PEDIATRIC ORTHOPEDIC EMERGENCIES

AUTHOR: Sarah Nossov, MD, House Officer—G, Department of Orthopaedic Surgery, University of Michigan Health System
APPROVING AUTHOR: G. Ying Li, MD, Assistant Professor, Department of Orthopaedic Surgery, C. S. Mott Children’s Hospital University of Michigan Health System

Article authors, or faculty planner Dr. Peter Ehrlich, have no financial relationships with any commercial interest producing health care goods or services r/t this article

Introduction

The care of children has been integral in the historic development of orthopedics as a surgical specialty. Formal fellowship training of pediatric orthopedists, however, only began in the late 1970s. Many orthopedic generalists provide emergency orthopedic care for children, and when on call, much of their charge is to determine the triage and treatment of traumatic injuries. This article will address identification and management of a few examples of pediatric trauma emergencies which may require immediate or urgent surgical intervention. There are some emergent injuries we treat similarly as adults: compartment syndrome and open fractures; and there are other injuries that have unique concerns for children such as supracondylar humerus fractures, femoral neck fractures, and distal femur fractures.

Caring for the Pediatric Orthopedic Injury

Fractures occur frequently in children, about 25% of traumatic injuries, more frequently in boys (42%) than girls (27%). The upper extremity is involved in 2/3rds of cases, with the radius being the most likely injured. Open fractures, in which the skin and soft tissue envelope is disrupted, are rare with approximately 2% of fractures classified as open. Most injuries occur at home.

Principals of trauma care. Pediatric orthopedic trauma evaluation follows the basic techniques and principles by which we approach adult injury care. Care must be taken to gather a careful history, exam, and obtain well-executed imaging. Consultation with a pediatric orthopedic specialist may be required, especially in the setting where the reading radiologist is not facile in interpreting pediatric imaging, or particular pediatric modalities are not available. If triage determines surgery is not urgently indicated, or non-operative management for fractures is initiated, appropriate immobilization is required before transfer or discharge.

Incidence. Incidence of multi-trauma injuries in a pediatric patient is 4%. Although fractures are commonly a part of the clinical picture, head injuries are more associated with mortality. Fractures of the spine, pelvis, and scapula are less common but are associated with longer hospital and ICU stays along with highest association with mortality. Damage control orthopedics is the strategy by which musculoskeletal injuries are temporized in the setting of a severely injured patient who is either not stable enough to undergo definitive care, or who is in a setting in which definitive care is not available or deemed emergent. The idea is that surgical intervention is essentially adding more trauma burden to a vulnerable patient. Patients who meet these criteria, in consultation with a pediatric trauma team, may undergo pelvic binding, external fixation, or splinting to stabilize fractures, and aid in hemostasis.

Anatomy of pediatric bone. Pediatric long bones have three main regions: epiphysis, physis and metaphysis (Fig. 1).

Epiphysis: each end of a long bone with associated joint cartilage.
Physis (growth plate): cartilage cells that create solid bone with growth.
Metaphysis: wide area below the physis, closest to the diaphysis/shaft.

Another key component of bone is the periosteum, which is a thick, nutrient layer that wraps circumferentially around bones. It serves a major role in healing the outer layer of bone.
Types of Fractures

The mechanisms of fractures change as children age. Younger children are more likely to sustain a fracture while playing and falling on an outstretched arm. Older children tend to injure themselves while playing sports, riding bicycles, and in motor vehicle accidents. Also, because a child’s ligaments are stronger than those of an adult, forces which would tend to cause a sprain in an older individual will be transmitted to the bone and cause a fracture in a child. Caution should therefore be exercised when assessing a young child diagnosed with a sprain.

Plastic deformation. A force produces microscopic failure on the tensile/convex side of bone which does not propagate to the concave side. The bone is angulated beyond its elastic limit, but the energy is insufficient to produce a fracture.

- No fracture line is visible radiographically.
- Unique to children
- Most commonly seen in the ulna, occasionally in the fibula. Bend in ulna <20° should correct with growth.

Buckle fracture. Compression failure of bone that usually occurs at the junction of the metaphysis and the diaphysis.

- Commonly seen in distal radius.
- Inherently stable
- Heal in 3-4 weeks with simple immobilization.

Greenstick fracture. Bone is bent and the tensile/convex side of the bone fails.

- Fracture line does not propagate to the concave side of the bone, therefore showing evidence of plastic deformation.
- If the bone undergoes plastic deformation, it is necessary to break the bone on the concave side to restore normal alignment, as the plastic deformation recoils the bone back to the deformed position.

“\textit{To shorten winter, borrow some money due in spring}” W. J. Vogel

Complete fracture. Fracture completely propagates through the bone. Classified as spiral, transverse, or oblique, depending on the direction of the fracture line.

Spiral fractures

- Created by a rotational force, low velocity injuries
- Intact periosteal hinge allows the orthopedic surgeon to reduce the fracture by reversing the rotational injury.

Oblique fractures

- Occur diagonally across the diaphyseal bone at 30° to the axis of the bone.
- Unstable, therefore alignment is necessary. Fracture reduction is attempted by immobilizing the extremity while applying traction.

Transverse fractures

- Created by a 3-point bending force.
- Easily reduced by using the intact periosteum from the concave side of the fracture force.

Physeal fractures. Fractures to the growth plate can be caused by i) crushing, ii) vascular compromise of the physis or iii) bone growth bridging from the metaphysis to the bony portion of the epiphysis.

- Damage to growth plate may result in progressive angular deformity, limb-length discrepancy or joint incongruity.
- The distal radial physis is the most frequently injured physis.
- Most physeal injuries heal within 3 weeks. This rapid healing provides a limited window for reduction of deformity.
- Physeal injuries are classified by the Salter-Harris (SH) classification system, based on the radiographic appearance of the fracture (Table 1).
Treatment
Although primary prevention of fractures is ideal, fractures remain a common presentation in pediatrics. Due to their immature, growing bones, care providers must remain vigilant regarding potential fractures, as they may present with subtle signs and symptoms. A high index of suspicion and appropriate treatment of orthopedic injuries can prevent the long-term morbidity associated with stunted growth potential and deformed limbs.

Remodeling. The remodeling potential in young healthy children is astounding, and there is evidence that in some simple fracture patterns, one can accept quite a large initial deformity. This can be seen in diaphyseal and metaphyseal fractures of the forearm, humerus, and femur. The younger the patient, the more ability the patient may have to remodel, or reshape, their deformities (Pics 1-3).

Given the remodeling and healing potential, much of pediatric fracture care had historically been non-operative. However, fractures which involve the physis may result in deformity or growth arrest. These cases are not always obvious to a practitioner inexperienced in evaluating incompletely ossified limbs. Certain fracture patterns are associated with vascular concerns, perhaps more obvious in the case of a displaced distal humerus fracture than a seemingly benign tibia shaft fracture. At times minor injuries can reveal more concerning underlying pathology such as tumors or infection. Trauma from non-accidental injury may also be identified based on fracture.

Improvement in technology, ability to utilize minimal and temporary implants, financial and social pressures that limit hospitalization, along with the expectation by the public for a perfect outcome in every case has resulted in greater operative trend in pediatric fracture care.

Emergent treatment. Most fractures can be acutely stabilized in a well-padded splint in a position of comfort in the field. Fractures with impending skin compromise or neurovascular complication require emergent reduction. Ischemic tissue can covert a closed fracture to an open fracture, which may require surgical debridement. Defects in the skin may be closed immediately, in a delayed fashion, or possibly require skin graft coverage. Immediate reduction can improve perfusion and at times may be the definitive treatment. Inability to reduce the fracture or persistent neurovascular symptoms in the emergency department may demand a formally anesthetized reduction with the potential necessity for an open reduction to relieve interposed tissue.

Open fractures. Open fractures are treated emergently, and are less associated with compartment syndrome. Outcomes have been directly related to time to initial antibiotics. Although initial gross irrigation and debridement may be done in the emergency department, most often definitive care of open fractures will proceed to the operating room for formal debridement and possible fixation unless clinical condition is prohibitive.

Based on Gustilo Grade of fracture (Table 2), a new adult open fracture initial antibiotic treatment plan was published in 2014 by the University of Michigan which showed comparable infection rates with a more streamlined design (Table 3, Page 6). Pediatric treatment is based on adult guidelines at UM for antibiotic type and is adjusted for dose and frequency. Appropriate antibiotic coverage should vary by region and local infectious disease data and resistance.
**High Risk Fractures**

**Supracondylar humerus fracture.** Supracondylar humerus (SCH) fractures are the most common fracture of the elbow in children, and most commonly present in children aged 5-6 years old. The large majority of these (96%) occur from a fall on an outstretched hand with elbow extended from a height, as when breaking a fall off the monkey bars. A much smaller subset of these fractures are from a flexion injury when the olecranon is the point of contact. This injury should be suspected in a child with pain at the distal humerus and unwillingness to move the elbow after a fall. Swelling may be variable and related to degree of severity along with ecchymosis. There may be evidence of “button-holing” of the soft tissue. Gross deformity should be noted in comparison to contralateral uninvolved extremity along with a thorough neurovascular exam, including radial, ulnar, and median nerve sensation and distal motor function in the fingers. In a study completed at the University of Michigan, obesity has been found to be associated with increased complexity of fractures and neuro-logic abnormalities.

**SCH complications.** The radial pulse may be compromised if it is draped over a proximal fragment spike. Volkmann’s ischemic contraction is the rare and most feared complication of this injury. Vascular and neurologic injuries occur in 1-12% and 7% of cases respectively. Most vascular findings resolve with reduction, but in 0.7-2.1% flow remains impaired. Urgent surgical intervention for vascular exploration is indicated in cases of post-reduction ischemia and loss of pulse in the setting of delayed capillary refill, but treatment is controversial in the instance of the “pink pulseless hand” in which collaterals suffice to grossly perfuse a likely obstruction in the brachial artery. Recent retrospective investigations have suggested that in a reduced SCH, even despite absence of palpable radial and ulnar pulse with Doppler evidence of brachial artery obstruction in a hand with good capillary refill, vascular intervention is not required. Furthermore, 3 year outcomes do not suggest ischemic complications and instead include return of radial pulses at 6 weeks. Still, there is no consensus on management, and post-reduction serial monitoring of neurovascular exam, along with pulse oximetry and assessment of analgesia requirement is recommended if exploration is not initiated. That decision should be reconsidered if any decline in exam, or if associated with any nerve palsy as these are associated with a higher risk of late complication.

**SCH diagnosis.** An AP and lateral x-ray should be sufficient to diagnose and classify a SCH fracture. Contralateral films can be helpful if the findings are subtle. On the lateral radiograph, a line drawn along the anterior border of the humerus should pass through the center of the capitellum if there is no displacement. Also on the lateral, evidence of a posterior fat-pad sign (a radiolucent area seen posterior to the distal part of the humerus, adjacent to the olecranon fossa) suggests a hemiarthrosis from an occult fracture. The AP can illustrate medial comminution.

**SCH classification.** The Gartland classification is commonly utilized and is based on degree of displacement and is associated with severity, stability, and necessity for surgical intervention. A Gartland type 1 fracture is non-displaced. Care should be taken to immobilize this fracture, as these may be successfully treated non-operatively. The presence of medial comminution may result in progressive loss of alignment in some cases. In the absence of that finding, they may be splinted or casted based on severity of swelling, with less than 90 degrees flexion. Gartland type 2 fractures are displaced, but have intact cortex posteriorly. Gartland type 3 fractures are displaced with implied disruption of periosteum. Historically, Gartland type 2 fractures typically are considered surgical, but not urgent, whereas Gartland type 3 were often addressed emergently (Pic 4). There is growing evidence that delay of these cases to an urgent, or “next morning” status does not result in clinical difference.

**SCH treatment.** Surgical intervention is aimed at restoring anatomic alignment and preventing cubitus varus deformity. Operative treatment of SCH involves general anesthesia and fluoroscopy confirmed reduction with percutaneous smooth pin placement for fixation. It is common to achieve an anatomic reduction with closed maneuvers, but open reduction may be required if a satisfactory alignment cannot be achieved or if neurovascular exploration is required. The patient may be discharged from recovery or after a short period of observation in a splint.

Pic 4

Lateral elbow x-ray views demonstrating the Gartland classification of supracondylar humerus fractures. Note that the dotted lines indicate the anterior humeral line which should cross/bisect the capitellum.
High Risk Fractures

<table>
<thead>
<tr>
<th>Other elbow fracture pearls...</th>
<th>Transphyseal elbow fractures</th>
<th>&lt; age 4, unclear incidence</th>
<th>Fall vs. abuse (if not walking), often mistaken for dislocations, may need US or MRI to identify</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral condyle fractures</td>
<td>Peak between 5-10yo, 37% of elbow fractures</td>
<td>Much less likely to be associated with neurovascular injury than supracondylar fractures, may need an oblique X-ray to see. Prone to late complications in recovery.</td>
<td></td>
</tr>
<tr>
<td>Monteggia fracture-dislocations (proximal ulna fracture + radial head dislocation)</td>
<td>Peak between 4-10yo, 0.4% of elbow fractures</td>
<td>On all radiographic views, a line drawn through the center of the radial head should pass through the center of the capitellum. Any deviation from this is not normal and requires further evaluation. “Pure” radial head dislocations may not exist in children.</td>
<td></td>
</tr>
</tbody>
</table>

"Winter is not a season, it’s an occupation"  
Sinclair Lewis

Physeal fractures of the knee. Physeal fractures around the knee occur with an incidence of 1-6% of physeal injuries. Distal femoral physeal fractures are considered to be analogous to knee dislocations in adults which should prompt a high level of suspicion for neurovascular injury (Pic 5). Identification of vascular injury may require emergent intervention by a vascular surgeon. Growth arrest is a worrisome complication, and multiple reduction attempts should be avoided. Proximal tibia physeal fractures are also considered homologue of an adult knee dislocation and may be associated with neurovascular injury or compartment syndrome. Both of these injuries should be evaluated promptly by an orthopedic specialist.

AP and lateral knee x-rays demonstrating a displaced femoral physeal fracture. This needs urgent reduction and evaluation of neurovascular status and is considered a pediatric version of a knee dislocation.
High Risk Fractures

Hip and femoral head fractures. Dislocation of a native hip is rare in children, but can occur after moderate trauma and is more common than a fracture of the hip in this population. A posterior dislocation usually presents with the leg flexed, adducted, and internally rotated compared to an anterior dislocation which would likely appear extended, abducted, and externally rotated. The reduction maneuver is a little different based on position of dislocation. Like most musculoskeletal reductions, the quality of anesthetic and subsequent muscular relaxation is directly related to success of the procedure, and is absolutely critical with hips. In patients with open physeal fracture of the femoral head can occur without adequate sedation. Loss of the blood supply to head of the femur (Fig 2) and subsequent avascular necrosis (AVN) occurs 10-16% of the time and is the feared complication which implies urgent necessity for reduction. If the hip cannot be reduced under sedation an open reduction may need to proceed in the operating room. Complications may also include a transient sciatic neuropraxia.

Femoral neck fractures are urgent for the same reasons that we worry about dislocated hips - preservation of the blood supply, with about 23% of cases resulting in AVN. In a recent systematic review, a delay in treatment of more than 24 hours was associated with higher rates of AVN. Due to robust bone density femoral neck fractures are far more rare in children compared to our commonly recognized geriatric counterpart and account for less than 1% of pediatric fractures and are often the result of high energy trauma such as motor vehicle accidents and falls from a height. They are associated with a high rate of deformity and problems with delayed fracture healing. These fractures in children are more unstable and decreased deformity is associated with anatomical surgical reduction and fixation.

“In seed –time learn, in harvest teach, in winter enjoy”  
William Blake

<table>
<thead>
<tr>
<th>Grade of Open Fracture</th>
<th>Recommended Antibiotic</th>
<th>Alternate if Penicillin Allergy</th>
</tr>
</thead>
<tbody>
<tr>
<td>I or II</td>
<td>Cefazolin 1-2 g load then 1g intravenously (IV) every 8 h for 48 h Preprotocol: same</td>
<td>Clindamycin 900 mg IV every 8 h for 48 h Preprotocol: Vancomycin 1g IV every 12 h for 48 h</td>
</tr>
<tr>
<td>III</td>
<td>Ceftriaxone 1 g IV every 24 h for 48 h Preprotocol: Cefazolin 1-2 g load then 1 g IV every 8 h for 48 h Gentamicin 1-2 g/kg (based on ideal body weight IV every 8 h for 48 h)</td>
<td>Clindamycin 900 mg IV every 8 h AND Aztreonam 1 g IV every 8 h for 48 h Preprotocol: Vancomycin 1 g IV every 12 h for 48 h instead of Cefazolin Clindamycin 900 mg IV every 8 h instead of Penicillin G</td>
</tr>
</tbody>
</table>

Table 3 A study at the U of M did not show significant rate of change in infections in adults with open fractures using a new streamlined protocol compared to “pre-protocol” antibiotics. This new protocol simplifies antibiotics to only cephalosporins with substitutions of clindamycin and aztreonam in the case of allergy. Note special conditions at the bottom of second column.
**ACTUAL CASE REVIEW**

A pictorial review of an orthopedic case treated by the Pediatric Orthopedic Department at C. S. Mott Children's Hospital

**History:** A healthy 6 year old child with a fall from the monkey bars presents to the C. S. Mott Children's Hospital Emergency Department (ED). She is neurologically intact with a warm pink hand and no palpable pulse on injured extremity. X-rays obtained in the ED (right) illustrate an extension type supracondylar humerus fracture, Gartland type 3.

**Treatment:** The patient was brought urgently to the Operating Room that evening for closed reduction, after which a pulse was able to be palpated. The reduction was verified to be sufficient under live fluoroscopy.

**Procedure:** The fracture reduction was held in the desired reduction using percutaneous pinning. Multiple small gauge Kirschner or "K" wire are advanced using a wire driver. Starting points and pin trajectory are identified using anatomic landmarks under fluoroscopic guidance. In this instance, two lateral and one medial pin was used. There is a small risk of iatrogenic injury to the ulnar nerve using the medial pin and many practitioners will obviate that risk by using three lateral pins. Either construct is typically sufficient to stabilize both the medial and lateral columns of the distal humerus. Final fluoro shots confirm stability.

**Post-Op/Recovery:** The post op images revealed restored anatomic alignment. The patient was admitted for a brief period of observation then discharged in a splint. The next week she was seen in clinic and overwrapped in a cast. Two and a half weeks later the pins were pulled in clinic and the patient was allowed gradual return to full activity.
Complications

Compartment syndrome. Compartment syndrome is a condition by which the pressure in a fascial compartment exceeds perfusion pressure which results in ischemia (Fig 3). When muscle bellies are contained in the fascial compartment under insult, they can ultimately undergo necrosis and result in contractures and loss of function. Compartment syndrome can result from external pressure from a circumferential dressing, direct pressure of body weight in an unconscious individual, excessive fluid from hematoma or iatrogenic extravasation. Other ischemic events may mimic or reproduce similar findings, such as vascular emboli or sepsis in children.

Unlike adults, conscious children are not reliable in verbally relaying symptoms and hinder interpretation of worsening “pain out of proportion” to injury with passive flexion, which is a sign of worsening pressures. Agitation, anxiety, and increasing analgesic requirements are the “3 A’s” of pediatric compartment syndrome, and should prompt suspicion for such. In the case of an unconscious patient, direct pressure monitoring may be necessary to rule out compartment syndrome. It is important to understand that compartment syndrome is a clinical diagnosis, and orthopedic management aims to intervene with surgical fasciotomy before compartment syndrome fully evolves and displays late findings of paresthesias, decreased motor function, or gross ischemia.

Although all fractures bleed, some are more associated with compartment syndrome such as closed, displaced tibia fractures associated with a fibula fracture and high mechanism of injury and tibial tubercle avulsions, should be closely evaluated if pain is not easily controlled. It is important to understand that symptoms may evolve over time in the first 24 hours. If you are worried about potential of an evolving compartment syndrome strict elevation of the extremity above the level of the heart, icing, and hourly clinical exams.

Article references:
http://learnpediatrics.com/body-systems/musculoskeletal-system/pediatric-fractures/

TAKE THE QUIZ!

KNOWLEDGE TEST AND AMA/PRA CATEGORY 1 CREDIT

After reading the article, continue the educational activity by taking the online CME quiz at:
https://cme.med.umich.edu/assessment/questions.asp?gid=171

After you initially take the test, the test will be immediately electronically scored. If fewer than 70% of the questions are answered correctly, the questions that were not answered correctly will be noted in red. Review the CME content related to those topics and retake the test. If 70% or more of the questions are answered correctly, the correct and incorrect answers for all questions will be shown along with explanations of the basis for the correct answer. The link to register and receive credit is shown at the end of the items and explanations. Complete the electronic credit request and activity evaluation. An electronic certificate of participation will be provided immediately. Print the certificate of participation for your personal records.

NURSES: Remember 1 CME = 1 CEU credit for nursing! This activity WILL count toward your 25 hours/2 yrs of required CEU for licensure