Fracture patterns in the paediatric ankle: an educational pictorial review

Poster No.: P-0094
Congress: ESSR 2016
Type: Educational Poster
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Keywords: Musculoskeletal system, Paediatric, Trauma, CT, Digital radiography, Diagnostic procedure
DOI: 10.1594/essr2016/P-0094

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Learning objectives

To understand the mechanism and common imaging features of fracture patterns which occur in the skeletally immature ankle.
Background

Ankle fractures are among the most common acute injuries of the lower extremity in the paediatric population. The ankle is also the second most common site of physeal fracture, second only to the distal radius. It accounts for 15-20% of all physeal injuries in children. Fractures of the distal tibia and fibula are most common between 10 and 15 years of age and occur more frequently in boys than in girls. These fractures also require operative intervention more frequently than distal radial fractures.

With incomplete ossification and open physes, the skeletally immature ankle presents complex and unique mechanical and biological characteristics. The distal tibial physis closes at approximately 12 years in girls and 14 years in boys. The process takes place over approximately 18 months and begins centrally, extends medially and is completed laterally. This distinct pattern of closure has important implications for the fracture patterns occurring in adolescence during physeal closure. The distal fibular physis closes approximately 1-2 years after closure of the distal tibial physis.

The distal tibial physis accounts for approximately 3 to 4 mm of limb growth per year and 15 to 20 percent of final leg length\(^1\). In younger children, proximal and distal tibial growth occurs proportionally. Thus, physeal injury in younger children can result in significant leg length discrepancy. Distal tibial physeal fractures have among the highest rates of complications of all physeal fractures, including premature physeal arrest, bar formation, angular deformity and articular incongruity\(^2,3\).

When assessing paediatric ankle imaging, both the mechanism of injury and stage of physeal fusion must be taken into consideration. Fractures involving the physis can be complicated by growth arrest and deformity and therefore must be identified and treated early. We provide a comprehensive educational pictorial review of paediatric ankle fracture patterns from our institution.
Imaging findings OR Procedure Details

Physeal fractures are unique to the paediatric population. The Salter-Harris (SH) classification system describes those fractures that involve the physis, dividing them broadly into five groups. This system guides both the prognosis and potential for growth disturbance. However, the complexity of ankle anatomy, and the deforming forces that can occur at the time of ankle injury, requires a classification system that provides information on the mechanism of injury.

The Dias and Tachdjian classification system⁴, the paediatric modification of the Lauge-Hansen classification system, classifies fractures into four groups based on the position of the foot and axial load at time of injury, direction of the deforming force and the Salter-Harris classification (Figure 1). It includes supination-inversion, pronation-eversion-external rotation, supination-plantar flexion and supination-external rotation injuries. This mechanistic classification system is most important in predicting the likelihood of achieving closed reduction and in determining the type of manoeuvre required to achieve reduction.

Most ankle fractures in children are treated with closed reduction. However, when operative intervention is required, the Salter-Harris classification best guides this treatment and correlates well with the incidence and type of complications.

Salter-Harris type I fractures, a transverse fracture through the physis, can occur from all mechanisms of injury. In the acute phase, plain radiographs are frequently normal. Subacutely, widening of the physis can be appreciated.

Salter-Harris type II fractures are the most common type of distal tibial fractures. These fractures extend though the physis and superiorly to involve the metaphysis. Again these fractures can occur from all mechanisms of injury. These fractures are often treated conservatively, with surgical intervention indicated infrequently.

Salter-Harris type III and IV fractures typically occur in supination-inversion injuries. They occur when the talus is impacted against the medial malleolus and imparts a greater force against the medial half of the distal tibia. A type III fracture extends from the articular surface of the epiphysis, through the physis and exits medially. In a type IV fracture, the epiphysis, physis and a portion of the metaphysis are completely split and superiorly displaced.
Salter-Harris type V fractures are axial-loading injuries and are often recognised late due to subsequent growth arrest. They are rare injuries, accounting for less than 1% of all distal tibial physeal fractures.\(^5\)

Furthermore, transitional fractures are specific adolescent fractures that occur during asymmetrical fusion of the growth plate, and include Tillaux and triplane fractures. Tillaux fractures are a type of Salter-Harris type III fracture and occur when the lateral distal tibial physis has not yet fused and an external rotation force is applied to the ankle. This results in an avulsion fracture of the anterolateral tibial epiphysis as the anterior inferior tibiofibular ligament pulls on this fragment.

A triplane fracture is thought to result from an external rotation force on a supinated foot and is so-called as it involves fracture lines in three planes. The coronal plane fracture begins in the physis and extends proximally though the posterior metaphysis; the sagittal plane fracture extends from the midjoint line to the physis resulting in an anteromedial and often an anterolateral fragment; and the transverse plane fracture extends through the physis. There are many variants of this fracture, including two-part, three-part and extra-articular fractures. In the latter variant, the sagittal fracture exits through the medial malleolus, and is important to recognise as it can be successfully treated with closed reduction.
Fig. 1: Dias and Tachdjian classification of ankle fractures in children.

Fig. 2: Sagittal (A), coronal (B) and 3-D volume rendered (C) CT demonstrating a SH II fracture of the distal tibial metaphysis. Post-operative plain film demonstrating screw fixation (D).

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**Fig. 3:** Coronal (A), sagittal (B) and 3-D volume rendered (C) CT of the right ankle demonstrating a SH III fracture of the medial malleolus, SH IV of the posterior tibial malleolus and a Weber B fracture of the distal fibula.

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**Fig. 4:** Axial (A, B), coronal (C) and 3-D volume rendered (D) CT demonstrating SH IV fracture of the distal tibia.
**Fig. 5:** Sagittal (A, C), coronal (B) and 3-D volume rendered (D) CT demonstrating SH IV fracture of the distal tibia and SH I fracture of distal fibula.
Fig. 6: Anteroposterior (A) and lateral (B) radiographs of the right ankle demonstrating subtle lucency and cortical irregularity in the distal epiphysis. Axial (C) and coronal (D) CT images demonstrate a mildly displaced Tillaux fracture.

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**Fig. 7:** Axial (A), coronal (B) and 3-D volume rendered (C) CT demonstrating Tillaux fracture with an adjacent avulsion fracture at the insertion of the anterior inferior tibiofibular ligament.

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Fig. 8: Lateral (A) and anteroposterior (B) radiographs and sagittal (C) and coronal (D) CT of the right ankle demonstrating a triplane fracture. There is an oblique coronal fracture through the distal tibial metaphysis, horizontal fracture through the physis and oblique sagittal fracture through the epiphysis.

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Conclusion

The ankle is a complex and frequently injured joint in the paediatric population and is associated with among the highest complication rates of all physeal fractures. It presents unique biological and mechanical characteristics that should be considered when assessing the skeletally immature ankle.