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Physiology, Anatomic Considerations, and Classification Scheme for Working Up and Treating Pediatric Fractures: A Literature Review

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Abstract: The purpose of this article is to discuss the etiology and underlying physiology associated with pediatric fractures in the lower extremity. A high prevalence of fractures occurs in the pediatric population and a high percentage of those will affect the lower extremity. Pediatric fractures present a unique challenge to the practitioner due to their difference in long bone anatomy as well as their ability to heal injuries compared to their adult counter parts. Since these patients are still growing the surgeon must be cautious to avoid further stress to the growth plate whether pursuing conservative or surgical management.

Key words: Pediatric, Periosteum, Physis, Epiphysis, Metaphysis and Salter-Harris

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Fractures in the pediatric population are very common. It's estimated that 50% of children will sustain at least one fracture by the age of 18. Lower extremity fractures will account for 10% of fractures but greater than 25% of those fractures will involve the growth plates. Lower extremity injuries are more common in boys than girls. Physeal fractures are most commonly due to outdoor and sporting activities. In rarer cases, high energy traumas such as motor vehicle accidents and crush injuries do occur[16].

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Physiological Differences:

It has been noted that children's bone differs from adult bone in several ways. First, children's bone is significantly more porous and has a higher water content than adults. This allows the pediatric bone to better absorb axial impact and dissipate fracture causing forces. Furthermore, due to this difference in bone content, the pediatric bone exhibits a more beneficial modulus of elasticity. This allows the pediatric bone to undergo a process of plastic deformation that is not seen in adults. In adults, the bone is more likely to fracture due to its brittle nature where the pediatric

bone would be less likely to fracture and more prone to the bony deformation[14].

The next key difference is periosteal thickness. The pediatric periosteum is thicker, more vascular, and more metabolically active. A thicker periosteum helps to minimize fracture displacement, making it easier to maintain alignment following an injury. The caveat of this is that the pediatric periosteum can get impinged between fracture pieces and be very hard to release with a closed reduction. The vascularity and increased metabolic activity promotes rapid callus formation allowing the bone to heal and remodel at an increased rate[13].

The final component to consider is the presence of the physis in the growing patient. The physis lies between the epiphysis and metaphysis in pediatric long bones. The physis is an area responsible for longitudinal bone growth. It is made up of several cellular levels. The germinal layer is the area closest to the epiphysis where the foundation for cell division takes place. The next major area is the proliferative zone where rapid cell division and growth begins to take place, which increases bone length. A layer of hypertrophy is just above it and is the area where the cells start to increase in size and start to undergo calcification. It is in this area that most of the fracture lines are thought to run. Due to the increasing size of cells, increased space between cells, and a decrease in cellular matrix it is considered the weakest area of the physis. Lastly, the cells begin to ossify and remodel in to bone[14,15]. The delicate cellular processes taking place in the physis is why preservation of this area is so important when deciding how to approach fractures in this population.

Anatomic Considerations:

Knowing the ossification centers of pediatrics gives the physician insight in to the amount of growth remaining in the child's physis. If the patient is close to the end of growth at the injured joint, the doctor could treat the fracture as they would in the adult population. Important to consider is that females mature earlier than their male counter parts. On average, it is expected that the female physis closes two years earlier than males.

Special consideration should be given to the distal tibial physis as it closes in a unique, undulating fashion. First, the central aspect of the distal tibial physis closes, next the anterior medial portion closes, then the posterior medial portion closes and finally, the lateral portion will start to close over the next 18 months.

Pediatric Workup:

As with any patient, regardless of age, a thorough exam should be done. Look for open wounds, ecchymosis, abrasions or anything that can jeopardize the soft tissue envelope. Verify that there has been no neurovascular compromise, rule out compartment syndrome, and make sure that there are no significant deformities that can lead to further compromise[1].

Radiographs are a mainstay in these patients. The Ottawa rules may not be as helpful in children as fractures associated with sprains are much more common[7,8]. The low risk ankle injury rule should be used in pediatric cases. Injuries that are lower risk in adults, such as sprains, should be evaluated more aggressively in children[1,2]. CT and/or MRI are usually necessary when there is intraarticular involvement and prior to surgical intervention.

Treatment of pediatric cases:

The main goal of treatment, it to try and reduce long term complications. Achieving anatomic reduction in the least invasive fashion is

imperative to reduce the risk of growth arrest, angular deformity, and limb length discrepancy[12]. While many classifications exist, the Salter-Harris (SH) classification system provides an idea of the prognosis as well as an outline for treatment.

SH type 1 fracture patterns occur when the fracture goes through the physis and does not exit into the metaphysis or the epiphysis. These fracture patterns typically have a very good prognosis. The proposed treatment algorithm in most of these patients is immobilization in a cast or cam walker and rest. Risk of growth disturbance is considered very low. Surgery is rarely indicated and only needed when the physis is displaced more than 2 mm.

SH type 2 fracture patters occur when the fracture starts in the physis and extends in to the metaphysis. Since these are extraarticular in nature the risk of degenerative joint disease and long term complications are low. The physis attached with the metaphysis is also known as the Thurstan-Holland sign. Treatment for SH type 2 fractures are based on the amount of displacement. If the fracture fragment is less than 2 mm displaced, conservative treatment is recommended[5]. However, if the displacement cannot be closed reduced, the patient will most likely require surgical intervention. When the original displacement is greater than 3 mm the likely reason for inadequate displacement is due to periosteal impingement. Percutaneous joy sticking with kirschner wires is a minimally invasive technique to attempt reduction before open reduction[9,10].

SH type 3 involves a fracture through the physis and then through the epiphysis. This fracture pattern is intraarticular in nature. Closed reduction aims to reduce fracture displacement as well as articular step off[11]. While these fractures can be close reduced, if anatomic alignment is not achieved the risk of post traumatic arthritis and growth deformities significantly increase. Kling et al found that patients treated with open reduction and internal fixation did better overall short term and long term[9].

SH type 4 is a fracture through the physis that involves both the metaphysis and epiphysis. These fractures are intraarticular and are prone to being more displaced than the previous fractures. Like SH type 3, closed reduction can be attempted but open reduction reliably provides better outcomes.

Finally, SH type 5 is a crush injury of the physis resulting in a significant risk of physeal growth arrest. While these injuries can be isolated, it is not uncommon to have these injuries concomitant with high injury mechanisms. Unfortunately, these have no clear algorithm of treatment but a poor prognosis is a mainstay of this fracture type[5,6,16].

Conclusion:

Pediatric fractures are a common pediatric problem that require accurate diagnosis and treatment for optimal outcomes. Radiographs are not always adequate at diagnosing the extent of the injury so CT imaging may be required, especially for surgical planning. Adequate reduction and stabilization is required to prevent complications to the patient when they become an adult.

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