "wind." These are typically blunt injuries as the victim's body strikes buildings, trees, vehicles, or the ground. Crush injuries, such as those caused by a collapsing building, are also considered tertiary blast injuries.

## QUATERNARY BLAST INJURY

Quaternary blast injuries are thermal injuries or those caused by combustion fumes. Examples include burns, asphyxiation, and inhalation-type injuries. These injuries are managed as they would be for any burn patients. Inhalation injuries and toxic effects vary with exposure to different burning agents.

FIGURE 28-4 A casualty with severe primary, secondary, and tertiary blast wounds. *(Courtesy of Mark Gunst, MD.)*

| | Effect | | |
|---|---|---|---|
| Pressure (psi*) | Eardrum Rupture | Lung Injury | Death |
| 5 | Possible | | |
| 15 | 50% chance | | |
| 30–40 | Almost certain | Possible | |
| 80 | | 50% chance | |
| 100–200 | | | Possible |
| 130–180 | | | 50% chance |
| 200–250 | | | Almost certain |

*psi = pounds per square inch

FIGURE 28-5 Short-duration pressure effects from blasts on unprotected persons. *(From National Association of Emergency Medical Technicians.)*

**FIGURE 28-6** Multiple fragment wounds from cluster bomblet. *(From Maj. Scott Gering. Eisenhower Medical Center, Rancho Mirage, CA.)*

**FIGURE 28-7** Roman tourniquet. *(Courtesy of Science Museum, London:* sciencemuseum.org.uk/broughttolife/objects/display.aspx?id=4304.*)*

## QUINARY BLAST INJURY

Quinary blast injuries are caused by chemical, biologic, or radiologic substances. These injuries result from exposure to postdetonation environment contaminants, including bacteria, radiation, and tissue reactions to fuels and metals.[21]

# TOURNIQUETS AND HEMOSTATIC AGENTS

The military medical community's focus on rapid hemorrhage control at the point of injury has saved lives on the battlefield and restructured priorities in managing severely injured patients in austere environments.[28] Tourniquets as a medical intervention are not a new concept. The earliest known use of a tourniquet dates back to 199 BC. Romans used tourniquets to control bleeding, especially during amputations. These tourniquets were narrow straps made of bronze covered with leather (Figure 28-7) that look similar to the modern Combat Application Tourniquet (C-A-T) used today (Figure 28-8). Jean Louis Petit, a French surgeon, developed a screw device in 1718. He coined the term tourniquet from *tourner* (to turn).

Tourniquets have proven safe and effective and are widely recommended for use (Figure 28-9).[27,28] Historically, there have been concerns about increased amputations, limb shortening, myonecrosis, nerve damage, and a host of other potential problems. These concerns are not supported by modern battlefield data.[28] The recommendation remains that tourniquets should be used for as short a duration as possible, but the maximal length of use has not been clearly established. Tourniquets tightened for less than 2 hours have a small likelihood of causing harm, and maximal benefit from tourniquet usage occurs when they are applied as early as possible.[26,28] Ischemia for more than 8 hours increases the risk of complications, especially myopathy. However, this may still be a relatively low risk, especially in distal extremities that have limited muscle mass.[26]

TCCC guidelines recommend immediate application of an approved tourniquet device for life-threatening extremity hemorrhage.[44] Immediate tourniquet application is an essential difference between combat casualty care and certain civilian prehospital protocols that recommend attempting direct pressure, elevation, or other measures prior to tourniquet placement. TCCC guidelines recommend placing the tourniquet on the skin 5.1 to 7.6 cm (2 to 3 inches) proximal to the wound. If bleeding persists, do not remove the previously applied tourniquet, because this may dislodge a partially formed clot and worsen bleeding. Instead, apply another tourniquet adjacent and proximal to the first one. Debate exists about the ideal location for extremity tourniquet placement. Some experts suggest placing all tourniquets as proximal as possible on an extremity, because compression against the single bone of the proximal extremity will theoretically optimize tourniquet performance.[36] However, a study documented more failures when the tourniquet is placed on the proximal versus the


**FIGURE 28-8** Commonly used military tourniquets, **A,** Tactical Medical Solutions SOF Tactical Tourniquet. **B,** Granite Tactical Gear U.S. Made NATO Tourniquet. **C,** C-A-Tourniquet. (**A** *from Tactical Medical Solutions, Anderson, South Carolina;* **B** *from Granite Gear; Two Harbors, Minnesota;* **C** *from North American Rescue, Greer, South Carolina.)*

**FIGURE 28-9** Tourniquet providing effective hemorrhage control to a casualty with an amputation. *(Courtesy of Mark Gunst, MD.)*

distal extremity.[27,28] All tourniquet sites should be exposed and clearly marked with the time of tourniquet application using an indelible marker. A "T" drawn on the patient's forehead is a common designation.[44] Tourniquets cause significant pain so providers should assess pain and use appropriate analgesia.

Military providers use a variety of tourniquets. The U.S. military primarily uses the C-A-T, although special forces units often use the special operations forces tourniquet. NATO forces, apart from the United States, frequently carry a NATO tourniquet (see Figure 28-8). Although there are significant design differences between these devices, they are all manually tightened until distal arterial flow is occluded.

Although they are remarkably effective, traditional tourniquets are only designed for use on extremity wounds. Newly developed "junctional" tourniquets offer an alternative for bleeding in the axillary and inguinal region (junction between the body and limb). These devices (Figure 28-10) place sustained direct pressure on axillary or femoral vessels, and were added to the 2013 TCCC guideline revision. The guidelines direct providers to immediately apply junctional tourniquets to appropriate anatomic sites as a first-line treatment for bleeding.[44]

If a junctional tourniquet is not available, or if the wound (e.g., a neck wound) is not appropriate for a junctional or traditional tourniquet, a hemostatic dressing should be used to


**FIGURE 28-10** Examples of junctional tourniquet devices. *(From SAM Medical Products, Wilsonville, Oregon, and Combat Medical Systems, Harrisburg, North Carolina.)*

**FIGURE 28-11** Military trainees practice placing combat gauze into a simulated casualty's wounds. *(Courtesy of Craig Goolsby, MD.)*

control hemorrhage. Although there are many hemostatic agents commercially available, current TCCC guidelines recommend using a kaolin-impregnated Z-fold gauze, sold as QuikClot Combat Gauze. Kaolin is the active agent in aluminum silicate. The hemostatic gauze is packed into the wound, and direct pressure is applied for at least 3 minutes (Figure 28-11). This pressure is essential to clot formation. Following direct pressure, a pressure dressing or a junctional tourniquet should be placed over the wound site (see Figure 28-10).[5,44]

Hemostatic agents and dressings are evolving. Some first-generation hemostatic agents generated significant adverse reactions, such as the exothermic reactions caused by zeolite-containing QuikClot, but third-generation products, such as QuikClot Combat Gauze, chitosan-containing Celox Gauze, and ChitoGauze, have demonstrated greater success with fewer side effects.[5]

It is vital to continually monitor for rebleeding after using any hemorrhage control measure. Devices or dressings may become dislodged, particularly during patient transport. IV fluid administration should be restricted to avoid dilution of coagulation factors or blood pressure normalization that could disrupt clotting.[25,30]

Tourniquets cause ischemia in the treated extremity. Ideally, a tourniquet should be released when definitive surgical control is available. Release of a well-placed and functioning tourniquet after several hours may release enough lactic acid and potassium generated by anaerobic metabolism and cell injury to cause patient harm.[7,26] Before removal of a tourniquet that has been in place for any significant period of time, consider the patient's hydration status and overall resuscitation. There have been anecdotal reports of using sodium bicarbonate administration as an adjunct to tourniquet release. Release the tourniquet slowly and assess for cardiac dysrhythmias. Fasciotomies may be needed when tourniquet time exceeds 2 hours, so patients should be monitored for compartment syndrome.[7]

## MANAGEMENT OF THE AIRWAY IN COMBAT AND CIVILIAN TRAUMA

Head, face, and neck injuries are common in combat. They make up 21% to 30% of the total injuries sustained by combat troops.[42] Combat-associated facial and airway trauma may present a frightening clinical picture but can be treated using standard airway assessment and management techniques.[38] Basic airway supportive maneuvers, such as a jaw thrust, or the use of nasopharyngeal or oropharyngeal airway devices, often suffice until definitive treatment is available. Algorithms developed in the prehospital trauma life support curriculum typically are effective.[37,38]

There are, however, several important differences between managing civilian and combat airway emergencies. These include the cause of the traumatic injury, recommendations for patient positioning, and use of surgical airways.

Most civilian head, face, and neck injuries are caused by blunt force trauma, but combat-related injuries are usually penetrating.[24] Blunt force trauma causes cervical spine (C-spine) injury in 2% to 6% of patients in civilian settings; however, unstable

C-spine injuries are infrequent in patients who survive their initial wounds in penetrating trauma.[3,34] This difference in causes creates differing management priorities.

Civilian medics are taught to provide C-spine control for all suspected neck injuries. This involves placing the patient in a supine position and using a rigid C-spine collar and spine immobilization board. Unfortunately, for combat injuries in austere environments, this spinal immobilization may cause further airway complications, make laryngoscopy more difficult, and make transport more challenging and dangerous.[3,34,45] TCCC guidelines specifically state, "Spinal immobilization is not necessary for casualties with penetrating trauma."[45] Foregoing a cervical collar and spine board can make injury identification and control easier for treating providers. Patients may also be able to manage their oral/nasal bleeding and secretions better by avoiding a supine position. If the patient is able and wants to sit up or remain in a tripod position, he or she should be allowed to do this rather than risk airway compromise.

Surgical airways are used much more readily for combat-related injuries than following civilian trauma. Devastating orofacial and neck injuries often make a cricothyrotomy the best option for definitive airway control in the prehospital or austere setting. Limited equipment in an austere environment, such as the absence of suction, could also render traditional orotracheal intubation impossible. The use of a lighted laryngoscope in certain environments might garner unwanted attention from enemy forces, making a cricothyrotomy necessary even if oral intubation is an option. In mass casualty situations, the threshold for cricothyrotomy is decreased due to time and resource constraints. Combat medics are trained to perform cricothyrotomy but not endotracheal intubation.[38]

# CHEST TRAUMA

Body armor used by modern fighting forces is highly effective at preventing torso injuries.[42] However, serious chest injuries still occur and can pose rapidly fatal breathing problems. TCCC care guidelines largely mirror civilian practice in this area, but there are important points to note.

Providers should consider tension pneumothorax in any patient with rapidly progressive respiratory distress in the setting of chest trauma.[44] The guidelines recommend decompression in the standard fashion in the second intercostal space at the midclavicular line. However, the guidelines also suggest the fourth or fifth intercostal space along the anterior axillary line as an acceptable alternative site for decompression.[14,29,44] Measurements of chest wall thickness at the midclavicular and anterior axillary sites indicate that the chest wall is significantly thinner at the anterior axillary site, making this a potentially desirable procedure site.[14,29]

Additional considerations include placing a vented chest seal on patients with an open pneumothorax. A nonvented seal is acceptable in the absence of a vented seal. Oxygen therapy should be provided to casualties with moderate-to-severe traumatic brain injury. The goal is to maintain an oxygenation saturation of more than 90% to prevent secondary brain injury.[44]

# FLUID RESUSCITATION

## GENERAL PRINCIPLES

Fueled by battlefield practice and research, casualty resuscitation has undergone significant changes in recent years. Long-standing treatments, such as large-volume fluid resuscitation for all trauma casualties, have been replaced by newer concepts of permissive hypotension and damage control resuscitation. These changes have important implications for both military and wilderness medical providers. The cornerstone of hemorrhage treatment now focuses on immediate bleeding control followed by limited use of optimal fluids.[25,40]

## VASCULAR ACCESS

Vascular access should be established after addressing life threats discovered during the primary trauma survey. Traditional practice directed providers to establish two large-bore peripheral venous catheters (18-gauge or larger) in trauma patients.[38,44] Although these peripheral IVs provide excellent vascular access, and are still the preferred option, they may be difficult to achieve in a hostile or austere setting. Poor lighting conditions, enemy activity, or severe patient injuries may make venous access difficult or impossible. IO access offers a safe, rapid alternative for vascular access in trauma patients; TCCC guidelines recommend IO access as an option.[15,44]

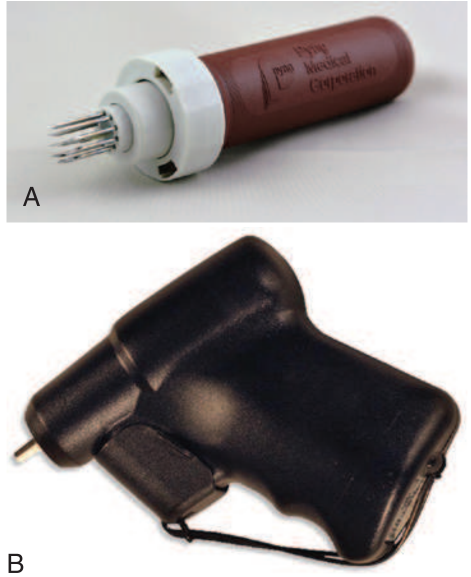


**FIGURE 28-12** FAST1 and EZ-IO intraosseous devices. (**A** *from Pyng Medical Corporation, Richmond, British Columbia, Canada;* **B** *from Arrow-Teleflex, Research Triangle Park, North Carolina.)*

There are a number of commercial IO choices. Combat medics in prehospital settings typically use a spring-loaded, single-use device, such as the F.A.S.T-1. Drill devices, such as the EZ-IO, are more commonly used in medical settings (Figure 28-12). The most commonly used nonsternal access sites are the proximal tibia or proximal humerus. Learning to use IO devices requires minimal training. The only absolute contraindication to IO use is fracture of the bone to be used as the access site. IOs are generally removed once alternative vascular access can be achieved in a more stable environment. However, they have been left in place for as long as 24 hours without complications. Osteomyelitis is a rare complication. Providers should be vigilant for possible fluid extravasation and resulting compartment syndrome.[15]

## FLUID SELECTION AND DOSING

After stopping bleeding and establishing vascular access, providers make two basic decisions. First, they decide if their trauma patient needs IV fluids. Second, if the patient does require fluids, they must choose which type of fluid and how much to administer.

Research has shown that excessive prehospital fluid harms patients.[25] Current TCCC guidelines recommend that patients who are not in hemorrhagic shock should receive *no* IV fluids.[44] The guidelines list two easily assessable criteria for hemorrhagic shock: absence of a palpable radial pulse or presence of the altered mental status in a patient without a head injury. If these signs are not present, the patient should not receive fluids, unless the patient desires oral fluids and is able to swallow.[44] Crystalloid and colloid parenteral fluids will dilute the patient's concentration of clotting factors, thereby making new clot formation more difficult. The fluids also serve to elevate blood pressure, which may dislodge existing clots and worsen bleeding.[6,25]

If the patient is in hemorrhagic shock, resuscitative fluids are appropriate. Once the patient exhibits an altered mental status or absent radial pulse, significant tissue hypoxia is occurring and fluids would be expected to be beneficial. Providers have three

FIGURE 28-13 Soldiers line up to donate blood for fresh whole blood transfusion to a casualty undergoing emergency surgery. *(Courtesy of Craig Goolsby, MD.)*

basic fluid choices: blood or blood components, colloid solutions, or crystalloid solutions.

Each fluid has relative advantages and disadvantages, in terms of collection, storage, administration, and patient benefits, but blood is the best choice for patients in hemorrhagic shock. TCCC guidelines recommend blood as the first choice if it is available and administered as part of an approved protocol. Whole blood is the preferred choice. However, it should be noted that whole-blood transfusion is exceedingly rare outside of a combat zone, and may not be compliant with Food and Drug Administration (FDA) guidelines.[44] If whole blood is not available, the next best choice is a 1:1:1 ratio of packed red blood cells, fresh frozen plasma (FFP), and platelets. If platelets are not available, the next best choice is a 1:1 ratio of packed red blood cells and FFP. Finally, dried plasma (reconstituted) or plasma alone, or packed red blood cells alone is the last choice of blood products.[44]

Most wilderness medicine practitioners will not have access to a stored blood supply, but it is important to know the ideal fluid replacement for severe casualties in austere environments. Fresh whole-blood, or "buddy," transfusion has been documented in battlefield literature (Figure 28-13). Although fresh whole-blood transfusion is not FDA-approved, it may be a consideration in certain extreme circumstances where blood types are known.[9,35]

If blood replacement is not available to the combat casualty in hemorrhagic shock, the provider should use an alternative fluid. The next best choice is the hetastarch-containing colloid solution Hextend.[44] One of the primary advantages of Hextend compared with crystalloid fluids is that smaller volumes of fluid can be used with similar effects. Because more of the colloid solution remains intravascular, medics can carry smaller, lighter packs into austere environments.[38] Unfortunately, like crystalloid fluids, Hextend does not replace the lost oxygen-carrying capacity or clotting factors of hemorrhaged blood. No more than 1000 mL of Hextend should be administered.

If Hextend is unavailable, the TCCC guidelines recommend using either lactated Ringer's solution or Plasma-Lyte A. Normal saline may be used as a resuscitation fluid, but large amounts are associated with hyperchloremia.[38]

TCCC guidelines recommend administering 500-mL boluses of either colloid or crystalloid solutions, and then reassessing the patient to determine if additional fluids are needed. Persistent absence of a radial pulse or an altered mental status would indicate the need for additional fluid resuscitation. A provider should administer the minimum volume of fluid necessary to improve the shock state. While addressing a different patient population than those faced by wilderness or combat casualty care providers, it is worth noting that the American College of Surgeons' ATLS guidelines have recently been modified. The standard 2-L crystalloid bolus has been modified to a 1-L bolus. Fluid should be discontinued when the casualty's mental state normalizes, the radial pulse becomes palpable, or a systolic blood pressure of greater than 80 mm Hg is present.[44] Casualties with TBI should maintain a systolic blood pressure above 90 mm Hg to prevent secondary brain injury. If hemorrhagic shock signs return, the provider should assess for new bleeding and then reinstitute fluid administration as noted above.

## MEDICATION

Military physicians have long sought a medication that could lessen bleeding in combat casualties, while being relatively inexpensive, and easy to transport, store and administer. Attempts with previous medications, such as recombinant factor VIIa, proved unsuccessful and were removed from practice guidelines.[22]

Tranexamic acid (TXA) has shown mortality benefit with limited risk. TXA is a synthetic derivative of the amino acid lysine. It inhibits fibrinolysis by blocking the lysine binding sites on plasminogen.[39] By reducing the body's normal clot breakdown process, TXA decreases bleeding and improves mortality rates. TCCC guidelines direct providers to administer 1 g of TXA in 100 mL of crystalloid solution (normal saline or lactated Ringer's solution) as soon as possible after injury, but no later than 3 hours after injury. An additional gram of TXA should be administered after any resuscitative fluid treatment is administered.[44] Administration of TXA is indicated for the treatment of any casualty who is expected to need a significant blood transfusion.[39,44]

Definitions of significant or massive transfusion vary, but the Joint Theater Trauma System's Clinical Practice Guidelines define it is as a patient who receives 10 units or more of packed red blood cells in 24 hours.[45] Estimating who will need this amount of blood in a field setting can be challenging. TCCC guidelines suggest using the following surrogate markers to make a decision about administering TXA: one or more major amputations, penetrating torso trauma, or evidence of severe bleeding.[44] TXA is currently the only medication recommended in TCCC guidelines to reduce the risk of death in bleeding trauma patients.[39,44]

## BURNS

Although current evidence recommends restricting IV/IO fluids in trauma patients, burn patients will continue to require significant volume fluid administration. However, if hemorrhagic shock is present, hemorrhage treatment takes precedence over burn treatment, and a patient should be resuscitated appropriately.

After performing the primary and secondary trauma surveys, the first step in burn management is to calculate the total body surface area (TBSA) burned. TCCC guidelines recommend using the U.S. Army Institute of Surgical Research (USAISR) Rule of Ten to calculate the initial fluid resuscitation of a burn victim (Table 28-3).[44]

First-degree (superficial) burns are not included when calculating the TBSA. Regardless of the fluid resuscitation formula chosen, the USAISR discourages fluid boluses, because excessive fluid volume can contribute to edema and increased rates of morbidity and mortality.[45]

## MILD TRAUMATIC BRAIN INJURY

Mild traumatic brain injury (TBI), commonly referred to as concussion, is characterized by the American Congress of Rehabilitation Medicine as a traumatically induced physiologic disruption of brain function that involves at least one of the following: loss of consciousness; loss of memory for events immediately before or after the event; alteration in mental status (e.g., feeling dazed,

**TABLE 28-3** Initial Burn Patient Fluid Resuscitation

| Step | Action |
|---|---|
| 1 | Calculate and round the affected body surface area (BSA) to the nearest 10%. Use a burn calculation sheet if possible. |
| 2 | For burns > 20% total body surface area, start fluid resuscitation as soon as access is obtained.<br>Use lactated Ringer's solution (preferred), 0.9%, normal saline, or Hextend (maximum 1000 mL of Hextend).<br>For smaller burns, use fluid resuscitation as described earlier in this chapter. |
| 3 | Initial intravenous/intraosseous fluid rate is calculated as:<br>Percentage BSA × 10 mL/hr for adults weighing 40 to 80 kg. |
| 4 | For every 10 kg more than 80 kg, increase initial rate by 100 mL/hr. |
| 5 | Maintain a urine output of 30-50 mL/hr. |

disoriented, or confused) at the time of the event; and/or focal neurologic deficit(s) that may or may not be transient.[31]

Most mild TBIs result from a direct or indirect blow to the head leading to violent "shaking" of the brain within the skull. Among military personnel, the most common causes (e.g., sports injuries, falls, or motor vehicle accidents) of mild TBIs are similar to those seen in the civilian sector; however, blast injury is also a frequent combat-related cause.

Although mild TBIs are not life-threatening, the symptoms can seriously affect a patient's quality of life. For head injury victims, the initial medical response should focus on identification and management of life-threatening injuries. This may lead to a delay in diagnosis of mild TBI. Signs and symptoms of mild TBI are variable, making diagnosis even more challenging to medical providers on the battlefield. Most people recover completely, but the process can sometimes take considerable time. This is especially true for older patients, those taking psychiatric medications, or those with previous head injuries. Additionally, although most patients make a full recovery, the time frame for resolution of symptoms varies greatly, making the condition more difficult to treat in a combat environment.[19]

Patients with mild TBI may be amnestic to the inciting event. The most commonly recognized complaint is headache.[2] Although headaches typically have a rapid onset after initial injury, they may persist for weeks to months. Common motor and sensory symptoms include dizziness, fatigue, sleep disturbances, and deficits involving vestibular and visual systems, as well as loss of motor strength and/or coordination.

Behavioral symptoms of mild TBI may include a range of disturbances in affect, cognition, and behavior and can be especially problematic on the battlefield. Many cognitive and affective behavioral symptoms begin subtly and do not become problematic for days to weeks. Disturbances in executive function, including decision making, judgment, and planning, may be present. The patient may become irritable, agitated, disruptive, or overtly aggressive and may demonstrate marked emotional instability or impaired impulse control. Cognitive symptoms often include slowed thinking, impaired judgment, distractibility, and impaired focus. Persistent symptoms may lead to emotional depression, substance abuse, or personality disorders.[2]

The approach used by the military for evaluating mild TBI has four components: assess, inform, monitor, and evacuate.

*Assess:* Combat environments do not typically allow immediate thorough assessment for mild TBI. In response, the military and Department of Veterans Affairs have developed a tool to screen for, assess, and longitudinally track and treat mild TBI. For first responders, the Military Acute Concussion Evaluation (MACE) screening tool can be a useful adjunct for evaluation of head injuries. The MACE tool is a four-part cognitive screening examination focusing on orientation, immediate recall, concentration, and memory recall. A copy may be obtained at pdhealth.mil/downloads/MACE.pdf.

*Inform:* By providing soldiers and military units information regarding the most common symptoms of mild TBI, casualties and their units are able to identify problems that may not manifest immediately. Medical providers should reinforce the fact that most patients recover completely and that treatment is available for persistent symptoms.

*Monitor and Evacuate:* If the situation allows, a casualty should be allowed to rest for at least 24 hours. Full physiologic recovery may take weeks. More severe symptoms (e.g., abnormal pupil examination, vomiting, blurred vision, sleepiness, drowsiness, slurred speech) warrant immediate evacuation to a higher level of care.

## INITIAL APPROACH TO WOUND CARE

Combat wounds range from minor abrasions and lacerations to devastating amputations. Regardless of the wound, all require meticulous care. Upon injury, wounded soldiers are instructed to take the antibiotic provided in their combat pill pack. This pack typically contains moxifloxacin 400 mg, taken orally one time upon initial wounding. If a casualty cannot take oral medications, then a medic will administer cefotetan 2 g or ertapenem 1 g parenterally. Additionally, even though soldiers' immunizations are updated prior to deploying, one must consider tetanus immunization status after any wounding.

All combat wounds, whether sustained from a blast, blunt, burn, or penetrating injury, may require initial damage control and resuscitation. TCCC guidelines should be followed to treat life-threatening injuries, such as hemorrhage, prior to routine wound care. Bleeding may be unimpressive initially, due to low perfusion pressure, but increase with resuscitation, warming of the casualty, and manipulation of the wound by medical providers. Initial primary closure of wounds is rarely considered for serious injuries at lower-echelon care.[8] Rather, temporizing measures to stop bleeding and keep wounds clean are employed until the casualty reaches more definitive care.[43]

Injuries to large arteries and veins need to be controlled using a tourniquet, pressure dressing, vascular shunt, or ligation for initial damage control. If a shunt is performed and the patient is to be transferred, a tourniquet should be placed loosely proximal to the shunt and prior to transport, in case of shunt dislodgment. Similarly, a loose tourniquet should be placed after amputation prior to transport.[28]

## PAIN MANAGEMENT

Pain is ubiquitous in combat-related injuries and should be addressed aggressively. There are many challenges for providing anesthesia for combat-injured patients, including transport to definitive care, the security situation of the patient and treating team in an austere environment, and severity of the injuries. Early, effective analgesia is tremendously important. It lessens suffering in the short term and reduces the likelihood of future problems, such as posttraumatic stress disorder (PTSD) related to undertreated pain.

All patients with combat-related injuries who have pain should be given analgesia. Table 28-4 summarizes the TCCC guidelines that recommend three options for battlefield analgesia based upon the severity of pain, patient's ability to continue fighting, and risk for shock or respiratory depression.[11,44] All of the patient's weapons should be removed prior to administering sedating medications.

This three-tiered pain treatment plan balances the need for aggressive pain management with the practical realities of treating pain in hostile or austere environments. There are additional considerations within this algorithm. Morphine can be used as an alternative to oral fentanyl if IV or IO access has been established. However, morphine in not a preferred option due to potential adverse effects, particularly decreased blood pressure and respiratory depression. Low-dose (subdissociative) ketamine (0.1 to 0.5 mg/kg IV; 0.4 to 1 mg/kg intramuscularly) is the preferred choice for patients in shock or with respiratory difficulty, due to its hemodynamic profile and preservation of protective airway reflexes. Ketamine can be combined with opiate medications for unrelenting pain. Antiemetics can be used as

**TABLE 28-4** Battlefield Analgesia Recommendations*

| Pain Severity | Casualty Can Still Fight? | Significant Risk for Shock or Respiratory Distress? | Initial Analgesia |
|---|---|---|---|
| Mild to moderate | Yes | No | Oral acetaminophen + nonsteroidal antiinflammatory drug (meloxicam) |
| Moderate to severe | No | No | Oral transmucosal fentanyl citrate 800 μg |
| Moderate to severe | No | Yes | Ketamine 50 mg IM or IN every 30 min as needed<br>OR<br>Ketamine 20 mg IV or IO every 20 min as needed |

*Adapted from U.S. Army Institute of Surgical Research: Tactical Combat Casualty Care Guidelines, 2014. jsomonline.org/TCCC.html.
IM, Intramuscular; IN, intranasal; IV, intravenous; IO, intraosseous.

needed to treat nausea associated with injury and narcotic administration. Combat medics currently carry promethazine. Splinting of fractures, patient positioning, and emotional support are important analgesic adjuncts to improve the patient's experience.

Once the patient arrives at a higher level of care, providers may consider higher doses, alternative medications, and different therapies for pain control. Regional nerve blocks offer excellent relief for a variety of extremity injuries and are widely used for combat injuries.[10]

# UNIQUE ASPECTS OF MILITARY TRIAGE AND MASS CASUALTIES

In all mass casualty situations, triage attempts to provide the greatest good for the greatest number of victims. In most cases, military triage categories mirror those seen in the civilian sector: immediate, delayed, minimal, and expectant. With mass casualty events in combat, due to the hostile environment, the security situation is often grim and transportation may be delayed. Because of this, triage categories can shift. For example, a potentially survivable injury in a stable environment may become expectant in a hostile setting. These shifts can be due to changing security situations, mission requirements, lack of available resources, and/or available personnel.

# TRAUMATIC EMOTIONAL STRESS: THE CONTINUUM OF EFFECTS

Traumatic emotional stress is a common and serious problem that is especially relevant to the field of wilderness medicine. This section reviews basic precepts, describes the general concept of traumatic stress, and cites some of the management strategies that have demonstrated utility in the field.

## CLINICAL ASPECTS OF PSYCHOLOGICAL TRAUMA

Two principal determinants of the severity of psychological trauma are the gradient of exposure and magnitude of personal loss. In general, the closer or more directly affected an individual is by the event, the greater the likelihood of significant psychological distress. The magnitude of personal loss describes the "comprehensiveness" of the event. Does the event produce meaningful physical or psychological pain or limit abilities because of injuries? Do losses affect areas such as physical mobility or capacity, employment, or future personal or professional opportunities? Were feelings of terror, horror, or helplessness involved? A final consideration is the total number of traumatic exposures, as it is not uncommon for military personnel to be repeatedly exposed to traumatic events during the course of a military operation.

Informally, the gradient of exposure and magnitude of personal loss might be reduced to the phrase "how close, how big, and how many?" Taken together, these are highly predictive of the degree of psychological distress.

## SOURCES OF PERSONAL TRAUMA

We define our world with our senses. Armed conflict is, at its core, an assault on the senses. Sights, sounds, smells, and physical pain create the psychological imagery of indelible memories, intrusive thoughts, and disturbed feelings that are the cardinal features of psychological trauma.

## HOW ARE MILITARY STRESS REACTIONS CHARACTERIZED?

In general, the military recognizes three types of stress reactions. In ascending order of severity, they are the combat and operational stress reaction (COSR), acute stress disorder (ASD), and posttraumatic stress disorder (PTSD). Although the military focuses principally on combat-related issues, the general template applies well to nonmilitary stress responses. Because the civilian sector does not use the term *combat,* one might substitute the word *initial* in its place for COSR. All three reactions may encompass a combination of common physical, emotional, and behavioral signs.

### Combat and Operational Stress Reaction

It is not unusual for combat exposure or other circumstances of interpersonal violence or imminent danger to create physical and emotional symptoms. Such reactions may occur as the result of combat-like conditions that are present during any aspect of military operations or training, such as direct engagement with enemy forces, civil support activities, humanitarian assistance, disaster response, and combat medical care.

Outward signs and symptoms of COSR often include a combination of physical, emotional, behavioral, and cognitive disturbances. Common physical complaints include fatigue, exaggerated startle response, sweating, sleep disturbance, rapid heartbeat, dizziness, frequent urination, dry mouth, and restlessness. Emotional distress may include grief, self-doubt, anger, rage, excessive guilt, loss of confidence, and rumination about distressing events. Common behavioral representations of these emotions can include indecisiveness, irritability, hypervigilance, social withdrawal, decreased arousal, decreased initiative, tearfulness, and inability to relax. Cognitive disturbances can include confusion, distractibility, inattention, and memory problems. Any of these can temporarily incapacitate an otherwise healthy individual. These impairments are temporary in the overwhelming majority of individuals and are not indicative of lasting pathology. Affected individuals will commonly initiate or increase the use of substances, commonly nicotine or alcohol, if available.

### Acute Stress Disorder

ASD represents a profound and severe time-limited reaction to trauma. ASD describes disturbances that develop within a month of exposure to extreme psychological trauma. Such extreme events include rape or other severe physical assault, near-death experiences, witnessing personal violence, and combat.[20]

Core symptoms of ASD include reexperiencing the event in the form of nightmares, intrusive thoughts, physiologic reactivity, maintaining a persistent negative emotional state, avoidance of feared places or thoughts, and hyperarousal similar to the COSR symptoms noted above. ASD may also include flashbacks, altered sense of reality, and dissociative amnesia. Flashbacks are severe intrusions of traumatic memory in which the individual dissociates from his surroundings. An altered sense of reality is a change in an individual's experience of one's own environment, where the world around him feels unreal and unfamiliar, or a change in an individual's self-awareness, such that he feels detached from his own experience, with the self, body, and mind seeming alien. It can also be characterized by a sense of the world as a dreamlike or unreal place and may be accompanied by poor memory of the specific events, which in its severe form is known as dissociative amnesia. There is currently no conclusive evidence that individuals affected by ASD will progress to develop PTSD.

### Posttraumatic Stress Disorder

PTSD results if the symptoms and behavioral disturbances persist or develop more than 1 month after the trauma, and if these features are associated with functional impairment or signifi-cant distress to the sufferer. These terms describe the outward manifestations of trauma-induced anxiety. Essentially, the individual's adaptive responses to an unstable environment have been internalized as a general mode of responding to *all* environments.

The symptoms of ASD and PTSD are similar. The proper diagnosis revolves around two historical questions: How long have the problems lasted? Are the problems getting better, worse, or remaining the same?

### Which Treatments Work?

In general, treatment focuses on helping people process their experiences in ways that decrease or eliminate the combat arousal state. Most treatments for COSRs occur within the affected group in the form of rest, feeding, reassurance, and temporary removal from combat duties, with most not requiring formal medical intervention. Treatment strategies for ASD and PTSD that have been shown to be useful include trauma-focused psychotherapy, eye movement desensitization and reprocessing, and pharmacologic treatment. These should be initiated by trained mental health professionals or in consultation with them.

## TELEMEDICINE

Telemedicine has been used successfully to diagnose acute medical conditions, provide shipboard advice, send radiologic studies for interpretation, and give reports on patients being evacuated to higher levels of care. Combat medics in remote sites have used email to communicate with their unit's medical provider to make determinations about evacuation and treatment of ill and injured soldiers. The U.S. Army Medical Research and Materiel Command and the Telemedicine and Advanced Technology Research Center have worked on surgical robots and mentoring programs to assist in surgery. Telemedicine technology and applications continue to advance and hold promise for future use in combat casualty care.

## UNEXPLODED ORDNANCE

Unexploded ordnance (UXO) may include aerial bombs, rockets, artillery and mortar shells, grenades, mines, and IEDs. Any location where a war has been fought within the past century has potential for retaining these items, and military training ranges often border wilderness areas. Areas of the shallow ocean accessible to scuba divers may contain sunken munitions and warships with unexploded bombs, shells, and torpedoes. Mines and booby traps may also surround illegal drug laboratories and fields.

UXOs may cause injuries to scores of victims. In the modern era, many military and civilian casualties have been caused by IEDs, which may be conventional explosives; improvised from fertilizer, propane, or other unconventional explosives; artillery, mortar, or other ordnance; or explosive charges removed from such ordnance. IEDs are commonly used by terrorist groups, which may detonate the devices either by timing mechanisms or by command, and sometimes in suicidal attacks. These devices are usually detonated in crowded areas or near important political or military targets to create the greatest impact. IEDs have been encountered frequently during combat operations in Iraq and Afghanistan.

Unexploded land mines represent a significant threat in Southeast Asia, the Balkans, Central America, Egypt, Iran, and Afghanistan. The International Red Cross estimates that someone is killed or injured by a land mine every 22 minutes. The average number of mines deployed per square mile in Bosnia is 152; in Iran, 142; in Croatia, 92; and in Egypt, 59. There are a total of 23 million mines in Egypt alone.[7]

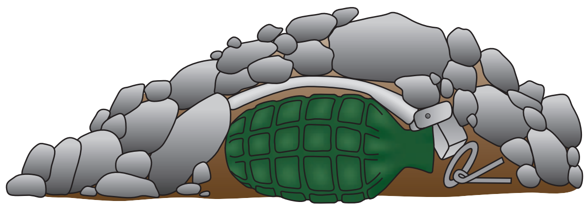

**FIGURE 28-14** An improvised mine, or booby trap, manufactured from a hand grenade and materials at hand.

Land mines may be commercially manufactured or produced locally from available materials (Figure 28-14). Locally produced mines have no standard size, shape, or detonation pattern and may be very difficult to detect and defuse. These types of land mines are used extensively in El Salvador, Malaysia, and Guatemala.

Land mines have two primary functions: cause casualties and destroy equipment. Antipersonnel mines may be of the blast or fragmentation type. Fragments may be accelerated at 4500 feet/sec (3068 mph), or double the speed of a high-velocity rifle (Figure 28-15). The second primary function is to destroy vehicles, such as tanks, so mines intended for this purpose are usually much larger.

All mines have three basic components: (1) triggering device, (2) detonator, and (3) main explosive charge. The triggering device differs depending on the type of mine. Blast mines usually involve a pressure type of trigger and occasionally are command detonated, especially for antitank purposes. Many antitank mines will not explode unless a pressure of 136 to 181 kg (300 to 400 lb) is applied. The M14 blast antipersonnel mine needs only 9 to 14 kg (20 to 30 lb) of pressure to trigger detonation. Fragmentation mines are usually triggered by trip wires or similar "touch" devices. The M18A1 fragmentation mine, or claymore mine, can also be command detonated by an electronic trigger.

The distribution of mines usually entails spreading them on the surface of the ground; by air along roads, railways, and defensive positions; or hiding them by burying or camouflage along trails or suspected routes of approach.

Four general patterns of injuries occur with land mines. *Pattern A injuries* occur with small blast mines, such as the U.S. M14 and the Chinese Type 72. These injuries usually involve only the leg below the knee. Complete or partial foot amputations are most common, and trunk or head injuries are rare. *Pattern B injuries*

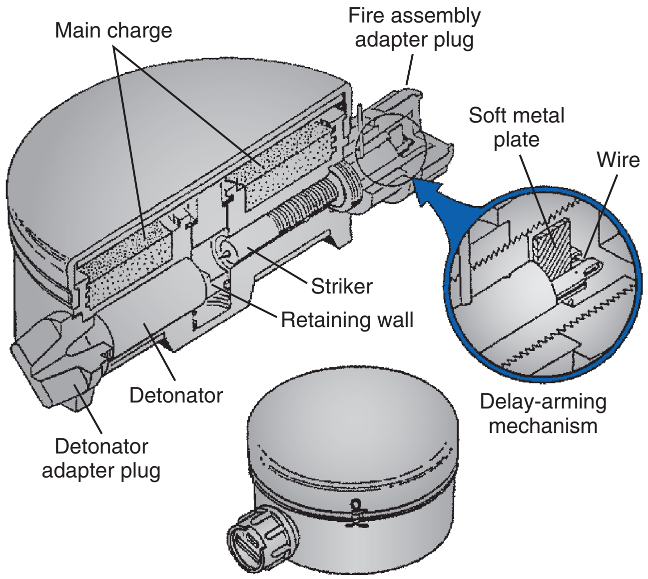


**FIGURE 28-15** An antipersonnel mine manufactured by the Soviet Union.

are caused by larger blast mines, such as the Russian PMN. These mines contain four to six times as much high-explosive material, and the cone of explosion is much larger. The injuries seen with this type of land mine usually involve massive soft tissue injuries to both legs below and above the knee and also commonly the pelvis, abdomen, and chest. *Pattern C injuries* are generally caused by Russian PFM-1, or "butterfly," mines. These mines are usually distributed by air, and the wings are designed to help spread the mines. They are triggered by pressure applied to the wings; handling the mine commonly does this. Most of the injuries involve amputation of the hand at the wrist; often the head, neck, and chest are also injured. Unfortunately, loss of one or both eyes is not uncommon with this mine. *Pattern D injuries* are caused by fragmentation mines. These may be bounding mines, such as the U.S. M16 or the Russian OZM, or directional mines, such as the U.S. M18A1 or the Russian MON. They are designed to spread metallic fragments over a wide area at the height of a person's waist. The fragments lose their energy much faster than a bullet projectile but at close range can be devastating. The lethal range is usually 25 to 50 m (82 to 164 feet), with casualties occurring out to 200 m (656 feet). The injuries are quite similar to gunshot wounds and are often multiple.

Any patient that has a retained UXO in his or her body requires extremely delicate handling. Transportations should be limited and surgical removal performed. An explosive ordnance disposal specialist should provide advice on the type of UXO and triggers. The surgical team performing UXO removal from the casualty should be limited to critical members. Every member of the team, and the patient, should wear protective gear, such as eyewear, and sandbags should be used to deflect any blast.

## DEATH

Decedent care is an important service for both the soldier's family and unit morale. The body of a fallen soldier is often brought to medical personnel in the area, though the responsibility for disposition of the remains belongs to the Army Quartermaster Corps, Air Force Mortuary Affairs, or Navy-Marine Corps Mortuary Affairs. The body is cooled if possible. As in a medical examiner's case in the United States, all medical procedure items are placed in the body bag with the deceased. Clothing and operational gear are transported with the remains. Any records of the incident are preserved and sent with the remains. The military performs an autopsy to determine the cause of death and enter the data into the trauma registry. In response to the loss, the unit usually holds a memorial service. The Fallen Soldier Battle Cross may represent the deceased soldier at the ceremony. The cross consists of the soldier's rifle with bayonet attached and stuck into the ground; the helmet is placed on top, accompanied by dog tags that hang from the rifle with the boots of the fallen soldier in front of it (Figure 28-16). The ceremony for the lost comrade is formal and used to honor the commitment and sacrifice of the soldier while mourning his or her loss. Commanders use this ceremony to reaffirm a sense of unity, cohesion, and commitment to their remaining soldiers as they continue to pursue their combat mission.

**FIGURE 28-16** The Fallen Soldier Battle Cross.

### ACKNOWLEDGMENT

*Special thanks to CDR James West for his assistance with the Traumatic Emotional Stress component of this chapter. The opinions in this chapter are those of the authors, and do not represent the official policy or opinion of the Department of the Air Force, Department of the Army, Department of Defense, or United States Government.*

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

# CHAPTER 29

# Injury Prevention: Decision Making, Safety, and Accident Avoidance

EUNICE M. SINGLETARY AND DAVID S. MARKENSON

For many, it is the *wild* in *wilderness* that fuels a passion for the wilderness experience. Wilderness areas are considered the last areas that humans do not control and have not developed. This lack of human control in undeveloped terrain, combined with the enthusiasm of wilderness explorers, is an ideal recipe for unintentional injury. Managing the risk through sound decisions and efforts to improve safety and reduce accidents is a critical component of wilderness medicine and the focus of this chapter.

Contributing to the overall risk for injury is the growing feasibility of exploration by wilderness novices, children, elders, and

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**FIGURE 29-1** Requirements that snowmobile groups seeking access into Yellowstone National Park be accompanied by guides and be limited in size not only lessen the environmental impact on natural resources but may help decrease the risk for injury from bison traveling in close proximity to the roadway. *(Courtesy Eunice Singletary.)*



persons with disabilities or chronic health issues by using off-road vehicles, watercraft, and aircraft or via improved access. For persons who venture into the wilderness, there are ongoing technological advances in communications equipment, Global Positioning Systems (GPSs), sporting equipment design, water purification and disinfection, and food processing and preservation techniques, all of which extend the duration of expeditions and permit exploration of remote wilderness once reachable by only the most skilled and experienced persons. Environmental hazards, such as exposure to cold, heat, snow, or altitude, can be minimized through proper planning and training. Wilderness sports activities, such as hunting, snowmobiling, and backcountry ski touring, are safer today not only because of advances in technological and safety equipment but because of efforts to educate the public about associated risks and how to manage or reduce these risks and efforts to train the public in wilderness first aid and medicine (Figure 29-1). Despite the growth in numbers of practitioners of wilderness medicine and the improved ability to provide care for many injuries and illnesses in remote settings, evacuation of injured victims from the wilderness remains daunting and can turn a minor problem into a major medical situation with a protracted rescue.

There are 78 million hectares (193 million acres) of land in the U.S. National Forests and Grasslands. Thousands of rivers and lakes are parts of the national forests, and there are 247,000 km (153,000 miles) of trails, primarily for nonmotorized use.[149,163] In 2013, there were more than 273 million recreational visits to National Park Service (NPS) sites, with 1.7 million categorized as backcountry overnight visits.[105] The National Sporting Goods Association estimates that between 1994 and 2004, the number of Americans involved in backpacking and wilderness camping climbed from 10.2 million to 13.3 million. During the same time period, the number of hikers increased from 25 million to 29.8 million.[106]

With increased access comes the potential for higher numbers of injuries, illnesses, and fatalities. According to the Centers for Disease Control and Prevention (CDC), in 2012, unintentional injury was the fifth leading cause of death in all age groups and responsible for 127,792 deaths.[28] The number of injuries and injury-related deaths as a result of wilderness activities is unknown and can only be extrapolated, particularly from NPS data. Between 1992 and 2007, there were 65,439 search and rescue (SAR) incidents in U.S. National Parks, involving 78,488 visitors and resulting in 2659 fatalities and 24,288 ill or injured visitors.[63,64] From a public health point of view, the physical, financial, and emotional consequences of injury can be wide ranging, devastating, and long lasting. The CDC's National Center for Injury Prevention and Control (Injury Center) was formed partially as a result of a recommendation of the 1985 Institute of Medicine report *Injury in America,* which concluded that supporting injury research is necessary to substantially reduce injury rates.[32] The Injury Center strives to prevent injury and reduce its consequences, using a public health approach that describes the problem, identifies risk and protective factors, develops and tests prevention interventions and strategies, and promotes widespread adoption of effective interventions and strategies. Although the Injury Center includes intentional as well as unintentional injuries in its focus on injury prevention, their efforts and approach may prove to be a model for future research and methods for injury reduction in the wilderness setting.

This chapter reviews basic principles of injury applied to the wilderness environment. Individual (human/host) factors and behavior and how they apply to injury risk and prevention are detailed, including preparation, planning, anticipation of problems, and errors of omission or commission. Problems are approached from the perspective of environmental hazards, rather than from a particular activity, because many hazards are common to different wilderness activities. Throughout this chapter, prevention of injury is the focus. Details of pathophysiology and treatment are found in the referenced chapters throughout this text.

## PRINCIPLES OF WILDERNESS INJURY AND PREVENTION

### THE INJURY FIELD: BASIC PRINCIPLES

Injury prevention is a key component of public health and medical care. It is a long-held belief of physicians and public health practitioners that injury prevention is essential to avoid injury treatment. Underlying injury prevention is the concept that when an injury occurs it is usually the result of a series of events under specific circumstances that, had they been identified in advance, might have been avoided, addressed, and/or eliminated to prevent or mitigate the injury. In the field of injury prevention, *accidents* are defined as unpredictable acts of fate or chance events, whereas *injuries* are defined as damages resulting from a sequence of accidents or intentional actions. Injuries are prevented by stopping or reducing the number of accidents causing them and/or eliminating the intentional actions and situations that lead to them. By applying this principle, practitioners of injury prevention estimate that 90% of all injuries are predictable and preventable. For example, by inspecting, testing, and replacing equipment, individuals may prevent accidents related to equipment failure. The need for this approach is greater in wilderness medicine than in many other fields of medicine. In medicine we attempt to prevent injury, but if that prevention fails, we provide emergency care and rehabilitation to limit the lasting effects of injury and return the person to good health. In the case of wilderness injuries, which may occur in areas with limited immediate care and often with significant distance and time to reach definitive care, our ability to limit the extent of injury is less, magnifying the need for prevention.

## THE CONTINUUM OF INJURY PREVENTION

The precepts of prevention can be inserted at many points along the continuum, beginning before injury through rehabilitation. In classic injury prevention and epidemiology, opportunities for prevention are divided into primary, secondary, and tertiary phases. Primary prevention avoids development of a disease. Most population-based health promotion activities are primary preventive measures. In addition, many environmental or regulatory controls are primary.

Secondary prevention activities are aimed at early disease detection, thereby increasing opportunities for interventions to prevent progression of disease and emergence of symptoms. In the field of injury prevention this would include early recognition of injury to limit the extent and impact of an injury should it occur. An example in wilderness medicine is early recognition of foot blisters and use of protective coverings or footwear alteration to prevent skin breakdown and further extension of blisters or infections. Wearing protective equipment is both primary and secondary if it limits the extent of injury. Interventions may cross multiple stages of prevention.

Tertiary prevention reduces the negative impact of an already established disease by restoring function and reducing disease-related complications. In the field of injury prevention, this traditionally includes prompt and appropriate medical rehabilitation. An example is early splinting of a fracture in the field to prevent further injury and to limit swelling and associated complications. Quaternary prevention is the set of health activities that mitigate or avoid the consequences of unnecessary or excessive interventions within the health system. This stage is the latest addition to the classic three stages of prevention and is not always included in descriptions of injury prevention.

## EPIDEMIOLOGIC FACTORS: HUMAN OR HOST, AGENT, AND ENVIRONMENT

One of the most commonly used methods of categorizing the factors that lead to injury is "human (host), agent, and environment." Numerous human factors can lead to injury and be used as opportunities for prevention. Examples include predisposition to injury, such as osteoporosis predisposing to fractures; behaviors that may be high risk for injury, such as alcohol consumption and intoxication; decision making, such as a choice to proceed on an icy trail; and different body habitus, ages, or conditions, such as pregnancy.

The next factor is the agent. Broadly defined, the agent is what causes the injury. Although this may seem straightforward, the lines can be blurred. For example, if someone decides to strike a branch with his or her hand to break it, is the branch the agent or is the human who made the decision the agent? Most would agree the branch is the agent and the human factor was the decision to strike it. Classic descriptions of agents would be propelled objects, items that strike people, falls from heights, or malfunctioning mechanical devices. In the wilderness, the items include failing ropes or belts when climbing, branches and rocks when falling, wet ground causing a slip, a poorly positioned or inappropriately worn backpack leading to back injury, or a hot object that causes burns.

The last factor is the environment, which includes the situation in which the injury occurred. This might be temperature conditions, such as extremes of heat or cold, but may also include a situation where there is only one option for moving forward through less-than-ideal terrain without the option to turn back.

## CONCEPTUAL MODELS

A more comprehensive conceptualization for intervention and prevention can be done by combining stages of injury prevention with the host, agent, and environment approach. This combination was proposed by Dr. William Haddon, Jr., who is widely considered the father of modern injury epidemiology.

Haddon's matrix is an injury prevention brainstorming tool originally designed for motor vehicle safety that combines the epidemiology triangle (host, agent, environment) and levels of prevention. This combination allows planning for injury interventions and prevention strategies by phases in time of the event. In addition to planning interventions, this matrix can also be used to collect data to determine the factors that cause injuries.

The following are the steps to complete Haddon's matrix:

1. Assess the contributing factors or characteristics of an injury from the perspective of the following:
   a. Host or human factors
   b. Agent of energy or vehicle (such as crashworthiness of a vehicle)
   c. Physical environment (such as roadway design or safety features)
   d. Social environment (such as passage and enforcement of seatbelt laws)
2. Then combine them with time phases:
   a. *Preevent:* What factors affect the host before the event occurs?
   b. *Event:* What are factors related to the crash phase?
   c. *Postevent:* What are factors related to the postevent crash phase?
3. Place the items with the possible intervention in the appropriate location in Haddon's matrix.

### Haddon's Ten Strategies for Reducing Injuries

In addition to developing the matrix, Haddon also proposed strategies for reducing injuries. These strategies have been grouped into 10 specific approaches, commonly known as Haddon's 10 strategies (with examples):

1. Prevent creation of the hazard.
   a. Perform preparticipation musculoskeletal physical examination to identify underlying pathologic problems of the knee joints.
   b. Provide treatment and rehabilitation before sports participation.
   c. Provide warm-up programs involving neuromuscular and proprioceptive training to stabilize the knee.
2. Reduce the amount of the hazard.
   a. Limit the physical areas for activities. Provide limitations on activities or exposure to the environment.
3. Prevent the release of the existing hazard.
   a. Ensure that waste is kept properly distant from potable water sources.
4. Modify the rate or partial distribution of release of the hazard from its source.
   a. Limit activity to an individual's ability.
   b. Substitute individuals as necessary during a specific activity.
5. Separate, in time or space, the hazard and that which is to be protected.
   a. Limit climbing to certain weather conditions.
   b. Perform strenuous activity only when ambient conditions are appropriate.
6. Separate the hazard and that which is to be protected by interposition of a material barrier.
   a. Use well-fitted gear.
   b. Employ protective gear.
7. Modify basic relevant qualities of the hazard.
   a. Avoid surfaces that increase the potential for injury.
8. Make what is to be protected more resistant to damage.
   a. Provide fitness training, including stretching, strengthening, and improving balance and movement.
9. Begin to counter the damage already done by the hazard.
   a. Seek and receive prompt medical care as soon as the injury is noted.
10. Stabilize, repair, and rehabilitate the object of the damage.
    a. Provide rehabilitation, and use stabilization devices, such as knee braces.

## ENVIRONMENTAL, EDUCATIONAL, AND ENFORCEMENT APPROACHES TO INJURY PREVENTION

In addition to describing possible interventions using Haddon's matrix approach, it may be helpful to characterize the type of intervention. One way to categorize injury prevention efforts is by the three *E*s:

- *E*nvironment makes the environment or product safer.
- *E*ducation provides information to individuals.
- *E*nforcement relies on change through laws.

Comprehensive injury prevention projects employ strategies that include all of these.

### Environmental Approach

The environment includes physical surroundings (e.g., roadway), products (e.g., vehicles), and the social environment (e.g., societal attitudes toward drinking and driving). The environmental approach is a strategy that does not depend on action by those being protected; it is passive, automatic, and constant in its protective effects. As a result, this approach is considered the most effective strategy. In some cases, the technology to make products safer is available, but industry has not adopted it, often because of economic disincentives.

In classic injury epidemiology, environmental interventions refer to the following:

- Physical surroundings
- Product design, protocols, and practices
- Social environment

The following are key concepts for environmental modification:

- Design safer surroundings
  - Pool fencing
  - Handrails
  - Antislip surfaces
  - Playground surfaces
  - Roadways
  - Bike/walking paths
- Design safer products
  - "Kill switches"
  - Childproof packaging
  - Crib slat spacing
  - Flame-resistant sleepwear
  - Vehicle design
- Protocols and practices
  - "Traffic calming"
  - Walk-light timing at crosswalks
  - Bus stop placement
  - Lighting for crime reduction
  - Factory settings for water heaters
- Social environment
  - Alcohol consumption and operating motorized devices while drunk
  - Domestic violence
  - Violence on television
  - Safety devices

### Educational Approach

Preventive measures defined as an educational approach involve education of large populations, targeted groups, or individuals and efforts to alter specific injury-related behaviors. Many injuries result less from lack of knowledge than from failure to apply what is known.

Three goals of educational interventions are as follows:

1. Provide information regarding injury risks and how to avoid them.
2. Change attitudes away from risks and toward safer practices.
3. Alter behaviors. It is not enough to know that seatbelts save lives, but one must actually use the seatbelt for it to be effective.

An educational approach may be appropriate in the following instances:

- New knowledge about a risk is needed (e.g., defective equipment, better approaches to an activity, newer and safer technology available)
- No other approach exists (e.g., an activity that is inherently unsafe and avoidance is the only strategy)
- To influence decision makers, lawmakers, and design engineers
- To teach specific behaviors and skills (dialing 9-1-1, crawling under smoke, self-care of injuries)

Limitations of the educational approach include the following:

- It uses an active approach. Passive approaches are preferred.
- It may be an inappropriate message for the target audience. Targeted, at-risk populations are not always reached through mass-media educational campaigns.
- There are variations in learning styles among adults and possible language barriers. In education, "one size does not necessarily fit all." There are variations in learning styles unique to children and adults, cultures, and socioeconomic status.
- There may not be cultural acceptance of the message. Messages should be tested with a focus group to be certain that they are not offensive.

### Enforcement Approach

This approach uses a strategy that seeks to require a change in a behavior, the environment, or a product by enacting law and policy. Enforcement initiatives and laws are directed toward individuals, products, and environmental conditions.

The following are examples of laws targeted to individuals:

- Requiring:
  - Seat belts
  - Child restraints
  - Helmet use
- Prohibiting:
  - Drunk driving
  - Excessive speed

The following are examples of laws targeted to products:

- Requiring:
  - Motor vehicle standards
  - Helmet standards
  - Childproof packaging
- Prohibiting:
  - Fully automatic weapons
  - Flammable fabrics

The following are examples of laws targeted to the environment:

- Requiring:
  - Swimming pool fence
  - Smoke detectors
- Prohibiting:
  - Firearms in airports/schools
  - Rigid structures on highways

Characteristics of successful laws include the following:

- There are few exceptions to compliance.
- Detection is easy (measuring speed with radar, observing helmet use).
- Punishment is certain, swift, and sure.
- There is publicity about enforcement. Enforcement and laws can have a much greater impact on changing behavior when enforcement is highly visible and media are used to let the public know about enforcement campaigns. Controversies arise when legislation is perceived to restrict personal freedoms.

## SOCIAL-ECOLOGIC MODEL

In addition to the classic epidemiology approach of host, agent, and environment enhanced by the stages of prevention and articulated by Haddon in his matrix, another conceptual model attempts to describe injury prevention but with more focus on the interplay of different factors. The social-ecologic model has its foundation in human development and has been refined to apply to injury prevention and epidemiology. The social-ecologic framework was created by Urie Bronfenbrenner[20] in the context of understanding human development and is very compatible with a broader view of public health.[81] Social-ecologic theory defines various levels of the social environment, depicting the nested roles of intrapersonal factors, interpersonal factors, institutional elements, and cultural elements. This social-ecologic framework enhances the standard public health model of agent-host-environment.[94,127,142]

With respect to understanding injury prevention, intrapersonal factors include both developmental and sociobehavioral features of individuals (i.e., the host), for example, a young child's curiosity and exploratory behaviors through touching, tasting, and crawling; an adolescent's propensity to take risks and the varied responses to parent and peer influences; or an older adult's suicide risk due to a sense of hopelessness in the face of an incurable chronic disease or avoidance of walking in certain locations because of fear of falling or assault. Likewise, biologic features of the host, such as a young child's lack of balance and strength, high center of gravity, and small size, relate to some of the hazards encountered. For an older adult, biologic characteristics such as bone brittleness; reduced visual acuity, reaction time, and balance; and thinner skin all increase susceptibility to injury events such as traffic crashes, pedestrian injuries, falls, and burns.

Interpersonal factors are those that result from the interactions between two persons, for example, intimate partners, parent and child, employer and employee, or adolescents. In the injury sphere, this relates to intentional injury as a result of behaviors associated with disciplinary practices or conflict resolution.

Institutional elements are those that reflect organizations in which individuals function, for example, schools, places of worship, and workplaces. How these organizations promote or control activities and environments can affect injury risks. Work sites contain many hazards and adopt many types of safety practices, whereas places of worship may either encourage or discourage certain safe or unsafe practices. Prehospital trauma care and inpatient health care systems are institutions that affect injury outcomes.[112]

Cultural elements include broad social values and norms as well as governmental policies that guide or mandate behaviors of individuals or organizations. Examples are values placed on individual freedom; social norms about drinking or corporal punishment; and laws, policies, and regulations about producing, selling, and storing firearms. Any health problem can be viewed as resulting from and being alleviated by the interactions among these dynamic factors.

## RISK AND EFFECT MODIFICATION IN INJURY PREVENTION EPIDEMIOLOGY

Two basic epidemiologic concepts are risk and effect modification. Risk is the likelihood of disease occurrence and is often operationalized as relative risk to aid in decision making. This is a method to describe how one option versus another option may lead to different disease outcomes. In injury prevention, one always must consider risk. Some activities are inherently risky, and all one can do is provide interventions that protect the individual or minimize the impact of a potential injury. In other cases, there may be several options, each with a different risk, so that one can determine the relative risk. Major human risk factor examples are age, gender, and experience.

Another basic epidemiologic concept that can be applied to injury prevention is that of effect modification. An effect modifier is a variable that lies in the pathway from the independent/main explanatory variable to the dependent/outcome variable. When applying this to injury prevention, one can think of an effect modifier as something that lies in the pathway between the event and the injury, and that can alter the injury outcome from similar events. An example might be wearing a helmet, so that if a person is thrown from a horse, the injury to the head is less serious than if the person were not wearing a helmet. Human factors can be considered from the perspective of effect modifiers. For example, when caught in bad weather, the more experienced hiker will be less likely than the novice to be injured.

## ACTIVE VERSUS PASSIVE INJURY PREVENTION STRATEGIES

Before proceeding to implement methods of injury prevention, it is important to recognize that injury prevention strategies are either active or passive.[119] Active injury prevention strategies require a change in behaviors by individuals before or when exposed to risks.[155] For example, individuals must be convinced that wearing seat belts reduces the risk for injury and then must take the action of buckling up. Passive injury prevention strategies are preferable because they require no action on the part of the individual.[56,78] For example, recent advances in automotive safety have been gained by placement of air bags. A more classic passive approach has been referred to as environmental controls. An example of this is a fence placed around a pool to prevent entry of unsupervised children, thus reducing drowning incidents.

## MORBIDITY AND MORTALITY STATISTICS FOR WILDERNESS INJURY

The difficulties of obtaining data about injury prevention in the wilderness are the diversity of activities covered and lack of a single source for the data. As a result, data are often only for a selected activity and in a single location. Some data involve several activities. An example is a CDC study released in 2008 of nearly 213,000 people who had been treated each year in emergency departments for outdoor recreational injuries from 2004 to 2005.[46] Of those injured, about 109,000 (51.5%) were young people between the ages of 10 and 24. For both men and women of all ages, the most common injuries were fractures (27.4%) and sprains (23.9%). Of these, most injuries were to the arms or legs (52%) or to the head or neck (23.3%). Overall, 6.5% of outdoor injuries treated were diagnosed as traumatic brain injuries. Researchers found that snowboarding (25.5%), sledding (10.8%), and hiking (6.3%) were associated with the highest percentage of injuries requiring emergency department visits. More recently, a retrospective review of incident reports involving children ages 0 to 6 years in 20 U.S. NPS units designated as backcountry wilderness destinations found 1672 incidents involving this age group, including 58 fatalities. The 0 to 6 years age group accounted for 18.4% of the total incidents for all age demographics, with hiking activities accounting for 20% of all incidents and 26% related to swimming and boating. More than half of the fatalities were related to swimming and boating incidents.[61] These studies point out that wilderness injury prevention begins with planning, preparation, and problem anticipation, which are discussed later in this chapter.

An example of event-specific data is for backpacking and camping. Data reveal that more than 11 million people participated in backpacking or wilderness camping in 1990. The morbidity and mortality figures from eight national parks in California between 1993 and 1995 are 1708 injuries and 78 fatalities.[102] Another event-specific activity for which there are data is long-distance, multiday bicycling. A retrospective review of incidents requiring transportation to a hospital during a 7-day, 500-mile event with more than 10,000 participants in Iowa found that females and older males between the ages of 60 and 69 years were more likely to require transport for injuries they sustained. Most injuries (77%) were due to rider factors related to carelessness and etiquette, such as contact or entanglement with other riders or rider equipment, and injuries sustained were most commonly lacerations, abrasions, or fractures located above the waist.[17] Epidemiologic data, such as data from this study, can be used by bicycle event organizers to educate riders to help prevent incidents and injuries.

In addition to event-specific data, one can examine equipment-based data, which can include data based on certain types of vehicles. For example, from 1990 through 1995, an estimated 32,954 persons were involved in injuries related to personal watercraft.[19]

Lastly, one may search data to learn about specific types of injuries or deaths. An example of this type of data is a western Washington study of 40 pediatric deaths related to wilderness between 1987 and 1996.[108] Ninety percent of the victims were male, and 83% were 13 to 19 years of age. The most common cause of death was drowning (55%), followed by closed head injury (26%). Injuries or deaths resulted from lack of preparation, lack of training for wilderness activities, and inadequate basic safety equipment; alcohol use and rescue delays were contributing factors. Of note, the presence of adults did not appear to be significant in reducing the incidence of death.

## PUTTING INJURY PREVENTION INTO PRACTICE

### Planning

Careful planning is the foundation for a safe activity that minimizes risk and avoids injury. Planning begins by gathering all relevant data for the planned activity. This includes up-to-date information regarding weather, trail, and campground conditions, best times to travel, permit requirements, equipment needed, and special considerations unique to the activity. After gathering all available information, one develops a plan for activities. The plan may be very brief and purely a mental exercise for some activities, such as brief hikes, camping trips, rock climbing attempts, or day diving activities. For longer excursions, the planning phase will include a detailed, written plan. Planning may include addressing unique risks or needs. For example, to plan for a climb to a high altitude, time for acclimatization is allowed during the ascent. Planning may include provision of equipment specific to the activity, such as scuba gear or helmets.

Two of the most important planning factors are personal limitations and required preparation. It is important to establish criteria under which the activity can be undertaken safely. The level of detail is based on the risks. For high-risk events or those with multiple risks, the criteria need to be detailed. There are many factors that figure into a "go" or "no-go" decision plan. Some factors, such as weather, local conditions, physical conditioning for the activity, sleep, and wellness, may apply to all activities, but others may be activity specific, such as water conditions for rafting and kayaking. Once the criteria are established, the most important thing is to adhere to them. Injuries often occur when the desire to perform an activity causes someone to participate in a situation that is either unsafe or exceeds personal abilities.

At a minimum, one must address the following:

- Predetermined "go" or "no-go" criteria, which may include the following:
  - Weather and environmental conditions at the activity site
  - Personal criteria such as sleep, preparation time, preexisting illness, departure time and window
  - Required participants
  - Equipment
- Comprehensive equipment checklist
- Timeline
- Alternative plans
- Communication methods, including emergency communications
- Emergency procedures, including the following:
  - Medical emergencies
  - Unexpected weather or local conditions
  - Equipment failure

### Preparation

After planning, the next step in a good injury prevention approach is to prepare for the activity so as to minimize risk and put into place factors that are targeted at the human, agent, and environmental issues that can lead to injury. Preparation activities can be grouped into human factors, including physical and mental preparation, and material factors, such as equipment preparation.

**Physical Preparation.** Physical preparation includes maintaining excellent fitness and health in anticipation of the activity and the added stresses over daily activities. This may include conditioning, medical evaluation for physical abilities and health to undertake the activity, better medication adjustment for persons with chronic illness, and/or disability-specific planning for those with disabilities. In addition to general physical preparation there are unique considerations for physical preparation related to the genitourinary tract (see Injury Prevention for the Genitourinary Tract, p. 605).

**Mental Preparation.** Mental preparation emphasizes thinking through the plan, ensuring that one is well rested, focusing on the activity, and being confident about the activity. Mental preparation also includes proper education and training. This should include training specific to the activity and emergency medical training. Discuss and agree on a travel route. Select a leader, and review each member's capabilities and what equipment and supplies are necessary.

**Equipment Preparation.** Material preparation involves acquiring proper equipment (both routine and for emergencies and unplanned events), testing and organizing equipment, and having backup equipment. Carry sufficient equipment to survive for extended periods if unforeseen changes occur and under the worst possible environmental conditions for the season. This includes ensuring that preventive maintenance has been performed for equipment and that equipment is in good working condition.

Review each person's responsibility for equipment. Make sure that equipment and weight are properly distributed, taking into account abilities. Equipment should be appropriate for the activity and the environment (e.g., waterproof, ruggedized). Selecting battery-powered items that require the same size and type of batteries minimizes the number of items to be carried. Maintain an equipment checklist. If using specialized equipment, know its proper use and maintenance. Courses are available through retail outlets, clubs, and wilderness organizations to prepare and train participants for most outdoor activities. The minimum equipment list should include, but is not limited to, the following:

- Emergency equipment
  - Emergency blankets
  - Emergency bag
  - First-aid kit
  - Flashlight
  - Maps, compass, navigation equipment
  - Communication and emergency communication equipment
  - Footwear
  - Skin and eye protection
  - Backpack
  - Water, extra food
  - Extra clothing
  - Timepiece
- Equipment for survival or unplanned conditions may include the following:
  - Fire starter, matches
  - Shelter (e.g., emergency tube tent)
  - Survival whistle
  - Water
  - Water disinfection system
  - Avalanche beacon
  - Personal locator beacon, rescue laser, ground insulation

### Problem Anticipation

Even with good planning and preparation, problems occur. For most activities and trips, major problems can be anticipated. A good exercise before undertaking any activity (and during the activity at various times) is to think through the five most likely problems and the two rare but significant problems, to both plan and prepare for them. Standard problem anticipation approaches include bringing adequate protection from environmental and recreational hazards, having all the appropriate immunizations, using safe drinking and food hygiene practices, and ensuring that everyone has a working knowledge of first aid.

### Physical Disabilities

For persons with disabilities, it may be a great challenge to spend time in the wilderness (see also Chapter 94). In federally designated wilderness areas, Congress reaffirms in the Americans with Disabilities Act that nothing in the Wilderness Act prohibits use of a wheelchair by a person whose disability requires its use. As of 2009, approximately 20% of U.S. adults 18 years of age and older have a disability.[26] The challenge for the future will be ensuring that persons with disabilities have the same opportunity to participate in wilderness activities and programs as do persons without disabilities, without necessarily making wilderness access easier.[162] The principles of injury prevention apply to people with disabilities who participate in wilderness activities. Their preparation, planning, and anticipation of problems must take into account the specific disability and unique physical and mental challenges of that disability.

# INDIVIDUAL FACTORS AND INJURY PREVENTION

## SPECIFIC TOOLS FOR PLANNING AND PREPARATION IN THE WILDERNESS

### Maps and Orienteering

People should have the ability to tell where they are and where they are going. A single wrong turn can have disastrous consequences. Maps are useful tools for planning, and the GPS gives an accurate determination of the actual location. Traditional two-dimensional maps, such as road maps, identify a sampling of features on the ground, with symbols to represent physical objects. Topographic maps, also known as "topo" maps or contour maps, use contour lines or shaded relief to represent the shape of land surface. Contour lines connect contiguous points at the same altitude. Topo maps usually depict significant bodies of water, forest cover, or other features and are prepared using interpretation of aerial photography or remote sensing techniques. The U.S. Geological Survey (USGS) (www.USGS.gov) produces several series of national topographic maps, the largest and best known of which is the 7.5-minute, 1:24,000 scale, quadrangle nonmetric scale map; each map covers an area of 0.125 degrees latitude by 0.125 degrees longitude spaced 7.5 minutes apart (an area of about 49 to 64 square miles). Digital PDF versions of the U.S. topographic maps are now available for free download from the USGS store (www.store.usgs.gov) and allow wilderness explorers to view layers, extract and analyze additional geographic information via three-dimensional digital representation of surface terrain or topography, and create custom maps for excursions.

Location-based services allow GPS-enabled mobile devices (such as cell phones, personal digital assistants, and laptop computers) to display a location in relation to fixed or mobile assets (such as a gas station or police car) or to relay a position back to a central server for display or other processing. This is a potentially useful application within national parks. Graphic Information Systems (such as the digital "US Topo" quadrangle topographic maps available from the USGS since 2009) have led to an explosion of Internet mapping services, such as Google Maps and MapQuest, which allow access to aerial satellite imagery useful in the planning and preparation stage of wilderness travel. Whether a two-dimensional planimetric, topographic, or graphic display map is used for wilderness travel, it is essential that the user carry the map and know how to read it. In addition, ingress points, checkpoints, and egress points should be established before traveling.

### Global Positioning System Devices

The GPS is a U.S. space-based global navigation satellite system that provides continuous positioning, navigation, and timing services to users from anywhere on Earth. Use of a GPS device requires an unobstructed view of four or more GPS satellites, each of which broadcasts signals that GPS receivers use to provide absolute locations in three dimensions (latitude, longitude, and altitude), velocity of movement and orientation, and precise time. GPS receivers have become commonplace for navigation on the ground, in the air, and on water. Modern GPS receivers often overlap graphic displays of terrain or nautical features to further assist navigation. A GPS unit can assist SAR organizations with recovery of lost or stranded travelers. Because a line of sight is required for GPS receivers to function, their use may be limited in dense forests or jungles or below steep cliffs or rock overhangs. In addition, they are sensitive to extremes of temperature, moisture or humidity, and mishandling. They depend on battery power, so users should carry spare batteries or a solar battery charger and consider a basic backup GPS unit in the event the primary unit malfunctions. The unit should not be used as a total replacement for traditional maps or compasses for navigation or positioning or use of natural references, such as sun position, wind, or topography.

### Communication Devices

Traditionally, emergency communications from wilderness settings have been limited to signaling with devices such as a mirror or other reflector, whistle, fire, smoke, or flare (Figure 29-2). Newer laser devices encased in waterproof housings have been found to be very effective in identifying people during aerial searches, particularly at night. Commercially available "rescue laser flares" are small, lightweight, and rugged handheld laser devices that project a wide line, rather than the pinpoint light normally associated with a laser. They allow the user to sweep across an area with a dispersed red or green light beam that can be seen from up to 30 miles away (3 miles in daylight). The device is powered by lithium batteries that when used continuously will last for up to 72 hours, depending on the model.[118] The international distress signal (SOS), which can be used with many signaling devices, consists of three short signals, followed by three long signals, and then three short signals, repeated at intervals. Signals may communicate the general location of an injured person, but to provide more detailed information about injuries or illness, some form of vocal or written communication is needed. Vocal communication allows rescuers to obtain an accurate, on-site victim report with a description of an injury, the mechanism of injury, and the specific location of the victim. Ongoing communications with a reporting party can help guide rescuers to the victim and allow them to provide advice about first aid before their arrival.

Cell phone technology is useful only when travel is within an area with cell phone relay stations, making its use limited in the wilderness. Wireless access for cell phone use is becoming more common inside U.S. national parks but is limited to the more developed areas. Signals may be weak or unreliable. Using cell phones in national parks and other wilderness settings is controversial. Conservationists argue that parks run the risk of becoming too civilized. Critics argue that the presence of cell phone towers in wilderness areas and national parks creates a false sense of security. Despite the controversies, cell phones are being used increasingly within national parks to notify authorities of mountaineering and recreational accidents. If a cell phone is used within a park, it is best to program in the direct number for park dispatch, because dialing 9-1-1 will often reach a county sheriff, who must then relay the call. Once dispatch is reached, state your location and call-back number early in the conversation in case of connection failure. A member of a party may need to hike to the nearest trailhead to obtain cell phone service. Completion of a standard incident report form before leaving the scene will allow the caller to provide critical information about the nature of the incident, location, and initial care provided. Most cell phones are equipped with GPS (E-9-1-1) technology, which if turned on can be useful for providing the location of an injured person. As a result of a mountaineering accident with three fatalities on Mt. Hood in 2007, the Oregon state legislature proposed bills that mandate electronic signaling devices (personal locator beacons, mountain locator beacon, GPS receiver with cell phone/two-way radio) for all climbs above 3048 m (10,000 feet) on Mt. Hood. Although local rescue personnel and climbers are reported to encourage the use of such equipment, they do not believe its use should be required.[134] One survey of climbers found that 14% of them always carry a cell phone. Twenty-one percent of climbers who reported carrying a cell phone indicated that they had used it to report an accident.[7] If a cell phone or GPS unit is carried into the wilderness, consider using a waterproof box or case to prevent damage from crushing, dropping, or water, along with a backup battery. The unit should be carried in a warm pocket because subfreezing temperatures can drain batteries or prevent the unit from operating. If a cell phone is not carried, an alternative safety device is a satellite GPS messenger, such as SPOT or SPOT2 Gen 3 (www.findmespot.com).


FIGURE 29-2 **A,** Smoke signal. **B,** Handheld flare. **C,** Marking location with flare. **D,** Rocket flare. **E,** The Rescue Laser Flare Magnum. (**A** to **D** *courtesy Eunice Singletary;* **E** *copyright Greatland Laser, Anchorage, Alaska.)*

In most cases, portable radios serve as a good choice for communication between party members. When carrying a portable radio, determine which frequencies are allowed for personal use and which frequencies are monitored in your area.

Radiofrequency interference from transmitting cell phones (code division multiple access) or two-way radios can cause interference with some avalanche beacons, and thus they and other devices such as digital cameras, iPods, MP3 players, SPOT emergency locators, and even battery-heated gloves should be turned off while traveling in avalanche terrain. A common intermediate (processing) frequency for cell phones or digital cameras is 455 kHz, which is very close to the 457 kHz radio frequency of avalanche beacons. In addition, false signals may be produced in some beacons from cell phones cycling their transmission to "handshake" with their cell. To ensure there is no radio frequency interference, electronic equipment, including cell phones, digital cameras, and headlamps, should be turned off while doing an avalanche transceiver search with any brand of digital or analog transceiver.[159] If you are using a transceiver in a search operation and need your cell phone or headlamp turned on, most interference can be eliminated by holding the search transceiver a full arm's length (at least 2 feet or 60 cm) from your body.[74] Satellite phones connect with orbiting satellites and have the potential to be used worldwide. The size and weight of early "sat phones" once limited their use in the wilderness, but current versions are as small as a "smartphone" or mobile personal digital assistant (Figure 29-3). The cost of newer satellite phones is between $600 and $1700 plus airtime fees, prohibiting their use by many wilderness adventurers. Less expensive rental plans are an option. In addition, most satellite phones will only work with a corresponding network and cannot be used if the network is switched.

Depending on the type of satellite phone service used, there may be a delay in transmission of voice or data. Geostationary satellite phone systems rely on a network of satellites that are fixed above the equator; these phones depend on line of sight for service. Low-Earth-Orbit systems rely on a network of satellites in orbit less than 2000 km (1243 miles) above the earth's surface, and depend less on line of sight. Two such systems in the United States are Globalstar (http://www.GlobalstarUSA.com) and Iridium (http://www.Iridium.com). Globalstar does not provide coverage of the polar caps because of the inclination of their orbiting satellites; Iridium claims worldwide coverage. Satellite phones are banned in a number of countries because their use bypasses local telecommunication systems, hindering efforts at censorship. In disaster situations, large spikes in call volumes may lead to cascading failures of a network, similar to cell phone network failures noted in past disasters. The choice of which phone to purchase depends on where one plans to use it.[145]

## Protective Gear

Engineering accomplishments have improved protective equipment for wilderness travel and recreational activities.


**FIGURE 29-3** Compact satellite telephones.

**Clothing.** Waterproof and breathable fabrics, sealed seams, lightweight high-loft insulation, quick-dry material, and material with sun-blocking properties have been at the forefront of outdoor clothing offerings. Sometimes referred to as technical clothing, these fabrics have temperature regulation properties embedded in the yarns and retained with washing. Microfiber materials are used as an alternative to down for insulation in sleeping bags and clothing, because they retain heat when damp or wet. Microfiber material wicks moisture and sweat away from the body and keeps wearers drier and warmer in cold weather and cooler in hot weather. A combination of yarn selection, fabric construction, and finishes is used to create sun-blocking protection, which is often rated with the Ultraviolet Protection Factor (UPF) system.[6] A rating of 15 earns a product a rating of "good"; a rating of 30, "very good"; and a rating of 40 or 50+, "excellent."

**Foot and Hand Wear.** Ideal footwear in the wilderness accommodates environmental factors (extremes of heat, cold, terrain), user comfort, and protection needs. Proper fit and hygiene are crucial for comfort and to prevent "hot spots," blisters, or toenail problems. The purposes of footwear are protection, cushioning, support, and grip. Selecting, fitting, breaking in, and caring for footwear help it last a long time and maximize comfort. It is important to properly size footwear, including accommodating for swelling that may occur during prolonged activities. Each foot should be properly fitted. When sizing footwear, it is important to consider not only the length and width, but the ball-to-heel (arch) length. For hiking, wear shoes that extend above the ankle to reduce the likelihood of an ankle sprain. Footwear should fit comfortably with moderate tension on the laces, so that they can be tightened or loosened as needed. To avoid blister formation, seams should not rub against any part of the foot. The tongue of the footwear should be aligned and laced properly. Otherwise, the tongue can slide into an incorrect position and cause blisters. Ankles should be comfortably supported by stiff heel counters or heel cups and should not slip with toe flexion, to avoid causing blisters because of repetitive rubbing. With the foot on the ground, there should be no more than 6 to 12 mm (0.2 to 0.5 inches) of heel lift.

Thermal insulation is the most important factor in footwear designed for protecting feet from cold and is influenced greatly by moisture control. Although foot comfort is affected by the interaction of sock, sole, and shoe, the choice of footwear is influenced by factors such as intended activity, fit, shoe weight, insulation, vapor barrier, waterproofing, protection, flexibility, and durability.

Mechanical injuries to the toes can be avoided with shoes or boots with integrated steel caps and soles. Sole design can prevent slippage; the design should be based on the intended use. Materials with good friction at moderate temperatures tend to become hard with cold temperatures and lose their grip. On wet ice, virtually all shoe materials become slippery. Insulation is an important factor with low ambient temperatures. Adding heat sources such as disposable chemical foot and toe warmers, warm air or water circulation, or battery powered electrical heaters can reduce heat loss. Additional heat sources generally reduce volume inside the shoe or boot, potentially compromising fit and maneuverability, and also add weight. A 100-g (3.5 oz) increase in the weight of footwear has been shown to increase oxygen consumption by 0.7% to 1%, the equivalent of adding five times that weight carried on the torso.[76,77,88]

Insulating qualities of footwear largely depend on air being trapped inside the fabric of the shoe and between the sole of the foot and the shoe, and can be increased by the addition of socks, so long as the footwear is large enough to accommodate the socks without becoming too tight.[83] Socks play a large role in moisture management by absorbing sweat. Sweat rates vary widely in the foot, with lower rates in cold weather of 3 g/hr at rest. Newer synthetic materials, such as polypropylene, Capilene, and Thermax, wick moisture quickly, making them good choices for an inner layer. Pile or fleece socks do not wick moisture very well. Wool offers many advantages. It is warm in winter, cool in summer, absorbs and wicks sweat, and keeps the feet warm when wet. Furthermore, during long trips, it rinses well in cold stream water, can be worn for days at a time without wear, and does not mat down like cotton socks with terry loop liners.

Impermeable or semipermeable footwear materials prevent external moisture from entering footwear and wetting insulation. Moisture from sweat inside a shoe reduces insulation qualities and increases heat loss by 5%. Walking and the subsequent pumping effect of moving air in footwear removes moisture and in ordinary shoes removes about 40% of humidity.[83] Footwear requires drying to retain insulation and protect feet from the cold. Moist socks and insoles should be changed, and shoes with removable liners should have the liners removed. Placing footwear in a warm, well-ventilated location will assist with drying.

Hand protection from cold requires gloves or mittens with insulation, a moisture barrier, and adequate space for air trapping. Mittens allow more air trapping and heat retention than do gloves, but with a tradeoff for dexterity. Mittens with glove liners or finger inserts allow improved dexterity without loss of insulation and may include pockets for placement of disposable chemical heaters. For other wilderness activities where gloves are needed but dexterity is critical (such as fly-fishing or climbing), fingerless gloves may be appropriate.

**Helmets.** Helmets are used for many wilderness and remote activities, including mountain biking, skiing and snowboarding, rafting, kayaking, and climbing. Most helmets are designed for specific activities. The use of helmets by recreational bicyclists dates back to the mid-1970s. Early helmets had polycarbonate hard shells with an expanded polystyrene liner and little or no ventilation. Helmets for children were not introduced until 1984. Since the 1990s, bicycle helmet design has evolved, with incorporation of vents—critical for cooling in high-exertion riding—and cradles to fit the head more precisely. Bicycle helmets today come in either a hard shell design or a soft/micro shell. Helmets for racers often have a streamlined, elongated back (Figure 29-4). The back of the head is covered less with bicycle helmets than with other helmets. For this reason, bicycle helmets are not appropriate for skating, skateboarding, and other activities in which falls backward are more common.

The Snell Memorial Foundation[138] created the first standards for helmet design in 1985. Today, the U.S. Consumer Product Safety Commission (CPSC)[148] requires standards for helmets sold in the United States. CPSC standards have been criticized as being less stringent than current Snell B95 standards and as having weakened over time.[154] The trend in bicycle helmet design today is to make them thinner and with larger vents, which may compromise the ability of certain helmets to protect against head injury. In addition, there is concern that the liners of many bicycle helmets are too rigid to properly cushion and protect the head.[33]

One of the most important elements of helmet selection for any activity is proper fit. One study showed that 96% of helmets were improperly fitted.[111] Fit can be adjusted on helmets using cushioned pads, or by use of a band inside the helmet that may be adjusted with a tightening wheel or plastic clips. The chinstrap can be adjusted to help with fit, and it should be kept fastened under the chin to help keep the helmet in place during falls. Should a helmet be damaged by a fall, or should the helmet exceed 5 years of age (or less according to the manufacturer), the Snell Memorial Foundation recommends replacement.[3] Helmets are not without criticism. Laws mandating use for bicyclists have been paradoxically blamed for a decrease in use. Helmets have been blamed for an increase in accidents, because some feel they restrict peripheral vision and decrease hearing. It is speculated that use of a helmet encourages risky behavior.

**FIGURE 29-4** Bicycle helmets in use. *(Courtesy Eunice Singletary.)*

***Goggles.*** Goggles provide a thermal barrier and help protect eyes from wind, snow, rain, dryness, and ultraviolet (UV) or bright light. Sunglasses provide some protection from the elements and UV light, especially when they "wrap" the face or have plastic or leather side guards. Goggles should fit well on the wearer's face. The foam on the frame should fit uniformly and snugly around the entire goggle, because gaps increase airflow and contribute to drying of the eyes. Depending on the activity of the wearer, other desirable features may include helmet compatibility, polychromatic or interchangeable lenses for varying light conditions and to improve contrast, and prescription lens inserts. Fogging lenses are a common problem. Most goggles are vented to help prevent fogging, and many have antifog coatings. Goggles with a spherical double lens provide high-quality optics and fog-free vision.

In general, ski goggle design has changed little over the years. Zeal Optics has designed a goggle (Transcend GPS) with an integrated display system that shows GPS, speed, altitude, vertical odometer, time, and temperature, all of which can be viewed on the spherical polarized lens by scrolling with buttons on the side of the goggle. Although more expensive than traditional goggles, this design may have applications for backcountry snow-sports enthusiasts.

**Body Armor.** Once popular with football players and dirt bike enthusiasts, body armor and padded clothing are promoted for water sports, snow sports, cycling, and other outdoor sports. Snowboard gloves or mittens with integrated wrist guards are purported to decrease the risk for hand, wrist, and forearm injuries in snowboarders, but may increase the risk for elbow, upper arm, and shoulder injuries.[58,128] Knee and elbow pads, padded pants or shorts, spine and back protectors, and upper body protectors are promoted to offer protection from injury, but with little evidence of effectiveness outside of football.[96] Such gear is often articulated, thermal-formed, or soft foam–padded clothing or wraps designed to be lightweight and flexible, usually fitting underneath underwear or outerwear. Some gear includes molded plastic plating or shoulder cups.

**Mouth Guards.** The efficacy of mouth guards in preventing or reducing dental trauma is debated. There are studies that show significantly lower rates of dental injuries and soft tissue injuries among users of mouth guards in football and basketball than among nonusers.[44,84] Other studies have found no significant difference in oral, head, or neck injuries between users and nonusers of mouth guards.[48] Although the American Dental Association reports that mouth guards can reduce the severity and incidence of oral injuries, they also recommend further research on currently available models.[49]

**Avalanche-Specific Protective Gear.** According to the Colorado Avalanche Information Center, there has been an annual average of 28 deaths in the United States due to avalanches over the 10 winters between 2003-2004 and 2013-2014, with 35 fatalities in the 2013-2014 season. Avalanche fatalities most commonly involve backcountry snowmobilers, skiers, and snowboarders, but ice climbers, snowshoers, and hikers are also occasionally killed (Figure 29-5). Fatalities from avalanches are most commonly due to asphyxiation, followed by trauma with asphyxiation, or trauma alone.[31]

The key to reducing the risk for being caught in or killed by an avalanche is not safety equipment, but rather education and training, along with avalanche awareness and smart decision making. The skills acquired require repeated practice. Traveling in avalanche country with a trusted and trained partner is a key element of avalanche safety. Additional tools that may help one avoid or survive an avalanche include a digital or analog transceiver; a lightweight shovel for digging test pits or for recovering a buried victim; a collapsible probe to pinpoint the exact location of a buried victim following a transceiver search; use of RECCO reflectors in clothing and equipment; and wearing and deploying an avalanche air bag.[135] Snowshoers and snowmobilers tend to underestimate avalanche danger when traveling in the backcountry.[136]


**FIGURE 29-5** **A,** Wet, loose backcountry slide. **B,** Backcountry slide with scattered gear. **C,** Inspecting a large slab. **D,** Snowmobiler buried by avalanche. *(**A** courtesy Eric Knoff; **B** and **D** courtesy Gallatin National Forest Avalanche Center; **C** courtesy Tom Leonard, Yellowstone Club Ski Patrol.)*

The RECCO Rescue System (http://RECCO.com) was introduced in 1983 and is used by over 600 rescue organizations worldwide, including more than 100 ski areas, rescue organizations, and helicopter companies in North America. It consists of a RECCO detector used by search organizers and a reflector permanently integrated into the helmet, boots, or clothing of the wearer. The system uses harmonic radar to pinpoint a victim's exact location. The reflector has advantages of requiring no batteries or training, but it is not designed for self-rescue or as a replacement for traditional avalanche transceivers. It is an additional tool for SAR that complements transceivers when worn in an area where the RECCO detector is readily available.

Avalanche air bags are a more recent technological advance designed to improve the chance of survival in an avalanche by reducing the degree of burial and thus the risk of death. The AvaLung is a 9-oz sling-type of apparatus worn over the shoulder that prolongs the time a victim can breathe while trapped under snow. Two other devices use one or two inflatable air bags holding up to 45 L of gas to allow a victim caught in an avalanche to float to the surface, avoiding burial and enhancing visibility for searchers. The ABS system deploys two air bags from a backpack when a handle is pulled. Nitrogen canisters that inflate the bags are replaceable, allowing the system to be reused. Snowpulse SA markets an air bag in a backpack that when released, envelops the head, providing similar flotation along with head protection. Snowpulse cartridges for air bag inflation are refillable (see Chapter 4). A recent retrospective analysis of avalanche incidents between 1994 and 2013 involving wearers of avalanche bags found an air bag noninflation rate of 20%, most commonly due to nondeployment by the user, and a risk for critical burial with noninflated air bags of 47% compared with 20% for inflated bags. The adjusted absolute mortality reduction for inflated airbags was minus 11% (from 22% to 11%; 95% CI minus 4 to minus 18 points) and adjusted risk ratio of 0.51, thus proving the value of avalanche bags.[57]

## Training and Education

William Haddon's strategy for reducing the magnitude and burden of injuries involves the preevent phase, the event phase, and the postevent phase.[144] The preevent phase focuses on prevention. Education and training in this phase includes courses that enhance the ability to recognize and avoid dangers in the environment and courses that teach basic skills and techniques necessary to safely perform activities in the wilderness. Such courses include topics such as avalanche awareness and safety, rock and ice climbing, rope use, caving, mountaineering, map reading, orienteering, and kayaking. Courses are available through clubs, colleges, and specialty organizations that represent these activities. The Outdoor Wilderness Leadership School, the National Outdoor Leadership School (NOLS), and Outward Bound are examples of organizations that offer instruction in many different wilderness activities, as well as courses for instructor development.

Education and training for wilderness medical care or SAR techniques are a component of the third (postevent) phase of Haddon's injury matrix. Salvaging people and property is the focus of this phase. Initial (field) emergency care SAR operations, extrication, and transportation to advanced medical care for victims of wilderness injuries all fall into this phase. Different levels of providers may provide emergency care in the wilderness. As the popularity of wilderness excursions and the field of wilderness medicine have grown, so have the number and variety of courses in wilderness emergency care.

Although there is no national standardized curriculum or certification for wilderness first aid, courses are available through organizations such as the American Red Cross, Wilderness Medical Associates, and Wilderness Medical Institute. These courses are generally 16 hours in duration.[157] Some organizations offer a 36-hour advanced wilderness first-aid course ideal for wilderness enthusiasts without medical backgrounds. Guides, SAR team members, and outdoor educators without medical

FIGURE 29-6 Children in wilderness activities are typically supervised by excursion guides, parents, or both. *(Courtesy Eric Becker.)*

backgrounds complete courses with more comprehensive curricula and practical training, such as a 70-hour wilderness first-responder course or a wilderness emergency medical technician (EMT) course. Unlike standard first-responder and EMT courses, these programs include content that prepares an individual to deliver emergency medical care in harsh environments, when evacuation times may be lengthy, and when equipment may need to be improvised. Wilderness EMT courses are designed for EMT personnel working in SAR, on expeditions, in disaster situations, or in remote settings. For medical professionals with Advanced Life Support certification, a 36-hour Wilderness Advanced Life Support course is offered by various organizations.

**Supervision and Buddy Systems.** The number of children and adolescents exploring backcountry wilderness areas has steadily increased; these young people account for 25% of backpackers and wilderness campers in the United States.[106] Children and adolescents typically enter wilderness areas either in a family group or through a sponsored group youth expedition or outing (Figure 29-6). Groups are accompanied and supervised by adults trained as instructors in various recreational disciplines or in wilderness emergency care. There are few studies looking at wilderness injuries or fatalities specifically in children or adolescents. A retrospective study of visitor fatalities at all NPS units for 2003 and 2004 found that of 356 fatalities, 13% (46) occurred in children and adolescents 19 years of age or younger.[66] A second study found that children and adolescents account for 21.2% of all NPS visitors nationwide requiring SAR assistance.[62] The most common activities reported at the time of request for SAR were hiking, mountaineering, and boating. A study in Washington State identified 40 recreational wilderness fatalities among children and adolescents between 12 months and 19 years, with hiking and swimming the most common activities preceding death. Four out of five pediatric fatalities in this study involved children drowning after falling out of boats or into water while playing at a campsite.[108] Supervision of children or lack thereof when wilderness fatalities or injuries occur is rarely mentioned in these retrospective studies, although a lack of personal flotation devices was noted for nonscuba drowning fatalities in the latter study. For supervised expeditions, one study found that only 13% of all 1646 reported health problems were related to trauma,[36] whereas a study by Sadnicka[129] found that 10% of medical problems among 2915 travelers between 15 and 18 years of age in 250 expeditions to multiple countries were the result of trauma. Organizations such as NOLS strive for safety in outdoor activities. Through their risk management program, NOLS decreased the number of injuries to a rate of 1.18 per 1000 program days for the years 2002 to 2005. NOLS attributes this reduction to prevention strategies that include having reduced (11-kg [25-lb]) backpack weights, traveling on carefully planned course routes, avoiding overly demanding terrain early in a trip, emphasizing warm-up and stretching before hiking and strenuous activities, and deliberately teaching students how to hike on rugged and uneven terrain.[99]

Just as risk management programs and supervision of participants in organized group wilderness recreation activities may potentially decrease the incidence of injury, use of a buddy system is desirable for individual activities. People who engage in climbing, backcountry skiing, snowmobiling, and other solo activities in the wilderness are encouraged to do these activities with a buddy (Figures 29-7 and 29-8). The two buddies should know each other; if they do not, the two should take part in a half-day outing at a lower level of activity to become acquainted with their skills, styles, and physical condition. Wilderness partners need to be aware of each other's previous experience for the planned activity and the level of training in pertinent topics such as avalanche fundamentals, companion rescue, or wilderness emergency medical care, and they should both know what medical supplies will be carried. Additional points that should be addressed include the following:

- What gear, specialty equipment, personal clothing, food, water, communication devices, and safety equipment are being carried?

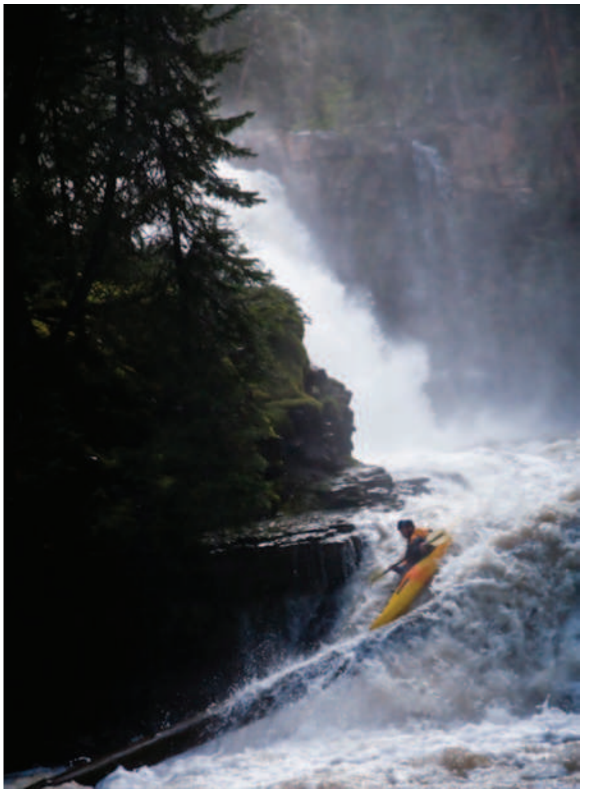

FIGURE 29-7 Lone kayaker surfing the falls. Having a buddy or spotter to accompany individuals in solo wilderness activities is advisable. *(Courtesy Haley Buffman.)*

FIGURE 29-8 This wilderness trek would be less risky with a buddy. *(Courtesy Haley Buffman.)*

- Maps and route of travel. What are the potential hazards and current condition of the planned route? What is the weather forecast? What are the contingency plans in case a route or access conditions have deteriorated? What will be the turn-around or pull-out time, and how will you decide whether to continue on or turn back?
- In the event of a serious event or injury, what is the emergency plan, and what resources are available?

Emergency contact information and pertinent medical information should be shared with each other and with a contact person who will not be traveling. Once wilderness travel plans have been made, it is best not to change them at the last minute. Likewise, it is a good idea not to change buddies or to add additional travel partners in haste.

### Problem Anticipation: Acute Illness and Injury

Even with the best preparation and planning, acute illnesses and injuries occur. When primary prevention fails, one needs to be prepared to address illnesses and injuries and minimize their impact. This is accomplished through medical clearance, vaccinations, and first-aid training and by ensuring that one has the proper first-aid supplies, medical supplies, and medications. Because supplies may be limited as a result of availability or what one can carry in the wilderness, one must be ready to improvise.

**First-Aid Training.** Every adult participating in wilderness activities at a minimum should have training in cardiopulmonary resuscitation and have completed a basic first-aid course that covers common illnesses and injuries. Additional training beyond first aid may be needed, depending on the activity, distance to more definitive medical care, and underlying medical conditions of participants. For example, if one is participating in a remote area with delayed time to further medical care, at least one person needs to have completed a formal wilderness first-aid training program with emphasis on remote conditions and prolonged care.

**Medical Clearance.** Before participating in any athletic activity, it is prudent to obtain medical clearance. This is especially important for the following:

- Activities in remote areas
- High-risk activities and extreme sports
- Person with chronic illness and/or physical limitations

The purpose of medical clearance is to determine appropriate activities, personal limits, and go/no-go decisions. For persons with chronic medical conditions, the goal may be to optimize these conditions. Examples include a diabetic who needs to alter the insulin regimen because of projected increased physical activity and an altered meal schedule, or a patient taking a medication that increases photosensitivity having to adapt to a sunny environment.

**Vaccinations and Prophylaxis.** Tetanus vaccination should be current. If the intended activity requires travel to remote areas or areas subject to endemic diseases, individuals should consult with a health care provider regarding the need for vaccination and/or drugs for prophylaxis. An example is the need for prophylaxis if hiking or camping in an area in which malaria is a risk.

**First-Aid or Emergency Medical Supplies.** For most activities, a first-aid kit should be available. For brief activities with low injury risk that do not require an overnight stay or travel to remote areas, a basic first-aid kit is appropriate.

The contents of commercially available first-aid kits vary greatly. In general, a kit should contain the items listed in Table 29-1.[156] These recommendations are expanded for more remote locations. For certain extreme sports, expeditions, or very remote locations, extrication equipment may be necessary, as well as optional tools, such as a small-pulse oximeter and point-of-care sodium and glucose test kits.

**Medications.** Prescription medications may need to be considered for wilderness activities. At a minimum, bring enough prescription medications for the entire trip and include an additional supply to cover unforeseen trip extensions. For a single-day trip, a rule of thumb is enough medication for 2 days; for prolonged trips or remote environments, enough for 1 week extra should be taken. Additional medications to consider are the following:

- Antibiotics
- Epinephrine autoinjector
- Bronchodilator metered-dose inhalers
- Intravenous fluids
- Oxygen
- Resuscitation medications

**TABLE 29-1** Wilderness First-Aid Kit

| Item | Quantity |
|---|---|
| **Dressings and Wound Care** | |
| Adhesive bandage (Band-Aid) | 12 |
| Adhesive tape (2-inch roll) | 2 |
| Conforming gauze bandage (Kling 3-inch roll) | 2 |
| Elastic bandage (Ace 3-inch wrap) | 1 |
| Moleskin (I5.5-square-inch sheets) | 2 |
| Spenco 2nd Skin (3-inch × 4-inch pads) | 4 |
| Sterile gauze compresses (4 inches × 4 inches) | 6 |
| **Equipment** | |
| Scissors | 1 |
| Thermometer | 1 |
| Tweezers | 1 |
| **Oral Over-the-Counter Preparations** | |
| Antacid (chewable tablet) | 6 |
| Antihistamine (diphenhydramine 50 mg) | 6 |
| Bismuth subsalicylate (Pepto-Bismol chewable) | 6 |
| Ibuprofen (200-mg tablets) | 6 |
| **Topical Over-the-Counter Preparations** | |
| Alcohol swabs (for cleaning equipment) | 10 |
| Antiseptic ointment (Neosporin 0.9-g packets) | 6 |
| Hydrocortisone 1% cream (30-g tube) | 1 |
| Povidone-iodine solution (individual swabs) | 8 |
| Tincture of benzoin (30-mL bottle) | 1 |

***Improvisation in Treatment.*** In many instances, drugs and supplies are inadequate. One may need to rely on improvisation to address these situations. Planned improvisation refers to situations where a specific piece of emergency equipment cannot be brought but there is a predetermined plan to improvise the device. The classic example is extrication equipment for a patient whose size and weight are prohibitive. Therefore, one must preplan how to convert existing equipment, such as backpack frames, should the need arise. Unplanned improvisation is exemplified by a major injury leading to uncontrolled bleeding. A tourniquet may be required but might not be standard equipment. In such a case, form a tourniquet from nontraditional material, such as a belt.

**Injury Prevention for the Genitourinary Tract.** To prevent genitourinary infections during outings, individuals should maintain attention to genital hygiene and hydration. Infections and irritation of the genitourinary tract are more common in women than in men because the female urethra is shorter, leaving the bladder more vulnerable to colonization by bacteria. The risk for infection can be exacerbated during wilderness activity because of infrequent urination and urethral trauma from vigorous activity or bruising from a bike seat, saddle, or climbing harness. One should provide adequate padding, allow for adequate bathroom breaks, and minimize urethral trauma.

To avoid vaginitis, women should keep themselves cool and dry by wearing loose-fitting clothing that maximizes air circulation and minimizes the optimal conditions for bacterial and fungal growth. Avoid nylon undergarments, because they retain humidity. Cotton undergarments or underwear made from a material such as polyester that wicks moisture and is fast drying is ideal.

Women may need to consider sanitary protection for menstruation. If menstruating while in the wilderness, women should change tampons or sanitary napkins just as frequently as at home to avoid infection. Women who handle tampons should make sure that hands are scrupulously clean before insertion. For environmental reasons, tampons with cardboard rather than plastic applicators should be used if wilderness disposal is a possibility.

**Injury Prevention for the Feet.** Proper footwear, including careful selection of shoes and socks, helps prevent problems such as blisters. The soles should be protected with layers of cushioning thick enough to prevent bruising, but pliable enough to allow natural heel-to-toe flexion. Thick soles insulate against cold and heat. The tread provides grip. Support comes from a fit that stops the foot from slipping inside the shoe, but that is not so tight that it prevents the foot from expanding when it swells. Check socks for loose threads, knots, or harsh stitching that might cause blisters or sore spots. Flat seams at the toes are important. Bulky seams rub and cause blisters. Consider wearing one pair of fairly heavy socks (rag wool) and one pair of light liner socks next to the skin. With one sock, the boot and the outer sock tend to move as a unit. They rub against the heel and the tops of the toes at the metatarsal heads. A lightweight liner sock tends to cling to the foot. As the boot moves, the socks rub against each other, not against foot skin. Some boots feature sock liners or booties made from vapor-permeable membranes, such as Gore-Tex and Sympatex, hung between the lining and outer aspect of the boot. These may be appealing initially because of the ability to prevent leaks, but over time they may leak. Their lack of breathability means that water vapor cannot penetrate the barrier, resulting in hot, sweaty feet.

In addition to appropriate footwear and socks, one must practice proper foot hygiene. Keep toenails short and cut square. Keep feet dry to avoid skin softening. Immediately stop walking and attend to the first sign of a sore or "hot spot" to prevent further injury. Carry supplies, such as moleskin, tape, or Molefoam, to allow protection of any reddened areas. The covering should extend beyond any redness.

If primary prevention fails to prevent blister formation, try to prevent rupture and infection. Relieve external pressure by applying a doughnut-shaped piece of Molefoam. A blister should not be unroofed unless absolutely necessary. If this is required, wash the area with soap and water, and insert a decontaminated needle ("sterilized" by a flame or with rubbing alcohol) into the edge of the blister. Gently press out the fluid. Apply a sterile dressing. If the blister has already broken, cleanse and cover the area. Topical antiseptic ointment may be beneficial.

## THE PHYSICAL ENVIRONMENT AND INJURY PREVENTION

The event phase of injury begins when physical forces exert themselves unfavorably on people or property. Prevention of injury at this stage involves intervention to prevent the harmful effects when excessive mechanical, thermal, chemical, electrical, or ionizing radiation energy is contacted. Harmful effects of excessive energy may occur acutely, as with thermal burns, or as a result of prolonged exposure with extended wilderness stays.

### ULTRAVIOLET EXPOSURE

UV light is the main cause for most skin cancers and cataracts. Anyone who has ever experienced a severe sunburn or UV keratitis is aware of the significant, even disabling pain associated with acute burns to skin and corneas from UV light. Even on a cloudy day, UV light can cause a serious burn. In the wilderness setting, injury from UV light is largely preventable. Photoprotection begins with behavioral changes. Limiting exposure to UV light is an essential prophylactic element and begins with avoiding exposure at peak times of the day (10 AM to 4 PM) and with covering the skin and eyes with UV-blocking clothing and sunglasses. The photoprotective properties of clothing depend on its thickness, weight, and color, with darker fabrics having greater photoblocking ability. Lightweight fabrics treated to enhance UV protection are especially useful in the wilderness setting. Hats

**FIGURE 29-9** Hat with extensions to shade the neck offer increased protection from sunburn. *(Courtesy Eunice Singletary.)*

provide photoprotection for the scalp, face, and neck; the amount of skin covered varies with the style of hat (Figure 29-9).

Sunglasses protect the eyes from the discomfort of bright lights, but not all sunglasses provide UV protection. In the United States, there is an American National Standards Institute (ANSI) standard for sunglasses that includes impact resistance and UV protection.[4] ANSI Z80.3 2010 standards require that a lens should have a UV-B (280 to 315 nm) transmittance of no more than 1% and a UV-A (315 to 380 nm) transmittance of no more than 0.3 times the visual light transmittance. When purchasing sunglasses with UV protection, choose a pair labeled "meets ANSI Z80.3 2010 [normal] or [strictest] UV blocking requirements" or "lenses block [X] % of UV-A and [X] % of UV-B" (as close as possible to 100%). Because of the intensity of light at altitude and the reflection of light off snow and ice, sunglasses used in winter wilderness settings often include leather blinders on the sides or broad temple arms to further block light transmission (Figure 29-10). Sunglasses worn for travel at altitude on snowpack or in polar regions should transmit 5% to 10% of visible light and block up to 100% of UV radiation. Some sunglasses also block high-energy visible, or "blue" light, which is postulated to contribute to macular degeneration.[54] A review of UV keratitis occurring on NOLS courses between 1984 and 2009 found 15 cases, with 14 of the 15 occurring in mountainous or snowy terrain and 1 of the 15 occurring while boating. The majority (87%) of cases occurred in individuals who were not wearing sunglasses, and 13% occurred in individuals who were not wearing side shields on their sunglasses.[98]


**FIGURE 29-10** Examples of traditional **(A)** and contemporary **(B)** sunglasses with side guards to help reduce ultraviolet light at altitude. *(Courtesy Julbo.)*

The best optic quality is achieved with glass lenses, but in the wilderness, glass lenses are easily broken or shattered. Plastic lenses are lighter and more resistant to breaking, but they scratch easily. The lightest and most shatterproof plastic lenses for sunglasses are made of polycarbonate. Polarizing lenses reduce glare and are popular with fishing enthusiasts because they allow one to see below the sunlit surface of water. Sunglasses designed for water sports are constructed for greater impact resistance and flotation and include a nose cushion and retaining strap to hold them in place. Lens color, polarizing characteristics, and price do not relate to UV protection, so sunglasses should be sought that meet the requisite UVA and UVB protection.

Sunscreens are topical products designed to protect the skin from the harmful effects of UV light by absorbing, scattering, or reflecting UV radiation. Topical "shielding" sunscreens are the most effective at preventing sunburn. Some sunscreens have been shown in animal models to also repair preexisting damage from UV radiation exposure.[80] Sunscreens are rated by their sun protection factor, with a higher number correlating generally with greater protection from UV-B. Fair-complected individuals should use a sunscreen of sun protection factor 30 or higher. Look for a product with broad UV-A and UV-B protection. It is important to apply an adequate amount of the product (≈ 1 oz for the uncovered skin of an average 150-lb adult), to apply the product 15 to 30 minutes before exposure, and to reapply the product 15 to 30 minutes after exposure begins.[39] When maximum protection from UV exposure is needed, a sunblock should be used. These products contain titanium dioxide or zinc oxide and are more opaque than are sunscreens. When sunscreens are needed on or in the water, use a product that is water resistant. Water resistance does not mean waterproof. The products will resist loss of protection from UV exposure after swimming or with sweating but may still require reapplication.

## TEMPERATURE EXTREMES

### Cold Injury

The spectrum of cold injuries ranges from localized cold injury (frostbite) to systemic hypothermia. A complete discussion of the pathophysiology and treatment for cold injury is found in Chapters 7 to 11. Prevention of cold injury begins in the preevent phase with preparation and planning. Weather forecasts should be studied and excursions or expeditions timed to avoid hazardous weather. Climbing, hiking, and backcountry skiing partners or groups should have a travel plan that includes turn-around times and an emergency or crisis plan for potential cold injury. Proper cold-weather clothing (above), including waterproof and windproof outerwear, and dressing in layers are essential for wilderness travel in extreme cold. For short periods of travel, some commercial products, including fleece jackets, vests, gloves, and foot beds, are available with wire or carbon microfiber heating elements that provide up to 5 hours of supplemental heat. Batteries are rechargeable or replaceable, making these garments impractical for excursions lasting more than a day or two, unless spare batteries or a source for recharging is carried. Disposable chemical heaters are available for use in gloves, mittens, shoes, or boots, as well as in pockets. The duration of heat varies; the temperature for most brands is high enough to cause burns if they are placed on bare skin.[130] Proper nutrition and hydration are essential for endogenous heat generation. Following an accident when a person has limited mobility, or during long excursions with extreme weather, clothing and nutrition may not be enough to keep a person warm. In these cases, shelters must be used (Figure 29-11) or improvised, and a source of exogenous heat is necessary. Sleeping bags offer additional insulation, and a second person in the bag will offer additional warming or protection from heat loss. The heat escape lessening position (HELP) is taught to prevent hypothermia in cold water and involves putting one's knees together and hugging them close to the chest with both arms. A group of people can gather in this position. A similar position can be used in outdoor settings when no shelter is possible. Figure 29-12 is a risk management process for preventing cold injury applicable to the wilderness setting.[24]

FIGURE 29-11 Constructed wilderness shelter. *(Courtesy Haley Buffman.)*

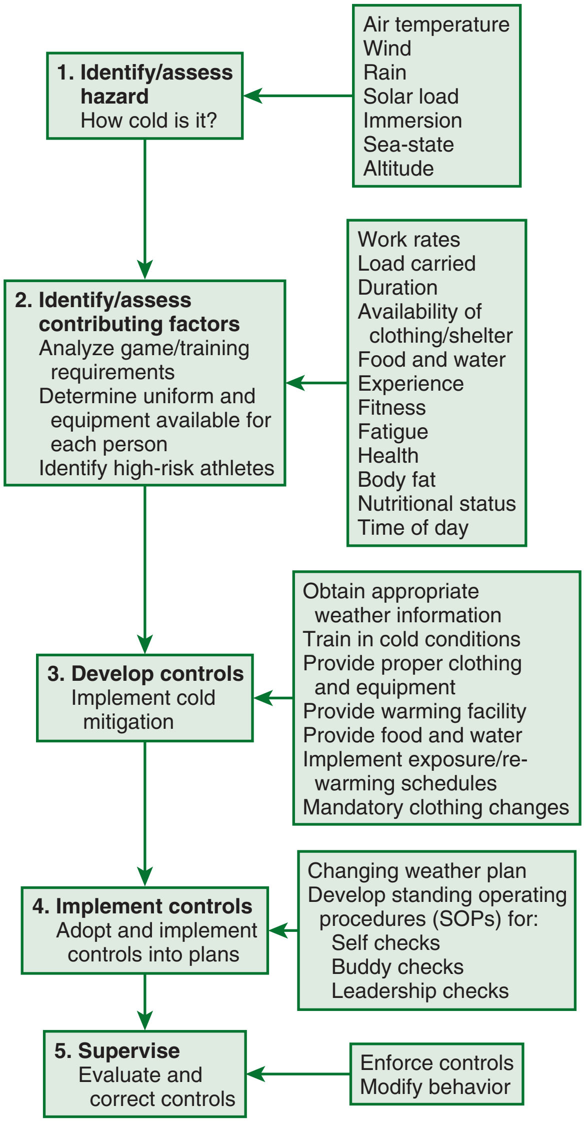


FIGURE 29-12 A risk management process for preventing cold injury that is applicable to the wilderness setting. *(From Castellani JW, Young AJ, Ducharme MB, et al: American College of Sports Medicine position stand: prevention of cold injuries during exercise,* Med Sci Sports Exerc *38:2012, 2006.)*

FIGURE 29-13 This trekker wisely evaluated his pretravel risk. *(Courtesy Eunice Singletary.)*

### Heat Illness

Heat illness is a spectrum of illnesses ranging from minor cramps and edema to heat exhaustion and life-threatening heatstroke. Heat illness results when heat gain overwhelms the body's heat-loss mechanisms and the body temperature rises. In terms of wilderness travel and reducing the risk for heat illness, sources of heat gain include strenuous physical activity and environmental acquisition through conduction, convection, and radiation. Dissipation of excess heat occurs primarily by radiation through the skin and is influenced by clothing. In high ambient temperatures, evaporation becomes the most effective means of heat loss. This is enhanced with sweating. Evaporation is less effective with high ambient humidity. Heat dissipation is hampered by dehydration, cardiovascular dysfunction, skin conditions, certain medications, lack of acclimatization, reduced sweating capability, extremes of age, and hypothalamic dysfunction.

When planning for wilderness trips, each participant needs to evaluate his or her risk based on age, presence of preexisting illnesses, and medications (Figure 29-13). If one is traveling during a period of high ambient temperatures and humidity, acclimatization takes 7 to 10 days, so the activity level initially needs to be limited. Plan to carry enough water and electrolyte-containing fluids and to wear loose-fitting, lightweight, and light-colored clothing that enhances evaporation by wicking, while providing shade and protection from the sun (Figure 29-14). Avoid strenuous exertion during the hottest part of the day, and take frequent breaks for hydration and cooling. NOLS guidelines for hydration call for 0.5 L of ingested liquid before strenuous exercise and 0.25 L every 20 minutes during exertion.[132] Wilderness excursion leaders who supervise group activities need to emphasize preventive measures, recognize the signs and symptoms of heat illness, know when evacuation is necessary, and be able to provide emergency care. Signs of impending heat illness include headache, dizziness, fatigue, and concentrated urine.

### Immersion (Trench) Foot and Pernio (Chilblains)

Immersion foot and chilblains are nonfreezing cold injuries. Immersion foot is seen when feet have been exposed to moisture at ambient temperatures near or above freezing for prolonged periods.[146] Dependent positioning of the feet and overly tight boots are believed to contribute. Keeping the feet dry for at least 8 hours a day often prevents this injury. Pernio (chilblains) is a vasculitis that follows exposure to damp, nonfreezing temperatures, most commonly below 10°C (50°F).[114] It is characterized by red to violaceous lesions on exposed skin and is most common in young to middle-age women with Raynaud's phenomenon or systemic lupus erythematosus. Keeping exposed skin to a minimum and exchanging wet or damp gloves, socks, and face and neck gaiters for dry wear will help prevent this injury.

## WIND AND RAIN

Wind has a primary effect of increasing convective heat loss, causing an exposed person to cool toward ambient temperature more rapidly than without wind. With moderate to strenuous exercise (intensity > 60% maximum oxygen consumption), heat production exceeds heats loss at a temperature of 5°C (41°F) in wet clothes with a wind velocity of 5 m/sec, and body temperature is maintained. With light or no exercise, heat loss exceeds heat production, and the core temperature declines. Exercise in rain leads to rapid declines in core temperature.[23,113,116] Wind reduces the insulating value of clothing. Wind-blocking outerwear can counter much of this effect (Figure 29-15).

Windchill is the apparent temperature felt on exposed skin and depends on wind speed and air temperature. The "windchill factor" is always lower than the ambient temperature; when the apparent temperature (what it feels like) exceeds the ambient temperature, a heat index is used. Windchill tables have been


FIGURE 29-14 Plan to carry enough water and electrolyte-containing fluids to hydrate adequately in warm weather. *(**A** courtesy Haley Buffman; **B** courtesy Eunice Singletary.)*

FIGURE 29-15 Wind is a significant risk factor for developing hypothermia. *(Courtesy Haley Buffman.)*

**NWS Windchill Chart**

Temperature (° F)

| Wind (mph) \ Calm | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 | -5 | -10 | -15 | -20 | -25 | -30 | -35 | -40 | -45 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 36 | 31 | 25 | 19 | 13 | 7 | 1 | -5 | -11 | -16 | -22 | -28 | -34 | -40 | -46 | -52 | -57 | -63 |
| 10 | 34 | 27 | 21 | 15 | 9 | 3 | -4 | -10 | -16 | -22 | -28 | -35 | -41 | -47 | -53 | -59 | -66 | -72 |
| 15 | 32 | 25 | 19 | 13 | 6 | 0 | -7 | -13 | -19 | -26 | -32 | -39 | -45 | -51 | -58 | -64 | -71 | -77 |
| 20 | 30 | 24 | 17 | 11 | 4 | -2 | -9 | -15 | -22 | -29 | -35 | -42 | -48 | -55 | -61 | -68 | -74 | -81 |
| 25 | 29 | 23 | 16 | 9 | 3 | -4 | -11 | -17 | -24 | -31 | -37 | -44 | -51 | -58 | -64 | -71 | -78 | -84 |
| 30 | 28 | 22 | 15 | 8 | 1 | -5 | -12 | -19 | -26 | -33 | -39 | -46 | -53 | -60 | -67 | -73 | -80 | -87 |
| 35 | 28 | 21 | 14 | 7 | 0 | -7 | -14 | -21 | -27 | -34 | -41 | -48 | -55 | -62 | -69 | -76 | -82 | -89 |
| 40 | 27 | 20 | 13 | 6 | -1 | -8 | -15 | -22 | -29 | -36 | -43 | -50 | -57 | -64 | -71 | -78 | -84 | -91 |
| 45 | 26 | 19 | 12 | 5 | -2 | -9 | -16 | -23 | -30 | -37 | -44 | -51 | -58 | -65 | -72 | -79 | -86 | -93 |
| 50 | 26 | 19 | 12 | 4 | -3 | -10 | -17 | -24 | -31 | -38 | -45 | -52 | -60 | -67 | -74 | -81 | -88 | -95 |
| 55 | 25 | 18 | 11 | 4 | -3 | -11 | -18 | -25 | -32 | -39 | -46 | -54 | -61 | -68 | -75 | -82 | -89 | -97 |
| 60 | 25 | 17 | 10 | 3 | -4 | -11 | -19 | -26 | -33 | -40 | -48 | -55 | -62 | -69 | -76 | -84 | -91 | -98 |

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

Wind chill (° F) = $35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$

Where, T=Air temperature (° F) V=Wind speed (mph)    *Effective 11/01/01*

**FIGURE 29-16** Windchill chart. *(From National Weather Service:* NWS windchill chart, *2001.)*

available through the National Weather Service since the 1970s, with the most recent revised index published in 2001. The index applies to temperatures of 10° C (50° F) or below and wind speeds of above 3 mph, calculates wind speed at 5 feet (typical height of a human face), and assumes no impact from the sun. Figure 29-16 shows a windchill chart from the National Weather Service.[107] Windchill is useful for planning wilderness travel in order to anticipate appropriate clothing and insulation. Wind speeds do not reflect man-made wind. For instance, a snowmobiler traveling 35 mph on a calm day will be exposed to wind speed of 35 mph across his or her body. In addition, wet skin exposed to wind chills faster than does dry skin. If wet skin is exposed to wind, the ambient temperature used in the windchill chart should be 10° C (18° F) lower than the measured actual ambient temperature.[18] When the windchill temperature falls below −27° C (−17° F), frostbite can occur in 30 minutes or less.

Travelers in mountain terrain should presume that wind speed would likely increase as altitude increases and natural barriers to wind (trees) become more sparse. Wind-blown snow is a potential travel hazard. Reduced visibility from blowing snow can cause a person to become disoriented, lost, and even to fall off rocky precipices or into a crevasse (Figure 29-17). Wind makes securing of shelters significantly more difficult and can turn natural and man-made objects into trauma-inflicting missiles.

## WATER

Between 2007 and 2011, there were 64,045 emergency medical services events reported in all NPS units. Medical causes accounted for 29% of such events, trauma accounted for 28%, and first aid for 43%.[38] The combined lake, ocean, and river environments accounted for 35% of the total SAR environments, nearly double the number within mountain environments. Motorized boating, swimming, and nonmotorized boating (e.g., canoeing, kayaking, rafting) were three of the top six activities reported by visitors at the time SAR operations were initiated.[64] An evaluation of visitor fatalities at all NPS units between 2003 and 2004 found that of 356 fatalities, 16% involved boating incidents or swimming. More than one-half of the swimming fatalities involved rip currents, river currents, and large waves, whereas one-half of boating fatalities involved boats capsizing (Figure 29-18). The most significant risks associated with water immersion or recreational activities on the water are drowning, hypothermia, and trauma from striking an object. Personal prevention of drowning from falls off boats or rafts begins with use of a personal flotation device.

Hypothermia is a significant risk from immersion, considering that convective heat loss in water is 25 times greater than that in air, and heat loss by conduction increases as thermal gradients increase in cold water.[53] The greater the surface area of a body that is immersed, the greater the heat exchange area and the faster the decline in core temperature.[86] Endurance athletes and swimmers are not immune to core temperature drop but can often partially compensate by adapting through cold-water training and by use of wetsuits. When people fall from a boat, kayak, or raft, they usually do not have the advantage of prior cold-water training or a wetsuit. According to the U.S. Coast Guard Executive Summary of Recreational Boating Statistics for 2013, there were 4062 accidents that involved 560 deaths, and 2620 injuries as a result of recreational boating accidents. This equates to a fatality rate of 4.7 deaths per 100,000 registered recreational vessels. Where the cause of death was known, 77% of fatalities were due to drowning, followed by trauma (18%), cardiac arrest (2%), hypothermia (1%), and carbon monoxide (CO) poisoning (1%). Of persons who drowned and where life jacket usage was reported, 84% were not wearing a life jacket. The top five primary contributing factors in these accidents were operator inattention, improper lookout, operator inexperience, excessive speed, and machinery failure. Alcohol use was the leading factor in 16% of deaths. Motorboats and personal watercraft accounted for the most common vessels involved in fatalities, followed by kayaks and canoes.[150]

A fall into water can be associated with traumatic injuries to the head or spine with subsequent drowning (Figure 29-19). If a fall is into swift water, contact with rocks or downed trees (strainers) increases the chance of additional trauma or becoming trapped underwater and drowning (Figures 29-20 and 29-21). For this reason, in swift-water boating activities, most wilderness excursion companies and leaders require a helmet to be worn (Figure 29-22). Participants are instructed that in the event of a fall into water, they should position themselves so they travel downstream feet first, which allows them to avoid hitting the head on rocks and to see and avoid objects in the water (Figure 29-23). Swift-water rescue training is one means of risk management for persons working in moving water. Available through various organizations and at varying levels, these courses teach evaluation of site safety and hazards that may contribute to drowning, fundamentals of survival, and how best to access drowning patients.

Alcohol ingestion is associated with a higher relative risk for death while boating, even when blood alcohol levels are low. The risk is the same for passengers as for operators.[27,40,137] One of the greatest preventive measures for both operators and passengers engaged in watercraft activities is to abstain from drinking alcohol.

## SNOW

To a wilderness enthusiast, nothing can be more delightful than fresh snow, and yet nothing can be potentially more

**FIGURE 29-17** **A,** Wind from blowing snow can reduce visibility and cause climbers or hikers to become lost or fall off rocky precipices. **B** and **C,** Wind can make posing for pictures on cliff edges especially precarious. *(**A** courtesy Haley Buffman; **B** and **C** courtesy Eunice Singletary.)*

dangerous. Snow becomes a hazard when it slides (avalanches), when it accumulates in heavy snowstorms to such great depths that a person can asphyxiate following a fall, and when a wilderness adventurer becomes wet, cold, or unable to see due to blowing snow.

Non–avalanche-related snow immersion death was described by Cadman[21] in 1999; more than 70 such documented deaths have occurred between 1990 and 2010.[152] Asphyxiation associated with snow immersion occurs when skiers or snowboarders fall upside down into a snowbank or into a tree well around a conifer. It has been proposed that snowboarders are at higher risk than are skiers from asphyxiation because of the lack of releasable bindings on snowboards. Preventing injury or death from non–avalanche snow immersion begins with basic precautions. Always ski or ride with a partner; in very deep snow following a snowstorm, always ski or ride a slope within eyesight or voice contact of your partner; ski or ride one at a time on slopes using a spotter; and avoid tree wells on gladed slopes.[151]

**FIGURE 29-18** Large waves and river currents are commonly involved in water-related fatalities. *(Courtesy Haley Buffman.)*

**FIGURE 29-19** A fall into water can be associated with traumatic injuries to the head or spine with subsequent drowning. *(Courtesy Eric Becker.)*

In case of accidental submersion, attempt to release bindings; if a ski pole is available, it may be the only means of releasing a binding short of twisting out. Several products designed for surviving avalanche burials are potentially useful to backcountry and sidecountry recreationalists to improve chances of surviving snow immersion. Avalanche airbags (see above) and the Snow Snorkel may increase survival time under snow by diverting expired air away from the face.[160] Devices with an inflatable air bag marketed for improving survival in avalanches (e.g., Snow Pulse) may help prevent snow immersion asphyxiation by allowing a skier or snowboarder to remain in a "head-on-top" position following a fall in deep snow.

## HYDRATION

If fluid intake is less than fluid loss, dehydration may result. Many individuals do not drink an adequate amount of fluids in the wilderness. In a cold environment, this is because when skin temperatures fall significantly, thirst is less noticeable than it is during hot weather.[79] In cold temperatures, moderate fluid loss may not be as important for exercise performance as during hot

**FIGURE 29-20** Downed trees or branches (strainers) increase the chance of additional trauma or becoming trapped underwater and drowning. *(Courtesy Haley Buffman.)*

**FIGURE 29-21** Removal of logs and branches from rivers can lessen the risk for injury or death after falling from a raft or kayak. *(Courtesy Haley Buffman.)*

weather.[29] If cold-weather clothing maintains the skin and core temperature to what would be expected during exercise in a temperate or hot environment, dehydration will likely have a negative effect on performance.[51] Individuals with hypohydration or hyperhydration who are exposed to intermittent exercise with normobaric hypoxia demonstrate greater physiologic-strain hypoxemia and acute mountain sickness (AMS) symptoms than do individuals with euhydration.[117]

Hydration status can be monitored in the wilderness by observing the color (and thus concentration), volume, and frequency of urine output. Oral fluids containing sodium have been shown to aid in fluid retention over several days of cold exposure, as well as in wildland firefighters in heat-stress conditions.[35,122] During wilderness excursions, a source of water needs to be readily available and easily reached to permit frequent, ad libitum fluid intake. There are many hydration systems used to prevent dehydration. These systems use bags ("bladders" or reservoirs) to hold water or other liquid inside an insulated carrier or are integrated into a backpack. Water is sucked through a bite valve from a dispensing tube extending from the reservoir up over the shoulder or through the inside of an insulated shoulder strap. "Wearable" hydration includes garments, such as cycling jerseys, that contain concealed reservoirs. Some hydration system manufacturers use antimicrobial compounds in the reservoir and bag to inhibit bacterial growth. Hydration systems are more difficult to clean than are water bottles but have the advantage of allowing a person to easily carry large amounts of liquids needed for maintaining hydration during prolonged physical activity.

Severe exercise-associated hyponatremia (EAH) results from overzealous hydration and impaired urinary water excretion, and is a well-described problem in endurance sports participants, particularly women, and individuals with low body weight.[94-97] Defined by a serum or plasma sodium concentration below the normal reference range of 135 mmol/L that occurs during or up to 24 hours after prolonged physical activity, EAH is infrequently encountered in the wilderness setting., although there are reports of EAH in hikers, trekkers, climbers, cold weather endurance athletes, and long-distance cyclists.[98-103] Symptoms reflect noncardiogenic pulmonary edema and cerebral edema and include nausea, vomiting, and headache followed by neurologic symptoms such as confusion, disorientation, seizures, or coma. Prevention begins with avoidance of overhydration during exercise. Moderate fluid intake is recommended based on the perceived need (ad libitum) rather than a specific amount.[15] Any fluid intake during prolonged exercise that exceeds the combined urine and sweat output (800 to 1000 mL/hr) should be considered high risk

**FIGURE 29-22** River excursion companies require helmets to be worn. *(Courtesy Haley Buffman.)*

**FIGURE 29-23** The former occupants of this raft should have positioned themselves so that they would have traveled downstream in a feet-first manner. *(Courtesy Haley Buffman.)*

for the development of EAH.[121] Additional preventive measures include avoiding excessive sodium supplementation for physical exercise of less than 18 hours' duration, and monitoring body weight in organized events. Should weight gain occur during exercise, fluid and sodium intake should be reduced until the weight returns to 2% to 4% of the body weight loss from the baseline level. Wilderness excursion leaders need to educate and advise their group members on appropriate fluid intake and be able to recognize early symptoms of EAH.

## ALTITUDE

Wilderness adventurers most commonly encounter changes in altitude during travel through mountainous terrain. As travelers ascend to a higher altitude, the barometric pressure decreases. Although the fraction of oxygen in the atmosphere remains constant, the partial pressure of oxygen decreases with ascent. Hypoxia is the physiologic insult that is responsible for acute altitude illness. The altitude where symptoms of altitude illness occur varies between persons. One study of tourists in Colorado found that 71% experienced symptoms of altitude illness following arrival at altitudes of 2103 to 2957 m (6900 to 9700 feet), which represents the elevation of many ski areas.[72] There is no absolute elevation where altitude illness can be predicted; rather, it is influenced by the rate of ascent, the altitude reached and where sleep occurs, the duration of exposure to altitude, and the level of physical activity. Individuals with a prior history of altitude illness are prone to future altitude illness,[153] and adolescent girls have a higher incidence than do boys.[37]

Prevention begins with education. Only just over one-half of respondents on a survey at a major U.S. ski area were aware of the existence of AMS, and one-third were unaware that it could be prevented.[60] Because slow, gradual ascent allows time for acclimatization to altitude, this is the primary means of prevention, particularly when ascending to high or extremely high altitude. If symptoms develop during ascent, additional time is needed for acclimatization before resuming the ascent. If symptoms do not abate, descent to an altitude 305 to 914 m (1000 to 3000 feet) lower, particularly for sleep, may be needed. The altitude at which a person sleeps is felt to be more important than that reached during waking hours, and travelers to altitudes above 3000 m (9843 feet) should not increase the sleeping elevation by more than 500 m (1640 feet) per day, and should include a rest day every 3 to 4 days.[91] The use of acetazolamide 125 mg twice daily (2.5 mg/kg every 12 hours for pediatric patients; maximum single dose, 125 mg), beginning 1 day before travel and continuing for several days at altitude, has been shown to prevent symptoms of AMS. Higher doses do not convey great efficacy and are associated with more side effects and thus not recommended.[1,15,30,43] If treatment is needed at high altitude, a dose of 250 mg twice per day has been shown to dramatically reduce symptoms.[48] Dexamethasone has also been found to prevent symptoms of AMS. The adult dose is 2 mg every 6 hours or 4 mg every 12 hours, not to exceed 10 days of treatment[15,42,120]

Risk factors and susceptibility for high-altitude pulmonary edema (HAPE) are similar to AMS and include a prior history of HAPE, rapid ascent, and higher altitudes. Additional risk factors include male gender, intense exercise, cold ambient temperatures, and preexisting respiratory tract infection.[41,73,139] As for AMS, primary prevention of HAPE is by gradual ascent. The ascent rate should be limited to no more than 300 to 350 m (984 to 1148 feet) per day above 2500 m (8202 feet) (sleeping altitude), with an additional day of acclimatization added for every 600 to 1200 m (1969 to 3937 feet) above 2500 m (8202 feet).[10] Pharmacologic prophylaxis aimed at preventing altitude-induced pulmonary hypertension is most commonly achieved with the calcium channel blocker nifedipine, 30 mg sustained release twice daily.[11] Sildenafil and tadalafil, both phosphodiesterase-5 inhibitors and pulmonary vasodilators, have been evaluated for prophylaxis and treatment of HAPE but have the potential side effect of causing significant headache. When taken beginning a day before ascent, dexamethasone reduced the incidence of HAPE by 78% and was superior to tadalafil in its efficacy.[12,92] For individuals who are prone to development of HAPE, the long-acting β-agonist salmeterol 125 mcg inhaled twice a day has been found to reduce the incidence of HAPE by 50%. Side effects, notably tachycardia, are similar to those of other β-agonists. Studies do not conclusively support the use of acetazolamide for prevention of HAPE.[90] Because of its safety profile and lack of serious side effects other than reflex tachycardia, nifedipine remains the prophylactic drug of choice for individuals with a prior history of HAPE.[140,91]

High-altitude cerebral edema (HACE) is the presence of a change in mental status and/or ataxia in a person with AMS, or the presence of both mental status change and ataxia in a person without AMS.[143] Symptoms typically occur at night, and after several days at altitude; many persons with HACE also have HAPE or AMS. Without rapid treatment, HACE progresses to coma and death. There are no studies showing a benefit to prophylactic treatment. However, slow ascent and prophylaxis against AMS are likely beneficial. In addition to slow ascent, pharmacologic prophylaxis is similar to that recommended above for acute altitude illness.[91] Additional information on prophylaxis and management of altitude illness can be found in Chapters 1, 2, and 3.

## BITES AND STINGS

The incidence of wilderness-acquired bites and stings and fatalities caused by then is difficult to ascertain, especially because many injuries go unreported, but there is likely a resemblance to statistics maintained by the American Association of Poison Control Centers. In 2013, more than 61,000 bites or stings were reported to the centers, with more than half due to insects.[104] On average, between 2001 and 2005, three-quarters (76%) of bites and stings were due to insects and spiders, 7.2% to snakes, 6.9% to mammals, and 3% to aquatic animals (Figure 29-24). Twenty-seven fatalities were reported for the period, with 16 from snakebites.[85] A study of long-distance hikers in Vermont found 6.6% of reported injuries in 155 hikers were due to insect bites. Heggie[61] found that 7% of wilderness injuries in children under 18 years and 1% of injuries in adults in Mt. Rainier National Park

**FIGURE 29-24** Most bites and stings reported to the American Association of Poison Control Centers are caused by insects and spiders. *(Courtesy Eunice Singletary.)*

PART 4 TRAUMA

and Olympic National Park in Washington were due to insect stings. Just over 2% of injuries reported by NOLS over a 4-year period were due to stings.[87]

Permethrin is a repellent that helps prevent bites from many crawling and blood-sucking insects. Some permethrin clothing treatment formulations reportedly last up to 6 weeks, even with weekly laundering.[131] In the United States, ticks transmit more diseases than do any other insects. When traveling in tick-infested country, wear long pants, bloused at the ankles and tucked into shoes or boots, and a long-sleeved, buttoned or pullover shirt tucked into pants and, if possible, covered with a jacket. Use of 0.5% permethrin spray on shoes and outer clothing is a barrier to ticks. A repellent that contains 20% or more DEET can also provide protection against ticks and mosquitos for several hours. Careful daily inspection of clothing and skin and removal of crawling insects while in tick-infested areas is recommended. Other precautions include avoiding sleeping on a cabin floor, avoiding sleeping in a bed that touches the wall, and changing and laundering all bed linens before use if a cabin has been unoccupied.[9] In general, mosquitos in North America cause little problem beyond minor itching and skin irritation. However, certain mosquitos transmit forms of encephalitis. Since 1999, West Nile virus has spread throughout the United States, infecting thousands and killing hundreds of people. In the Caribbean region and Central and South America, the incidence of both dengue fever and Chikungunya viral infections is on the rise and attributed to the daytime biting mosquitos *(Aedes aegypti and Aedes albopictus)*. Chikungunya virus has reached North America, primarily Florida and other southern states. Both infections cause fever with headache. Chikungunya virus is noted for causing polyarthralgias that can persist for months.[45] Zika virus infection is another emerged mosquito-borne disease. Primary prevention of mosquito-borne illness is by avoidance of mosquito bites. Wearing long pants and sleeves is an effective measure while outdoors. Mosquito netting is a physical barrier for sleeping areas and is sometimes used on hats to protect the face and neck.

*N,N*-diethyl-3-methylbenzamide (DEET) is an insect repellent used to reduce mosquito bites, including the species responsible for transmission of West Nile virus in the United States. The higher the percentage of DEET in a repellent, the longer the insect-repellent effect lasts. Concentrations of at least 23.8% are highly effective in reducing mosquito bites for up to 5 hours.[50] Newer formulations allow a lower percentage of DEET to be as effective as a higher-percentage formulation by mixing DEET in a controlled-release lotion vehicle that can last up to 20 hours. DEET can be absorbed through skin and should not be used on children under 2 years of age. Flies, gnats, and no-see-ums are not repelled as effectively as are other insects by DEET. When traveling in areas with these bothersome insects (coastal regions, southwestern United States), consider a repellant containing di-*N*-propyl isocinchomeronate, or R-326. Other repellents recommended by the CDC include picaridin, oil of lemon eucalyptus or PMD, and IR3535. Efficacy and duration of protection vary between products. Some insect repellants are combined with sunscreens, but this may decrease the effectiveness of the repellant and/or the sunscreen.

Certain spider bites cause significant problems. Prevention includes awareness of habitat; inspection of clothing, shoes, and sleeping bags; and shaking out items before use.

Stings from hymenoptera cause local and allergic reactions (Figure 29-25). Limiting exposure to these insects is not easily accomplished. Wilderness travelers with known allergy to hymenoptera may prevent serious reactions to stings by prior desensitization therapy and should carry injectable epinephrine, oral antihistamines, and a corticosteroid. Avoiding brightly colored clothing, perfume or fruity scents, and walking barefoot in areas where stinging insects may be present are maneuvers to help prevent hymenoptera stings.

Between 2001 and 2004, an estimated 9873 snakebites were treated each year in emergency departments in the United States, with nearly one-third due to venomous species, 18.7% while the patient was outdoors hiking or camping, and over 25% requiring hospitalization. The overall majority (69%) were due to rattlesnakes.[110] It is estimated that five people die each year in the United States from venomous snakebites.[25] Preventing snakebites begins with being aware of the presence of snakes and their typical habitats. Snakes tend to hide under debris, rocks, and other objects in the outdoors, so caution is urged when lifting up fallen wood or logs. It is important to not step on or near snakes. Use a flashlight to check for snakes in dark holes, and be aware that snakes can swim. If a snake is spotted, back away from it slowly and do not attempt to capture it. One study found that up to 67% of snakebites were the result of intentional interaction, and up to 40% of snakebite victims had consumed alcohol before the bite occurred.[103] Snakes have a strike distance of one-third to one-half of body length. Because snakebites are typically to the lower leg, outfitters recommend special snake boots. Hiking boots and several layers of pants legs also help divert bites from many snakes. Keep tents zipped closed, and check inside sleeping bags and clothing before use.

**FIGURE 29-25** Stings from hymenoptera commonly cause pain and local allergic reactions. *(Courtesy Eunice Singletary.)*

Mammalian attacks in the wilderness are unusual and typically provoked. Attacks by bears are a common preoccupation of hikers and campers, although the actual incidence of attacks is believed to be very low. Herrero[68] found 77 people with reported injury from 66 incidents involving grizzly bears in North American national parks between 1900 and 1970, most involving bear sows with cubs. Attacks were frequently provoked either intentionally or unintentionally (i.e., surprising/startling a bear in its habitat). Only five fatalities were reported in this review, but more than a dozen fatal attacks by bears in the wild have been documented in North America between 2009 and 2014.[158] Attacks by black bear sows are much less common than those by brown bears (Figure 29-26). Hikers often wear bells to create noise while hiking to prevent inadvertently startling a bear and provoking an attack. Avoiding high-risk areas, such as where carrion or bear scat is located, is a way to avoid an encounter with a bear. It is recommended to keep food out of tents and in bear-proof containers and to burn garbage at least 300 feet downwind of a campsite. In the case of an encounter with a brown bear, it is best to avoid eye contact, to avoid running or turning away, and to assume a submissive posture ("play dead") until the bear has left the area.[55] Predatory encounters by a black bear should be dealt with by standing still, by attempting to intimidate and appear larger by raising one's arms above the head, or by fighting back with any available weapon or object.[47] Pepper spray (5% to 10% capsicum oleoresin) may be an effective deterrent in the event of a charge by a bear.[69] For some predatory species, such as mountain lions and wolves, it may be best to display aggressive behavior or fight back in the event of an attack.[14,101]

Other mammals that may inflict injuries or fatalities in the wild include bison, cougars, bats, deer and elk, coyotes, wolves, moose, porcupines, foxes, raccoons, skunks, and rodents (Figure 29-27). Human attacks by foxes are usually by rabid animals. One general method of preventing attacks by wild animals includes never approaching or attempting to capture or restrain an animal. Postexposure rabies prophylaxis is a concern for wilderness travelers exposed to bites from wild mammals such as skunks, raccoons, foxes, and bats.

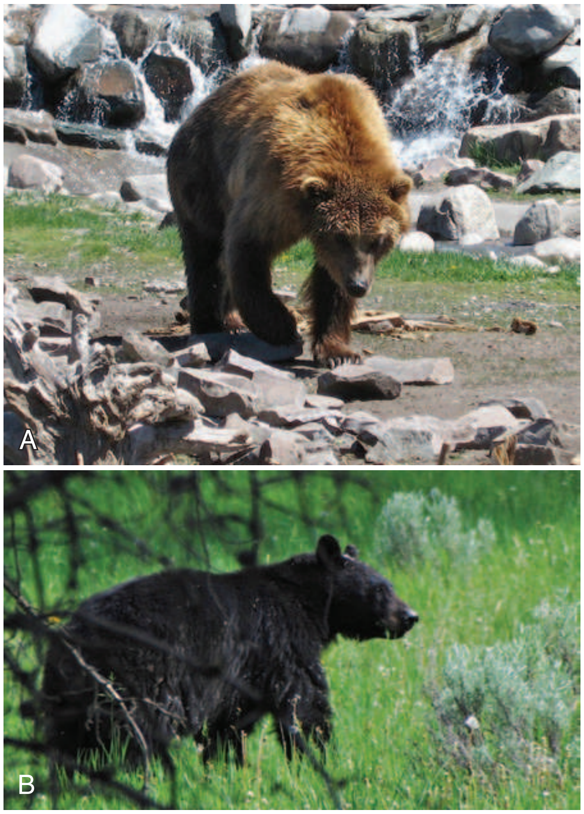


**FIGURE 29-26** **A,** Brown (grizzly) bear. **B,** Black bear. *(Courtesy Eunice Singletary.)*


**FIGURE 29-27** Attacks by mammals, such as coyotes **(A)** and porcupines **(B)**, are uncommon. *(Courtesy Eunice Singletary.)*

## TOXIC EXPOSURES

Exposure to inhaled toxins may stem from natural or man-made sources. The most common man-made exposures are most likely smoke from campfires. Fatalities are reported not infrequently from carbon monoxide (CO) inhalation due to accumulation inside poorly ventilated tents after using camp stoves. Injury or death is preventable by being aware of the symptoms of CO poisoning, by ventilating tents, cleaning ice or snow off tent fabric, using maximum blue flames and avoiding low flames, and avoiding prolonged simmering.[89] Wilderness travelers at altitude need to be especially alert to the symptoms of possible CO poisoning, because symptoms may be similar to those of altitude illness, although no relationship has been found between increased CO exposure and AMS symptoms.[124,125] Climbers on descent were found to have higher carboxyhemoglobin levels and an increased risk for CO exposure with increased hours of stove operation.

Volcanoes are another source of possible toxic inhalation injury in wilderness adventurers. Volcanic laze is a dense plume of concentrated hydrochloric acid and seawater mist that forms when hot lava enters ocean waters. It has been identified as the cause of two fatalities in Hawaii and is a risk for wilderness adventurers seeking close views of active volcanos.[65] Volcanoes release a number of potentially toxic gases, including sulfur dioxide, hydrogen fluoride, and carbon dioxide. Injury prevention includes avoiding standing under or downwind of a laze plume, avoiding depressions where carbon dioxide may settle, avoiding proximity to volcanic fumaroles, and avoiding exposure to volcanic ash.[22]

Poison ivy, oak, and sumac are common sources of allergic plant contact dermatitis caused by exposure to urushiol found throughout the plant (Figure 29-28). Exposure may be the result of direct contact, from inhalation of smoke particles from burning plants, and from contact with contaminated clothing, shoes, or gear. A skin protectant containing 5% bentoquatam (quaternium-18 bentonite) in a lotion form has been found to be effective at preventing allergic contact dermatitis from poison oak.[95] When combined with skin cleansing using isopropyl and cetyl alcohol wipes and education to recognize offending plants, it may be especially effective at preventing contact dermatitis from *Toxicodendron* species.[133] Prevention of adverse reactions from plants begins with being aware of potentially toxic plants that may be encountered in the area of planned travel, and being able to identify and avoid them. Wearing long-sleeved shirts and pants will help decrease exposure, but contamination is still possible from clothing. If contact with a potentially toxic plant is suspected, the area of contact should be washed thoroughly with water and mild soap and sun exposure to the area avoided.

The opportunity to ingest poisons in the wilderness is practically limitless. Mushrooms, berries, roots, fruits, leaves, and other vegetation are tempting to many hikers or campers. Prevention involves being able to definitely identify toxic plants and to not ingest them in a harmful form.

**FIGURE 29-28** Contact dermatitis from poison ivy. *(Courtesy Eunice Singletary.)*

## WATER, GERMS, AND HYGIENE

Water in wilderness areas is used for drinking, cooking, cleaning, and recreation. When wilderness travelers are concerned about possible water contamination in an area where they plan to drink that water, they should use a viable option for water disinfection. Water disinfection and treatment techniques are discussed in Chapter 88. Chlorine dioxide and iodine (TGHP) tablet-disinfected water typically has an unpleasant taste, but this disinfection technique is easy and inexpensive. The addition of ascorbic acid (45 mg/L) to completely treated water has been found to greatly improve palatability without eliminating germicidal activity.[67] A number of commercial water disinfection devices are available for backcountry use to purify water from streams, lakes, snow run-off, or springs. It is prudent to deploy a device that can remove *Giardia* and *Cryptosporidium*. Perhaps the most important means of preventing infectious diarrhea in the wilderness is fastidious hand hygiene and education on hygienic techniques for food handling and preparation. Proper disposal of human waste in all wilderness areas is encouraged. Exposure to a travel or climbing companion with diarrhea increases the risk for developing infectious diarrhea.[100] A revised three-bowl system of washing eating utensils was recently recommended for cleaning and reducing bacterial contamination on expeditions where running water is not available. The first bowl contains detergent to remove food residue and grease. A second bowl contains 20 mL of 4% bleach and is used to wash utensils until visibly clean, and a third bowl of drinkable water is used as a rinse to remove the smell and taste of disinfectant.[59]

# UNIQUE RISKS OF SELECT WILDERNESS ACTIVITIES

## BACKPACKING

The two basic types of backpacks are those with external frames and those with internal frames (Figure 29-29). The frames are designed to transfer the weight of the backpack from the shoulders and back to the hips and legs. An ideal backpack weight distribution is 20% on the shoulders and 80% on the hips. This distribution lowers the body's center of gravity, making the fit more stable, and places weight on the location best suited to carrying the weight. Backpack size is an important consideration for injury prevention. Individuals need to be sure that all equipment necessary for the duration of the trip can be carried without putting excessive strain on the shoulders and back muscles. In addition to backpack design, the prime concern regarding stress on the back and muscles is the proper amount of weight an individual can carry. This is determined by the size, body weight, and fitness level of the person. For multiday trips, where there is repetitive stress, a good rule of thumb is to limit the contents to 25% of body weight. To minimize the chance of back injury and allow better stability, the goal is distribution of the weight via maximal use of the frame. To achieve this goal, 50% of the weight should be in the upper one-third of the pack. To accomplish this distribution, lighter and bulkier items should be packed in the bottom and heavier items should be packed in the top close to the frame.

FIGURE 29-29 To prevent injuries, a backpacker should limit the contents of a backpack to 25% of body weight. *(Courtesy Jandd Mountaineering, Vista, Calif.)*

### Backpacks with External Frames

A backpack with an external frame may be preferred because it allows a larger amount of weight to be carried, using a ladder-like frame commonly made of aluminum or plastic. A hip belt and shoulder strap are attached to the frame, usually with clevis pins and split rings. A backpack that is adjustable to fit the length of the spine is best. One should optimally select a design that prevents injuries. Lumbar padding and increased stability via a conical hip belt allow for comfort. Recurved shoulder pads or straps and a chest compression strap improve weight distribution and increase comfort. Additional advantages of a backpack with an external frame are allowing air space between the back and the pack, thus reducing sweating and skin breakdown; and weight carried higher in the pack, allowing for more upright posture. However, the pack may wobble side to side during walking, potentially compromising balance.

### Backpacks with Internal Frames

The advantages of an internal frame backpack are that if it is well designed and fitted, it will conform more to the body, allowing for better balance, and can be worn comfortably for longer periods of time. With this advantage comes the absence of airflow, leading to problems with back perspiration and possible skin breakdown. Because the weight is carried lower, one must bend more, which in turn alters proper posture and can predispose to low back strain.

### Backpack Lifting

Proper lifting techniques are the key to minimize injury. The least injurious method for donning a backpack is to have someone hold and stabilize the pack while the carrier slips his or her arms into the shoulder straps. If a second person is not available, the backpacker can lift and rest the backpack on an object that is waist high and then slip into it. If a backpack must be donned from the ground, the wearer should lift the backpack onto a bent knee and slide one arm through the shoulder strap. After adjusting the strap so that the backpack rests on the shoulder, the carrier should lean forward and rotate the body slightly, allowing the free arm to slide through the other shoulder strap. While still leaning forward with bent knees, the backpacker adjusts the second strap and hip belt.

### Backpacks and Children

There are specially designed child carriers. Be certain to use a well-structured carrier that provides appropriate support and weight distribution. A child-carrying device should be equipped with restraints that prevent an active child from climbing out. One should not use an ordinary backpack to carry small children. Risks include strangulation if a child becomes entangled in the carrier's harness, and head and body injury if a child wiggles out of the harness and falls or is struck by an overhead obstruction, such as a tree branch.

## HIKING

Environmental hazards to be anticipated during hiking include those common to many wilderness activities, such as altitude illness, temperature extremes, UV exposure, plant and insect exposure, and hygiene and water effects. Negotiating trails and uneven and hazardous terrain, including snow, ice, and mud, can be challenging. Because a trail is marked or exists on a map does not mean it is safe, clear, and well maintained. Plan to check actual conditions on the day of travel. The key to a safe and injury-free trip is ensuring proper balance. Watch for unstable rocks and boulders. Keep the body weight over the feet, with knees bent, and do not lean backward. When crossing rivers and streams, remember that water is very powerful. Use predefined crossing points, safety ropes, or watercraft and flotation devices.

A common injury during hiking and backpacking is low back pain. The most common reason for back injuries is carrying excessive or poorly distributed loads. Using a properly designed backpack and proper lifting techniques can help avoid these injuries. A useful injury prevention adjunct is a hiking pole or staff to provide stability on rough ground and diminish the impact on knees and ankles. A staff can support a good walking rhythm and prevent imbalance when carrying a heavy load. Hiking poles allow for probing and identifying hidden rocks and deep spots and can hold back bushes, barbed wire, stinging plants, and other trail obstructions. Although one pole can be helpful, it can often lead to uneven balance and weight shift. Using two poles takes the load off the legs and hips and redistributes part of the weight to the upper body musculature. On a steep area, hiking poles enable tripoding, which is having three points of contact with the ground.

## HAMMOCK SAFETY

Hammock safety issues exist. The priorities are strong and secure attachments with clear knowledge by the user of the weight tolerances for the hammock and the hanging hardware. A slight modification to the traditional hammock is the lightweight minihammock, which is popular for camping and backpacking. These hammocks have no spreader bars and can be folded easily. The CPSC warns that children can become trapped and strangle in certain minihammocks; two deaths and one nonfatal incident have involved minihammocks or backpacker hammocks. If a hammock is rigged too high off the ground, a child will have difficulty climbing into it and may become trapped or entangled, leading to strangulation. To prevent injuries, install a minihammock near the ground.[147]

## HUNTING

More than 35,000 firearm fatalities have occurred in the United States each year since 1989, and it is estimated that there are three nonfatal firearm injuries for each death associated with a firearm.[5] The key elements to injury prevention while hunting are, at a minimum, the following:

- Proper training for hunting and use of firearms, focusing on safety
- Hunters wearing appropriate protective clothing; wearing international orange clothing articles when traveling in areas frequented by hunters; and wearing ear and eye protection
- Hunting only in approved areas and at safe distances from residential or populated areas
- Compliance with all local and state laws and regulations

Hunter safety courses are available in every state and are a prerequisite in most states to obtaining a hunting license. Key recommendations include warning nonhunters of hunting season, limiting hunting to designated hunting areas, and wearing international orange clothing articles when traveling in areas frequented by hunters. Hunters should always be sure of the target before shooting. Care should be taken to use appropriate techniques when cleaning game to prevent lacerations. Eye protection with impact-resistant lenses should always be worn to prevent injury from ricocheting fragments and shotgun pellets. Ammunition should always be stored separately from guns. A safety harness should be worn when using a tree stand.

The greatest potential serious injury from hunting is a gunshot wound, but this is actually uncommon. A 9-year retrospective review of illnesses and injuries in hunters found that firearm-related trauma accounted for only 45% of emergency department visits by hunters, with the majority of injuries being knife injuries associated with the field dressing of game. The most common medical visits were for cardiac signs and symptoms, and all emergency department deaths were due to cardiac causes.[115] Cardiac

FIGURE 29-30 Icefall climbers are at risk for avalanches. An avalanche at this popular climbing location killed a climber. *(Courtesy Jay Pape.)*

evaluation of big game hunters with risk factors for cardiac disease prior to hunting should be considered. A retrospective review of trauma databases from two level I trauma centers in Ohio of hunting-related injuries during a 10-year period found that of the 130 patients identified, 50% of the injuries resulted from falls, with 92% of falls from tree stands. Gunshot wounds accounted for 29% of injuries. Of injuries due to falls from tree stands, 59% of victims sustained spinal fractures, 47% had lower extremity fractures, 18% had upper extremity fractures, and 18% had closed head injuries. Permanent neurologic injuries were noted in 18% of fall victims. Thus, in this review, tree stand falls were the most common mechanism related to hunting resulting in admission to a level I trauma center.[34]

### Horseback Riding

In 2005, an estimated 73,576 people were treated in hospital emergency departments for horseback-riding injuries.[49] Horseback-riding injuries most frequently occur to the upper extremity as riders try to break a fall. Serious horseback-riding injuries involve the spine, pelvis, internal organs, and head. The following precautions should be taken to prevent horseback-riding injuries:

- All riders should always wear riding helmets that meet proper safety standards.
- Wear properly fitted, sturdy leather boots with a minimal heel.
- Inspect all riding equipment for damage.
- Be sure the saddle and stirrups are appropriate for your size and are properly adjusted.
- Secure all riding equipment properly.
- Amateurs should ride on open, flat terrain or in monitored riding arenas.
- Jumps and stunts require a higher level of riding skill. Do not attempt these without supervision.

## CLIMBING

Climbing is a wilderness activity that poses risks common to many other wilderness activities, such as hypothermia, dehydration, heat illness, altitude illness, trauma from falls, and injuries from avalanches (Figure 29-30). Hand injuries, including fractures, tendon ruptures, and digital amputations, are common in climbers.[93,123] Use of stiffer ropes, reducing rope slack, and grabbing rope in a controlled manner during a fall have all been suggested as means for preventing digital injuries in climbers.[75] A retrospective review of climbing accidents on Mt. Rainier from 1997 to 2006 found 89 incidents, including 18 fatalities. Falling snow, ice, and rock contributed to injuries.[97]

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