Pediatric Emergency Medicine Reports

The Practical Journal of Pediatric Emergency Medicine

Volume 15, Number 7 / July 2010 www.ahcmedia.com

Authors:

Lilliane M. Sarraff, MD, Fellow, Department of Emergency Medicine, Drexel University College of Medicine, St. Christopher's Hospital for Children, Philadelphia, PA.

Christopher J. Haines DO, FAAP, FACEP, Assistant Professor of Emergency Medicine and Pediatrics, Drexel University College of Medicine; Director, Department of Emergency Medicine and Medical Director, Critical Care Transport Team, St. Christopher's Hospital for Children, Philadelphia, PA.

Peer Reviewer:

John Santamaria, MD, FACEP, Affiliate Professor of Pediatrics, University of South Florida School of Medicine, Tampa, FL.

Statement of Financial Disclosure

To reveal any potential bias in this publication, and in accordance with Accreditation Council for Continuing Medical Education guidelines, we disclose that Dr. Dietrich (editor), Dr. Skrainka (CME question reviewer), Dr. Haines (author), Dr. Sarraff (author), Dr. Santamaria (peer reviewer), Mr. McKagen (executive editor), and Ms. Weaver (managing editor) report no relationships with companies related to the field of study covered by this CME activity.

AHC Media LLC

Common Orthopedic Injuries in the Pediatric ED

Pediatric fractures are commonly encountered in the emergency department (ED). Approximately 50% of children will fracture a bone during childhood. The unique injury patterns, especially those involving the physis, require that clinicians have a complete and thorough understanding of appropriate diagnostic and management strategies to maximize a child's potential for an optimal outcome. Part I of this two-part series on common orthopedic injuries in the pediatric ED focuses on injuries to the clavicle and upper extremities. Part II will focus on injuries to the lower extremities.

— The Editor

Introduction

Musculoskeletal injuries account for approximately 10%-15% of the 10 million annual visits to U.S. pediatric EDs.[1] Skeletal fractures represent the majority of injuries, with rates continuing to increase. It is estimated that approximately half of all children will fracture a bone during childhood.[1] Most childhood fractures occur as a result of mild to moderate trauma during play and sports. Although fractures vary considerably with age, sex, and maturation, the peak occurs in early puberty.[2] Further, it is important to consider other possible etiologies when a child presents with bony pain, especially without a history of trauma. The differential diagnosis should include the following: physical abuse, malignancy, osteogenesis imperfecta, and rickets.

Anatomy

The major anatomic regions of growing bone include the epiphysis, physis (growth plate), metaphysis, and diaphysis. The metaphysis is the wider part of the end of the long bone, adjacent to the epiphyseal disk. The diaphysis is the shaft of the long bone. The epiphysis is the secondary ossification center located at the end of long bones and is separated from the rest of the bone by the cartilaginous physis. The epiphysis is cartilaginous at birth, with the exception of the distal femur.[3] This cartilaginous epiphysis serves as a shock absorber, transmitting forces to the metaphysis. Throughout childhood and adolescence the cartilage skeleton begins to ossify with subsequent increase in force transmission to the physis.[4] The physis, or growth plate is located between the distal epiphysis and the proximal metaphysis, and is the primary center of longitudinal long bone growth. The epiphyseal cartilage cells grow toward the metaphysis and form columns of cells that degenerate, undergo hypertrophy, and then calcify to form new bone. The epiphyseal cartilage cells stop duplicating at the end of puberty. As a result, epiphyseal growth develops at the site secondary to replacement by bone. This epiphyseal growth promotes rapid healing of fractures in the pre-pubertal population.

The major anatomic differences between the adult and pediatric skeletal

Executive Summary

- Four unique types of fractures that are seen in children include plastic deformity, buckle fractures, greenstick fractures, and physeal fractures.
- The Salter-Harris classification scheme is most frequently utilized for treatment and prognosis of pediatric physeal injuries. Types III and IV fractures require anatomic reduction for optimal outcomes. Types I and V can be difficult to diagnose and require a high degree of suspicion.
- The mnemonic
  C (capitellum – 1 year)
  R (radial head – 3 years)
  I (internal or medial epicondyle – 5 years)
  T (trochlea – 7 years)
  O (olecranon – 9 years)
  E (external or lateral epicondyle – 11 years)
  assists clinicians with the appearance of the ossification centers in the elbow.

system include the presence of the preosseous cartilage, physis and a stronger osteogenic periosteum. Additional differences between pediatric and adult orthopedic injuries can be attributed to the mineral content of bone and the strength of ligaments. Secondary to lower mineral content, the long bones of children are less dense and more porous than those of adults. This difference in mineral content allows the absorption of more energy prior to fracture and deformation. In addition, ligaments of children are stronger than the immature bones in which they are attached. As a result, injury patterns are the opposite of the adult population with pediatric fractures occurring more commonly than ligamentous injuries.[5]

Healing Differences

Fracture healing involves the following three stages: inflammatory, reparative, and remodeling. Healing of a fractured bone in children begins immediately after the injury with resultant bleeding, inflammation and swelling. Mesenchymal cells are then activated and start laying down new bone. The stronger periosteum in children enhances more rapid formation of a callus and healing. The most unique property of immature bone is the capacity to remodel over time via a combination of periosteral resorption and new bone formation.[4] This remodeling potential allows for a greater degree of longitudinal misalignment and angulation.[3] However, there are several factors that can affect fracture remodeling including age, proximity to the joint, and the relationship of the deformity to the joint axis of motion. Specifically, fractures that occur in younger children as well as those that occur in close joint proximity have greater potential for remodeling. On the contrary, displaced intra-articular fractures, diaphyseal fractures, and deformities not in the plane of joint axis of motion, will remodel less effectively and therefore require more precise anatomic reduction.[6]

Fracture Patterns

Pediatric fracture patterns can be approached methodically. When describing a fracture, the following should be included; anatomic location, configuration of the fracture, relationship of the fracture fragments, as well as the relationship of the fracture fragments to the adjacent tissue.

The configuration of the fracture can be classified into the four unique types of fractures seen in children; plastic deformity, buckle (torus) fractures, greenstick fractures, and the physeal fractures.[2,7]

Plastic Deformity. A plastic deformity is also known as a bowing deformity. This deformity occurs when longitudinal force exceeds the ability of bone to recoil to normal position. As a result the cortex of the diaphysis bends, without visible fracture secondary to the thick pediatric periosteum. Microscopic fractures occur dissipating energy along the side of tension with resultant bowing and plastic deformity. These fractures commonly occur in the long bones of the lower arm and leg and may be associated with a second fracture. This fracture pattern decreases in incidence with increased bone maturity. Radiographically, a fracture line will not be visible, and the bone will display excessive bowing without actual cortical disruption.[1,3,6] *(See Figure 1.)* In addition, if plastic deformity is suspected, additional comparison views may aid in the diagnosis. These fractures typically are stable, and when the bowing deformation is less than 20°, or occurs in a younger child, the angulation will frequently correct itself through remodeling and will not require orthopedic surgical intervention.[3]

Buckle (Torus) Fractures. A torus fracture occurs at the junction between the porous metaphysis and the denser diaphysis. This fracture type is the result of longitudinal forces on the bone with compressive buckling secondary to the porous nature of pediatric bone. This buckling appears as a bulge in the metaphyseal cortex with concomitant disruption of the normal bone contour. *(See Figure 2.)* This fracture pattern occurs most commonly in the distal radius but can be seen in any long bone as a result of longitudinal trauma. These fractures are stable and heal in 2-3 weeks with immobilization.[1,3,5,6]

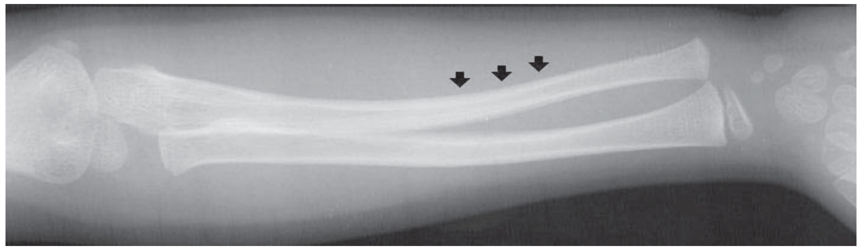
Greenstick Fractures. A greenstick fracture occurs when a bone is angulated beyond the limits of plastic deformity. This pattern is characterized as an incomplete fracture with metaphyseal cortical disruption on the side of tension and an intact bending, or plastic deformity, on side of compression. *(See Figure 3.)* This fracture type is stable and heals within 3-4 weeks. This type of fracture may have the highest risk of re-fracture, as some authors have published rates of greater than 80%.[1,8]

Physeal Fractures. The most significant difference between pediatric and adult fractures is the presence of long-bone growth plates. These growth plates are highly susceptible to fracture, since their cartilaginous composition represents a weak point in the bone.

Physeal injuries have been reported to represent up to 18% of all pediatric fractures. This injury type occurs commonly during times of rapid growth through the weakest part of the physis, the hypertrophic cell zone.[5] Fractures in this zone can result in asymmetric bone growth followed by deformity if not treated properly. Growth plate injuries occur most commonly in the following age ranges: 9-12 years for females, and 12-15 years for males.[1] The separation of the distal radial physis is the most common growth plate injury.[7]

Several classification schemes exist to describe physeal injuries including Salter-Harris, Odgen, Peterson, and many others. The Salter-Harris classification system is used most frequently secondary to the ease of application and relevance to the treatment and prognosis of pediatric fractures.

Figure 1. Plastic Deformity or Bowing Deformity of the Left Ulna



Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center For Women And Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1999; Vol. 6, Case 16. Available at www.hawaii.edu/medicine. Used with permission.

Figure 2. Left Radius and Ulna Buckle Fractures

Image courtesy of St. Christopher's Hospital for Children Radiology Department, Philadelphia, PA.

Figure 3. Greenstick Fracture

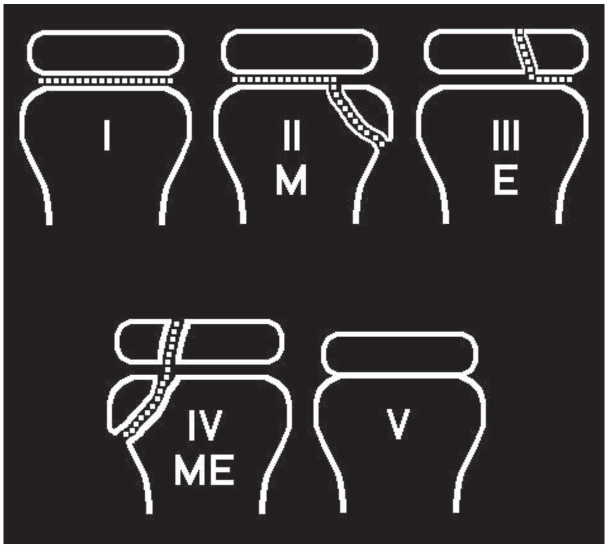
Salter-Harris Classification

This classification system grades physeal fractures as types I through V. Although controversial and joint dependent, generally the higher the Salter-Harris fracture type number, the greater the chance of growth plate arrest and joint incongruity.[1] *(See Figure 4.)*

Type I Salter-Harris Fracture. A type I fracture involves the separation of epiphysis from the physis with the reproductive cells of the physis remaining attached to the epiphysis. These injuries can result in both displaced and nondisplaced epiphyses. Radiographic abnormalities consistent with type I fractures may be subtle with only soft tissue swelling and / or joint effusion without visible fracture.[5] *(See Figure 5.)* The clinical presentation of a Salter-Harris type I fracture is generally significant point tenderness over the affected growth plate. The treatment of nondisplaced type I fractures consists of immobilization, ice, elevation, and outpatient referral to an orthopedic surgeon for further care; displaced fractures require orthopedic consultation. Fortunately, these fractures rarely result in growth disturbances and prognosis is excellent with proper treatment and referral.[1]

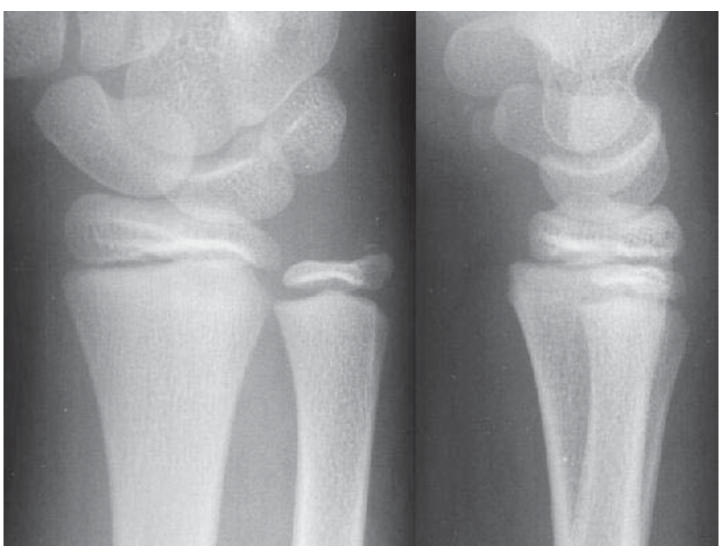
Type II Salter-Harris Fracture. Type II fractures are the most common Salter-Harris fracture

Figure 4. Salter-Harris Classifications



Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1994; Vol. 1, Case 18. Available at www.hawaii.edu/medicine. Used with permission.

Figure 5. Salter-Harris Type I Fracture



Lateral view shows displaced radial epiphysis; also visible is a small fracture of the ulnar styloid.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1994; Vol. 1, Case 18. Available at www.hawaii.edu/medicine. Used with permission.

involving the physis and metaphysis. This fracture type results in a triangular metaphyseal fragment that is commonly referred to as the Thurston-Holland fragment. *(See Figure 6.)* This fragment of metaphysis remains attached to the epiphysis. The treatment and prognosis are similar to that of a Type I fracture.[1,3,5]

Type III Salter-Harris Fracture. A type III fracture begins intra-articularly and involves the epiphysis and the physis. *(See Figure 7.)* The treatment and prognosis of type III fractures are directly related to the achievement of anatomical fragment alignment. Although closed reduction can be achieved in the minority of cases, open reduction is common and minimizes the potential for growth and joint abnormalities. Immediate ED treatment while awaiting orthopedic consultation should include pain control and immobilization.[1,3,5]

Type IV Salter-Harris Fracture. Type IV fractures originate in the articular space and travel through the epiphysis, physis, and the metaphysis. *(See Figure 8.)* Similar to type III fractures, there may be significant growth disturbance without precise anatomic alignment. As a result, the preferred method of repair includes open surgical reduction with internal fixation.[1,3,5]

Type V Salter-Harris Fracture. In type V fractures, compressive forces are transmitted through the epiphysis into the physis. This force results in a crush injury with disruption of the germinal matrix, hypertrophic region, and vascular supply. This type of fracture occurs most commonly in joints that move in one plane (knee and ankle) and is frequently misdiagnosed as a type I fracture.[9] These fractures can be difficult to diagnose secondary to normal appearing radiographs with minimal epiphyseal displacement or joint effusion. The clinical history and the mechanism of injury (axial load) in combination with normal appearing radiographs should alert

Figure 6. Salter-Harris Type II Fracture

Fracture extends from the metaphysis into the physis, with associated physeal widening; associated greenstick fracture of the distal ulna.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine. 1994; Vol. 1, Case 18. Available at www.hawaii.edu/medicine. Used with permission.

Figure 7. Salter-Harris Type III Fracture

Fracture of the distal tibia involving the articular surface. The fracture extends through the epiphysis and physis.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine. 1994; Vol. 1, Case 18. Available at www.hawaii.edu/medicine. Used with permission.

Figure 8. Salter-Harris Type IV Fracture

Fracture of the medial malleolus extending from the inferior articular surface of the tibial epiphysis through the physis and metaphysis.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine. 1994; Vol. 1, Case 18. Available at www.hawaii.edu/medicine. Used with permission.

the clinician to the potential for a type V fracture. *(See Figure 9.)* The prognosis for this injury is poor secondary to the risk of premature growth cessation and subsequent limb shortening. Treatment should include pain management, immobilization, and orthopedic consultation.

Complete Fractures. Complete fractures propagate through the entire bone.[7] These fractures are sub-classified by fracture line appearance: transverse, spiral, oblique, and comminuted. A transverse fracture line occurs at a right angle to the long axis of the bone. Spiral fractures have fracture lines that are oblique, encircling a portion of the shaft of the bone. Oblique fractures have fracture lines that are 30° to 40° perpendicular to the long axis of the bone. A comminuted fracture site reveals multiple fragments.[9]

Clavicle Fractures

Introduction / Etiology. The clavicle is the most common location of a pediatric fracture. This fracture is seen at all ages and represents 10%-15% of all pediatric fractures.[10] Newborn clavicle fractures occur as a result of birth trauma, whereas the mechanism of injury for children and adolescents typically includes a fall on an outstretched arm, shoulder, or direct blow.[11] In infants and young children, clavicle fractures are usually greenstick type going unnoticed until callus formation. In older children, there is a greater tendency for complete displacement.[7] The most common fracture location is the mid-shaft of the clavicle, which represents approximately 80% of all fractures. Although the clavicle is the first bone to ossify, (at five weeks of gestation) the physis is the last to close (at approximately 25 years of age).[10] Therefore, as a result of the clavicle's active physis and strong vascular supply, there is potential for rapid healing and remodeling.

Anatomy. The clavicle serves as the connection between the upper extremity and the trunk. It articulates laterally with the acromion of the scapula (acromioclavicular joint) and medially with the sternum (sternoclavicular joint). The clavicle serves two purposes including upper extremity stability as well as protection of underlying neurovascular structures.[10-12]

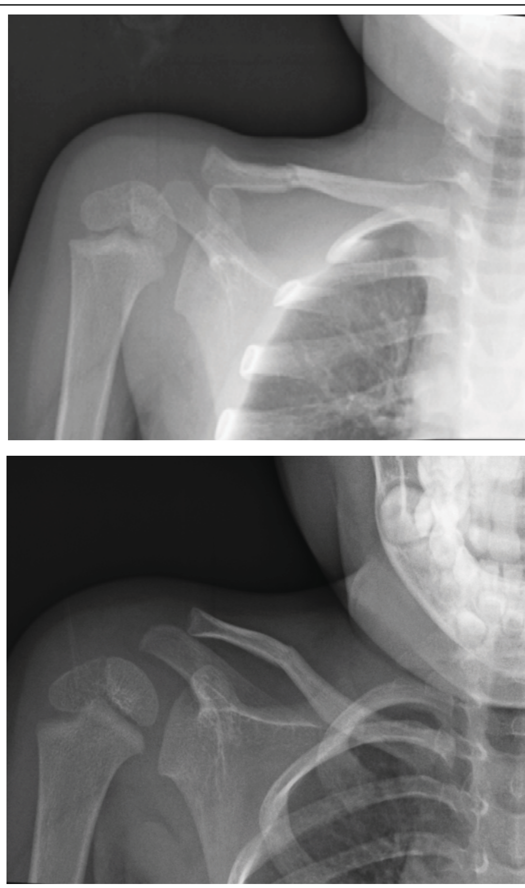
The Allman classification divides the clavicle into thirds and is used to describe fracture location. Group I fractures are the most common involving the middle third of the clavicle where the bone is weakest. In addition to representing the weakest area of the clavicle, the middle third has minimal

Figure 9. Salter-Harris Type V Fracture

Salter-Harris Type V fracture of the distal tibia was suspected after a fall from second-floor balcony.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1994; Vol. 1, Case 18. Available at www.hawaii.edu/medicine. Used with permission.

Figure 10. Right Mid-shaft Clavicle Fracture — AP and 45° Views



Images courtesy of St. Christopher's Hospital for Children Radiology Department, Philadelphia, PA.

muscular and ligamentous support, which leads to predisposition to fracture. Group II fractures are the second most common location (15%-25%) involving the lateral or distal third of the clavicle. Group III fractures are the least common (5%) involving the medial, proximal third of the clavicle.[11,14]

Evaluation. Children with clavicle fractures may present to the ED with a variety of signs and symptoms. In a recent published study, symptoms of clavicle fracture were variable with up to 18% percent of patients presenting with normal physical exams.[12,14] Commonly, children with clavicle fractures present to the ED with their arm adducted close to the body with the opposite extremity supporting the weight of the affected side.[11,12,14] In addition, as a result of the fracture, the tension on the sternocleidomastoid muscle may cause head tilt toward the affected side with rotation of the chin to the contralateral side. Physical exam findings may be significant for point tenderness/crepitus with palpation, ecchymosis, or edema. Further, with completely displaced fractures, the physical exam may be significant for a shoulder that appears to be displaced inferiorly and medially. Although the incidence of complications is low, a careful exam should include neurovascular status, lung auscultation as well as close skin inspection to assess for an open fracture.

Radiographs. Children with suspected clavicle fractures should be imaged utilizing standard radiographs including an anteroposterior view and cranial/caudal tilt views. The cranial/caudal tilt views minimize rib and scapula overlap while assisting with visualization of fractures that are anteriorly and posteriorly displaced.[10-12] *(See Figure 10.)* In rare cases, computed tomography (CT) may be needed for complex comminuted as well as distal/proximal clavicle fractures. In addition, CT imaging will allow better visualization of fractures involving the articular space.[11]

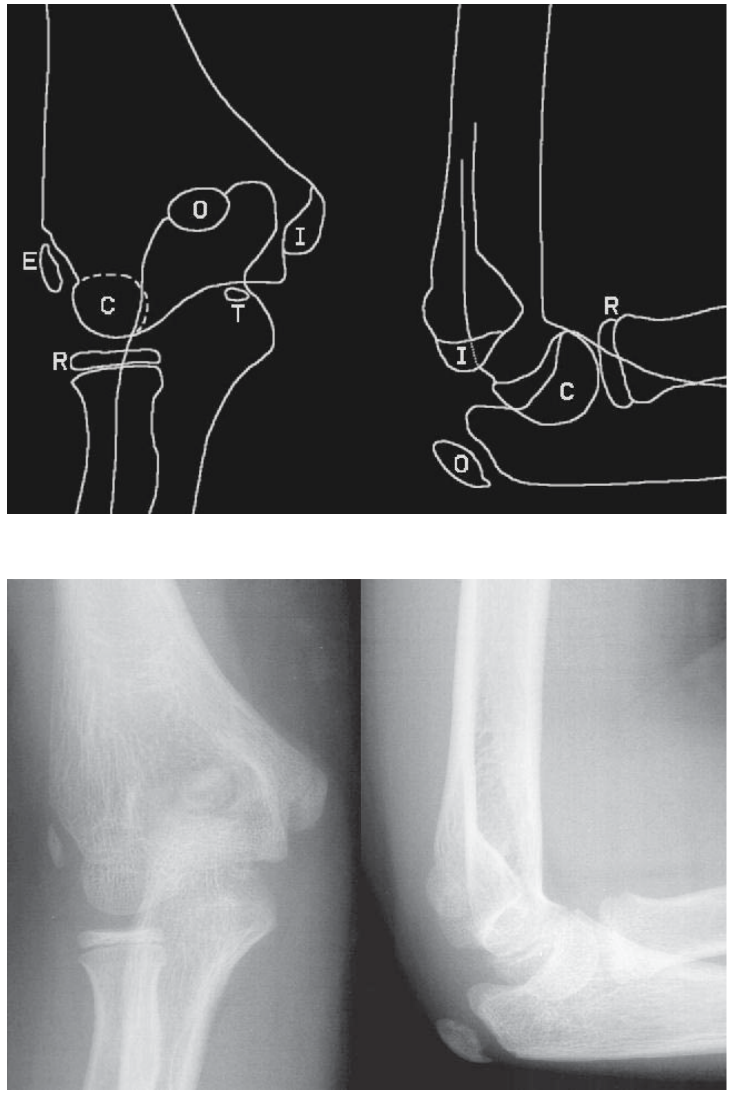
Treatment

The treatment goals include the restoration of normal anatomy, limitation of pain, and promotion of rapid recovery. In comparison to adults, most pediatric clavicle fractures heal rapidly without complication. The treatment of choice for clavicle fractures is immobilization, which should be utilized to provide comfort and pain control. The most common immobilization methods include a sling or figure-of-eight dressing. Although both methods have shown no difference in outcome, slings are more commonly used secondary to comfort and ease of use.[12] The duration of immobilization varies based on child specific pain/comfort levels but is usually recommended for 1-4 weeks.

ED discharge instruction should include range of motion exercises and strengthening activities that may be started as tolerated. In addition, parents should receive education regarding the development of a callus after fracture. The callus will typically develop approximately 10 days after the initial injury and may remain for up to 6 months.[12,14,15] Children with clavicle fractures should generally be referred to orthopedics for long-term follow-up and assistance with recommendations for full return to activity or sports.

It is common for young infants to present to the ED with swelling in the region of the clavicle. This presentation is typical of a clavicle fracture that was sustained at birth and noticed by parents in the first 10 days of life after callus formation. These infants require no further treatment with the exception of reassurance and education regarding the progression of the callous. Neonatal clavicle fractures typically heal rapidly and have an excellent prognosis.[11,14,15]

Figure 11. Diagram of Elbow Ossification Centers



Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1994; Vol. 1, Case 11. Available at www.hawaii.edu/medicine. Used with permission.

Surgical Indications

Pediatric clavicle fractures rarely require surgical management with most pediatric orthopedic surgeons preferring conservative management compared to open reduction.[7] However, recent published studies have suggested that surgical management may be indicated and improves outcomes in select pediatric patients.[16,17] Although more studies are needed, the current accepted indications for surgical management include open fractures, fracture associated with neurovascular injury, greater than one hundred percent displacement with skin tenting, or multiple fractures associated with a compromised chest wall.

Elbow Fractures

Introduction. Elbow fractures represent 15% of all pediatric fractures with supracondylar fractures occurring most commonly (50%-70%) followed by lateral condyle fractures.[18] The unique anatomy of the elbow in conjunction with a potential for significant complications, requires prompt, accurate diagnosis and treatment.

Anatomy. The pediatric elbow consists predominantly of cartilage, with secondary ossification centers of the elbow becoming calcified during childhood. During adolescence, these secondary ossification centers fuse to their respective long bones.[19] The ossification growth centers in children appear in a predictable fashion based on the child's age and gender. The mnemonic CRITOE is used as an aid to assist clinicians in regard to time of ossification. *(See Figure 11.)* Knowledge of this sequence of ossification is paramount in distinguishing a fracture from a normal finding in the elbow. The capitellum "C" is the first ossification center to appear, and is usually formed by 1-2 years of age. The radial head "R" is the next to appear at 2-5 years of age, which is then followed by the medial or internal epicondyle "I" at 5-7 years. The trochlea "T" appears at 7-10 years of age, while the two final ossification centers; olecranon "O" and the lateral or external epicondyle "E" appear between 9-11 years of age. The ages of each center's appearance may be approximated by using odd numbers; capitellum (1 year), radial head (3 years), medial/internal epicondyle (5 years), trochlea (7 years), olecranon (9 years), and lateral/external epicondyle (11 years).[14,20,21] The ossification sequence occurs slightly earlier in females when compared to males secondary to the onset of puberty. Although knowing the sequence and timing of ossification center fusing is helpful, there will likely be times when a comparison view is helpful to determine if a fracture is present.

Supracondylar Humerus Fractures

Epidemiology. Supracondylar humerus fractures are more common in males with the peak incidence occurring at 5-7 years of age. The vast majority of these fractures occur in the first decade of life secondary to falls. Factors contributing to the incidence include both ligamentous laxity and weakness in the bony architecture of the elbow.[21-24] There are two major classifications of supracondylar fractures that are based upon mechanism of injury. Extension-type fractures represent 95% of all supracondylar fractures; the mechanism of injury is commonly a fall on an outstretched extremity. This mechanism causes the ulna and the triceps to exert an unopposed force on the distal humerus resulting in posterior displacement (lateral or medial) of the fracture.[14] Less commonly, a flexion-type supracondylar fracture may result from a direct blow to the posterior aspect of the elbow during flexion with anterolateral displacement of the condylar complex.[18,20,21]

Evaluation of the Pediatric Patient. Examination of children with elbow fractures may be difficult secondary to pain and anxiety. The physical examination should begin with inspection for any swelling, asymmetry, or misalignment. As these fractures can be associated with significant neurovascular injury, assessment should occur upon arrival to the ED and serially. Children with supracondylar fractures typically present with their arm in a pronated position with a refusal to move the extremity while displaced fractures generally present with significant elbow swelling and localized tenderness with or without obvious deformity. Contrary to the displaced supracondylar fracture, non-displaced fractures may present in a more subtle fashion, with minimal findings except refusal to move the affected arm.[12,18,21]

Neurovascular Injury. Supracondylar humerus fractures have a high potential for neurovascular compromise and residual deformity. A thorough exam to assess neurovascular status should include palpation of distal pulses, skin color, temperature, capillary refill, and sensory and motor aspects of the median, ulnar, and radial nerves. Approximately 10%-15% of supracondylar fractures will have an associated neurologic injury. Specifically, the median nerve is most commonly injured followed by the radial and ulnar nerves.[18,21] The likelihood of neurovascular injury is directly related to the degree of fracture displacement.[18,21,25] Knowledge of anatomy, injury mechanism, and the direction of fracture displacement should be utilized as tools to determine which neurovascular structures may have been injured. The median nerve crosses the elbow with the brachial artery and may be damaged with a posterolateral displacement due to an anteromedial displacement of the proximal fragment.[21] Damage to the median nerve results in weakness of flexor muscles of the hand and loss of two-point sensation in the index and middle fingers. Injury to the anterior interosseous nerve, a branch of the median nerve, is the most common nerve injury associated with pediatric supracondylar fractures. A partial injury to this nerve results in a weakness of the flexor pollicis longus or the flexor digitorum profundus to the index finger. This nerve can be examined by asking the patient to make an "okay" sign with their hand. In contrast, the radial nerve is usually damaged with posteriormedial humeral displacement. The patient can be asked to perform a "thumbs up" sign to assess the function of the radial nerve.[20,21] The ulnar nerve crosses the elbow posteriorly to the medial epicondyle and is most commonly damaged during a flexion type supracondylar fracture with resultant anterior displacement.[14,22]

Vascular insufficiency/injury occurs in approximately 10% of children with supracondylar fractures. Vascular examination includes distal evaluation of capillary refill as well as brachial and radial pulses by palpation or ultrasound. The brachial artery is injured in approximately 7%-12% of supracondylar fractures.[14] Vascular injury occurs most commonly with posterolateral humeral displacement and is associated with an absent or weak radial pulse. In published studies, authors have concluded that although pulses are

Figure 12. Fat Pads

Mild soft tissue swelling as well as anterior and posterior "sail" signs consistent with joint effusion.

Image courtesy of St. Christopher's Hospital for Children Radiology Department, Philadelphia, PA.

an important aspect of the assessment of a child with a supracondylar fracture, it is the absence of brisk capillary refill that best indicates the likelihood of long-term vascular injury.[12,14,18,20,21]

Supracondylar fractures are at high risk for the development of compartment syndrome, which mandates a timely diagnosis. Patients with suspected compartment syndrome should be assessed for the five "Ps" (pain, pallor, pulselessness, paralysis, and paresthesias).[3,12,14] The most reliable sign of compartment syndrome associated with supracondylar fractures is pain with passive range of motion of the distal fingers.[18] In addition to the initial assessment, serial exams should be performed, as compartment syndrome of the volar forearm can develop 12-24 hours after the injury. Finally, missed or delayed diagnosis of compartment syndrome may lead to significant complications including muscle necrosis/fibrosis, deformity and loss of function.

Radiographic Findings. Standard radiographs with a suspected

Figure 13. Posteriorly Displaced Supracondylar Fracture

The capitellum is posterior to the anterior humeral line.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1995; Vol. 2, Case 18. Available at www.hawaii.edu/medicine. Used with permission.

supracondylar fracture should include an anteriorposterior view in extension as well as a lateral view in 90°of flexion. Additional oblique radiographs of the elbow should be obtained if there is a high degree of suspicion for a medial or lateral condyle fracture. In addition to the findings of an obvious fracture, it is important to utilize radiographic signs of an occult elbow fracture.[9,14,15,18,21,26] Each of these signs will be described in detail below.

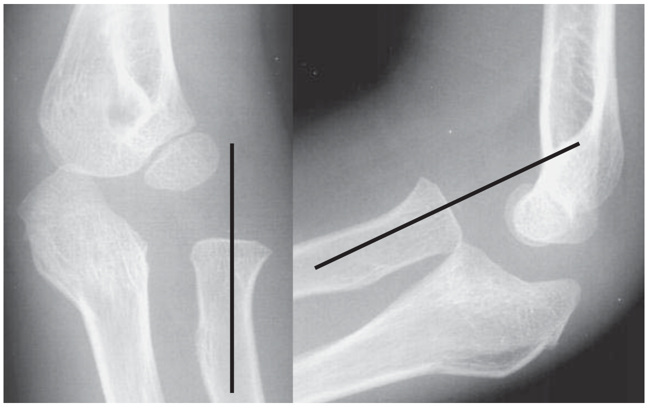
Fat Pads. Fat pads are a nonspecific marker for a joint effusion. There are two fat pads that overlie the anterior and posterior aspects of the elbow joint capsule. In the normal child, the anterior fat pad of the elbow lies over the coranoid fossa.[14,15,18,25,26] Radiographically, it can be seen as a thin radiolucent line at the anterior border of the distal humerus. However, when the elbow joint capsule becomes distended by effusion secondary to a fracture, the anterior fat pad becomes more displaced anteriorly and superiorly forming a triangle shape that resembles a sail of a ship (sail sign).[9,18,25,26] The posterior fat pad normally lies over the more concave, and deeper olecranon fossa. As a result of this difference in location, it should never be visualized on normal radiographs. The presence of a posterior fat pad, regardless of size, (even a thin radiolucent line) on a true lateral view radiograph is pathognomic for an intra-articular fracture of the elbow.[9,14,18,25,26] *(See Figure 12.)*

Anterior Humeral Line. The anterior humeral line is drawn along the anterior surface of the distal humerus and should only be utilized with a true lateral radiographic view of the elbow. To identify a true lateral, the medial posterior cortical contour and the lateral posterior cortical contours should be distinctly different. In a child without a fracture, this line should intersect the middle third of the capitellum. Additionally, in young children, the anterior humeral line may pass through the anterior third of the capitellum secondary to the small size of the ossification center.[27,28] In the presence of a posteriorly displaced supracondylar fracture, the anterior humeral line will pass through the anterior third of the capitellum, or completely anterior to the capitellum without intersecting the anterior surface. *(See Figure 13.)* A displaced capitellum secondary to a physis fracture may also result in an abnormal anterior humeral line.[25,26]

Radiocapitellar Line. The radiocapitellar line can be visualized on both the anteriorposterior and lateral radiographic views of the elbow. In a child without injury, this line is drawn along the central axis of the radius, intersecting the middle third of the capitellum in both views. Failure of the radiocapitellar line to transect the capitellum represents radial head dislocation and/or a fracture through the radial neck region.[14,18,25] *(See Figure 14.)*

Figure of Eight. The figure of eight, or hourglass configuration, of the distal humerus should be visualized in a true lateral view of the elbow. Disruption of the

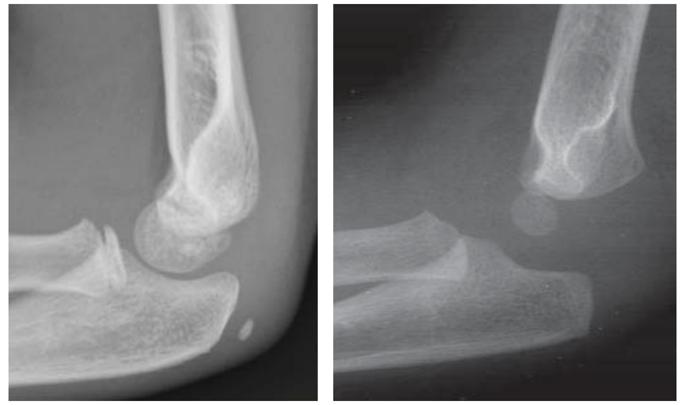
Figure 14. Abnormal Radiocapitellar Line



AP and lateral views of the elbow, representing a dislocated radial head.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1995; Vol. 2, Case 18. Available at www.hawaii.edu/medicine. Used with permission.

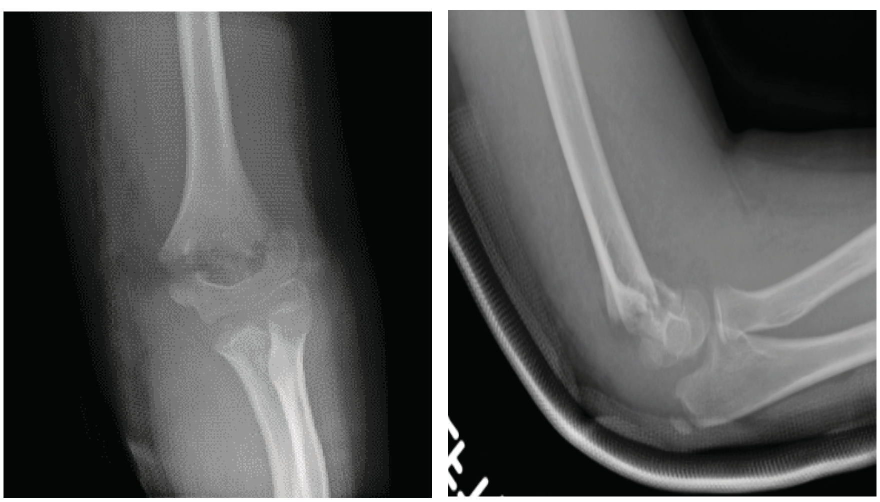
Figure 15. Figure of Eight



L: Normal figure of eight sign. R: Distorted figure of eight sign, consistent with supracondylar fracture.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1995; Vol. 2, Case 18. Available at www.hawaii.edu/medicine. Used with permission.

Figure 16. Type II Supracondylar Humerus Fracture



AP/lateral views

Images courtesy of St. Christopher's Hospital for Children Radiology Department, Philadelphia, PA.

figure-of-eight indicates an occult supracondylar fracture.[14,15,25] *(See Figure 15.)*

Classification. The Gartland classification system is used for extension-type supracondylar fractures. A type I fracture is non-displaced and will have limited radiographic evidence with a posterior fat pad sign as the only positive finding. Type II fractures are angulated and displaced with the posterior cortex of the humerus intact. The distal fragment maintains a connection to the humerus and appears to be hinged posteriorly to the humeral shaft. *(See Figure 16.)* Type III fractures have a complete displacement of the distal fragment with loss of connection to the more proximal humerus. *(See Figure 17.)* In both Type II and III fractures the anterior humeral line will fall anterior and not intersect the capitellum.[12,18]

Management. Immediate ED therapy should include pain management, immobilization, arm elevation, and orthopedic consultation. Management of extension-type fractures is based on the Gartland classification. Type I fractures should be splinted with a posterior long-arm splint with ninety degrees of elbow flexion with forearm in neutral position. These patients may be discharged home if their neurovascular status is intact and adequate follow-up is arranged (in less than one week).[14,15,25,29] Type II and III fractures are displaced fractures requiring orthopedic consultation and subsequent reduction to decrease the risk for cosmetic deformity and poor functional outcome.[30-32] In regard to management of type II supracondylar fractures, older published literature supported

Figure 17. Supracondylar Humerus Fracture

Type III fracture

Image courtesy of St. Christopher's Hospital for Children Radiology Department, Philadelphia, PA.

Figure 18. Lateral Condyle Fracture

Oblique view of the elbow with a lateral condyle fracture. An associated fracture of the capitellum is also present.

Image courtesy of St. Christopher's Hospital for Children Radiology Department, Philadelphia, PA.

hyperflexion casting after closed reduction as an alternative to operative management. However, in comparison to hyperflexion casting, more recent literature suggests that type II supracondylar fractures without neurovascular compromise, may have more favorable outcomes with closed reduction and delayed percutaneous pinning.[20,25,28,30]

Complications. Volkmann's ischemic contracture is a complication of undiagnosed or under diagnosed compartment syndrome secondary to supracondylar fracture. This uncommon complication is characterized by fixed elbow flexion, forearm pronation, wrist flexion, and joint extension of the metacarpal-phalangeal joint. Frequent neurovascular monitoring and timely use of fasciotomies, may prevent this complication. Additional long-term complications of supracondylar fractures include cubitus varus or "gunstock" deformity. This occurs when a supracondylar fracture heals with a varus deformity resulting in a cosmetic deformity without loss of function.[14,15,18,25]

Lateral Condyle Fractures

Lateral condyle fractures are the second most common (10%-20%) elbow fracture. The mechanism of injury and age distribution are similar to that of supracondylar fractures.[14,15,18] This fracture type is an oblique fracture of the lateral portion of the joint surface. It occurs as the result of varus or valgus stress secondary to the radial head impacting the capitulum of the humerus during a fall.[14,15,24] This fracture may be difficult to diagnose and will frequently have the appearance of a Salter-Harris II fracture. Despite this appearance, the majority of lateral condyle fractures are highly unstable Salter-Harris IV fractures.[24]

Evaluation. Children with these fractures complain of swelling, localized tenderness, and decreased range of motion of the elbow. When compared to supracondylar fractures, patients with this fracture type have more lateral ecchymosis as a result of tearing of the lateral intermuscular septum.[12,14] The physical evaluation should include a thorough neurovascular examination. However, in comparison to supracondylar fractures, the risk of neurovascular compromise is much lower.[14,18,20,24]

Imaging. As with all elbow radiographs, true anteroposterior and lateral views should be obtained. If the clinical suspicion for lateral condyle fracture is high, oblique views should be considered and may aid in the diagnosis. In displaced fractures, radiographic confirmation is made by an abnormal capitellum-radial head relationship. This abnormality will be visualized by lateral displacement of the condyle and capitellum in reference to the radial head. In addition, the most common radiographic finding is the presence of a posteriorly displaced metaphyseal fragment known as a Thurston-Holland fragment.[14,15,18] *(See Figure 18.)*

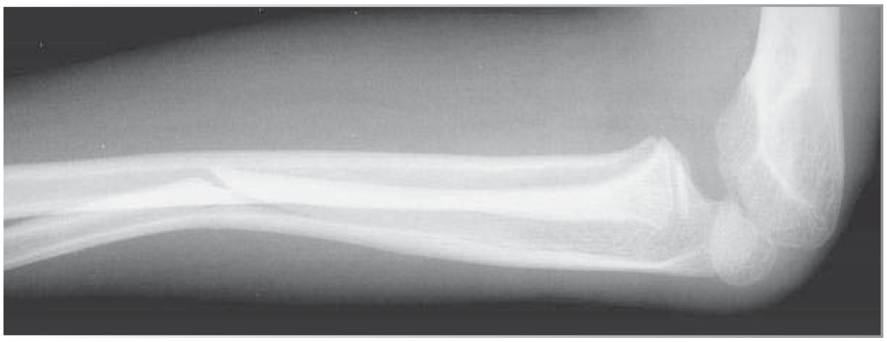
Management / Complications. The ED management of lateral condyle fractures is similar to that of types II and III supracondylar fractures. The majority of these fractures require surgical repair and long-term follow up to prevent complications including nonunion, avascular necrosis, cubitus valgus/varus deformity, ulnar nerve palsy, and physeal arrest.[14,15]

Forearm Fractures

Introduction. Fractures of the radius and/or ulna represent 10%-45% of pediatric fractures.[6,12,14,23] These injuries vary in severity and complexity involving one or both bones of the forearm. Buckle (torus), greenstick, metaphyseal and physeal fractures are the most common types of fractures of the forearm.[6,12,14]

Forearm fractures are most commonly the result of a fall on an outstretched hand but may occur as a result of direct trauma. The majority of forearm fractures are classified according to location, degree of displacement, and severity of angulation. In general, the treatment for forearm fractures is immobilization and/or closed reduction secondary to the ability of pediatric bone

Figure 19. Monteggia Fracture



Fracture of the proximal third of ulna with radial head dislocation

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1994; Vol. 1, Case 11. Available at www.hawaii.edu/medicine. Used with permission.

Figure 20. Galeazzi Fracture

Distal third radius fracture with distal ulnar dislocation.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1994; Vol. 1, Case 16. Available at www.hawaii.edu/medicine. Used with permission.

to vigorously remodel.[35] Operative management may be required for open fractures, arterial injuries, failed reductions, and patients with skeletal maturity.[14,15,23]

Evaluation. The examination of children with displaced forearm fractures will include positive findings such as swelling, obvious deformity, and point tenderness.[12,14,15] However, a thorough examination should be conducted, as signs and symptoms of fracture may be subtle with a plastic deformity or small buckle fracture. In addition, the exam should include a careful inspection of the skin to rule out an open fracture. Further, it is common for children with minor fractures of the forearm to present to the ED several days after the initial injury with intermittent pain and decreased use of the extremity.

Imaging. A minimum of two radiographic views of the forearm should be obtained, including anteroposterior and lateral views. In addition, elbow and wrist radiographs should be obtained to exclude fractures that have associated joint dislocation.

Nightstick Fracture. This fracture type involves the ulna and usually results from direct trauma to the midshaft. Typically, the trauma occurs as the forearm is held in a protective position during an altercation. This fracture occurs more commonly in the adolescent and adult age group. Treatment involves immobilization in a posterior long-arm splint with 90° of elbow flexion and a neutral hand position.[14,15,34]

Monteggia Fracture. A Monteggia fracture was first described as the combination of a proximal ulnar fracture with anterior dislocation of the radial head. *(See Figure 19.)* Currently, the Monteggia fracture-dislocation includes several different types of ulnar fractures with radial head dislocation. The classic form of a Monteggia injury is uncommon in children, comprising 2% of all pediatric elbow fractures. Children that have sustained this fracture present with limited mobility of the arm, pain with movement, point tenderness, and significant swelling. This is an important fracture type secondary to the complications that may arise if the diagnosis of the concomitant radial head dislocation is missed. It further emphasizes not only the need for radiographs that image the joint above and below the site of injury, but also the need for clinicians to search for multiple injuries. Complications that may arise with failure to diagnose this fracture type include nerve palsies (radial/median nerves) as well as long-term deformity and loss of function. Specifically, physical findings associated with nerve injury secondary to a Monteggia fracture include weakness and inability to extend the fingers and thumb (injury of the posterior interosseous nerve, a branch of the radial nerve). These fractures require orthopedic consultation for closed reduction and immobilization. However, if closed reduction is not successful, operative intervention is required.[14,15,34]

Figure 21. Colles Fracture

Figure 22. Smith Fracture

Wrist / Distal Forearm Fractures

Introduction. The majority (up to 84%) of radius and ulna fractures involve the wrist and distal forearm. The fracture mechanism is typically a fall on an outstretched hand with subsequent displacement the result of wrist position during the injury. Specifically, a fall with a dorsiflexed wrist will result in a dorsal angulation or displacement. Conversely, a fall with a volar flexed wrist will result in volar angulation or displacement.[14,15, 34] Important to mention is that injury to the carpal bones is uncommon in the pediatric population, due to the immaturity of these bones. Common mechanisms that cause bony wrist injuries in adults, result in fractures of the forearm in children.[25]

Evaluation. Children will complain of swelling, and localized tenderness that is worsened with movement. In addition, patients may have significant deformity, which is dependent upon the degree of fracture angulation. Patients with suspected forearm fractures should undergo a thorough neurovascular and skin exam.

Treatment. Physeal fractures of the distal forearm are classified by the Salter-Harris system. Treatment for physeal fractures was mentioned previously, as well as treatment for buckle (torus) fractures. Greenstick fractures are usually managed with closed reduction and long-arm or sugar-tong casting if the angulation is less than 15°. Parents should be cautioned of the increased risk of re-injury with these fractures.[14,15,34]

Galeazzi Fractures. A Galeazzi fracture is a fracture of the distal radius with associated disruption of the radioulnar joint. These fractures are rare in children and immediate orthopedic consultation is required for a closed reduction.[14,15,34] *(See Figure 20.)*

Colles Fracture. A Colles fracture is a transverse fracture that occurs proximal to the distal radial physis with dorsal displacement of the distal segment and volar angulation.[14,15] *(See Figure 21.)* This fracture is also known as a dinner fork deformity due to the subsequent appearance of the forearm. A neurovascular exam should be done to exclude median nerve injury. In children that are skeletally immature, a 40° displacement is well tolerated because of the ability of pediatric bone to remodel. However, if there is significant rotational deformity, a closed reduction may be needed. Orthopedic consultation may help direct definitive care for angulated fractures.

When reduction is required, the distal radius should be restored toward the normal volar tilt.[14,25] Immobilization is successful in a sugar tong splint with slight volar angulation at the wrist.[14,15,25,34]

Smith Fracture. A Smith fracture is the reverse of a Colles fracture, with volar displacement and dorsal angulation. *(See Figure 22.)* This fracture type occurs less commonly than the Colles fracture but has a similar risk of injury to the median nerve. Further, this fracture has a tendency to be less stable, and generally only 10° of angulation is tolerated prior to the need for closed reduction and/or operative repair. For all angulated fractures, consider orthopedic consultation for definitive management.

Conclusion

Part I of this two part series on common orthopedic injuries in the pediatric ED focused on upper extremity injuries, their unique pediatric presentations, diagnostic evaluation and treatment options to optimize outcomes. Part II will focus on common injuries in the lower extremities.

References

1. Mathison JD, Agrawal D. General principles of fracture management: Fracture patterns and description in children. www.uptodate.com/home/index.html. Accessed June 14, 2010.
2. Goulding A. Risk factors for fractures in normally active children and adolescents. *Med Sport Sci* 2007;51:102-120.
3. Della-Giustina K, Della-Giustiina DA. Emergency department evaluation and treatment of pediatric orthopedic injuries. *Emerg Med Clin North Am* 1999;17:895-922.
4. Hart ES, Albright MB, Rebello GN, et al. Broken bones: Common pediatric fractures-Part I. *Orthop Nurs* 2006;25:251-255.
5. Davenport M, Nesbit C. An evidence-based approach to pediatric orthopedic

emergencies. *Pediatr Emerg Med Pract* 2009;6:1-16.

6. Gholve, PA. Common Fractures. In: Kielgman RM, et al, eds. *Nelsons Textbook of Pediatrics,* 18th ed. Philadelphia: Saunders; 2007:682.
7. England SP, Sundberg S. Management of common pediatric fractures. *Pediatr Clin N Am* 1996;43:991-1012.
8. Park HW, Yang IH, Joo SY, et al. Refractures of the upper extremity in children. *Yonesei Med J* 2007;48:255.

9. Frick SL. Skeletal Growth, Development, and Healing as Related to Pediatric Trauma. *In: Green & Swiontkowski: Skeletal Trauma in Children*. 4th ed. Elsevier 2008;1:1-18.
10. Shannon EG, Hart ES, Grottkau BE. Clavicle fractures in children: The essentials. *Orthop Nurs* 2009;28:210-214.
11. Pecci M, Kreher JB. Clavicle fractures. *Am Fam Phys* 2008;77:65-69.
12. Hart ES, Grottkau BE, Rebello GN. Broken bones: Common pediatric upper extremity fractures-Part II. *Orthop Nurs* 2006;25:311-324.
13. Soto F, Fiesseler F, Morales J, et al. Presentation, evaluation, and treatment of clavicle fractures in preschool children presenting to an emergency department. *Pediatr Emerg Care* 2009; 25:744-747.
14. Carson S, Woolridge DP, Colletti J, et al. Pediatric upper extremity injuries. *Pediatr Clin N Am* 2006;53:41-67.
15. Benjamin HJ, Hang BT. Common acute upper extremity injuries in sports. *Clin Ped Emerg Med* 2007;8:15-30.
16. Wiesel BB, Getz CL. Current concepts in clavicle fractures, malunions and nonunions. *Curr Opin Orthop* 2006;17: 325-330.
17. Hill JM, McGuire MH, Crosby LA. Closed treatment of displaced middle-third fractures of the clavicle gives poor results. *J Bone Joint Surg Br* 1997;7: 537-539.
18. Shrader MW. Pediatric supracondylar fractures and pediatric physeal elbow fractures. *Orthop Clin N Am* 2008;39:163-171.
19. Smith JR, Kozin S. Identifying and managing physeal injuries in the upper extremity. *JAAPA* 2009;22:39-45.
20. Green NE. Fractures and dislocations about the elbow. In: Green NE, Swiontkowski ME, eds. *Skeletal Trauma in Children*. 4th ed. Philadelphia: Elsevier; 2008:207-282.
21. Baratz M, Micucci C, Sangimino M. Pediatric supracondylar humerus fractures. *J Hand Clinic* 2006;22:69-75.
22. Brubacher JW, Dodds SD. Pediatric supracondylar fractures of the distal humerus. *Cur Rev Musculosket Med* 2008;1:190-196.
23. Skaggs D. Pershad J. Pediatric elbow trauma. *Pediatr Emerg Care* 1997;13:425-434.
24. Spiegel PG et al. Fractures. In: Skinner: *Current Diagnosis and Treatment in Orthopedics.* 4th ed. Columbus, OH: McGraw-Hill Companies; 2008:11; 635-643.
25. Menckhoff C, Welter C, Sessums C. Pediatric wrist and elbow injuries: Mechanisms of injury, findings, and treatment. *Pediatr Emerg Med Reports* 2008;8:93-108.
26. Emery KH. Imaging of sports injuries of the upper extremity in children. *Clin Sports Med* 2006;25:53-568.
27. Skaggs DL, Mirzayan R. The posterior fat pad sign in association with occult fracture of the elbow in children. *J Bone Joint Surg Am* 1999;81:1429-1433.
28. Wu J, Perron AD, et al. Orthopedic pitfalls in the ED: Pediatric supracondylar humerus fractures. *Am J Emerg Med* 2002;20:544-550.
29. Carmichael KD, Joyner K. Quality of reduction versus timing of surgical intervention for pediatric supracondylar humerus fractures. *Orthopedics* 2006;29:628-632.
30. Farley FA, Patel P, Craig CL. Pediatric supracondylar humerus fractures: Treatment by type of orthopedic surgeon. *J Child Orthop* 2008;2:91-95.
31. Valiati R, Ibrahim D, Abreu MER. The treatment of condylar fractures: to open or not to open? A critical review of this controversy. *Int J Med Sci* 2008;5: 313-318.
32. Kamath AF, Baldwin K, Horneff J. Operative versus non-operative management of pediatric medical epidcondyle fractures: A systematic review. *J Child Orthop* 2009;3:345-357.
33. Keppler P, Salem K, Schwarting B. The effectiveness of physiotherapy after operative treatment of supracondylar humeral fractures in children. *J Pediat Orthop* 2005;25:314-316.
34. Dolan M. Fractures and Dislocations of the Forearm, Wrist, and Hand. *In: Green & Swiontkowski: Skeletal Trauma in Children*. 4th ed. Elsevier 2008;8:159-205.

CME Questions

1. All of the following are true regarding the anatomy of pediatric bone *except*:
   a. The major anatomic regions of pediatric bone include the metaphysis, epiphysis, physis, and diaphysis.
   b. The growth plate is the primary center of longitudinal growth.
   c. Long bones of children are less dense and more porous than those of adults.
   d. Ligaments in children are weaker than the bone to which they are attached.
   e. Pediatric bone has lower mineral content

2. Which of the following statements is correct?
   a. Four fracture patterns specific to the pediatric population include buckle, plastic deformity, greenstick, and physeal fractures.
   b. Plastic deformity appears as a bulge in the cortex.
   c. Greenstick fractures heal in approximately 1-2 weeks.
   d. There are four types of Salter-Harris fractures.

e. The Salter-Harris classification system may be used for definitive treatment and prognosis of all pediatric fractures.

3. All the following statements are true regarding Salter-Harris type fractures *except:*
   a. Salter-Harris type II fractures involve the physis and epiphysis
   b. Salter-Harris type IV fractures involve the physis, metaphysis, and epiphysis
   c. Salter-Harris type IV fractures have a high risk for growth disturbance
   d. Salter-Harris type V fractures may be misdiagnosed as Salter-Harris type I fractures
   e. The preferred method of repair for a Salter-Harris type IV fracture includes open reduction and internal fixation

4. Which of the following statements is true about clavicle fractures?
   a. Clavicle fractures are the second most common location of a pediatric fracture.
   b. The most common location of a clavicle fracture is the proximal third.
   c. Commonly, pediatric patients with clavicle fractures will present with their arms abducted away from their bodies.
   d. The most common immobilization method for a clavicle fracture includes a posterior long-arm splint.
   e. Pediatric clavicle fractures rarely require surgical repair and heal quickly in 2-4 weeks.

5. Which of the following statements is *incorrect* regarding ossification centers of the elbow?
   a. There are seven ossification centers of the elbow.
   b. The capitellum is the first ossification center to appear.
   c. The ossification sequence is predictable.
   d. The external epicondyle in the last ossification center to appear.
   e. The trochlea ossification center appears at 7-10 years of age

6. Which of the following is / are radiographic signs of an occult supracondylar humerus fracture?
   a. Posterior fat pad
   b. Disrupted figure of eight sign on a true lateral radiograph of the elbow
   c. Anteriorly displaced anterior humeral line
   d. All of the above

7. Which of the following statements is correct?
   a. Supracondylar fractures are low risk for neurovascular injury.
   b. The majority of lateral condyle elbow fractures are stable.
   c. Supracondylar humerus fractures may be classified using the Gartland system.
   d. Volkman's ischemic contracture is a common complication of a misdiagnosed supracondylar fracture.
   e. The median nerve is the least common neurovascular injury associated with supracondylar fractures.

8. Which of the following is / are true about physeal injuries?
   a. Typically occurs during times of rapid growth through the hypertrophic cell zone
   b. May result in asymmetric bone growth
   c. May result in deformity if not treated appropriately
   d. All of the above

9. Which of the following statements about type III Salter-Harris fractures is true?
   a. Anatomic fragment alignment is optimal.
   b. They involve the metaphsis and physis.
   c. Closed reduction is always successful.
   d. They are never intra-articular.

10. Which nerve is most commonly injured in a child with a supracondylar fracture?
    a. Median
    b. Ulnar
    c. Radial
    d. Brachial

ANSWERS: 1. d, 2. a, 3. a, 4. e, 5. a,
6. d, 7. c, 8. d, 9. a, 10. a

Pediatric Emergency Medicine Reports

CME Objectives

Upon completion of this educational activity, participants should be able to:
1. recognize specific conditions in pediatric patients presenting to the emergency department;
2. describe the epidemiology, etiology, pathophysiology, historical and examination findings associated with conditions in pediatric patients presenting to the emergency department;
3. formulate a differential diagnosis and perform necessary diagnostic tests;
4. apply up-to-date therapeutic techniques to address conditions discussed in the publication;
5. discuss any discharge or follow-up instructions with patients.

CME Instructions

Physicians participate in this continuing medical education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge.

To clarify confusion surrounding any questions answered incorrectly, please consult the source material. After completing this activity, you must complete the evaluation form that will be provided at the end of the semester and return it in the reply envelope provided to receive a credit letter. When your evaluation is received, a credit letter will be mailed to you.

Pediatric Emergency Medicine Reports™ (ISSN 1082-3344) is published monthly by AHC Media LLC, 3525 Piedmont Road, N.E., Six Piedmont Center, Suite 400, Atlanta, GA 30305. Telephone: (800) 688-2421 or (404) 262-7436.

Vice President/Group Publisher: Don Johnston
Executive Editor: Coles McKagen
Managing Editor: Allison Weaver
Director of Marketing: Schandale Kornegay
GST Registration No.: R128870672
Periodicals Postage Paid at Atlanta, GA 30304 and at additional mailing offices.

POSTMASTER: Send address changes to ***Pediatric Emergency Medicine Reports***, P.O. Box 740059, Atlanta, GA 30374.

Back issues: $65. Missing issues will be fulfilled by customer service free of charge when contacted within one month of the missing issue's date.

Subscriber Information

Customer Service: 1-800-688-2421
Customer Service E-Mail Address:
customerservice@ahcmedia.com
Editorial E-Mail Address: allison.weaver@ahcmedia.com
World-Wide Web page: http://www.ahcmedia.com

Subscription Prices

1 year *with* 30 ACEP, AMA, or AAP Category 1 credits: $439;
1 year without credit: $389;
Add $17.95 for shipping & handling
Multiple copies:
Discounts are available for group subscriptions, multiple copies, site-licenses or electronic distribution. For pricing information, call Tria Kreutzer at 404-262-5482.
One to nine additional copies: **$350 each;**
10 or more additional copies: **$311 each.**
Resident's Rate: **$194.50**
All prices U.S. only. U.S. possessions and Canada, add $30 postage plus applicable GST.

Accreditation

AHC Media LLC is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

AHC Media LLC designates this educational activity for a maximum of 30 *AMA PRA Category 1 Credits™*. Physicians should only claim credit commensurate with the extent of their participation in the activity.

Approved by the American College of Emergency Physicians for 30 hours of ACEP Category 1 credit.

This continuing medical education activity has been reviewed by the American Academy of Pediatrics and is acceptable for up to 30 (2.5 per issue) AAP credits. These credits can be applied toward the AAP CME/CPD Award available to Fellows and Candidate Fellows of the American Academy of Pediatrics.

This CME activity is intended for emergency and pediatric physicians.

It is in effect for 36 months from the date of the publication.

Dear *Pediatric Emergency Medicine Reports* Subscriber:

This issue of your newsletter marks the start of a new continuing medical education (CME) and provides us with an opportunity to review the procedures.

Pediatric Emergency Medicine Reports, sponsored by AHC Media LLC, provides you with evidence-based information and best practices that help you make informed decisions concerning treatment options and physician office practices. Our intent is the same as yours — the best possible patient care.

The objectives of *Pediatric Emergency Medicine Reports* are to help participants:

a.) Quickly recognize or increase index of suspicion for specific conditions;
b.) Describe the epidemiology, etiology, pathophysiology, historical and physical examination findings associated with the entity discussed;
c.) Correctly formulate a differential diagnosis and perform necessary diagnostic tests;
d.) Apply state-of-the-art therapeutic techniques (including the implications of pharmacologic therapy discussed) to patients with the particular medical problems discussed;
e.) Provide patients with any necessary discharge instructions.

Each issue of your newsletter contains questions relating to the information provided in that issue. After reading the issue, answer the questions at the end of the issue to the best of your ability. You can then compare your answers against the correct answers provided in an answer key in the newsletter. If any of your answers were incorrect, please refer back to the source material to clarify any misunderstanding.

At the end of each semester you will receive an evaluation form to complete and return in an envelope we will provide. Please make sure you sign the attestation verifying that you have completed the activity as designed. Once we have received your completed evaluation form we will mail you a letter of credit. This activity is valid 36 months from the date of publication. The target audience for this activity is emergency and pediatric physicians.

If you have any questions about the process, please call us at (800) 688-2421, or outside the U.S. at (404) 262-5476. You can also fax us at (800) 284-3291, or outside the U.S. at (404) 262-5560. You can also email us at: customerservice@ahcmedia.com.

On behalf of AHC Media, we thank you for your trust and look forward to a continuing education partnership.

Sincerely,

Valerie Loner

Valerie Loner

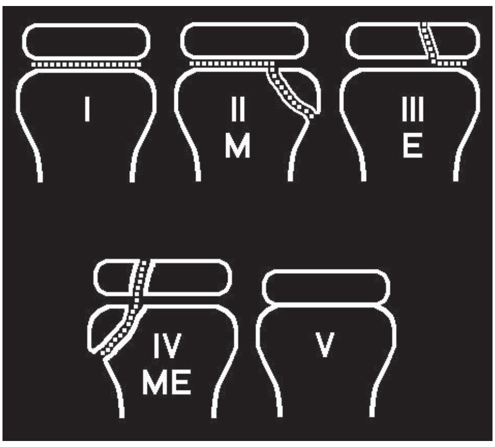
Director of Continuing Education
AHC Media, LLC

Pediatric Emergency Medicine Reports

The Practical Journal of Pediatric Emergency Medicine

Common Orthopedic Injuries – Part I

Salter-Harris Classifications



Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1994; Vol. 1, Case 18. Available at www. hawaii.edu/ medicine. Used with permission.

Left Radius and Ulna Buckle Fractures

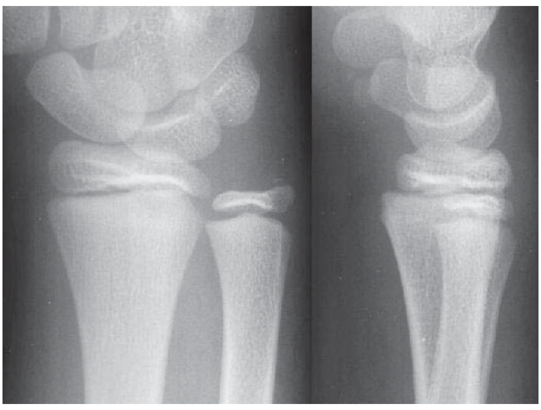
Image courtesy of St. Christopher's Hospital for Children Radiology Department, Philadelphia, PA.

Plastic or Bowing Deformity, Left Ulna

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center For Women And Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1999; Vol. 6, Case 16. Available at www.hawaii.edu/ medicine. Used with permission.

Greenstick Fracture

Salter-Harris Type I Fracture



Lateral view shows displaced radial epiphysis; also visible is a small fracture of the ulnar styloid.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1994; Vol. 1, Case 18. Available at www. hawaii.edu/medicine. Used with permission.

Salter-Harris Type II

Salter-Harris Type III

Salter-Harris Type IV

Images of Salter-Harris Types II, III, and IV:
Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine. 1994; Vol. 1, Case 18. Available at www.hawaii.edu/ medicine. Used with permission.

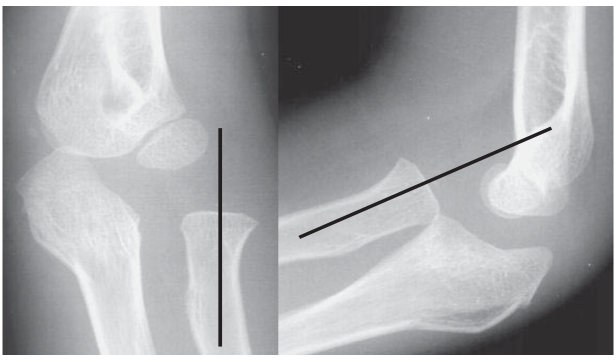
Salter-Harris Type V

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine. 1994; Vol. 1, Case 18. Available at www.hawaii.edu/ medicine. Used with permission.

Displaced Supracondylar Fracture

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1995; Vol. 2, Case 18. Available at www. hawaii.edu/medicine. Used with permission.

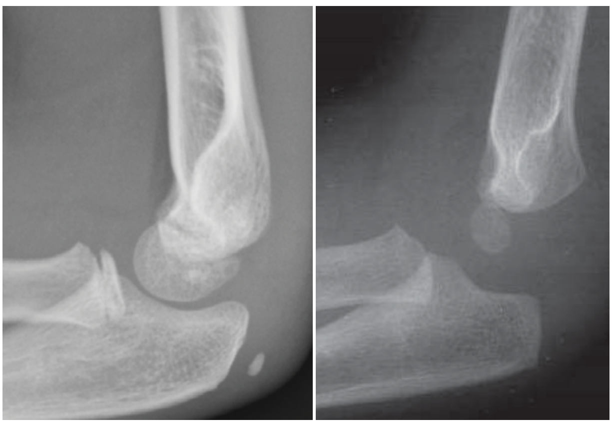
Abnormal Radiocapitellar Line



Dislocated radial head.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1995; Vol. 2, Case 18. Available at www.hawaii.edu/ medicine. Used with permission.

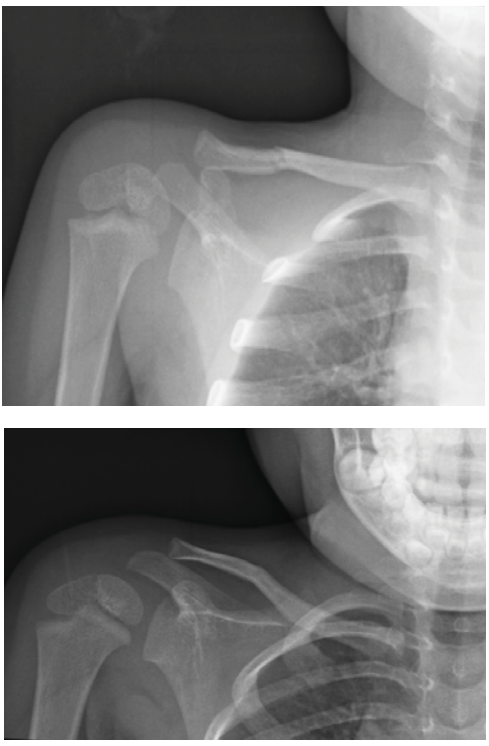
Figure of Eight Sign



Far left: Normal figure of eight sign. Near left: Distorted figure of eight sign, consistent with supracondylar fracture.

Yamamoto L, Inaba A, DiMauro R. Radiology cases in Pediatric Emergency Medicine. Medical Center for Women and Children, Department of Pediatrics, University of Hawaii John A. Burns School of Medicine 1995; Vol. 2, Case 18. Available at www.hawaii.edu/ medicine. Used with permission.

Right Mid-shaft Clavicle Fracture



AP and 45° views.

Images courtesy of St. Christopher's Hospital for Children Radiology Department, Philadelphia, PA.

Supracondylar Humerus Fracture

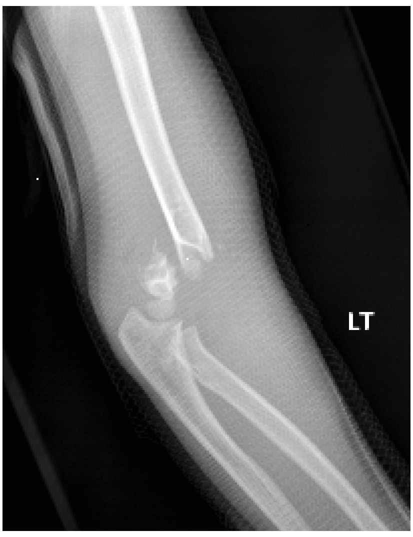


Image courtesy of St. Christopher's Hospital for Children Radiology Department, Philadelphia, PA.

Lateral Condyle Fracture

Image courtesy of St. Christopher's Hospital for Children Radiology Department, Philadelphia, PA.

Supplement to *Pediatric Emergency Medicine Reports*, July 2010: "Common Orthopedic Injuries in the Pediatric ED." Authors: **Lilliane M. Sarraff, MD**, Fellow, Department of Emergency Medicine, Drexel University College of Medicine, St. Christopher's Hospital for Children, Philadelphia, PA. **Christopher J. Haines DO, FAAP, FACEP,** Assistant Professor of Emergency Medicine and Pediatrics, Drexel University College of Medicine; Director, Department of Emergency Medicine and Medical Director, Critical Care Transport Team, St. Christopher's Hospital for Children, Philadelphia, PA. *Peer reviewer:* **John Santamaria, MD, FACEP,** Affiliate Professor of Pediatrics, University of South Florida School of Medicine, Tampa, FL.
Pediatric Emergency Medicine Reports' "Rapid Access Guidelines." Copyright © 2010 AHC Media LLC, Atlanta, GA. **Senior Vice President and Group Publisher:** Don Johnston. **Editor-in-Chief:** Ann Dietrich, MD, FAAP, FACEP. **Executive Editor:** Coles McKagen. **Managing Editor:** Allison Weaver. For customer service, call: **1-800-688-2421**. This is an educational publication designed to present scientific information and opinion to health care professionals. It does not provide advice regarding medical diagnosis or treatment for any individual case. Not intended for use by the layman.

AHC Media LLC

Evidence-Based Medicine for the ED

Trauma Reports

Enclosed in this issue: CNE/CME Evaluation

Vol. 11, No. 3

Supplement to *Emergency Medicine Reports* and *Pediatric Emergency Medicine Reports*

May/June 2010

Trauma is the single greatest cause of morbidity and mortality in the pediatric and adolescent populations. Management of pediatric trauma patients is highly specialized, requiring a team approach of nurses, technicians, therapists, social workers, and physicians. Special considerations must be made for pediatric trauma, as children cannot be treated as "small adults." Superior survival outcomes have been demonstrated for the most severely injured children when treated at a dedicated pediatric trauma center.[1]

The initial assessment of pediatric trauma proceeds much like that for adults as outlined in the Advanced Trauma Life Support (ATLS) course of the American College of Surgeons.[2] The primary survey, with immediate correction of life-threatening problems, is followed by a detailed secondary survey and imaging studies of the cervical spine, chest, and pelvis.[3] Next, additional imaging and laboratory testing may be ordered on a case-by-case basis, depending on the findings of the data gathered during the initial resuscitation.

There is growing concern about the use of CT scanning in the pediatric and adolescent population due to exposure to ionizing radiation and the potential development of excess cases of neoplastic disease.[4] Ideally, imaging would be tailored to each individual patient instead of being applied in an algorithmic fashion, subjecting those not likely seriously injured to the potential hazards of unnecessary testing.

In this issue, the authors focus on trauma to the pediatric chest and abdomen. Specifically reviewed are the pediatric mechanisms of injury, potential injury patterns, physical exam findings, and initial stabilization, concluding with a look at imaging and some of the controversies surrounding management of these patients.

— The Editor

Considerations in Pediatric Thoracic and Abdominal Trauma

Authors: **Chadd E. Nesbit, MD, PhD,** Assistant Professor of Emergency Medicine, Drexel University College of Medicine; Attending Physician, Allegheny General Hospital, Pittsburgh, PA; and **Kara Iskyan, MD**, Resident, Emergency Medicine and Internal Medicine, Allegheny General Hospital, Pittsburgh, PA.

Peer Reviewer: **John P. Santamaria MD**, Affiliate Professor of Pediatrics, University of South Florida School of Medicine, Tampa, FL.

Now available online at www.ahcmedia.com/online.html or call (800) 688-2421 for more information.

Statement of Financial Disclosure

Dr. Dietrich (editor in chief); Drs. Nesbit and Iskyan (authors), and Santamaria (peer reviewer); and Ms. Behrens (nurse reviewer) report no relationships with companies related to this field of study.

Epidemiology

In children, death by injury exceeds all other causes of death combined. Injury is the leading cause of death of children older than the age of 1 year, and, in this population exceeds all other causes of death combined. Injury results in more years of life lost than sudden infant death syndrome, cancer, and infection combined together.[5] Most deaths in the youngest children are from unintentional injury, but homicide and suicide become more prevalent as the population nears young adulthood. The Centers for Disease Control and Prevention report that more than 50,000 children died in motor vehicle accidents from 1999 to 2006, the largest single cause of death in the pediatric and adolescent population.[6]

Non-fatal injuries take an even greater toll on the pediatric population. Nearly 30 million children visit an emergency department (ED) every year in the United States alone. Male children have a higher rate of visits than females, while younger children have higher visit rates than older children.[7] About 40% of the yearly ED visits are for traumatic injury. The International Classification of Diseases (ICD) codes for "unintentional fall" and "unintentional struck by/against" account for most of these visits.[6,8]

The aftermath of these injuries can be staggering, psychologically, financially, and physically. Nearly a decade ago, Miller and colleagues estimated that childhood injuries resulted in $1 billion in resource expenses, $14 billion in lifetime medical spending, and $66 billion in present and future work losses.[9] In 1996, injury left more than 150,000 children and adolescents with a permanent disability, which in many cases will require lifelong medical care. Trauma continues to be a costly and devastating disease among the youngest and most vulnerable of our population. Trauma and accidental injury claim many lives and dramatically impact on many more.

Etiology

Pediatric thoracic trauma is overwhelmingly caused by blunt mechanisms.[10] The most common causes of pediatric blunt chest trauma are motor vehicle collisions (MVCs), pedestrians struck by vehicles, and falls. The vast majority of these are deemed accidental. There are patterns that are somewhat predictable based on age. MVCs and abuse are the leading causes of chest trauma for infants and toddlers. Once children start to attend school, pedestrian accidents come into play; impulsivity can lead them to run into the paths of cars, or their inquisitive nature causes them to play or hide around cars. As they age, skateboarding and cycling start to emerge as causes of significant trauma.[10] Pulmonary contusions, rib fractures, pneumothorax, and hemothorax are the most common injuries after blunt thoracic trauma.[10-12] Aortic, esophageal, diaphragmatic, cardiac, and tracheobronchial injuries are uncommon in children.[10,11] Unfortunately thoracic trauma is rarely a child's only injury, as more than 50% will have more than one intrathoracic injury while about 70% will have additional extrathoracic injuries.[12] Peclet and colleagues report that in children with multiple injuries, death is 10 times more likely if a thoracic injury is present.[13]

Likewise, the vast majority of pediatric abdominal trauma is from blunt mechanisms. The most common causes are associated with MVCs, handlebar injuries, and intentional injury. The pattern of injury changes with age. Children younger than 2 years of age are the most likely to suffer intentional injury, while older children are typically involved in physical activities that may lead to injury. They may suffer collisions during bicycling, sledding, snowboarding, sporting activities, or aggressive play. The solid organs, namely liver and spleen, are most frequently injured.[11,14,15] Bowel, bladder, and kidney injuries also occur, but are much less frequent.[16]

Penetrating thoracic and abdominal trauma, when it does occur, is usually the result of violence. Stabbing and gunshot wounds are the most common mechanisms seen as the pediatric population approaches adulthood.[17] The majority of these types of injuries will likely require operative intervention. Simultaneous assessment and resuscitation of the patient should occur in parallel with preparation of an operating room. If necessary, arrangements to rapidly transfer the patient should be made during the initial assessment and resuscitation.

Pathophysiology

Children differ considerably from adults anatomically and physiologically. Proportionally different, children have larger heads than adults, raising their centers of gravity and contributing to different patterns of injury than seen in adults.[18] Thoracic trauma accounts for about 5% of injuries in hospitalized chil-

Trauma Reports™ (ISSN 1531-1082) is published bimonthly by AHC Media LLC, 3525 Piedmont Road, N.E., Six Piedmont Center, Suite 400, Atlanta, GA 30305. Telephone: (800) 688-2421 or (404) 262-7436.

Vice President and Publisher: Don Johnston
Associate Publisher: Coles McKagen
Managing Editor: Allison Weaver
Director of Marketing: Schandale Kornegay

POSTMASTER: Send address changes to ***Trauma Reports***, P.O. Box 740059, Atlanta, GA 30374.

Subscriber Information

Customer Service: 1-800-688-2421

Customer Service E-Mail: customerservice@ahcmedia.com
Editorial E-Mail: allison.weaver@ahcmedia.com

World Wide Web page: http://www.ahcmedia.com

FREE to subscribers of *Emergency Medicine Reports* and *Pediatric Emergency Medicine Reports*

Subscription Prices

United States
$249 per year. Add $17.95 for shipping & handling
Multiple Copies
Discounts are available for group subscriptions, multiple copies, site-licenses or electronic distribution. For pricing information, call Tria Kreutzer at 404-262-5482.
All prices U.S. only. U.S. possessions and Canada, add $30 postage plus applicable GST.
Other international orders, add $30.

Accreditation

AHC Media LLC is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

AHC Media LLC designates this educational activity for a maximum of 2.5 AMA *PRA Category 1 Credits™*. Physicians should only claim credit commensurate with the extent of their participation in the activity.

Approved by the American College of Emergency Physicians for 2.5 hours of ACEP Category 1 credit.

AHC Media LLC is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center's Commission on Accreditation.

Provider approved by the California Board of Registered Nursing, Provider # 14749, for 1.5 Contact Hours.

AHC Media LLC

This CME/CNE activity is intended for emergency, family, osteopathic, trauma, surgical, and general practice physicians and nurses who have contact with trauma patients.

It is in effect for 24 months from the date of publication.

For Customer Service,

Please call our customer service department at **(800) 688-2421.** For editorial questions or comments, please contact **Allison Weaver**, Managing Editor, at allison.weaver@ahcmedia.com.

dren, but is the second leading cause of death in pediatric trauma.[11,12,18] Differing injury patterns are partially due to the flexibility of pediatric thoracic structures. The chest wall of a child is elastic and pliable due to increased ligamentous laxity, less rib mineralization, and incomplete ossification of the ribs. Instead of breaking, children's ribs bend when compressed, transmitting more energy to the lungs and thoracic contents.[10,12] In addition, the mediastinum of children is more mobile. Consequently large pneumothoraces or hemothoraces can cause dramatic mediastinal shift resulting in more respiratory or vascular compromise than adults.[11] Lastly, the higher metabolic demands and decreased pulmonary function residual capacity of children results in faster development of hypoxemia.[12]

Abdominal trauma accounts for about 10% of all pediatric trauma admissions, and the abdomen ranks second in the list of most commonly injured sites.[16,19] The abdominal walls of children are thinner, with less developed musculature and fat, than those of adults. This provides less protection to the abdominal organs, allowing the transmission of greater force to the abdominal and retroperitoneal organs.[14] Proportionally, the abdominal organs of a child are also larger, providing a greater surface area over which to absorb force.[14,16] Additionally, the mesentery is less adherent in children, allowing for greater mobility of some organs, possibly contributing to greater bowel injury in deceleration type trauma such as MVCs or falls from a height. Seemingly minor injuries involving handlebar-to-abdomen impacts are associated with injuries to the small bowel and pancreas and are actually a greater risk for injury than flipping over the handlebars.[20] The bladder of very young children is partly located in the abdomen, descending into the pelvis as they age. Thus, bladder injury should also be considered in the younger child presenting with abdominal trauma.[16]

Abdominal trauma in children should also raise concern for spine injury. The spinal columns of children have significantly greater ligamentous laxity, less supporting musculature, and a higher fulcrum of flexion than those of adults.[21] Children restrained only by a lap belt may suffer the so-called "lap belt syndrome" of abdominal wall injury, intra-abdominal organ injury, and vertebral fracture.[22]

The physiological differences between children and adults can lull us into a false sense of security based on "normal" vital signs taken out of context with the overall picture of the patient. Children's vital signs vary significantly with their age and it is important to realize that normal vitals signs in one age group may be an ominous sign in another group.[23] *(See Table 1.)* A minimum systolic blood pressure can quickly be calculated by multiplying the age in years of the child by 2 and adding 70 to the result.[23] The finding of hypotension in an injured child is ominous, as children have a greater capacity to compensate for volume loss, and may occur later in children than it does in adults. Normal or nearly normal vital signs do not exclude significant hypovolemia secondary to blood loss. Children may lose 30% of their blood volume before showing the obvious signs of shock.[17] Frequent vital sign checks are imperative. Simply having a child on continuous monitoring may be insufficient, as the numbers may be deceivingly reassuring. Altered mental status, tachycardia, tachypnea, and diaphoresis may also be indicators of hypoperfusion with impending decompensation. Speaking with the child, if he or she is verbal and old enough, may better allow the additional assessment of perfusion of the brain based on mental status. Helping calm an otherwise frightened and anxious child is an additional benefit.

Table 1. Pediatric Vital Signs by Age Group

AGE	PULSE (UPPER LIMIT)	RESPIRATORY RATE (UPPER LIMIT)	SYSTOLIC BP (LOWER LIMIT)
0-1 mo.	180	60	60
2-12 mos.	160	50	70
1-2 yrs.	140	40	75
2-6 yrs.	120	30	80
6-12 yrs.	110	20	90
> 12 yrs.	100	20	90

Key: BP = blood pressure

Clinical Features

The clinical features of pediatric thoracic and abdominal trauma are very similar to those of adults. Unfortunately, the history and physical exam in pediatric patients may not be reliable and is often more difficult. Depending on the child's age, history may be provided exclusively by those around the child, or it may not be available except as reported by the emergency medical technicians (EMTs), paramedics, or flight crew. The physical exam, especially in those younger than 5 years old, is often hampered by a child's lack of verbal skills, fear, apprehension, and separation from family. Other injuries are extremely distracting and may influence the physical exam.[14,24]

Physical exam findings on children with thoracic injuries may include chest crepitance, subcutaneous emphysema, nasal flaring, diminished or absent breath sounds, tachypnea, dyspnea, or low oxygen saturation.[12] Children with significant thoracic injury may have very little in the way of external signs of trauma due to compliance of the chest wall.[17] Remember that a normal external superficial exam does not exclude significant internal injury.

Signs of abdominal injuries include abrasions, abdominal tenderness, or distention, Cullen's sign (ecchymosis in the periumbilical region), Turner's sign (lateral abdominal wall ecchymosis), and vomiting.[14] There is debate about the importance of the "seat belt sign," which is abdominal erythema, ecchymosis, or abrasions across the abdomen. While Sokolove and colleagues showed the seat belt sign is more common in those with intra-abdominal injuries than in those without injuries after MVCs, Chidester's retrospective study of 331 pediatric patients with abdominal trauma discovered that children with seat belt sign were 1.7 times more likely to sustain abdominal injury, but that it was not statistically significant.[25,26] At the very least, signs of external abdominal injury should alert the team to the potential presence of internal injury that will necessitate further examination and possible imaging or lab studies to assess for injury.

Diagnostic Studies

The ultimate question for all trauma patients is, "Does this patient have injuries that require immediate operative intervention?" Additionally, if you are at a hospital without full surgical capabilities, transfer may be required for definitive care.

The decision to perform surgery is based mainly on clinical findings and potential deterioration, not imaging studies. Computed tomography (CT) scans, however, do affect diagnosis, management plans, and level of monitoring.[11] To this end, the use of CT scanning for pediatric trauma patients should not be a knee-jerk response, but rather a calculated decision. Imaging should be guided by a review of the mechanism of injury, vital signs, and physical examination. Many adult trauma centers employ the "pan-scan" approach, scanning the head, neck, thorax, abdomen, and pelvis of all trauma patients. There is evidence to suggest that this approach may be beneficial in adults.[27] In children, however, there is less literature on the subject. It is undisputed that the use of CT scan uncovers many injuries, but does the detection of these injuries effect management and, ultimately, outcomes of patients?[28,29]

Of all CT scans, the chest CT is the least commonly used to evaluate trauma patients. Despite this finding, Fenton and colleagues showed that CT scans of the chest are most likely to show injury in excess of a screening chest x-ray.[4] Similarly, a retrospective review of 333 pediatric trauma patients by Markel and colleagues found that conventional chest x-ray remained an acceptable screening tool to evaluate for thoracic trauma. Of the six patients that required emergent surgery for cardiac or arterial compromise, all the injuries were seen on chest x-ray or the scout view of the chest CT. Unfortunately, 5% of chest x-rays in their series falsely reported normal findings that may have ultimately altered management.[30]

There are similar findings when abdominal trauma is considered. In the past, abdominal injuries were diagnosed and managed mainly through an exploratory laparotomy. Today, however, about 95% of children with liver or spleen injuries are managed non-operatively.[31] Holmes and his group reported that 95% of 1,818 patients with solid organ injury were managed non-operatively. The median time to failure (requiring operative intervention) for the remaining 5% was only three hours.[32] The non-operative approach decreased lifetime risk of asplenic sepsis and was associated with shorter hospital stays, fewer blood transfusions, and decreased overall mortality.[31] As most abdominal injuries are managed expectantly via cautious observation, the question becomes "Is any imaging necessary initially?" The decision to operate should ultimately be based on the patient's physiologic response to the injury, not the imaging findings.

Although CT scans provide invaluable information, are there alternatives for the detection of serious thoracic and abdominal injuries? As outlined above, the routine chest x-ray, combined with physical examination, provides excellent information about the likelihood of serious thoracic injury. The use of ultrasound and diagnostic peritoneal lavage (DPL) for the evaluation of abdominal injury requires further evaluation.

The use of ultrasound assessment of the abdomen is routine in many adult trauma centers and the focused abdominal sonography for trauma (FAST) exam is an adjunct to the ATLS protocols for management of trauma patients. Intuitively, pediatric patients seem ideal for a FAST exam as they have small abdominal cavities without large abdominal fat deposits.[4] However, there is considerably less evidence of the utility of FAST in assessment of pediatric trauma.

A paper by Eppich and Zonfrillo reviews the literature regarding management of blunt abdominal trauma.[33] In this review, based on four papers, they note that FAST in children for the detection of blunt abdominal trauma demonstrates variable sensitivity (55%–92.5%) and negative predictive value (50%–97%) but consistently good specificity (83%–100%) when compared to abdominal CT scanning. While the FAST exam does miss some patients with free fluid, the clinical significance of this is not clear given that most abdominal injuries in children are managed expectantly. One of the four papers, that by Soudack and colleagues, concludes that a positive FAST exam necessitates further "definitive imaging."[24]

More recently, Holmes and colleagues conducted a meta-analysis of the use of ultrasonography in pediatric blunt abdominal trauma.[34] Their analysis included 3,838 children from 25 articles. They concluded that a negative ultrasound exam has "questionable utility as the sole diagnostic test to rule out the presence of IAI [intra-abdominal injury]" and go on to state that a positive ultrasound in the hemodynamically stable child should lead to immediate CT scanning. They additionally conclude that children with a moderate pretest probability of intra-abdominal injury should undergo abdominal CT scanning regardless of the findings on abdominal ultrasound.

One of the criticisms of the FAST exam is its inability to identify solid organ injury that may not produce hemoperitoneum. In the meta-analysis by Holmes, it was found that the additional ultrasound evaluation of solid organs only slightly increased the sensitivity of the standard FAST exam in pediatric patients, to 82% from 80%. However, the question was raised concerning the ability of non-radiologists to ultrasound solid organs.[34]

The use of DPL has fallen out of favor given the discomfort to the patient and lack of specificity of the exam. It is not recommended for the assessment of an isolated abdominal injury, but is useful to diagnose children with abdominal trauma who sustained multiple injuries and require immediate surgery for another injury, often a subdural or epidural hematoma.[14]

Can laboratory testing help in identifying children who should undergo CT scans for injuries? Capraro, Mooney, and Waltzman examined the utility of the "trauma panel" in the assessment of blunt abdominal trauma.[35] In a retrospective review of 382 pediatric patients, they found that none of their regularly tested chemical or hematological parameters had sufficient sensitivity or negative predictive value to be helpful as a screening tool. Cotton and Beckert considered both clinical and laboratory data. They determined that 23 variables were potentially associated with intra-abdominal injury.[36] Logistic regression identified four positive predictors for injury: tenderness, abrasions, ecchymosis, and elevated ALT. Holmes and colleagues published two papers in May 2002 addressing this subject in both abdominal and thoracic trauma.[19,37] They derived clinical decision rules to identify children with thoracic or intra-abdominal injuries after blunt trauma. The prospective series for abdominal trauma enrolled 1,095 children younger than 16 years with blunt trauma. They identified 107 patients with intra-abdominal injuries. Statistical analysis identified six findings associated with abdominal injury: low systolic blood pressure, abdominal tenderness on exam, femur fracture, serum AST >200 U/L or serum ALT >125 U/L, urinalysis with >5 RBCs per high-powered field, and an initial hematocrit of less then 30%. Of the 107 children with an intra-abdominal injury, 105 had at least one of these findings, while absence of any of the six was seen in all but two children with injury. The authors acknowledged some limitations, as they did not evaluate the use of ultrasound in their decision rule and not all of the children with abdominal trauma underwent imaging due to "ethical considerations."[19]

In another series, the Holmes group applied the same type of analysis to children with thoracic injury.[37] Nine-hundred-eighty-six patients with thoracic trauma were enrolled, and 80 of them were found to have injuries. Analysis identified the following predictors of thoracic injury: low systolic blood pressure, elevated age-adjusted respiratory rate, abnormal thorax exam, abnormal chest auscultation, femur fracture, and Glasgow Coma Scale (GCS) score of < 15. Seventy-eight of the 80 injured patients had at least one of these findings, while two did not have any of these findings. The two missed cases did not require intervention for their thoracic injuries.

Holmes and colleagues have recently published a paper on validation of their derived prediction rule for blunt torso trauma.[38] In this series of 1,119 children with blunt torso trauma, they identified 149 of 157 injured children. Of the eight patients that were missed, only one underwent laparotomy for a serosal tear and mesenteric hematoma that did not require "specific surgical intervention." Application of their decision rule would have resulted in a reduction of CT scans by 33%. They conclude that further refinement of their prediction rule is needed before it is ready for widespread use.

Management

The management of pediatric abdominal and thoracic trauma is similar to that of adults. Standard ATLS protocols should be followed.[3] In the primary ATLS survey, all life-threatening injuries must be identified and addressed before progression with the detailed secondary survey. *(See Table 2.)* All pediatric patients being assessed for trauma must be continuously monitored for blood pressure, heart rate, respiratory rate, and blood oxygen saturation. In addition, every child should have a recorded temperature and be protected from hypothermia. Supplemental oxygen should be provided. Adequate intravenous (IV) access is imperative. If two peripheral IV lines cannot be rapidly secured, intraosseous access or central venous access should be considered.

Table 2. Immediately Life-threatening Thoracic Injuries

- Airway obstruction and injury
- Lung and chest wall injuries
- Open pneumothorax
- Tension pneumothorax
- Hemopneumothorax
- Flail chest
- Widened mediastinum / aortic disruption
- Cardiac tamponade

Any signs of shock should be treated aggressively with fluid resuscitation. First-line fluids should be crystalloids given in 20 mL/kg boluses. Packed red blood cells (PRCBs) should be transfused at 10 mL/kg if the blood pressure does not respond to two fluid boluses.

After the initial resuscitation is complete, a thorough secondary survey should evaluate for other injuries. A head-to-toe examination is undertaken for signs of injury and disability. The entire surface of the child's body must be exposed for this examination. It is important to remember to examine the child's back, as well. Vital signs should be reassessed frequently throughout the resuscitation. Any deterioration in the condition of the patient should prompt immediate reassessment, starting with the primary survey. During this time, the physician should attempt to gain additional knowledge concerning past medical history, allergies, and medications. The AMPLE mnemonic is useful for this purpose.[3] *(See Table 3.)*

As previously discussed, non-operative management with close observation is now the mainstay of most pediatric thoracic and abdominal trauma. Nearly 90% of blunt pediatric chest injuries can be managed non-operatively or with a thoracostomy tube.[12] Indications for a thoracotomy include tracheobronchial injuries, esophageal injuries, diaphragmatic rupture, major vascular injury, retained hemothorax, return of 20%–30% of a child's blood volume through a chest tube, or persistent hemorrhage (defined as continued bleeding of 2–3 mL/kg per hour over a four-hour period).[12]

Greater than 90% of pediatric abdominal trauma is successfully managed non-operatively. If a patient is hemodynamically stable without peritoneal signs, non-operative management should be attempted.[39] The argument has also been made that the hemodynamically unstable child who responds to boluses

Table 3. The AMPLE History

A	Allergies
M	Medications
P	Past illness
L	Last meal
E	Events related to injury

of PRCBs may avoid the operating room.[40] Failure of non-operative management usually occurs within four hours and nearly always within 12 hours of presentation. Children with severe or multiple solid organ injuries and pancreatic injuries are nine times more likely to require operative intervention.[41] Despite previous perceptions, a cohort study by Tataria and colleagues of 2,944 children with blunt abdominal trauma showed that delayed operative management or failure of non-operative management does not change outcome in terms of mortality, ICU length of stay, hospital length of stay, or blood transfusions.[39]

Figures 1 and 2 summarize a general approach to assessing the child with thoracic or abdominal trauma. These figures are meant to serve only as a rough outline of a thought process that could be used to assess the victim of pediatric trauma, and not as specific protocols.

Current Controversies

Unnecessary Exposure to Radiation. There has been concern raised over the last two decades about the use of CT scanning in the both the adult and pediatric populations.[42] There are more than 60 million CT scans done each year in the United States. This is 20 times the number of scans performed in 1980. About four million of these are done in children.[42] Today, the medical imaging radiation dose, which is primarily from CT scans, is the largest source of radiation, besides background radiation, received by the U.S. population.[43] That CT scanning has altered diagnostic algorithms and made detection of injury more sensitive can not be argued. However, the risk of radiation is twofold: increased risk of cancer due to radiation exposure, and missing a diagnosis due to suboptimal image quality due to decreased radiation exposure settings.[44]

The authors of several papers, especially in the radiology literature, have looked at the increased risk of cancer due to radiation from CT scanning.[45-47] It has been estimated that the risk of developing a fatal cancer from a CT scan may be in the range of about 1 in 1,000.[45] In addition to their body tissues being more sensitive to radiation, children have a longer lifespan over which to develop a cancer.[46] While the risk to an individual is relatively small, this small risk multiplied by a large number of scans results in a relatively large number. Based on the above numbers, CT scans may be responsible for causing 4,000 fatal cancers a year. The number of non-fatal cancers is likely to be higher.

The Alliance for Radiation Safety in Pediatric Imaging launched the "Image Gently" campaign in 2007 to raise awareness of these important issues.[48] The "as low as reasonably achievable" (ALARA) principle is also promoted by this campaign. A recent paper by Arch and Frush finds that since a prior survey in 2001, the peak kilovoltage and tube current settings, the two principal parameters determining radiation dose from CT scanning, have decreased significantly for pediatric body multidetector CT.[49] It may be that increased awareness of the potential hazards of radiation is having an effect.

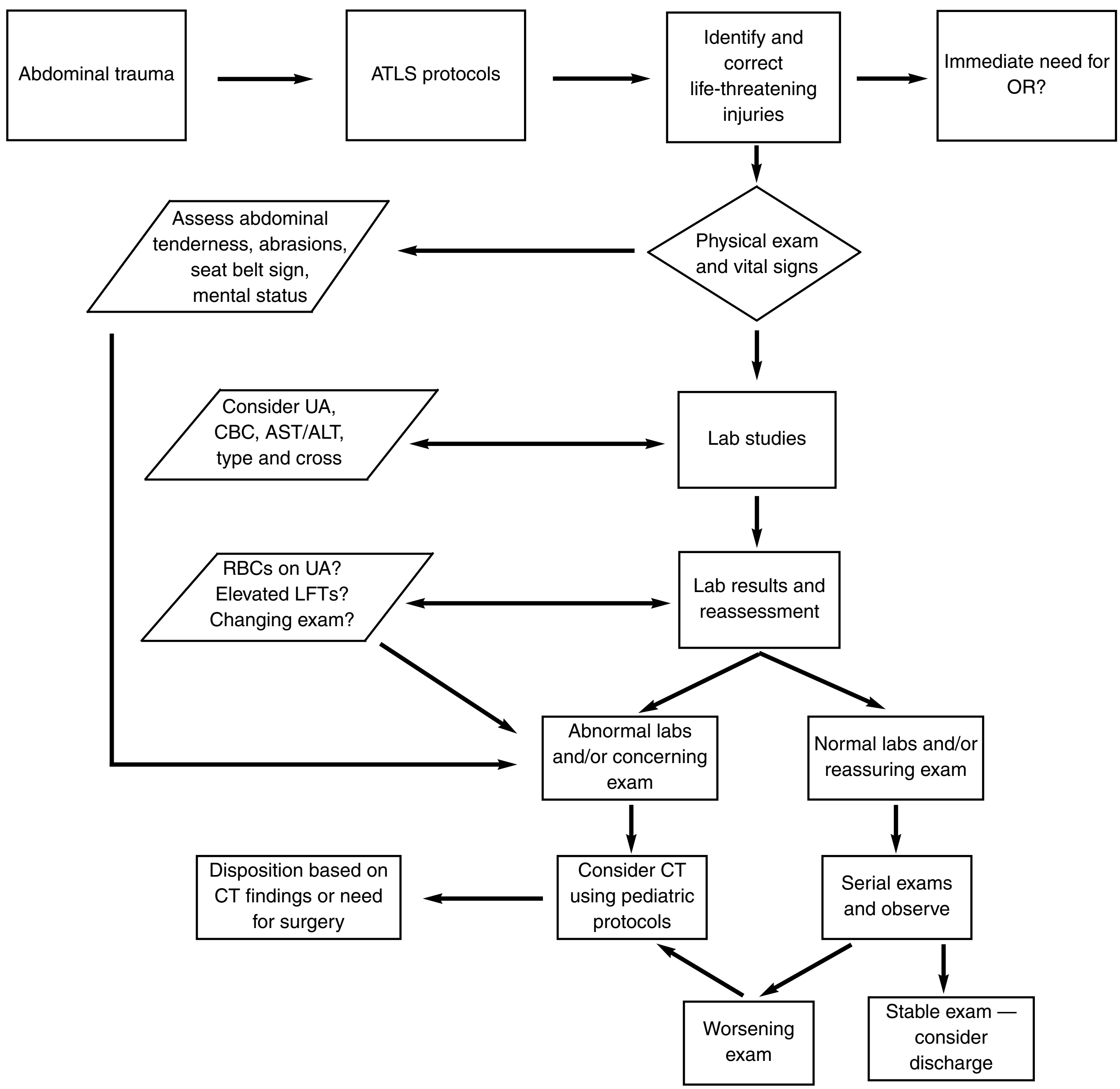
In an effort to reduce radiation exposure, Cohen raises an interesting point: How low can you reduce the dose before the radiologist becomes uncomfortable making an accurate diagnosis?[44] Lower radiation dosages equate to a lower risk of cancer, but this reduction comes with a possible reduction in diagnostic certainty. Where does the radiologist draw the line between diagnostic certainty and patient safety?

Obviously, the best way to reduce radiation exposure to pediatric trauma patients is to avoid unnecessary CT scans. While evidence based medicine and clinical judgment help determine which patients need CT scans, there are a number of other factors contributing to unneeded CT scans. Donnelly cites overcautious ordering of CT scans due to potential malpractice litigation, public pressure to use high-end technical exams, and Americans' need for immediate results as reasons for unnecessary CT scans.[50] Both physicians and the public will have to work together to decrease the number of unnecessary CT scans on children.

CT Scans and the Transfer of Pediatric Trauma Patients. When a pediatric trauma patient is being transferred to a tertiary facility for further care, should the CT scans be done at the referring facility or the receiving facility? ATLS recommends the transfer of appropriate patients without delay to a designated trauma center. Therefore, further diagnostic studies should not be undertaken, as they will not change the immediate care of the patient.[4] Additionally, just as a CT scan should not be used to determine if a patient requires the OR, a CT scan should not be used as a tool to determine if a patient should be transferred to a trauma center.[51] The decision to transfer a patient to a higher level of care is based on hemodynamic stability and the ability to provide care. The drawbacks in obtaining a CT prior to transfer include the inability to provide definitive care, the time delay in obtaining the scans, increased vulnerability of trauma patients if decompensation occurs in radiology or during transport, the lack of pediatric protocols to decrease radiation exposure at some referring facilities, and the possible need to repeat the study at the receiving facility.[4,51] Depending on location, transfer to a specialized pediatric trauma center may require a significant amount of time. Nance and colleagues recently published an interesting paper reporting that 71.5% of the pediatric population of the United States was within 60 minutes of a verified pediatric trauma center by either ground or air transport.[52] If only ground transport was considered, the percentage of the population that had access within an hour was only 43%. This percentage varies significantly from state to state and from rural to urban settings.

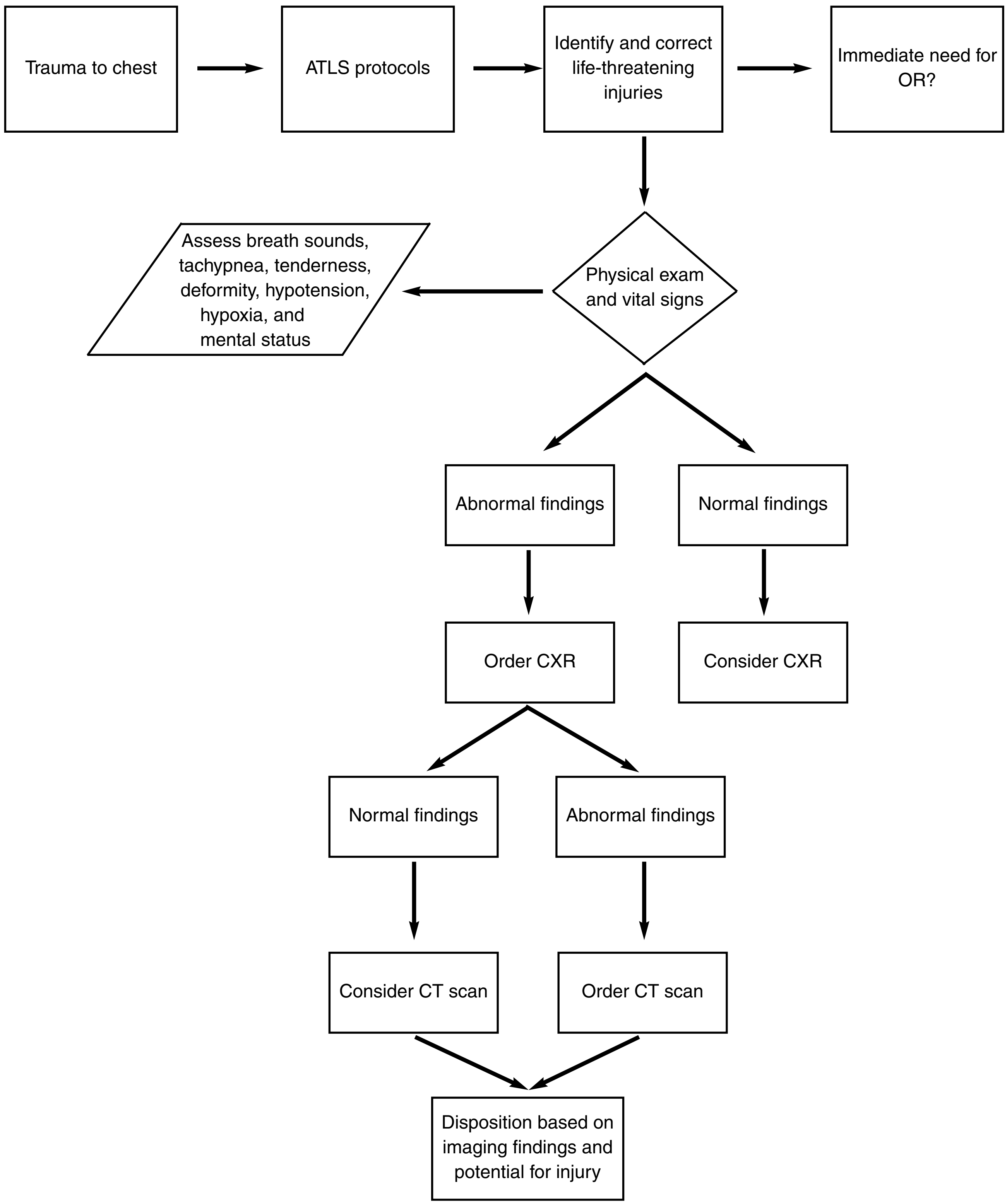
"Blush" on CT. A blush on CT indicates bleeding in or

Figure 1. Algorithm for the Evaluation of Blunt Abdominal Trauma



around an organ due to injury of a large arterial branch. While it has been described for the liver, kidney, adrenal gland, and mesentery, the spleen is the most common organ for a blush to be found.[53] In adults, the finding of a blush of a solid organ, specifically the spleen, on CT scan indicates a higher chance of non-operative failure and warrants early embolization or surgery.[53,54] In children, however, there has been controversy about whether there is a relationship between splenic blush and need for operative intervention. First, splenic blush is often missed on CT scan. In a retrospective study of 216 pediatric abdominal trauma patients, 27 whom had a splenic blush, the contrast blush was "frequently not identified" by the radiology resident and mentioned in "only a few" of the dictations by the attending radiologist.[54] Next, contrast blush can look identical on CT scan to areas of damaged splenic parenchyma or stable hematoma, making the diagnosis of a blush questionable.[54] Most importantly, studies surrounding splenic blush and the failure of non-operative management in children have been

Figure 2. Algorithm for the Evaluation of Blunt Thoracic Trauma



inconsistent. The largest study by Nwomeh and colleagues of 27 patients with splenic blush found a statistically significant correlation between contrast blush of the spleen and operative management as 46% of the children with blush went to the OR.[54] Two other smaller case series by Cox and Lutz had even higher rates of children with contrast blush requiring operative intervention.[40,53] In a case series of blunt splenic injuries, five pediatric patients with splenic blush were identified.[55] Only one of these required operative management due to hemodynamic instability. Despite conflicting results, the conclusion of all the authors is essentially the same: CT scan can accurately define the anatomic grade of an intra-abdominal organ injury, but cannot predict the failure of non-operative management of splenic injuries. The decision for operative intervention should be based on physiologic response to the injury rather than radiographic findings.

Patient Advocacy

Given the vulnerability of children, abuse should always be considered with pediatric trauma. Two thirds of the victims of abuse are younger than 3 years of age, and one third are younger than 6 months old.[56] In particular, child abuse should be considered with rib fractures, duodenal hematoma, pancreatitis, and pancreatic fractures.[11] Rib fractures occur in only 1%–2% of pediatric trauma; however, 82% of rib fractures in children younger than 3 years of age are related to child abuse.[10-12] There is no pathognomonic fracture indicative of abuse.[57] If there is no history of trauma, or there is a history of trauma that does not match the pattern of injury, child abuse should be suspected. The American Academy of Pediatrics 2007 guideline for the evaluation of suspected child physical abuse lists five circumstances that are concerning for intentional trauma.[58] They are:

1. No or vague explanations for significant injury.
2. Change in an important detail.
3. Explanation inconsistent with the pattern, age, or severity of the injury.
4. Explanation inconsistent with the child's physical and/or developmental capabilities.
5. Discrepancies among the stories of witnesses.

The presence of any of these circumstances should prompt further investigation and admission of the child until the details of the injury can be thoroughly investigated.

Disposition

Whether a pediatric trauma patient should be admitted is often based on clinical judgement. There have been a handful of studies evaluating whether a child who suffered from abdominal trauma with a normal abdominal CT scan can be safely discharged home. In a large, prospective, observational cohort study, Awasthi and colleagues followed 1,085 pediatric blunt trauma victims who had normal CT scans in the ED.[59] Of the 32% who were discharged to home, none returned to the hospital. Two of the 737 admitted for observation had an abdominal injury on repeat CT scan, but neither required intervention. They conclude that a child with a normal abdominal CT scan and a normal abdominal exam (no tenderness, distention, ecchymosis, or abrasions) can be discharged home, while a child with a normal abdominal CT scan and an abnormal exam should be carefully observed in or out of the hospital. To our knowledge, there are no studies that have directly evaluated the disposition of children after having a normal chest CT following trauma. If a child has undergone a CT scan to evaluate for potential thoracic trauma, he or she likely should be admitted for observation and repeat exams.

Prevention

It should not require stating that the best way to care for the pediatric trauma patient would be to prevent the trauma from ever occurring. Physicians and nurses are obligated to educate patients and their parents when given the opportunity to do so. A child sustaining a mild head injury in a fall from a bicycle should not be discharged without instructions for head injury. Likewise, if the child was unhelmeted, the importance of wearing a helmet should be addressed. If the child was wearing a helmet, reinforce the positive, and remind parents that the child needs a new helmet. Instruct parents on the proper use of car seats and seatbelts. Remind children to wear pads and helmets when skateboarding or rollerblading. There are numerous ways for all of us to educate; take a moment and do so.

Conclusions

Trauma is a significant cause of morbidity and mortality in children. A heightened awareness of potential thoracic or abdominal injuries can facilitate an appropriate diagnostic evaluation.

CT scanning is one of the most important medical advances in the last 100 years. However, improvements in imaging come with the increased risks associated with radiation, especially in the pediatric population. CT scanning undoubtedly saves lives, but imaging should be tailored to each patient after consideration of mechanism of injury, vital signs, physical examination and selected laboratory values. Further refinement of clinical decision rules may help to limit the number of questionably necessary CT scans performed for pediatric chest and abdominal trauma.

References

1. Pracht E, Tepas JJ, Langland-Orban B, et al. Do pediatric patients with trauma in Florida have reduced mortality rates when treated in designated trauma centers? *J Pediatr Surg* 2008;43:212-221.
2. Carmont M. The Advanced Trauma Life Support course: A history of its development and review of related literature. *Postgrad Med J* 2005;81:87-91.
3. *Advanced Trauma Life Support for Doctors,* 8th ed. Chicago, IL: American College of Surgeons, Committee on Trauma; 2008.
4. Fenton S, Hansen KW, Meyers RL, et al. CT scan and the pediatric trauma patient–are we overdoing it? *J Ped Surg* 2004;39: 1877-1881.
5. Academy of Pediatrics. Management of pediatric trauma. *Pediatrics* 2008;121:849-854.
6. Centers for Disease Control and Prevention. Web-based Injury Statistics Query and Reporting System. Available at www.cdc.gov/injury/wisqars/index.html. Last updated 8/20/2009. Accessed 03/06/2010.
7. Merrill C, Owens P, Stocks C. Pediatric emergency department visits in community hospitals from selected states, 2005. HCUP Sta-

tistical Brief #52. Agency for Healthcare Research and Quality, 2008. www.hcup-us.ahrq.gov/ reports/statbriefs/sb52.jsp. Accessed 03/06/2010.
8. Centers for Disease Control and Prevention and National Center for Injury Prevention and Control. National Estimates of the 10 Leading Causes of Nonfatal Injuries Treated in Hospital Emergency Departments, United States, 2007. 2009 (cited August 20, 2009). Available from: www.cdc.gov/injury/Images/LC-Charts/10lc%20-%20Nonfatal%20Injury%202007-7_6_09-a.pdf.
9. Miller T, Romano E, Spicer R. Unintentional injuries in childhood. *The Future of Children* 2000;10:137-163.
10. Moore M, Wallace EC, Westra S. The imaging of paediatric thoracic trauma. *Pediatr Radiol* 2009;39:485-496.
11. Donnelly LF. Imaging issues in CT of blunt trauma to the chest and abdomen. *Pediatr Radiol* 2009;39 (Suppl 3):406-413.
12. Sartorelli KH, Vane DW. The diagnosis and management of children with blunt injury of the chest. *Semin Pediatr Surg* 2004;13: 98-105.
13. Peclet M, Newman KD, Eichelberger MR, et al. Thoracic trauma in children: An indicator of increased mortality. *J Pediatr Surg* 1990; 25:961-965.
14. Wise B, Mudd S, Wilson M. Management of blunt abdominal trauma in children. *J Trauma Nurs* 2002;9:6-14.
15. Wegner S, Colletti J, Wie DV. Pediatric blunt abdominal trauma. *Pediatr Clin North Am* 2006;53:243-256.
16. Saxena A, Nance ML, Lutz N, et al. Abdominal trauma. 2008 January 11, 2008. [Accessed May 29, 2009.] Available from: www.emedicine.medscape.com/article940726.
17. Alterman D, Daley BJ, Kennedy AP, et al. Considerations in pediatric trauma. Available from: www.emedicine.medscape.com/ article/435031. [Cited May 29,2009.]
18. Chakravarthy B, Vaca FE, Lotfipour S, et al. Pediatric pedestrian injuries: Emergency care considerations. *Pediatr Emerg Care* 2007;23:738-744.
19. Holmes J, Sokolove PE, Brant WE, et al. Identification of children with intra-abdominal injuries after blunt trauma. *Ann Emerg Med* 2002;39:500-509.
20. Nadler EP, Potoka DA, Shultz BL, et al. The high morbidity associated with handlebar injuries in children. *J Trauma* 2005;58: 1171-1174.
21. Huada II W. Pediatric Trauma. In: *Emergency Medicine—A Comprehensive Study Guide,* 6th ed. Tintinalli J, Kelen G, Stapczynski J, Eds. New York: McGraw-Hill; 2004:1542-1549.
22. Achildi O, Betz R, Grewal H. Lapbelt injuries and the seatbelt syndrome in pediatric spinal cord injury. *J Spin Cord Med* 2007;30 (Suppl 1):S21-S24.
23. Mellis P. The Normal Child. In: *Emergency Medicine—A Comprehensive Study Guide,* 6th ed. Tintinalli J, Kelen G, Stapczynski J, Eds. New York: McGraw-Hill; 2004:727-731.
24. Soudack M, Epelman M, Maor R, et al. Experience with focused abdominal sonography for trauma (FAST) in 313 pediatric patients. *J Clin Ultrasound* 2004;32:53-61.
25. Sokolove P, Kuppermann N, Holmes J. Association between the "seat belt sign" and intra-abdominal injury in children with blunt torso trauma. *Acad Emerg Med* 2005;12:808-813.
26. Chidester S, Rana A, Lowell W, et al. Is the "seat belt sign" associated with serious abdominal injuries in pediatric trauma? *J Trauma* 2009;67(1 Suppl):S34-6.
27. Self M, Blake A-M, Whitley M, et al. The benefit of routine thoracic, abdominal, and pelvic computed tomography to evaluate trauma patients with closed head injuries. *Am J Surg* 2003;186:609-614.
28. Broder J, Fordham L, Warshauer D. Increasing utilization of computed tomography in the pediatric emergency department, 2000-2006. *Emerg Radiol* 2007;14:227-232.
29. Livingston DH, Shogan B, John P, et al. CT diagnosis of rib fractures and the prediction of acute respiratory failure. *J Trauma* 2008;64:905-911.
30. Markel TA, Kumar R, Koontz NA, et al. The utility of computed tomography as a screening tool for the evaluation of pediatric blunt chest trauma. *J Trauma* 2009;67:23-28.
31. Sims C, Wiebe D, Nance M. Blunt solid organ injury: Do adult and pediatric surgeons treat children differently? *J Trauma* 2008;65: 698-703.
32. Holmes J, Wiebe DJ, Tataria, MO, et al. The failure of nonoperative management in pediatric solid organ injury: A multi-institutional experience. *J Trauma* 2005;59:1309-1315.
33. Eppich WJ, Zonfrillo MR. Emergency department evaluation and management of blunt abdominal trauma in children. *Curr Opin Pediatr* 2007;19:265-269.
34. Holmes J, Gladman A, Chang C. Performance of abdominal ultrasonography in pediatric blunt trauma patients: A meta-analysis. *J Ped Surg* 2007;42:1588-1594.
35. Capraro AJ, Mooney D, Waltzman ML. The use of routine laboratory studies as screening tools in pediatric abdominal trauma. *Ped Emerg Care* 2006;22:480-484.
36. Cotton BA, Beckert BW, Smith MK, et al. The utility of clinical and laboratory data for predicting intraabdominal injury among children. *J Trauma* 2004;56:1068-1075.
37. Holmes J, Sokolove PE, Brant WE, et al. A clinical decision rule for identifying children with thoracic injuries after blunt torso trauma. *Ann Emerg Med* 2002;39:492-499.
38. Holmes JF, Mao A, Awasthi S, et al. Validation of a prediction rule for the identification of children with intra-abdominal injuires after blunt torso trauma. *Ann Emerg Med* 2009;54:528-533.
39. Tataria M, Nance ML, Holmes JH 4th, et al. Pediatric blunt abdominal injury: Age is irrelevant and delayed operation is not detrimental. *J Trauma* 2007;63:608-614.
40. Cox CS Jr, Geiger JD, Liu DC, et al. Pediatric blunt abdominal trauma: role of computed tomography vascular blush. *J Pediatr Surg* 1997;32:1196-200.
41. Holmes JH 4th, Wiebe DJ, Tataria M, et al. The failure of nonoperative management in pediatric solid organ injury: A multi-institutional experience. *J Trauma* 2005;59:1309-1313.
42. Brenner DJ, Hall EJ. Computed tomography – An increasing source of radiation Exposure. *N Engl J Med* 2007;357:2277-2284.
43. Frush DP, Applegate K. Computed tomography and radiation: Understanding the issues. *J Am Coll Radiol* 2004;1:113-119.
44. Cohen MD. Pediatric CT radiation dose: How low can you go? *Am J Roentgenol* 2009;192:1292-1303.
45. Brenner DJ, Elliston CD, Hall EJ, et al. Estimated risks of radiation-

induced fatal cancer from pediatric CT. *Am J Roentgenol* 2001;176: 289-296.
46. Kleinerman R. Cancer risks following diagnostic and therapeutic radiation exposure in children. *Pediatr Radiol* 2006;36:121-125.
47. Lee C, Forman H. The hidden costs of CT bioeffects. *J Am Coll Radiol* 2008;5:78-79.
48. Goske MJ, Applegate KE, Boylan J, et al. The Image Gently campaign: Working together to change practice. *Am J Roentgenol* 2008; 190:273-274.
49. Arch ME, Frush DP. Pediatric body MDCT: A 5-year follow-up survey of scanning parameters used by pediatric radiologists. *Am J Roentgenol* 2008;191:611-617.
50. Donnelly LF. Reducing radiation dose associated with pediatric CT by decreasing unnecessary examinations. *Am J Roentgenol* 2005; 184:655-657.
51. Chwals WJ, Robinson AV, Sivit CJ, et al. Computed tomography before transfer to a level I pediatric trauma center risks duplication with associated increased radiation exposure. *J Pediatr Surg* 2008; 43:2268-2272.
52. Nance M, Carr B, Branas C. Access to pediatric trauma care in the United States. *Arch Pediatr Adolesc Med* 2009;163:512-518.
53. Lutz N, Mahboubi S, Nance ML, et al. The significance of contrast blush on computed tomography in children with splenic injuries. *J Pediatr Surg* 2004;39:491-494.
54. Nwomeh BC, Nadler EP, Meza MP, et al. Contrast extravasation predicts the need for operative intervention in children with blunt splenic trauma. *J Trauma* 2004;56:537-541.
55. Cloutier DR, Baird TB, Gormley P, et al .Pediatric splenic injuries with a contrast blush: Successful nonoperative management without angiography and embolization. *J Pediatr Surg* 2004;39:969-971.
56. Berkowitz C. Child Abuse and Neglect. In: *Emergency Medicine—A Comprehensive Study Guide,* 6th ed. Tintinalli J, Kelen G, Stapczynski J, Eds. New York: McGraw-Hill; 2004:1846-1850.
57. Kemp AM, Dunstan F, Harrison S, et al. Patterns of skeletal fractures in child abuse: Systematic review. *BMJ* 2008;337:a1518.
58. Kellogg N. American Academy of Pediatrics Committee on Child Abuse and Neglect. Evaluation of suspected child physical abuse. *Pediatrics* 2007;119:1232-1241.
59. Awasthi S, Mao A, Wooton-Gorges SL, et al. Is hospital admission and observation required after a normal abdominal computed tomography scan in children with blunt abdominal trauma? *Acad Emerg Med* 2008;15:895-899.

CME Questions

1. What is the most common cause of morbidity and mortality in the pediatric population?
   A. Accidental trauma
   B. Non-accidental trauma
   C. Ingestions of toxins
   D. Congenital abnormalities

2. Which of the following injuries is immediately life-threatening, according to the ATLS Primary Survey?
   A. Chest contusion
   B. Airway obstruction

CNE/CME Objectives

Upon completing this program, the participants will be able to:
a.) discuss conditions that should increase suspicion for traumatic injuries;
b.) describe the various modalities used to identify different traumatic conditions;
c.) cite methods of quickly stabilizing and managing patients; and
d.) identify possible complications that may occur with traumatic injuries.

CME / CNE Instructions

Physicians and nurses participate in this CME/CNE program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material. **After completing this activity, you must complete the evaluation form provided and return it in the reply envelope provided in order to receive a letter of credit.** When your evaluation is received, a letter of credit will be mailed to you.

C. Simple pneumothorax
D. Rib fracture
E. Head laceration

3. Which of the following types of trauma is the most common cause of death in the pediatric population?
A. Thoracic
B. Abominal
C. Head
D. Musculoskeletal

4. How is most pediatric blunt trauma managed?
A. Laparotomy
B. Laparoscopy
C. Celiotomy
D. Cautious observation

5. In which of the following groups is a systolic blood pressure of 70 mmHg acceptable as a minimum?
A. Older than 12 years old
B. 6–12 years old
C. 2–6 years old
D. 2–12 months old
E. Never acceptable

6. What percentage of the pediatric population lives within 60 minutes of a pediatric trauma center by either ground or air transport?
A. 20%
B. 30.5%
C. 50%
D. 71.5%
E. 95.6%

7. Based on the assumption that CT scanning causes one fatal cancer in 1,000 scans, about how many cancers in the pediatric population may be attributable to CT scanning each year?
A. 4
B. 40
C. 400
D. 4,000
E. 40,000

8. Which of the following is the most effective way to reduce radiation exposure from CT scanning in children?
A. Specific pediatric protocols
B. Lead shielding
C. Limiting CT scan to area of interest
D. Avoid CT scanning if possible

9. When compared to adults, the thoracic wall of the child is:
A. more rigid.
B. more protective.
C. more compressible.
D. more ossified.

10. What type of bony fracture is associated with the "lap belt syndrome"?
A. Femur
B. Rib
C. Pelvis
D. Vertebral

Answers: 1. A, 2. B, 3. C, 4. D, 5. D, 6. D, 7. D, 8. D, 9. C, 10. D

In Future Issues:

Adult Thoracic and Abdominal Injury

Trauma Reports
Evidence-Based Medicine for the ED

TR050110TM

PLEASE NOTE: If your correct name and address do not appear below, please complete the section at right.

Please make label address corrections here or PRINT address information to receive a certificate.

Account #________________________

Name: ________________________

Company: ________________________

Address:________________________

City: ________________________

State:__________ Zip ________

Fax: ________________________

Phone: ________________________

E-mail: ________________________

CNE/CME Evaluation — Vol. 11, No. 3: Pediatric Thoracic and Abdominal Trauma

Please take a moment to answer the following questions to let us know your thoughts on the CNE/CME program. Fill in the appropriate space and return this page in the envelope provided. **You must return this evaluation to receive your letter of credit. ACEP members — Please see reverse side for option to mail in answers.** Thank you.

CORRECT ⬬ **INCORRECT**

1. In which program do you participate? ◯ CNE ◯ CME
2. If you are claiming physician credits, please indicate the appropriate credential: ◯ MD ◯ DO ◯ Other ________
3. If you are claiming nursing contact hours, please indicate your highest credential: ◯ RN ◯ NP ◯ Other ________

After participating in this program, I am able to:

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
4. Discuss conditions that should increase suspicion for traumatic injuries.	◯	◯	◯	◯	◯	◯
5. Describe the various modalities used to identify different traumatic conditions.	◯	◯	◯	◯	◯	◯
6. Cite methods of quickly stabilizing and managing patients.	◯	◯	◯	◯	◯	◯
7. Identify possible complications that may occur with traumatic injuries.	◯	◯	◯	◯	◯	◯
8. The test questions were clear and appropriate.	◯	◯	◯	◯	◯	◯
9. I detected no commercial bias in this activity.	◯	◯	◯	◯	◯	◯
10. This activity reaffirmed my clinical practice.	◯	◯	◯	◯	◯	◯
11. This activity has changed my clinical practice.	◯	◯	◯	◯	◯	◯

If so, how?________________________

12. How many minutes do you estimate it took you to complete this activity? Please include time for reading, reviewing, answering the questions, and comparing your answers with the correct ones listed. _____ minutes.
13. Do you have any general comments about the effectiveness of this CNE/CME program?

____

I have completed the requirements for this activity.

Name (printed) ________________ **Signature**________________

Nursing license number ***(required for nurses licensed by the state of California)***________________

Optional for ACEP members: In accordance with ACEP requirements, below we provide the option for ACEP members to submit their answers for this CME activity. If you wish to submit answers for this activity, please refer to this issue (Vol. 11, No. 3) and circle the correct responses.

1. A
   B
   C
   D

2. A
   B
   C
   D
   E

3. A
   B
   C
   D

4. A
   B
   C
   D

5. A
   B
   C
   D
   E

6. A
   B
   C
   D
   E

7. A
   B
   C
   D
   E

8. A
   B
   C
   D

9. A
   B
   C
   D

10. A
    B
    C
    D

Trauma Reports

2010 Reader Survey

In an effort to learn more about the professionals who read *Trauma Reports,* we are conducting this reader survey. The results will be used to enhance the content and format of *Trauma Reports.*

Instructions: Fill in the appropriate answers. Please write in answers to the open-ended questions in the space provided. Please insert this survey in the provided envelope along with your continuing education evaluation. Return the questionnaire by **July 1, 2010.**

1. Are the articles in *Trauma Reports* written about issues of importance and concern to you?

- O A. Always
- O B. Most of the time
- O C. Some of the time
- O D. Rarely
- O E. Never

2. How would you rate your overall satisfaction with your job?

- O A. Very satisfied
- O B. Somewhat satisfied
- O C. Somewhat dissatisfied
- O D. Very dissatisfied

3. What are you most dissatisfied with in your job?

- O A. staffing
- O B. heavy workload
- O C. low morale in your department or facility
- O D. impact of cost-cutting on quality of care
- O E. other ______________________

Questions 4-9 ask about coverage of various topics in *Trauma Reports.* Please mark your answers in the following manner:

A. very useful B. fairly useful C. not very useful D. not at all useful

4. Imagin in Pediatric Abdominal Trauma (July/Aug. 2009)	O A	O B	O C	O D
5. ATLS Update (Sept./ Oct. 2009)	O A	O B	O C	O D
6. Traumatic Brain Injury (Nov./Dec. 2009)	O A	O B	O C	O D
7. Hand and Wrist Injuries (Jan./Feb. 2010)	O A	O B	O C	O D
8. Genitourinary Trauma (March/April 2010)	O A	O B	O C	O D
9. Pediatric Thoracic and Abdominal Trauma(May/June 2010)	O A	O B	O C	O D

10. How do you receive *Trauma Reports*?

- O A. I am a paid subscriber (proceed to question 11)
- O B. I receive it as a supplement to another publication (skip to question 12)

11. Do you plan to renew your subscription to *TR*? O A. yes O B. no

If not, why? ____

12. How would you describe your satisfaction with your subscription to *TR*?

- O A. Very satisfied
- O B. Somewhat satisfied
- O C. Somewhat dissatisfied
- O D. Very dissatisfied

13. What is your title?

- O A. Practicing emergency medicine physician
- O B. Trauma surgeon
- O C. Emergency department or surgical nurse
- O D. Physician assistant
- O E. Professor/academician
- O F. Emergency medicine manager/director
- O G. Resident

14. On average, how much time do you spend reading each issue of *TR*?

- O A. fewer than 30 minutes
- O B. 30-59 minutes
- O C. 1-2 hours
- O D. more than 2 hours

15. On average, how many people read your copy of *TR*?

- O A. 1-3
- O B. 4-6
- O C. 7-9
- O D. 10-15
- O E. 16 or more

16. On average, how many articles do you find useful in *TR* each year?

- O A. 1-2
- O B. 3-4
- O C. 5-6

17. How large is your hospital?

- O A. fewer than 100 beds
- O B. 100-200 beds
- O C. 201-300 beds
- O D. 301-500 beds
- O E. more than 2,000

Please rate your level of satisfaction with the following items.
A. excellent B. good C. fair D. poor

18. Quality of newsletter	O A	O B	O C	O D
19. Article selections	O A	O B	O C	O D
20. Timeliness	O A	O B	O C	O D
21. Length of newsletter	O A	O B	O C	O D
22. Overall value	O A	O B	O C	O D
23. Customer service	O A	O B	O C	O D

24. What type of education credits do you earn from *Trauma Reports*?

O A. Continuing medical education
O B. Nursing contact hours
O C. I do not participate in the CNE/CME activity.

25. With which publication do you receive *Trauma Reports*?

O A. Emergency Medicine Reports
O B. Pediatric Emergency Medicine Reports

26. Would you subscribe to *Trauma Reports* if it were available as a 12-month subscription?

O A. yes
O B. no

27. To what other publications or information sources do you subscribe?

28. Please list the top three challenges you face in your job today.

29. What do you like most about *Trauma Reports*?

30. What do you like least about *Trauma Reports*?

31. What specific topics would you like to see addressed in *Trauma Reports*?

Contact information (optional):