Ankle Injuries in the Pediatric Emergency Department

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Abstract: Ankle injuries are a common reason for presentation to the pediatric emergency department. An understanding of the anatomy of the ankle joint, the mechanism of injury, and a thorough history and physical examination can help narrow the differential diagnosis. This article will discuss the management of common ankle injuries, including ankle sprains, dislocations, and pediatric fractures, including transitional triplane and Tillaux fractures. A brief review of the literature regarding radiographic evaluation of the ankle and various ankle rules is also discussed.

Key Words: ankle sprain, ankle fracture, ankle dislocation, Tillaux fracture, triplane fracture

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TARGET AUDIENCE

This CME activity is intended for all practitioners who care for pediatric patients presenting to the emergency department with ankle injuries, including general pediatricians, pediatric emergency medicine physicians, general emergency physicians, pediatric intensive care physicians, advanced practice providers, and orthopedic surgeons.

LEARNING OBJECTIVES

After participating in this activity, the reader should be better able to:

1. Explain the epidemiology and pathophysiology of ankle injuries in children.
2. Describe the emergency department presentation, examination, and evaluation of common ankle sprains and fractures.
3. Identify the acute management for ankle injuries, including sprains, fractures, and dislocations.

Ankle injuries account for 2 million pediatric emergency department (ED) visits annually in the United States and Canada.[1] Sports participation is associated with a significant number of ankle injuries, including nearly half of all ankle sprains.[2] The age range and peak incidence of ankle sprains varies by sex; males have a peak incidence between 15 and 19 years of age at 8.9 per 1000 persons per year, and females have a peak incidence between 10 and 14 years of age at 5.4 per 1000 persons per year.[2] High ankle sprains have the lowest incidence in patients younger than 18 years (1 per 100,000 persons per year[3]) and only account for about 1% of pediatric ankle injuries.[4] Specific risk factors for high ankle sprain include sports that involve collisions or rapid direction changes from cutting and pivoting (eg, soccer, football, rugby, basketball, handball, lacrosse) or sports involving rigid immobilization of the ankle (eg, hockey, skiing).[5–7] Ankle fractures are among the top 3 most common physeal fractures,[8] with an incidence of 1 per 1000 persons per year.[9] Risk factors for ankle fracture include specific activities (eg, trampolines, scooters, soccer, basketball, skating, skiing), high-energy trauma, and elevated body mass index in skeletally immature patients.[8]

ANATOMY AND PATHOPHYSIOLOGY

The ankle joint consists of the tibia, the fibula, and the talus. These bones are stabilized laterally by the anterior talofibular ligament (ATFL), the posterior talofibular ligament, and the calcaneofibular ligament (CFL) and medially by the deltoid ligament (Fig. 1). The ankle is further stabilized by the tibiofibular syndesmosis, which is made up anteriorly by the anterior tibiofibular ligament, posteriorly by the posterior tibiofibular ligament, and between the tibia and fibula by the transverse tibiofibular ligament and the interosseous ligament.

In skeletally immature pediatric patients, these ligaments attach to the relatively weaker epiphysis of the tibia and fibula, leading to an increased risk of fractures rather than ligamentous sprains. Fractures involving the physis of a long bone are classified according to the Salter-Harris system (Fig. 2). Of note, Figure 2 includes the Salter-Harris VI fracture type, which is rare and involves the peripheral region of the physis.[10] This fracture type can result from severe, open avulsion injuries (such as from the blades of a lawnmower) or from closed, minimally displaced fractures that disrupt the peripheral aspect of the physis.[11]

HISTORY AND PHYSICAL EXAMINATION

Obtaining a pertinent history can help in determining the risk for severe ankle injury. The acute injury history includes the time of injury, mechanism of injury, ability to bear weight after the injury, the therapies attempted before presentation (eg, medications, ice, compression, immobilization), and the result of these therapies. Further history should include leg dominance (if present), history of previous sprains/fractures/surgeries of the same ankle, and medical history, including connective tissue disorders such as Ehlers-Danlos or Marfan syndromes.

A thorough physical examination of the ankle begins by visualizing the lower leg, ankle, and foot for edema, bruising, obvious deformities, or skin lesions. Palpate the posterior tibial and dorsalis pedis pulses and check the capillary refill in the toes. Next, palpate for point tenderness and crepitus along the bones, including the metaphysis of the tibia and fibula, the physes, the malleoli, and the tarsal and metatarsal bones, as well as the supporting ligaments. Check the passive and active range of motion of the ankle joint, including dorsiflexion, plantarflexion, inversion, and eversion. Observe ambulation, which may be limited because of acute pain, for gait abnormalities. Perform a sensory examination to light touch distal to the injury. The physical examination should include the uninjured side for comparison.

Examination for instability includes the anterior drawer and talar tilt inversion and eversion tests (Fig. 3). The anterior drawer test assesses the integrity of the ATFL. Place the heel in the palm of examiner's dominant hand and use the nondominant hand to

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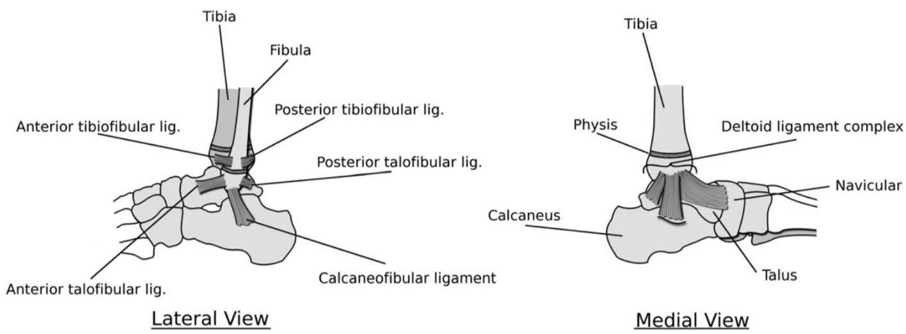

FIGURE 1. Ankle anatomy. Reprinted from Blackburn EW, Aronsson DD, Rubright JH, et al. Ankle fractures in children. *J Bone J Surg Am.* 2012;94:1234–1244, with permission from Wolters Kluwer Health. Available at https://journals.lww.com/jbjsjournal/Fulltext/2012/07030/Ankle_Fractures_in_Children.13.aspx.

stabilize the distal tibia and fibula. Gently, but firmly, move the heel and slightly plantarflexed foot forward. The test is positive if there is more anterior displacement when compared with uninjured ankle. The inversion talar tilt test assesses lateral ankle stability, including the ATFL and CFL. The distal tibia and fibula are stabilized by the examiner's nondominant hand while the dominant hand firmly inverts the heel to assess for increased laxity or instability compared with the uninjured ankle. Both the ATFL and CFL must be torn to cause gross ankle instability with this maneuver. The eversion talar tilt test is like the inversion tilt test but assesses for integrity of the deltoid ligament. Firmly evert and abduct the heel while stabilizing the distal tibia. Compare stability to the contralateral uninjured ankle. Talar tilt tests are positive if there is increased laxity compared with the uninjured side. Unfortunately, laxity tests such as these may not be reliable in the first 48 hours after acute ankle injury because of swelling and pain.[12]

The squeeze test can be performed to evaluate injury to the tibiofibular syndesmosis. Apply a compressive force to the tibia and fibula at the midcalf while assessing for pain at the ankle syndesmosis. No single physical examination finding can accurately and reliably diagnose a syndesmotic injury,[13] but this test can provide additional evidence to raise suspicion for an injury to the syndesmosis.

The localization of pain can be difficult in young children. Pain originating anywhere along the tibia, fibula, or the foot may refer to the ankle. It is important to remember the adage "examine a joint above and a joint below" in young children to avoid missing injuries with referred pain.

DIFFERENTIAL DIAGNOSIS

Understanding the mechanism of an acute ankle injury can help identify the cause. As noted previously, fractures are more common in skeletally immature patients because of the relatively weaker physis. Inversion injuries in skeletally immature patients most commonly result in a less severe Salter-Harris I fracture or avulsion fracture of the distal fibula but in severe cases can also include the medial malleolus in a Salter-Harris III or IV fracture of the distal tibia.[14] In comparison, eversion injuries to the ankle in skeletally immature patients are more likely to result in a fracture pattern including a Salter-Harris II fracture of the distal tibia as well as a transverse fracture of the fibula.[14]

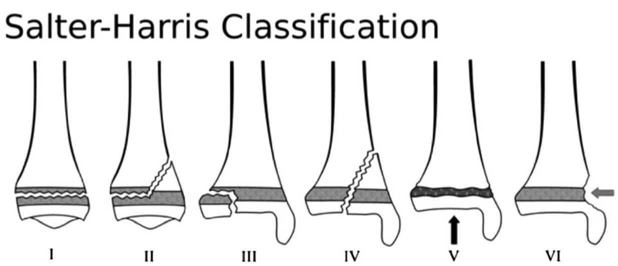

FIGURE 2. Salter-Harris classification of physeal fractures. Modified and reprinted from Blackburn EW, Aronsson DD, Rubright JH, et al. Ankle fractures in children. *J Bone J Surg Am.* 2012;94: 1234–1244, with permission from Wolters Kluwer Health. Available at https://journals.lww.com/jbjsjournal/Fulltext/2012/07030/Ankle_Fractures_in_Children.13.aspx.

In skeletally mature patients, inversion injuries are more likely to result in a lateral ankle sprain.[15] Most commonly, patients present with tenderness over the ATFL. It is possible to have a sprain of the deltoid ligament medially with an eversion injury, but this is not common because of the anatomic limitations of eversion. Ankle sprains are graded based on severity: grade I sprains are due to mild stretching of the ligament without macroscopic changes, grade II sprains include a partial tear of the ligament, and grade III sprains involve complete rupture of the ligament.[16] However, grading a sprain based on abnormal laxity may be difficult in the first 48 hours because of pain and swelling.[12]

High ankle sprains result from excessive external rotation of the ankle, often when the ankle is in dorsiflexion.[15] These ankle sprains can result from injury to the anterior or posterior tibiofibular ligament, the transverse tibiofibular ligament, or the interosseous ligament. Syndesmotic injuries are classified into stable or unstable injuries based on the presence of diastasis of the tibiofibular joint, which may be latent.[17] Of note, syndesmotic injuries can also be associated with fractures of the fibula, including a fracture of the proximal fibula in the Maisonneuve fracture or fractures of the posterior and medial malleoli.[16]

Other traumatic etiologies of acute ankle pain may include soft tissue contusions, bone contusions, tibiotalar dislocation, hemarthrosis, pathologic fractures, or Achilles tendon rupture. Nontraumatic causes of ankle pain to consider include infectious etiologies such as septic joint, osteomyelitis, and soft tissue abscess; inflammatory etiologies such as tendonitis, synovitis, and apophysitis; hematologic and oncologic etiologies such as sickle cell pain crisis, deep vein thrombosis, Ewing sarcoma, and osteoid osteoma; cardiac or renal etiologies resulting in fluid overload; and rheumatologic etiologies such as juvenile idiopathic arthritis, rheumatic fever, and reactive arthritis.

INITIAL EVALUATION

The initial evaluation of patients presenting with acute ankle injuries to the ED includes a focused history and physical as previous. Pain management is patient and injury dependent; options include ice, immobilization, acetaminophen, ibuprofen, or opiates. For obvious deformities or patients in severe pain, intranasal or intravenous analgesics administered before obtaining radiographs may facilitate image acquisition.

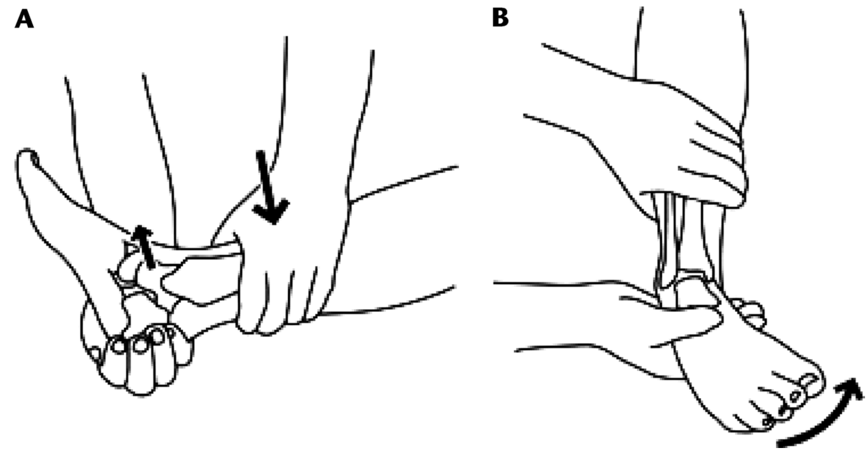

FIGURE 3. Ankle laxity testing. The anterior drawer test (A) assesses ATFL laxity, the inversion talar tilt test (B) assesses for ATLF and CFL laxity, and the eversion talar tilt test (not pictured) assesses deltoid ligament laxity. Reprinted from Polzer H, Kanz K-G, Prall W, et al. Diagnosis and treatment of acute ankle injuries: development of an evidence-based algorithm. *Orthop Rev*. 2012;4:e5 22–32, with permission via Creative Commons public license.

When Should Imaging Be Obtained in the ED?

Determining which ankle injuries are mild enough to forgo imaging to limit radiation exposure is an ongoing challenge. A careful physical examination can be difficult to perform because of an uncooperative child or a young child who struggles with localizing specific point tenderness. Multiple rules have been developed over the past few decades to stratify the risk of fracture and determine need for imaging.

Initially reported in an adult population, the Ottawa ankle rules (OAR) state that imaging for an ankle injury is required if there is pain in the malleolar zone and one of the following: (1) bone tenderness along the distal 6 cm of the posterior edge of either the medial or lateral malleolus or (2) inability to weight bear 4 steps immediately after the injury and in the ED.[18] The rules also discuss foot radiographs for midfoot pain with point tenderness over the navicular bone or the base of the fifth metatarsal. Despite the differences in skeletal maturity that can affect the incidence of fractures, the OAR have been applied to the pediatric population with reassuring results in patients older than 5 years.[19]

The low-risk ankle rules (LRAR) were developed in a pediatric population and attempted to rewrite the imaging rules specifically for children. Low-risk injuries include any child with tenderness and/or swelling isolated to the distal fibula and/or adjacent lateral ligaments distal to the tibial joint line.[20] This rule allows low-risk fractures including avulsion, buckle, and nondisplaced Salter-Harris I and II fractures of the distal fibula to forgo imaging. These low-risk fractures have been shown to have excellent outcomes with nonoperative management and splinting alone.[21]

A third set of clinical rules, the malleolar zone algorithm (MZA) was developed to maximize the sensitivity for identifying children with significant fractures after acute twisting injuries to the ankle. This algorithm states that the patient has a low risk of an ankle fracture if (1) there is no bone tenderness at either malleolus or just proximal to the fibular malleolus or (2) they are able to walk 4 steps in the ED and have no swelling at either malleolus, even if there is bone tenderness.[22]

In a single study comparing these 3 rules, the OAR are the most sensitive (sensitivity, 0.99; 95% confidence interval, 0.93–1.00) for fractures and the LRAR are the most specific (0.56; 95% confidence interval, 0.49–0.63) for fractures.[23] The implementation of these rules has varied success in decreasing radiograph use between 7% and 45%, with the LRAR having the most significant decrease.[23] The LRAR missed 13% of clinically important fractures, defined in this comparison study as any fracture other than a Salter-Harris I fracture of the distal fibula.[23] However, the aforementioned rules are meant to look for different clinically important fractures, and a clear consensus on the best rule to use for all patients and all situations remains elusive; local practice will depend on the expert opinion in your area.

Patients with obvious deformities or those identified to have high-risk ankle injuries should have plain radiographs performed, including 3 views of the ankle—anteroposterior (AP), lateral, and mortise. For younger patients or those unable to localize pain well, consider radiographs of the tibia/fibula and/or foot to rule out other injuries, which may cause referred ankle pain.

Advanced imaging such as computed tomography (CT) or magnetic resonance imaging for ankle injuries have fewer indications in the ED than plain radiographs. However, fractures involving the intra-articular surface of the ankle joint benefit from CT imaging, in consultation with an orthopedic specialist, to determine the extent of the injury and need for surgical repair.[24]

ED MANAGEMENT

Low Ankle Sprains

Patients with an examination consistent with an ankle sprain can be managed using the PRICE-FM (protection, rest, ice, compression, elevation, follow-up, and mobility/medication) acronym.[25] An air stirrup is preferred over a compression wrap because it provides protection, compression, and support.[26] Patients with severe pain may require crutches and weight bearing only as tolerated.[26] Nonsteroidal anti-inflammatory medications should be recommended for pain and swelling unless contraindications exist. For grade III sprains, a short period of immobilization may be required.[16] Many low ankle sprains can be managed as an outpatient by primary care providers, although some patients may require referral for professional rehabilitation. For athletes, the return to play timeline with lateral ankle sprains is variable and can range from 10 days to 6 weeks, depending on the severity of injury, preinjury abilities, and rehabilitation availability.[16]

High Ankle Sprains/Syndesmosis Injuries

High ankle sprains and tibiofibular syndesmotic injuries are notoriously more variable in their course. Stable tibiofibular syndesmotic

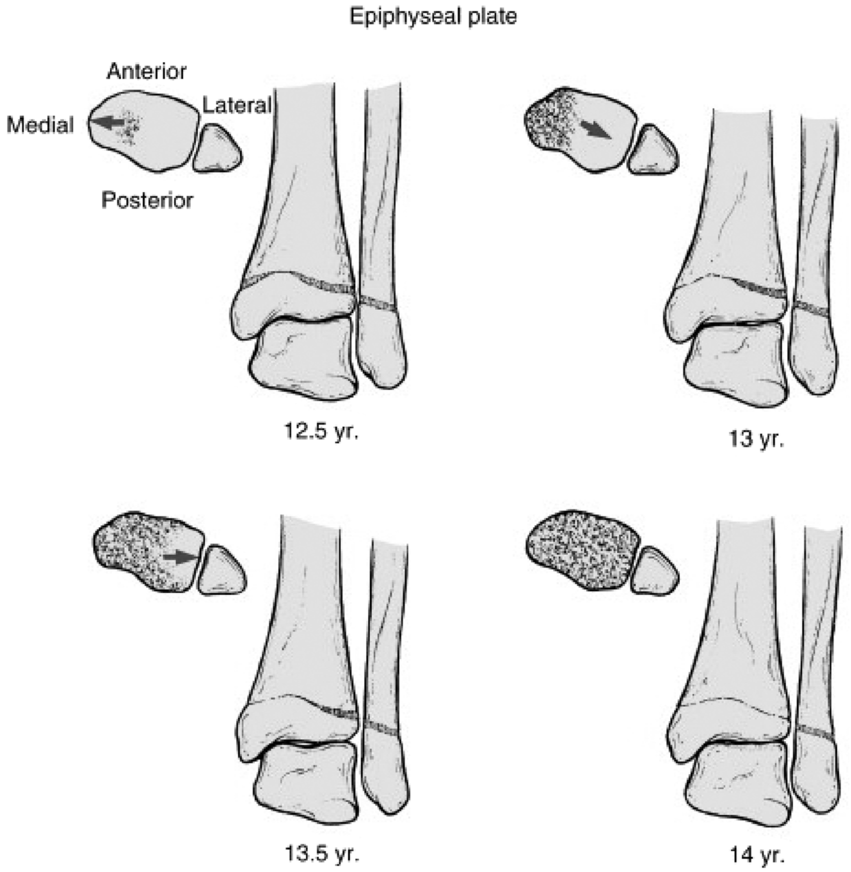

FIGURE 4. Distal tibial epiphysis closure pattern. The distal tibial physis begins closing centrally, extending medially, and finally anteriorly and laterally. Reprinted from Crawford AH, Mehlman CT, Shital PN. Fractures and dislocations of the foot and ankle. In: Mencio GA and Swiontkowski MF, *Green's Skeletal Trauma in Children e-book*. 5th ed. Philadelphia, PA: Saunders; 2015:473–542, with permission from Elsevier.

injuries can be treated like a low ankle sprain. However, the return to play timeline is 6 to 8 weeks for stable low-grade syndesmotic injuries.[16] Because of the longer rehabilitation and more variable course, patients with a stable tibiofibular syndesmotic injury may benefit from referral to an orthopedic or sports medicine specialist to follow recovery and rehabilitation. Unstable tibiofibular syndesmotic injuries require operative repair,[17] which can occur as an urgent outpatient referral.

Distal Fibula Fractures

Historically, patients with tenderness along the distal fibular physis but negative radiographs were thought to have a Salter-Harris I fracture of the distal fibula. However, a recent magnetic resonance imaging study demonstrated that only 3% of these patients had Salter-Harris I fractures, with the majority instead being ligamentous injuries (80%).[27] Furthermore, even patients with isolated distal fibular fractures were found to have a more effective recovery of ankle function and a faster return to baseline activities when treated with a removable ankle brace, crutches, and a 5-day period of non–weight bearing.[21] Treatment for patients with isolated distal fibular fractures or patients with negative radiographs despite distal fibular physeal pain can be appropriately treated the same as a low ankle sprain.

Patients who have both a distal fibula and distal tibia fracture often have a stable fibular fracture that is reduced with reduction of the tibial fracture.[28] Concurrent fractures of the distal tibia

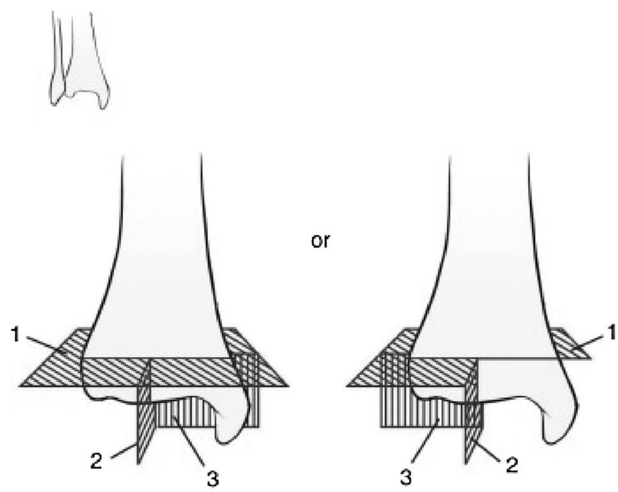

FIGURE 5. Triplane fracture planes. The triplane fracture is named for the 3 planes in which the fracture occurs—axial, sagittal, and frontal. Reprinted from Riccio AI, Wilson PL, Wimberly RL. Lower extremity injuries. In: Herring JA, *Tachdjian's Pediatric Orthopedics e-book*. 5th ed. Philadelphia, PA: Elsevier Health Sciences; 2013: 1353–1516, with permission from Elsevier.

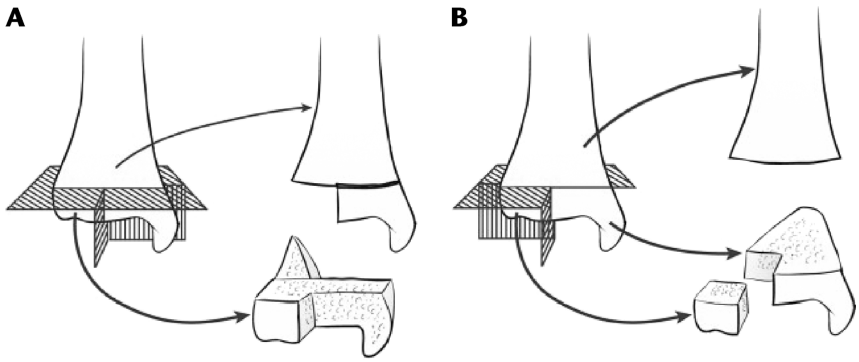

FIGURE 6. Triplane fracture patterns. Multiple fracture patterns exist and are grouped by the number of fracture fragments. Examples of the 2-part (A) and 3-part (B) fractures are shown; 4-part fracture patterns are not pictured. Reprinted from Riccio AI, Wilson PL, Wimberly RL. Lower extremity injuries. In: Herring JA, *Tachdjian's Pediatric Orthopedics e-book*. 5th ed. Philadelphia, PA: Elsevier Health Sciences; 2013: 1353–1516, with permission from Elsevier.

and fibula should be managed as discussed hereinafter under distal tibia fractures.

Distal Tibia Fractures

Ankle fracture management depends on the location, stability, and displacement of the fracture. Displaced Salter-Harris I or II fractures of the distal tibia require closed reduction. After reduction or for nondisplaced Salter-Harris I or II fractures, place a splint or cast and make the patient non–weight bearing.[28] Orthopedic consultation for these fractures is not required emergently, but close follow-up with an orthopedic provider within 1 to 2 weeks is recommended.

Displaced Salter-Harris III or IV fractures of the distal tibia also require closed reduction. After reduction or for nondisplaced Salter-Harris III or IV fractures, a cast should be placed by a trained provider. Because of the intra-articular involvement of these fractures, CT imaging may be required. Some of these fractures require operative repair, depending on the degree of articular involvement and displacement of greater than 2 mm.[28] Follow-up is determined in coordination with a pediatric orthopedic specialist.

Salter-Harris V fractures are rare and often result from severe axial compression of the physis.[8] Suspect this injury in patients with a history of a significant axial load, such as landing on their feet after a fall from a great height. The acute management depends on severity of symptoms in the ED, including careful consideration of additional injuries, such as to the lumbar spine. Initial radiographs are often normal in Salter-Harris V fractures of the distal tibia, and diagnosis usually occurs in retrospect on follow-up radiographs, which would demonstrate premature physeal closure.[8]

Salter-Harris VI fractures are also rare. Open injuries due to the blades of a lawn mower, severe burns, gunshot wounds, bicycles, or other mechanisms of skin and soft tissue avulsion require emergent orthopedic consultation, as well as potential vascular surgery, burn surgery, or plastic surgery consultations, depending on the degree of injury and the involved structures. Closed and nondisplaced Salter-Harris VI fractures are nonoperative in the acute phase but require long-term orthopedic follow-up to monitor for bony bridge formation.[11] Bony bridge formation obliterates physeal cartilage, resulting in physeal growth arrest and predisposing to angular deformity.

For any open ankle fracture, consultation with orthopedics is required, in addition to tetanus prophylaxis, if needed, and appropriate antibiotic coverage.

Transitional Fractures

During the transition from skeletal immaturity to maturity, adolescent patients are at risk for transitional fractures. The distal tibial physis begins closing centrally, extending medially, and finally anteriorly and laterally (Fig. 4).[8] Closure of the distal tibial physis takes approximately 18 months and usually begins between 12 and 15 years of age, with timing dependent on the onset of puberty and results in significant differences between males and females.[29] During the earlier phase of this physis maturation, patients are at risk of a triplane fracture of the ankle (Fig. 5), often caused by an external rotation force at the joint.[30] These 2, 3, or 4-part complex Salter-Harris IV fractures may vary in morphology depending on when during physeal closure the fracture occurs (Fig. 6).

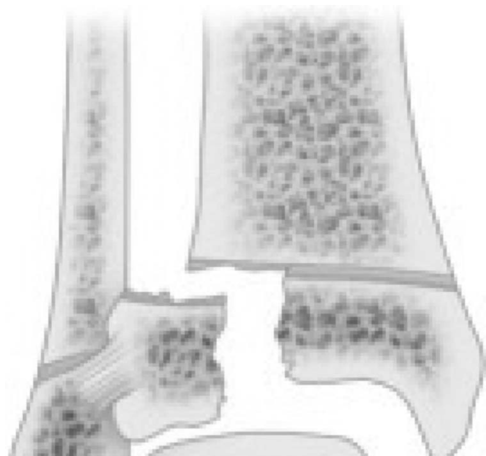

FIGURE 7. Tillaux fracture. The Tillaux fracture is a Salter-Harris III fracture of the distal tibial physis. Reprinted from Sawyer JR, Spence DD. Fractures and dislocations in children. In: Azar FM, Beaty JH, eds, *Campbell's Operative Orthopedics e-book*. 13th ed. Philadelphia, PA: Elsevier; 2016:1423–1561, with permission from Elsevier.

The Tillaux fracture pattern (Fig. 7), like the triplane fracture, is a transitional fracture of the distal tibia and occurs because of an external rotation injury.[30] These fractures occur closer to skeletal maturity and result in a Salter-Harris III fracture involving the anterolateral distal tibial epiphysis. The Tillaux fracture results from the persistent relative weakness of the anterolateral epiphysis compared with the ATFL.

Both the triplane and Tillaux fractures should undergo closed reduction and casting (long leg for triplane to prevent rotation and short leg for Tillaux[31]) by a trained provider. After reduction, a CT scan is helpful to understand the intra-articular complexity of these fractures.[24,31–33] This CT scan may be obtained in the ED before discharge or in close follow-up with orthopedic providers. Fractures with more than 2 mm of displacement will require surgical intervention (pinning or open fixation) to appropriately align joint fragments.[34]

Tibiotalar Dislocations

Tibiotalar dislocations, commonly referred to as ankle dislocations, are uncommon without fractures and often represent a high-energy trauma such as motor vehicle collisions or sports that involve jumping.[35] Tibiotalar dislocations are at risk of neurovascular compromise, which must be recognized and treated promptly. Plain radiographs before reduction may be obtained if there are no signs of vascular compromise. Reduction should be completed as quickly as possible, with sedation. For posterior dislocations, lay the patient supine with the knee flexed to relax the Achilles tendon. Grasp the foot with both hands—one on the heel and the other on the dorsum of the foot. While one assistant applies counter traction at the midproximal tibia, apply traction on the slightly plantar-flexed foot, moving the heel anteriorly. A second assistant applies downward pressure on the distal end of the tibia while the heel is moved anteriorly.[36] For anterior dislocations, patient positioning and counter traction at the midproximal tibia by one assistant is the same. However, instead of grasping the foot in plantar flexion, dorsiflex the foot to free the talus. The second assistant applies upward pressure on the distal end of the tibia while the operator applies longitudinal traction and pushes the foot in a posterior direction.[36] After reduction, splint the ankle in a long leg splint with the ankle at 90 degrees.[36] Orthopedics should be consulted immediately to aid in reduction and postreduction management, especially for fracture dislocations or for open dislocations.

COMPLICATIONS

There is a risk of decreased functional ankle mobility after any type of ankle injury, especially those resulting in prolonged immobilization. For mild injuries with shorter periods of immobilization, this risk can be minimized with range of motion exercises at home, including the use of exercise bands. Patients with more severe sprains should undergo early active range of motion exercise, as well as rehabilitation with strengthening, proprioception, and functional exercises.[16] Patients who undergo cast immobilization should be rehabilitated according to the sports medicine or orthopedic provider with whom they follow-up. Along with decreased functional mobility, fractures involving the articular surface are at risk of radiographic evidence of arthritis,[37] although functional outcomes for transitional fractures are good if residual displacement is less than 2.5 mm.[38]

Pediatric fractures present a unique challenge when the physis is involved because this can result in premature physeal closure. Premature physeal closure can cause leg length discrepancies or angular deformities that may require operative intervention.[34] In patients with at least 3 years of growth remaining, serial radiographs should be obtained annually or biannually until growth is shown to be symmetric.[34] This is most important for the tibia, as isolated fibular physeal arrest is rarely an indication for operative management.[34] Transition fractures occur near the end of growth and rarely cause growth disturbance.[39]

Complex regional pain syndrome may also result from trauma or a fracture.[40] This is more common among female patients, and the lower extremity is more commonly involved.[40] This syndrome is characterized by a variety of symptoms, including pain and hyperalgesia, as well as sensory, motor, and dermal changes. Treatment is multidisciplinary and includes medications, physical therapy, and psychological evaluation and therapy.[41]

CONCLUSIONS

Ankle injuries are a commonly encountered ED chief complaint. History and physical examination, in conjunction with a clinical decision support tool such as the OAR, the LRAR, or the MZA, can help to determine the need for radiographs of the ankle joint or nearby structures. Ankle sprains and isolated Salter-Harris I or II fractures of the distal fibula can be managed with a brace, crutches, and weight bearing as tolerated. These injuries benefit from early initiation of range of motion exercises. Distal tibia fractures, including transitional fractures, require anatomic reduction and those with articular involvement benefit from CT imaging to fully understand the fracture and determine need for surgical correction. In general, a pediatric orthopedic specialist should be consulted for ankle fractures in skeletally immature patients, any patient with neurovascular compromise, open fractures, or dislocations; and all transitional fractures.

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