AMERICAN HEALTH CONSULTANTS® A Medical Economics Company

The Practical Journal for Emergency Physicians

Emergency Medicine Reports™

Volume 16, Number 24

November 27, 1995

Each winter, ice and snow provide abundant opportunities for recreation and enjoyment. Skiing, snowboarding, sledding, tobogganing, and skating are enjoyed by millions of adults and children. Unfortunately, these sports also have a legacy of producing serious injuries and, occasionally, even death.

Etiological and predisposing factors associated with winter sports-related injuries are well-documented. Skiers glide gracefully downhill on groomed slopes at speeds that can exceed 60 mph. Typically, these slopes are littered with other skiers, trees, rocks, moguls, and precipices. Advanced skiers revel in these hazards and go out of their way to find "maximum" vertical slopes to increase both the speed and feeling of hazard. On the other hand, snowboarders revel in edged turns and jumps whereas sledders and tobogganers seek maximum speed and jumping opportunities to add excitement to their runs.[1-4]

Each year, downhill skiers make about 50-60 million visits to their favorite slopes. For every 1000 visits, about three will result in an injury serious enough to require immediate medical care. Unfortunately, many of these individuals will seek definitive care after they have returned home, where practitioners may not be familiar with the spectrum or potential seriousness of injuries sustained during such activities. In addition, it is estimated that as many as 40% of alpine ski-related injuries, especially those of minor severity, are never reported to a physician.[1-3]

This review provides a practical and comprehensive review of both minor and serious injuries associated with such winter sports as alpine skiing, cross-country skiing, sledding, snowboarding, and tobogganing. Emphasizing mechanism of injury, historical features of the accident, and physical evaluation, this article guides emergency physicians toward specific diagnoses and strategies for definitive management.

— The Editor

Winter Sports Injuries: A State-of-the-Art Review of Diagnosis and Treatment in the ED

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Downhill Ski Injuries: Demographics, Risk Factors, and Environmental Precipitants

Demographics. Not surprisingly, it is difficult to determine the "real" injury rate on recreational ski slopes. First, many accidents sustained by skiing enthusiasts simply are not reported; second, skiers can have minor, and sometimes even major, injuries serviced elsewhere for initial care. In some ski areas, when given a choice between an exorbitant medical bill and a bit of pain and suffering while the patient is evacuated by family and friends, many patients will prefer to be treated at facilities far from the slopes.

There are other confounding variables. For example, some injuries are not thought to be "that bad" until the following day, when the patient seeks medical care off the slope. In some cases, experienced skiers may consider the injury to be part of the sport, while "softer" novices seek medical care for equivalent injuries. Consequently, injury figures provided by a ski patrol reflect only those patients who seek medical

Table 1. Incidence of Selected Injuries Due to Downhill Skiing

INJURY	INCIDENCE
Sprains, strains	45%
Cold injury	20%
Lacerations, abrasions	11.5%
Fractures	9.5%
Contusions	5%
Dislocations	3%

Adapted from: Foster CR, Garrick JG, Steadman JR, et al. When skier turns tumbler. *Pat Care* 1987;21:24-44.

care from the patrol, rather than all who eventually require medical care.[2,3]

Injury Rates. Given the aforementioned limitations, it is estimated that males have an injury rate of about 4.9 injuries per 1000 days of skiing, whereas the rate for females is 7.9/1000.[5] Juvenile skiers have at least three times the injury rate of adult skiers,[6] with at least one-third of all injuries occurring among skiers who are less than 16 years of age.[7] The highest rate of head and neck injuries is reported in the 11- to 13-year age group.[8]

Experience and athletic proficiency appear to be major factors in reducing the risk of injury associated with skiing. For example, entry-level skiers have 2-3 times the injury rate observed in more experienced skiers.[7] Not only is the inexperienced skier more likely to sustain injury, but he or she is more likely to cause injury to another skier.[9] When asked to identify the reason for their injuries, one-third of all skiers injured felt that they were going too fast for their expertise and/or the condition of the slopes.[9]

Snow Conditions. Environmental conditions play a major role in ski-related injuries. Skis are more likely to get entrapped in heavy, wet snow, in which twisting knee and ankle injuries are more likely to occur. In contrast, during icy conditions, upper-extremity injuries are more likely to occur because skis slide out from under the skier. In these accidents, the skier may fall on the face, shoulders, and upper body in the process of trying to break a fall. As might be expected, powder snow is associated with the lowest frequency of injuries.

Fatigue. Temporal considerations also play a role. For example, more injuries occur in afternoons—between 1 p.m. and 4 p.m.—when skiers are tired and hungry.[10] Not only is the skier fatigued at this point of the day, but there is sometimes a mad frenzy to get in "just one more run" before the slopes close for the day. From a prevention point of view, skiers should recognize their physical limits and not ski when exhausted.

Alcohol. Injuries are reported at a higher rate and tend to be more serious if alcohol consumption prevents the skier from being able to concentrate on the mechanics of skiing.[11,12]

Prevention: Protective Equipment and Safety

As might be expected, innovations in the design of skiing equipment have made a dramatic impact on ski-related trauma.

Boots. The contemporary ski boot consists of a high, hard plastic outer shell coupled to a soft inner liner. The plastic outer shell is designed to transmit foot and leg forces to the ski in order to increase control over the ski. The liner is a thick sock-like bootie that surrounds the foot with a moldable form. The body heat molds the liner around the foot so that the bony parts of the foot are protected from the hard outer shell. Padding is provided for the anterior shin with a wide, thick foam tongue on the boot liner. Forces from the skis are transmitted through the boots and are applied at the mid-third of tibia.

Because the ankle and foot are reinforced, there are fewer ankle and foot injuries. Over the past 25 years, the incidence of tibial and fibular fractures has been reduced by 72% and 43%, respectively, because of improvements in boot design.[7] Low boots similar to old style downhill boots are often used with cross-country skis, particularly in Telemark skiing. These boots allow the stresses of a fall to be absorbed by the relatively weak ligaments of the ankle and lower portion of the tibia and fibula. Ankle movement is freer and rotation abduction of the leg can occur about the ankle. This can result in both ankle injuries and mid-distal-third tibia fractures.

Bindings. Of all of the factors that determine whether the skier will still be skiing at the end of the day, the type and appropriate function of the bindings are most significant. Bindings have two competing functions. First, they must rigidly attach the skier's foot to the ski. Second, they must release this attachment under any stress that could injure the skier. Current dual-mode bindings release in two different directions: toe rotation and heel lift. This protects the skier from most rotation-based injuries. When combined with high-topped boots, the ankle is almost completely protected.

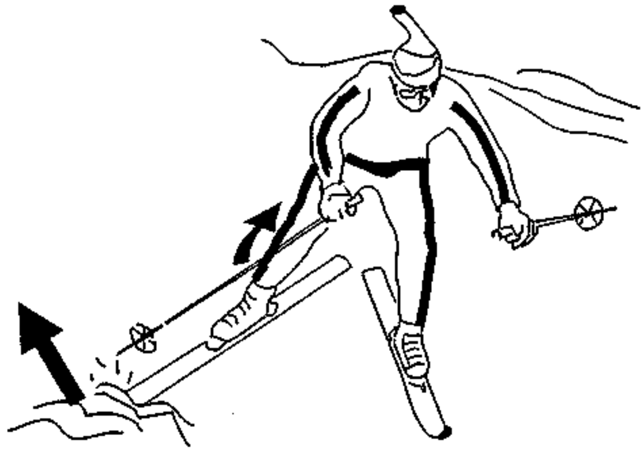
Unfortunately, the knee then becomes the main shock absorber in trauma to the lower extremity. The knee is quite vulnerable to this trauma for the following reasons:[13,14] Rotational forces that used to cause ankle injuries are transferred to the knee by the high boots as described above. Forces that are not protected by the dual-mode binding can cause injury to the knee. (Upward release at the toe would decrease some of these injuries.) Criteria for protection of the tibia from injury are based on cadaver studies on fractures of the tibial plateau. Unfortunately, this protection does not extend to the ligaments of the knee. Finally, the binding may fail to protect the patient in deep and wet snow conditions.

Probably the most significant failing of the bindings occurs before they are put on, when the skier adjusts the tightness. If the binding is too tight, then it will not release under forces that will fracture or seriously damage the knee. Failure of the release mechanism accounts for 44 % of downhill injuries and 70% of lower leg fractures and serious knee injuries.[15] This may be due to either improper maintenance or improper adjustment of the bindings.[7,16]

Mechanisms and Categories of Injury: General Principles

From a practical perspective, skiing accidents can be grouped into two main categories—falls and collisions. In addition, skiers may also develop so-called "overuse" injuries of unprepared muscles, ligaments, and joints. *(See Table 1.)*

Figure 1. External Rotation in Downhill Skiing



Collisions. Collisions account for 5% of all injuries sustained on the slopes and 67% of all admissions.[17] In particular, high-speed collisions with immovable objects such as trees, buildings, support towers, or even snow-grooming machines can cause massive blunt trauma and impalement injuries.[17] Not surprisingly, the most common cause of fatal ski-related injuries is collision, most often with a tree; the majority of these deaths are associated with head injury.[18,19] The nature of collision injuries is not predictable and varies widely depending on the part of the body involved and the speed.

Overuse Injuries. Overuse syndromes are probably the most common type of injury sustained by skiers. These injuries are common and, because they are usually minor in severity, are often ignored by both novice and experienced skiers. Since symptoms associated with overuse injuries usually do not declare themselves until the following day, estimates on their incidence are inaccurate. The most common overuse injuries are characterized by muscle discomfort and pain in the quadriceps femoris, the gastrosoleus, and the paravertebral muscles of the back *(see Emerg Med Rep 1995;16:129-140 on back pain).* Aggressive use of ski poles may also lead to triceps tendinitis.

Treatment of overuse injuries includes reduction in intensity of activity, strengthening exercises, nonsteroidal anti-inflammatory drugs (NSAIDs), and application of ice. Although frequency, duration, and intensity of exercise should be reduced, complete cessation of activity usually is not necessary.

Falls and Lower-Extremity Injuries. More than 87% of all reported ski injuries are caused by a fall.[20] Fortunately for emergency care providers, injury patterns resulting from ski-related falls are predictable, well-studied, and permit a systematic approach to patient evaluation and management. The most common injuries, in order of occurrence, are: thumb injuries, knee injuries, lacerations of the face and head, leg contusions, shoulder injuries, ankle sprains, tibia fractures, knee contusions, and dislocations of the shoulder.

As many sports medicine experts have noted, strapping a ski onto the foot produces an increased lever arm and, in turn, "enhances" the chances of an injury with any given fall. If the tip of the ski becomes fixed in deep snow or is lodged against a tree, the resultant forces can be enormous and cause massive musculoskeletal damage. In these accidents, as the skier falls or rotates, the increased lever arm of the ski-foot-leg combination will exceed the tensile strength of the human musculoskeletal system. The clinical result can range from muscle strains and tears to ligament injuries and compound fractures.

Recognizing the mechanics predisposing to such injuries, ski equipment manufacturers have invested millions of dollars in order to develop ski bindings that will release *before* muscles, ligaments, or bones tear or break. In fact, when properly fitted, affixed, and adjusted, these bindings can prevent a great deal of injury.

From a clinical perspective, torsion and twisting forces associated with falls generally produce injury in several well-defined and predictable patterns. In the lower extremity, for example, there are four such patterns: external rotation, internal rotation, forward falls, and backward falls. The first three patterns commonly produce injury, whereas the fourth is a less frequent mechanism of injury.

External Rotation. External rotation ("catching an inside edge"), which usually is associated with ankle abduction, is the most frequent mechanism of injury. In these cases, when the skier "catches an edge," the inside edge of one of the skis is fixed in place. As the skier continues forward, his or her body weight shifts to the other ski and the "caught" leg is externally rotated and abducted. These forces may fracture the lateral malleolus, cause spiral fractures of the tibia and fibula, or produce ankle sprains and knee sprains. *(See Figure 1.)*

Internal Rotation. Internal rotation ("catching an outside edge") injuries occur in exactly the opposite manner from that described for external rotation injuries. The skier, who is usually a novice, will catch the outside edge of the ski during a turn or when the skis cross. The internal rotation forces that result can produce an ankle sprain of the anterior talofibular ligament, a medial malleolus fracture, or a tibial fracture.

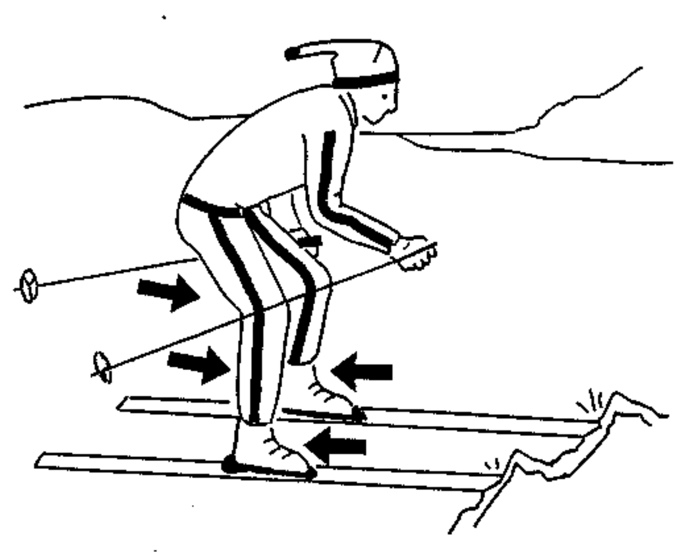
Forward Fall. Forward falls most often occur when the skier digs a tip of the ski into the snow and continues in forward motion as the ski stops. The lower leg angulates over the boot top as the skier's forward momentum is terminated abruptly by the ski, which remains wedged in the snow. If the binding fails to "give," the musculoskeletal system will be disrupted and produce one of three injuries: boot-top fractures, Achilles tendon ruptures, or dislocation of the peroneal tendon. If the skier extends the arms to protect the face, upper-extremity injuries also may occur. *(See Figure 2.)*

Specific Injuries of the Leg, Foot, and Ankle

Midfoot Sprains. Midfoot sprains occur when the skier digs a ski tip into the snow. The resulting hyperflexion of the foot can cause pain over the dorsum of the foot as well as swelling and tenderness. Midfoot sprains are more common with poor-fitting boots and when skiers have loosened their boot buckles.

Pressure Injuries. Pressure injuries to the foot occur when the skier is wearing boots that are either too small or buckled

Figure 2. Forward Fall in Downhill Skiing



too tightly. Even with integral padding, the pressure of tight-fitting boots may decrease distal circulation and exacerbate cold-mediated injuries. Because anesthesia of the area may accompany this type of injury, the skier may not notice the problem until the boots are removed and the pressure is relieved. Subungual hematomas (skier's toes) and injuries to the bony prominences are common signs of direct pressure trauma. In extreme cases, anesthesia may persist due to pressure-mediated peroneal nerve palsy.

Rest, elevation, and cessation of skiing until healing occurs are appropriate therapeutic maneuvers. Unfortunately, convincing a skier who has booked a "once-in-a-lifetime" vacation to avoid skiing may be difficult. Recovery is relatively quick in most cases.

Ankle Sprains. Contrary to what many clinicians may think, ankle sprains have become relatively uncommon injuries in downhill skiing since the introduction of high-padded boots. Overall, they now represent less than 1% of all ski injuries.[1-3] However, when older boots and less effective release mechanisms were in common use, ankle injuries *(see Emerg Med Rep 1995;16:39-48 on ankle injuries)* accounted for more than 25% of all ski-related injuries.[3,4]

Prevention-oriented measures should be emphasized to the patient. If boots are not fastened properly, ankle sprains are more likely to occur. The most common fastening problem occurs when the skier unfastens buckles to relieve a tight-fitting boot or ankle discomfort. To minimize the likelihood of injury, the buckle over the ankle joint should be fastened first. It should also be the tightest in order to keep the heel seated during downhill maneuvers.[21] All other buckles can be fastened to comfort. It should be stressed that even the best ski boot available does not protect the ankle completely from severe rotational forces. Fortunately, however, dual-mode bindings release easily with rotational stress and protect the ankle from these potentially destructive forces.

Most ankle sprains associated with *properly* adjusted boots occur when the skier catches the inside edge of the ski and both abducts and externally rotates the ankle. Anatomically, the talus is forced against the lateral malleolus and stretches the anterior talofibular ligament. If the ligament is disrupted, an unstable ankle injury may result. Treatment depends on the severity of the sprain. Grade I sprains are treated with rest, ice to the area, compression dressings, and elevation (RICE). Weight-bearing may be resumed when pain is no longer present.

Grade II and III sprains may show evidence of instability. If the patient complains of pain without weight-bearing and has severe swelling, suspect a grade II sprain. A grade III sprain represents complete ligamentous disruption, which requires fixation with plaster and, in some cases, may even necessitate surgical repair. Patients with either grade II or grade III sprains are treated with ankle immobilization and should be referred to an orthopedic surgeon for further treatment.

Lateral Malleolus Fracture. In the setting of ski-related trauma, the lateral malleolus fracture is often produced by a forward fall, particularly if the fall is combined with external rotation. The most serious injuries occur when the skier catches a ski tip and falls forward and rotates the ankle during forward movement. Most of these orthopedic injuries are isolated lateral malleolar fractures, although medial malleolus and comminuted fractures may also be seen. Not uncommonly, tibiofibular ligament sprains are be associated with the injury, and, occasionally, the neck of the talus may be fractured rather than the medial malleolus. Since these fractures are easy to miss, a high index of suspicion is required for their detection.

On physical examination, lateral malleolar fractures present with the usual swelling, pain, and tenderness on palpation of the fracture site. Ecchymosis may or may not be present. Deformity should suggest a displaced and unstable fracture. Fractures of the *neck* of the talus are characterized by tenderness on both sides of the ankle, in a location anterior to the medial and lateral malleolus.

Diagnosis of a fracture of the ankle is best made with appropriate radiographs. If a fracture of the neck of the talus is suspected, ask for a tangential view of the neck of the talus. This view is taken with the foot placed flat on the film. Treatment requires appropriate immobilization in a splint, ice, elevation of the extremity, and orthopedic referral.

Achilles Tendon Rupture. This injury occurs when the skier runs into a mogul or other object and the skis stop while the skier continues in forward motion. This produces a forward fall, which is accompanied by marked dorsiflexion of the ankle. The patient may note a tearing or popping sound as the tendon rips. Males older than 35 are at high risk for this injury.

Following the accident, the patient may be able to walk, have little or no pain, and be able to plantar flex the foot despite a tear of the Achilles tendon. On physical examination, however, the patient will have tenderness and swelling along the tendon sheath, with a palpable defect present about 2-3 cm proximal to the calcaneus. In some cases, the patient will have a obvious foot drop and will be unable to plantar flex the foot. Thompson's test of the calf, which may demonstrate disruption of the Achilles tendon, is performed on a sitting patient with legs in a dangling position. When the middle third of the calf is squeezed, the foot should plantar flex. If there is no plantar flexion, suspect an Achilles tendon tear.

If an Achilles tendon tear is strongly suspected, the patient should be immobilized in a long leg splint and referred to an orthopedic surgeon. Partial tears can be treated with immobilization alone but still require evaluation by an orthopedic surgeon.

Peroneal Tendon Rupture. Although dislocation of the peroneal tendon is considered a rare injury in a typical orthopedic practice, it is considered one of the more common ski-related ankle injuries.[22] Moreover, peroneal tendon rupture or dislocation is also one of the most under-reported and *overlooked* skiing injuries.[23] Dislocation can occur when the skier forcefully edges the downhill ski during a turn. At this point, because the peroneal tendon is supporting the full weight of the ski and foot, the peritoneal retinaculum is subject to tears.[22] If the tendon sheath alone is torn, the tendon may dislocate anteriorly.[24]

About 1% of all reported skiing injuries involve the peroneal tendon.[22] This injury also can occur when the skier hits a mogul or some other object and continues in forward motion while the skis stop. If the skier falls forward with the foot in dorsiflexion and external rotation, the peroneal retinaculum or the peroneal tendon may be torn. Typically, the patient will describe the fall, followed by pain, swelling, ecchymosis, and tenderness that occur *posterior* to the lateral malleolus.

On physical examination, the physician should palpate for tenderness on the lateral and posterior aspect of the malleolus. If the peroneal tendon subluxes during dorsiflexion and external rotation, the diagnosis is confirmed. Radiographs may demonstrate little more than a small avulsion fracture of the posterior lateral malleolus, right at the attachment of the peroneal retinaculum (a fracture fragment may be demonstrated on an overrotated lateral view of the ankle).[25] When detected, this subtle fracture is highly suggestive of a torn peroneal tendon or sheath.

These patients require surgical repair of the tendon and/or tendon sheath. In the emergency setting, the patient requires immobilization, ankle elevation, and referral to an orthopedic surgeon.

Tibia Fractures. Fractures of the tibia are common and dramatic reminders of the magnitude—and potential destructiveness—of forces that act on the falling skier. If a prominent rotatory component is present, a *spiral* fracture of the tibia and fibula may result. However, when the primary force is a bending motion at the top of the boot, a boot-top fracture should be suspected. If some combination of both forces is present, elements of both injuries may be found. These fractures are usually easy to diagnose with AP and lateral x-rays of the lower leg.[7]

The incidence of these fractures has remained constant or slightly increased in frequency.[26] Spiral fractures have decreased markedly since the 1960s. Since torque at the toe will release current dual-mode bindings, these are precisely the fractures that modern bindings are designed to prevent.

Children who fall and develop shin pain should be assumed to have a tibial or fibular fracture.[27] In childhood, ligaments and muscles are strong and do not easily give. Special attention should be paid to the joints and epiphysis in children. Fractures at this age are more common than sprains. Isolated tibial fractures are more common in children than adults. If the child has tenderness near the joint, look for an epiphyseal fracture.

Standard care for fractures includes immobilization and referral to an orthopedic surgeon. Appropriate elevation and pain medication are essential. Open fractures should be cultured and the patient should be started on IV antibiotics.

Fibula Fractures. Most fibular fractures are found in association with fractures of the tibia. If an isolated fibular fracture is confirmed, the emergency physician should assume there is an associated severe ankle injury until proven otherwise. If a spiral fracture is found, a major ankle injury is extremely common. A backward or lateral fall may cause a boot-top fracture of the fibula alone, but this is unusual. Radiographs of the lower leg will usually confirm presence of the injury. Boot-top fractures of the fibula are often subtle, hairline fractures; therefore, detection of these injuries may require a magnifying glass.[28]

Treatment requires immobilization of the ankle and lower leg. If an isolated boot-top fracture is confirmed, a compression dressing, ice, NSAIDs, elevation, and limitation of weight-bearing are adequate therapy. Weight-bearing can be resumed when the patient is pain-free.

Knee Injuries

About 20% of all downhill ski injuries involve the knee.[29] Although overall injury rates have been reduced, knee injuries have increased in the last 20 years.[28] Fortunately for skiers, 90% of these knee injuries are minor.[29] Most are ligament sprains, but bony fragments may be torn free. Skiers may also sustain lacerations, contusions, or patellar injuries if the knee strikes other objects or the ground. Dislocations of the knee are rare.

Medial Collateral Ligament Sprains. Catching the inside edge of the ski will rotate the ski and attached foot externally, a motion that will stress the medial collateral ligament of the knee on the same side. This is a common injury in skiers and—with or without rupture of other ligaments—may account for as many as 60% of all ski-related knee injuries and 83% of all knee *ligament* injuries.[30] If the external rotation and lateral forces are pronounced, then the anterior cruciate ligament also may be involved. Both medial and lateral collateral ligament strains may demonstrate tenderness around the involved ligament. It should be emphasized that if the ligament is completely torn, laxity of the knee with medial (varus) and lateral (valgus) knee stress will be noted on exam. Evaluation is enhanced if the knee is examined both in full extension with 20-30° of flexion.

The acute injury should be treated with immobilization, ice, and decreased weight-bearing. Referral to an orthopedic surgeon for management of rehabilitation is appropriate. Lateral collateral ligament sprains are far less common, probably because it is more difficult for skiers to catch an outside edge at high speed. Consequently, this injury accounts for about 4% of all knee sprains.[28,30]

Anterior Cruciate Injuries. During early surveys of skiing injuries, only 7% of knee sprains involved the anterior cruciate ligament (ACL).[29] However, as a result of improved bindings and boots designed to protect the *tibia*, ACL injuries have rapidly increased in incidence and now account for more than 33% of all skiing injuries.[7] In fact, the ACL is now the most frequently injured part of the lower extremity.

As might be expected, this injury is produced when the skier hyperextends the knee and stresses the ACL. Typically, this mechanism of injury is encountered in the following ski-related movements: 1) When the skier catches the inside edge of the ski with the tip pointed outward and continues traveling forward.[13,14] This rotates the skier's knee internally and places valgus (lateral) stress on the knee. In this case, the medial collateral ligament and the medial meniscus may also be involved. 2) When the skier sits down to stop or regain control of forward motion. This is a common technique used by less-experienced skiers. In this case, a single ski may slide forward and the other knee flexes. The boot top forces the tibia forward, and the ACL is torn by anterior "drawer" loading. 3) When the skier lands on the tails of the skis from a jump or fall and one of the skis shoots forward. This is analogous to the novice's stopping technique and also forces the tibia forward and stretches the ACL. Finally, "isolated" ACL injuries may also occur with these mechanisms, which tend to occur when the skier is wearing high and stiff boots.

It should be stressed the ACL tear may be a very subtle injury; consequently, the emergency physician must carefully consider an ACL whenever the patient presents with knee pain after skiing. The skier will often describe both feeling and hearing a "pop" in the knee during the injury. Immediately following the accident, a joint effusion is often found on physical examination and, if aspirated, it will usually be bloody. In fact, the presence of a rapidly evolving effusion after a fall while skiing is associated with a 75% or greater chance of an ACL sprain.[31,32] An anterior "drawer" sign also may be positive. This test is performed on a supine patient. The hip is bent at a 45° angle and the knee is bent to 90°. The foot should be immobilized by sitting on it. The calf is pulled forward while the examiner palpates the anterior knee. Anterior motion of the tibia is found with an ACL injury.

There is substantial controversy regarding treatment of ACL injuries. Generally, ACL injuries are most often treated with surgical repair and may involve a protracted recovery period. Rarely, ACL injuries result in permanent disability of the skier. Emergency treatment of the injury is immobilization, ice, and relief of pain, followed by prompt orthopedic referral.

Posterior Cruciate Injuries. Only 1% of knee sprains are posterior cruciate ligament injuries.[33] These injuries most frequently occur when the skier hits a fixed object with knee flexed.

Meniscus Injuries. About 7% of knee injuries involve the meniscus.[33] Patients with these injuries often present with complaints of intermittent locking or giving way of the joint. Pain, clicks, and effusions are also associated with these injuries. Meniscal tears may occur without any other significant knee injury. These isolated meniscal tears may occur when an aggressive skier lands during mogul skiing or jumping over small hills. In many cases, the skier doesn't even fall. Orthopedic consultation and arthroscopy will improve diagnostic accuracy.

Patellar Injuries. Lateral dislocations of the patella occur when the skier catches the inside edge of the ski and externally rotates the leg. Contraction of the quadriceps muscle forces the patella laterally and out of the femoral groove. Diagnosis and treatment of this injury are straightforward. The patella may be relocated with medial pressure and passive extension of the knee. Immobilizing the knee in a cylindrical plaster cast for four weeks has been advocated. In most cases, a knee immobilizer is sufficient.

As with dislocation of the patella, treatment of patellar fracture requires routine immobilization of the knee. The clinician should exclude complete disruption of the patellar ligament by having the patient lift the straightened leg off of the bed. Inability to perform this motion usually means that the patient will require urgent surgical repair.

Ski-Related Injuries of the Upper Extremity

Equipment improvements have made the sport far safer for the ankle and lower leg. Unfortunately, the upper extremity and hand have not had the same protection.

Skier's Thumb. The term "skier's thumb" has been used since 1981 to denote a tear of the ulnar collateral ligament of the metacarpophalangeal joint of the thumb.[34] Prior to 1981, this injury was often called a gamekeeper's thumb, which was a chronic laxity rather than an acute injury.[35] In any event, a tear of the ulnar collateral ligament of the metacarpophalangeal joint of the thumb may be the most common injury sustained in skiing, with a reported incidence of up to 9% of all skiing injuries.[35,36] On indoor (dry) training slopes, as many as 70% of all injuries sustained are to the hand and thumb.[37]

Various mechanisms of injury have been proposed to explain ulnar collateral ligament injuries in skiers.[38] In general, however, it is agreed that these injuries occur when the skier sustains forced abduction of the thumb, which, in the context of skiing, is most likely to occur when the skier attempts to break a fall with an outstretched hand while the hand is still interlocked with the ski pole and strap. Alternatively, this injury may also occur when the skier strikes the ground or has the thumb entangled in the strap,[39] in which case the pole, ground, or strap will push the thumb backward and outward. In the process, the ligament will be stretched, torn, or avulsed from the base of the first phalanx.

When the thumb is examined, the clinician will note tenderness over the ulnar collateral ligament. If the ligament has been displaced, there may be a bulge over the site of the ulnar collateral ligament. The physician should be gentle when examining sprains of the ulnar collateral ligament since the ligament may be further displaced by a vigorous examination and, in rare cases, may subject the patient to surgery. Prudent care dictates that an x-ray of the thumb be obtained in *all* thumb sprains, even if they appear minor. A fracture may be associated with the sprain in up to 30% of cases.[40] Surgery is required if the fracture is significantly displaced or if it involves a significant portion of the articular surface.

A significant complication results when the ulnar collateral ligament is *completely torn and displaced*. In some cases, the torn end may be displaced outside of the adductor aponeurosis. When the thumb heals in this position, the patient develops a pinch grip instability. This complication is called a Stener's lesion and must be surgically reduced.[41] Unfortunately, there is

Table 2. Classification of Skier's Thumb[80,81]

INJURY CLASSIFICATION	FINDINGS	TREATMENT
Grade 1	Pain without instability of UCL on stress testing	Symptomatic treatment, protect the thumb from re-injury
Grade 2	Instability on stress testing with a firm endpoint Undisplaced or chip fracture	Cast for 2-4 weeks and follow-up with orthopedic surgeon
Grade 3	Instability on stress testing with a firm endpoint Displaced fracture fragments	Immediate referral to orthopedic surgeon

Adapted from: Rettig AC, Wright HH. Skier's thumb. *Phys Sports Med* 1989;17:65-75; Rettig AC, Wright HH. Skier's thumb. *Phys Sports Med* 1989;17:65-75.

no generally accepted nonsurgical method that will distinguish an undisplaced, torn ulnar collateral ligament from one that has significant displacement.[42]

Probably the best diagnostic technique is stress examination of the ligament. The normal amount of lateral motion of the metacarpophalangeal joint ranges from 0-30° in extension. With the joint in full flexion, there is an average of about 1° of radial deviation.[42] It is important to examine the uninvolved thumb and note whether the skier has had an injury to the uninvolved thumb. To test the integrity of the ulnar collateral ligament, first stabilize the metacarpal with the thumb and index finger. Then apply radial stress to the distal phalanx. This should be checked with the thumb both flexed and fully extended. When the thumb is fully flexed, the ulnar collateral ligament is assessed. When the thumb is fully extended, the accessory collateral ligament and the volar plate are tested. The injury may be graded from 1 to 3. *(See Table 2.)*

If the patient wishes to continue skiing with a grade 1 injury, a thumb spica splint should be molded to fit around the ski pole to prevent any further damage. The patient may remove the splint daily and use ice and range-of-motion exercises. An unstable injury should not be treated in this manner. If the patient has significant pain or swelling, then more conservative therapy is indicated.

A thumb spica cast is used for patients with either an incomplete tear or an avulsion fracture. After adequate immobilization in a thumb spica splint, these patients should be referred to an orthopedic surgeon familiar with this injury. A delay of more than three weeks before surgery increases the risk of diminished thumb function.[5] Treatment of a serious (grade 2 or 3) injury is either surgical repair or immobilization in a thumb spica cast. Surgical repair is usually reserved for those with displaced fractures and completely torn ligaments (grade 3). These patients should be referred on an immediate basis to an orthopedic surgeon for further management.

Shoulder Injuries. The most common type of shoulder injury sustained in downhill skiing is the anterior dislocation (52%), followed by rotator cuff tears (20%).[43] *(See Emerg Med Rep 1995;16:95-104 on shoulder injuries.)* Acromioclavicular separations account for an additional 18% of shoulder injuries.[43] *(See Table 3.)* Two different mechanisms of injury account for these dislocations. Most (60%) have the arm externally rotated and forcibly abducted; the ski pole is implicated in 50% of these hyperabduction shoulder injuries.[3,4] About 40% of patients fall directly onto the shoulder and sustain a dislocation from this mechanism.[43] Ten percent of shoulder dislocations have a minimally displaced fracture of the greater tuberosity.[4,5] Dislocations are best managed with immediate reduction. The patient should be carefully examined for associated fractures and upper extremity neurological problems.

Rotator Cuff Tears. Rotator cuff tears occur when the skier falls on his or her side with the arm in abduction to ward off the impact from a fall. Since partial rotator cuff tears are not always easy to diagnose, these injuries are probably underreported. However, they are more likely to occur in older patients (40 years or older) and in patients who have had a previous shoulder injury. The most important physical finding elicited in a rotator cuff tear is the inability to actively abduct the arm.

Acromioclavicular (AC) Separation. Patients who sustain an AC separation universally describe a fall directly on the point of the shoulder. Physical findings and treatment of AC separations are unchanged from any other mechanism that produces these injuries. Fractures of the area around the shoulders are relatively rare. The most common ski fracture of the shoulder is a fracture of the greater tuberosity, usually minimally displaced. This may occur when the patient falls on the elbow and the force is directly transmitted to the shoulder. Fractures of the clavicle may occur from direct trauma to the area.

Clavicle Fractures. Clavicle fractures result from direct trauma to the clavicle or from falls on the outstretched arm. If the skier falls with the ski pole held diagonally across the body, then the pole may produce impact against the clavicle and fracture it. Neither the diagnosis nor the treatment differ from usual management of clavicle fractures associated with other causes.

Table 3. Incidence of Shoulder Injuries in Downhill Skiing

INJURY	INCIDENCE
Anterior dislocation	52%
External rotation and abduction from the ski pole	*60%*
Direct fall on the shoulder	*40%*
Rotator cuff tear	20%
Direct impact (AC separation)	18%
Fractures	4%

Adapted from: Weaver JK. Skiing-related injuries to the shoulder. *Clin Orthop Rel Res* 1987;216;24-29.

Snowboarding Injuries

Snowboards are large, flat boards that resemble oversized skateboards. They vary from about 140-190 cm and are about 30-40 cm wide. The skier is firmly fixed to the board in non-releasable boots and bindings. The front foot is set at 45° to the board, and the rear foot is positioned perpendicular to the board. Snowboard riding techniques are similar to those of surfing and skateboarding. The rider's weight is mostly over the front foot and turns are made by shifting weight and swinging the back end of the board around and then setting the edges.

Most snowboarders are well-conditioned males with an average age of about 21 years.[44] The most common mechanism of injury is direct impact of the rider against the slope. Typically, the full impact of the fall is absorbed by the upper extremities, a mechanism that can produce damage to the shoulder, elbow, wrist, or hand. If the lower extremity is injured, the front leg is involved in about 75% of cases.[44] Because both feet are fixed to the same board, far fewer torsion injuries to knee and ankle are found. Snowboarders are also less likely to sustain lacerations, boot-top contusions, and thumb injuries. Unfortunately, they are more likely to have buttock contusions, spinal injuries, and distal radius fractures than downhill skiers.[45]

Ulnar collateral ligament injuries also are far less frequent. The most common non-impact injuries to snowboarders are caused by hyperdorsiflexion of the ankle as the rider falls forward.[45] This can cause Achilles tendon and gastrocnemius injuries. The rider is also more likely to sustain hyperplantarflexion foot and inversion and eversion ankle injuries, since these individuals are falling with a soft boot that is rigidly fixed to the board. Hard-shelled boots or inserts as well as ankle supports help to prevent these injuries.

Cross-Country Skiing Injuries

In general, cross-country (Nordic) skiing can be performed wherever there is snow. Downhill skiing, on the other hand, requires a lift up the slope before skiing down it. This lift requirement limits the areas servicing alpine skiers to those around resorts. In contrast, the cross-country skier can travel to quite isolated areas. For this reason, there are significant differences in both skiing styles and equipment favored by these two types of skiers.

In spite of the growing interest in Nordic skiing, there is much less documentation in the literature about the injuries that can be sustained by the cross-country skier. There are several reasons for this paucity of literature. It is suspected that cross-country skiers are injured less frequently than their alpine counterparts, and that these injuries are often less severe. Unfortunately, if under-reporting is a problem when the alpine skier is injured at the resort, it is far worse for injuries resulting from cross-country skiing.

Cross-country skiers are often superior athletes. Nordic skiing is "real work." Caloric expenditures for cross-country skiers range from 0.098 Kcal/min/kg for leisurely skiing on level ground to 0.274 Kcal/min/kg for maximal uphill skiing on hard snow.[46] This corresponds to an energy expenditure of 446 to 1244 Kcal per hour for the standard 70 kg body weight.[47] Athletes at this level of experience and conditioning often will take care of their minor injuries with self-care. These well-conditioned athletes will often not be involved in the same kind of accidents that afflict less-conditioned novices.

Risk Factors. In the few reports that are available, it appears that cross-country skiers are injured at one-tenth the rate seen in downhill skiers.[48] Generally speaking, more gentle slopes are used by Nordic skiers than are used by alpine skiers. Nevertheless, injuries from Nordic skiing are becoming more severe than in the past, in large part because of the popularity of faster, more rigid skis and heel fixation devices that give more edge control.[48] In many respects, the modern Nordic skier has merely replicated injury patterns observed in alpine skiing prior to the extensive development of safer equipment. Heel fixation devices, lower boots, and more rigid skis used in Nordic skiing are similar to those used by downhill skiers 20-30 years ago, but permit faster speeds than these skiers were able to achieve.

Not surprisingly, 88% of all acute injuries to cross-country skiers occur on downhill terrain.[49,50] Telemark skiing, a downhill variant of cross-country skiing, brings the skier full circle to downhill skiing with older-style bindings and lower boots. Cold injuries comprise about 20% of reported injuries,[51] an incidence much higher than found in alpine skiers, probably due to the remote terrain sought by cross-country skiers.

The most common fatalities associated with cross-country skiing are from avalanche and hypothermia.[52] To all of these troubles must be added the problem of evacuation. Since many cross-country skiers seek remote areas for their avocation, this is often a major problem. These skiers, unlike those found in alpine resorts, do not have the services of a paid or highly trained volunteer ski patrol for evacuation and care.

Overuse Injuries. Since cross-country skiing is "real work," most cross-country skiing injuries are due to overuse.[51]

Diagonal Stride Overuse Injuries. With the classic stride (also called the diagonal stride), the most common overuse syndromes are shin splints, Achilles tendinitis, and low back pain.[7] Since this is the most common stride used by recreational skiers, these injuries are most often encountered in the less-conditioned skier.

Skating Overuse Injuries. A “freestyle” or skating stride is often used by racing skiers. Freestyle skiers or those using a skating technique will have more trouble with the adductors and internal rotators of the hip.[53,54] The anterior and medial compartment muscles of the lower leg will also be stressed.[55] Longer ski poles put additional stress on the wrist and carpal tunnel, increasing the incidence of extensor tendinitis and carpal tunnel syndrome.

Skier’s Toe. Increased stress to the flexor hallucis longus muscle during the pushoff part of the skating technique (dorsiflexion of foot) can cause a stress injury. This injury of the flexor hallucis longus muscle is termed “skier’s toe.”

Most of these injuries are neither reported nor come to formal medical attention, and treatment is simple: Reduce the stress by decreasing the intensity or duration of the exercise; apply ice to the area for 10-20 minutes after the exercise. Stretching and strengthening exercises are often helpful. NSAIDs will both reduce the inflammation and relieve the pain in acute injuries.

Lower-Extremity Injuries. The knee is the joint injured in about 31% of cross-country ski injuries.[49] Since the ankle remains free, the number of ACL injuries is lower, but the medial collateral ligament is injured more frequently.[56] Heel fixation with cross-country bindings increases the number of twisting, lower extremity injuries. With these devices, sprains of the ankle are common. Fortunately, cross-country skiing is not associated with the high incidence of ankle fractures described with older skiing equipment. This may change as Telemark skiing gains popularity.

Upper-Extremity Injuries. Upper extremity injuries associated with cross-country skiing can be divided into overuse injuries and injuries due to falls.

Upper-Extremity Overuse Injuries. As noted earlier, cross-country skiers have an increased incidence of both extensor tendinitis of the wrist and carpal tunnel syndrome. This is thought to be due to the high position of the wrists when using properly adjusted Nordic ski poles. Ulnar collateral ligament sprains of the thumb occur in the same manner as described for alpine skiers and are the single most common hand injury.[56]

Falls. The most common shoulder injury encountered in cross-country skiing accidents is anterior shoulder dislocation. Shoulder dislocations are usually caused by catching the arm or pole in underbrush as the skier passes by. The arm is then forced into abduction and external rotation with resultant dislocation.

Treatment of this injury in the field is a dilemma. Most providers are simply not adequately trained in how to reduce a dislocated shoulder. On the other hand, the injured skier, especially in the remote wilderness, is a distinct liability. Probably, a single attempt at shoulder reduction in the field by an appropriately trained provider is reasonable. If this is not successful, repeated attempts without x-ray are unlikely to be beneficial. The patient should be transported to a medical facility. Acromioclavicular separations are usually caused by direct trauma and are the second major shoulder injury found in the Nordic skier.[56]

Ski Jumping

Although ski jumping is quite spectacular and gives the appearance of being very dangerous, it has a surprisingly low injury rate.[57] Injury rates for non-World Cup competitions and World Cup competitions were 4.3 and 1.2 injuries per 1000 skier days, respectively.[57] Ski jumpers tend to be young, aggressively trained athletes in outstanding physical condition. The sport is rigidly controlled, and those who have not been properly trained essentially are not allowed on the jump. These well-supervised conditions result in exceptionally low injury rates. Moreover, the jump is controlled so that the skier lands on the steep downhill portion of the hill. As long as the jumper lands in this part of the hill, the kinetic energy can be dissipated by sliding. On the other hand, if the fall is very long or very short, the jumper can be badly injured by a failed jump.

Ten percent of ski jump injuries involve visceral organ damage due to the impact.[57] The most common injuries are contusions, abrasions, and dislocations, primarily of the shoulder. Fractures account for about 15% of the total injuries, most of which involve the upper extremity injuries.[57]

Sledding

Generally considered to be a benign winter sport,[58] downhill sledding is a common recreational activity for children and adults. Sledders may use commercial sleds, toboggans, or saucers, and makeshift cardboard boxes or inner tubes can be recruited. Injury statistics suggest that younger people are at higher risk for injury.[59] Since this is a traditional children’s sport, younger children are often supervised by only slightly older children. Poor judgment is commonly implicated in cited injuries. Children will often choose a “quiet” street on a hill for their course with potentially disastrous results if a vehicle is on the street at the wrong time.[60]

Sledding and tobogganing require relatively little snow. A sunny day followed by a cold night may produce a fast course on icy slopes with hard ground. During icy conditions, the rider may have high-velocity impacts with hidden obstacles such as rocks, stumps, and moguls.

The most common injuries are lacerations, followed by contusions and strains. The standard sled can be steered when ridden in the prone position. This is the most common position of riding. The rider can also sit upright and control steering with the feet. When the rider is prone, head and facial injuries are more common.[61] *(See Emerg Med Rep 1995;16:59-70 on facial trauma.)*

Serious injuries occur in as many as 21% of sledding injuries.[62] Abdominal injuries result from bumps or after impact with the ground. When the rider sits erect, the spine is more susceptible to hyperflexion injuries.

Toboggan injuries usually produce injury to the lower extremities. Toboggans and inner tubes are ridden in the seated position, with riders often leaning forward with their back arched. It is thought that this position enhances the likelihood and severity of a spinal injury. Even more life-threatening injuries have been reported in tubing than in tobogganing.[59,63] It is possible that these devices can be made somewhat safer for our children. Steerable devices, such as sleds and toboggans, are safer than nonsteerable devices, such as saucers, tubes, or cardboard boxes. Finally, a bicycle helmet may provide impact protection while riding a sled in the prone position.

Summary

Winter sports are associated with a distinct spectrum of orthopedic injuries. Diagnosis of these injuries is facilitated by recognizing specific mechanisms of injury and performing appropriate radiographic studies. In general, treatment is similar to that required for fractures, strains, and ligamentous tears seen in non-skiing injuries. Finally, prevention of these injuries is possible if newly developed equipment is used appropriately.

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Physician CME Questions

81. Cold injuries comprise about what percentage of reported cross-country ski injuries?
    A. 5%
    B. 20%
    C. 50%
    D. 75%
    E. 90%

82. Overuse injuries comprise about what percentage of reported cross-country injuries?
    A. 10%
    B. 20%
    C. 30%
    D. 40%
    E. 75%

Annual Statement of Ownership, Management, and Circulation

Postal Bulletin 21875, 9-1-94, Page 17

UNITED STATES POSTAL SERVICE

Statement of Ownership, Management, and Circulation
(Required by 39 U.S.C. 3685)

1. Publication Title	2. Publication No.	3. Filing Date
Emergency Medicine Reports	0745-2506	9/30/95
4. Issue Frequency	**5. No. of Issues Published Annually**	**6. Annual Subscription Price**
Bi-Weekly	26	$219.00

7. Complete Mailing Address of Known Office of Publication *(Street, City, County, State, and ZIP+4) (Not Printer)*
3525 Piedmont Road, Bldg. 6, Ste. 400, Atlanta, Fulton County, GA 30305

8. Complete Mailing Address of Headquarters or General Business Office of Publisher *(Not Printer)*
3525 Piedmont Road, Bldg. 6, Ste. 400, Atlanta, GA 30305

9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor *(Do Not Leave Blank)*
Publisher *(Name and Complete Mailing Address)*
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Editor *(Name and Complete Mailing Address)*
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Page 18, 9-1-94, 21875 *Postal Bulletin*

13. Publication Name	14. Issue Date for Circulation Data Below	
Emergency Medicine Reports	September 18,1995	
15. Extent and Nature of Circulation	**Average No. of Copies Each Issue During Preceding 12 Months**	**Actual No. Copies of Single Issue Published Nearest to Filing Date**
a. Total No. Copies *(Net Press Run)*	6960	7519
b. Paid and/or Requested Circulation (1) Sales Through Dealers and Carriers, Street Vendors, and Counter Sales *(Not Mailed)*	418	452
(2) Paid or Requested Mail Subscriptions *(Include Advertisers' Proof Copies/Exchange Copies)*	5849	6322
c. Total Paid and/or Requested Circulation *(Sum of 15b(1) and 15b(2))*	6267	6774
d. Free Distribution by Mail *(Samples, Complimentary, and Other Free)*	45	45
e. Free Distribution Outside the Mail *(Carriers or Other Means)*	0	0
f. Total Free Distribution *(Sum of 15d and 15e)*	45	45
g. Total Distribution *(Sum of 15c and 15f)*	6312	6819
h. Copies Not Distributed (1) Office Use, Leftovers, Spoiled	648	700
(2) Return from News Agents	0	0
i. Total *(Sum of 15g, 15h(1), and 15h(2))*	6960	7519
Percent Paid and/or Requested Circulation *(15c / 15g x 100)*	99	99

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83. Skiing injuries have decreased over the past few years. All of the following factors have contributed to this increased safety *except:*
    A. slope grooming.
    B. multiple-angle release bindings.
    C. high, rigid plastic boots.
    D. longer skis.

84. The most common ski injury seen today is:
    A. spiral fracture of the tibia.
    B. anterior dislocation of the shoulder.
    C. knee ligament strains.
    D. patellar dislocation.
    E. peroneal tendon dislocation.

85. When do most ski injuries occur?
    A. Early in the morning
    B. At night
    C. About suppertime
    D. early in the afternoon

86. In children, the most common type of ski injury is:
    A. fracture of the clavicle.
    B. ligament sprain.
    C. tendon rupture.
    D. contusions.

87. What is the most common injury sustained by a snowboarder?
    A. ACL knee injury
    B. Ulnar collateral ligament injury
    C. Direct impact injury
    D. Shoulder dislocation
    E. Eversion ankle injury

88. Sledding injuries involve a *serious* injury to the sledder approximately what percentage of the time?
    A. 20%
    B. 50%
    C. 70%
    D. 90%

In Future Issues:

Non-MI Chest Pain

Emergency Medicine Reports™ (ISSN 0746-2506) is published biweekly by American Health Consultants, 3525 Piedmont Road, N.E., Six Piedmont Center, Suite 400, Atlanta, GA 30305. Telephone: (800) 688-2421 or (404) 262-7436.

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GST Registration No.: R128870672

Second-class postage paid at Atlanta, GA. **POSTMASTER:** Send address changes to ***Emergency Medicine Reports***, P.O. Box 740059, Atlanta, GA 30374.

Back issues: $15

Subscriber Information

Customer Service: 1-800-688-2421

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