Supracondylar Humerus Fractures

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Supracondylar humerus fractures are common elbow injuries in children that occur in a vulnerable anatomical location with risk for sequelae ranging from neurovascular compromise to residual deformity. While nondisplaced fractures can be managed nonoperatively, both closed and open surgical reduction techniques are indicated when fractures are displaced or associated with neurovascular injury. This paper describes the techniques employed in the surgical treatment of pediatric supracondylar humerus fractures.
Oper Tech Orthop 29:11-16 © 2019 Elsevier Inc. All rights reserved.

KEYWORDS humerus fracture, pediatric elbow fracture, supracondylar

Introduction

Supracondylar humerus fractures are one of the most common fractures in children and account for 60% of all pediatric elbow fractures with an incidence of 177.3 per 100,000 children per year.[1-4] The majority (95%) of these fractures are extension-type injuries and predominantly occur in children between 5 and 7 years who suffer trauma to the elbow during a fall from height onto an outstretched hand or during other recreational activities with the elbow in full extension.[5,6] Flexion-type fractures account for approximately 3% and a small subset can have multidirectional instability, which can be caused by the injury itself or during reduction. Closed reduction and percutaneous pinning have become the standard of care for displaced fractures; however, open reduction is sometimes required with irreducible fractures and open exploration of the antecubital fossa indicated in patients with pulseless, poorly perfused hands. The presence of the rarer flexion-type fracture pattern may signify a lower threshold for open reduction in difficult cases because of concern about involvement of the ulnar nerve.[3,7,8]

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Mechanism of Injury

The supracondylar distal humerus contains a thin region of bone connecting the medial and lateral columns of the humerus between the olecranon fossa and coronoid fossa that is particularly vulnerable to the linear force exerted during hyperextension of the elbow which, in conjunction with the force from the olecranon pressing into the olecranon fossa, creates the anterior tension that leads to anterior supracondylar failure in the common extension-type fractures. The force continues to propagate posteriorly with increasing displacement of the posterior cortex and disruption of the periosteum with subsequent instability during reduction.[3,9] Flexion-type fractures represent 5% of pediatric supracondylar injuries and occur when there is a direct blow to the posterior aspect of the flexed elbow. Vigilance for neurovascular injury given the density of these structures at the elbow is of critical importance in the initial evaluation of all injuries; the flexion-type injury is particularly associated with a high rate of initial or subsequent injury to the ulnar nerve.

Clinical Presentation and Exam

A pediatric patient with elbow pain or refusing to use an upper extremity after a fall should be evaluated with high suspicion for elbow fractures. Patients will present with varying degrees of swelling and tenderness to palpation about the distal humerus as well restriction of elbow range of motion, most commonly extension given the prevalence of extension-type injuries. Depending on the severity of the injury, there may be visible deformity about the elbow and even skin tenting or anterior arm ecchymosis signifying penetration of the brachialis

muscle by the spike of the proximal fracture fragment.[10] Evaluation for compartment syndrome must be performed and accurately documented, as this can be a devastating sequela of the injury; this evaluation should include tenseness of the forearm compartments as well as passive extension and flexion of the fingers. It is also critical to perform a careful distal neurovascular exam to evaluate for neurapraxia or vascular injury, as these may guide operative or postoperative decision-making. Vascular status, to include distal pulse and perfusion exam, has ramifications for decision-making in regards to possible open exploration of the brachial artery in pulseless, poorly perfused upper extremities.[7] Motor and sensory examination of the radial, ulnar, and median nerve, to include the anterior interosseous nerve (AIN), should be performed to the extent to which the child will allow as neurapraxia will commonly occur with both extension-type (AIN, radial) and flexion-type (ulnar) injuries and can also be affected by iatrogenic injury, particularly during medial percutaneous pinning (ulnar).[3,11]

Radiographic Evaluation

Dedicated anteroposterior (AP) and lateral radiographs are obtained to assess for displacement, rotation, translation, degree of comminution, and intra-articular extension. It is also important to keep in mind that the presence of a posterior fat pad sign without obvious fracture can represent an occult elbow fracture and it is recommended to obtain repeat imaging several weeks later, as 76% of children with initial negative radiographs were found to have a fracture later.[12,13]

The anterior humeral line (AHL) has been widely used for assessment of sagittal plane displacement and is formed by a line, which lies along the anterior humeral cortex and should intersect the middle third of the capitellum (Fig. 1). Herman et al have shown that the AHL intersects the middle third of the capitellum in most healthy children older than 4 years of age but may lie in the anterior one-third of the capitellum in those aged <4 years.[14] A more recent study by Ryan et al has shown that the AHL touches the ossific nucleus of the capitellum in 100% of patients; however, in children less than 5 years of age, the AHL fell outside the middle third, and in

Figure 1 Lateral elbow radiograph demonstrating placement of the anterior humeral line, which lies along the anterior humeral cortex and should intersect the middle third of the capitellum but may lie in the anterior one-third of the capitellum in younger children.

Figure 2 Anteroposterior elbow radiograph demonstrating Baumann's angle which is formed by the intersection of a line drawn down the humeral shaft axis and a line drawn along the physeal line of the lateral condyle.

children less than 2 years of age, the AHL was found to be in the anterior third in 30% of the cases.[15,16]

Baumann angle is useful to assess coronal plane deformity on an AP radiograph and is formed by the intersection of a line drawn down the humeral shaft axis and a line drawn along the physeal line of the lateral condyle (Fig. 2). A normal angle ranges from 70° to 75° and a study by Silva et al confirmed excellent intraobserver reliability.[6,17-19]

Classification

Gartland first introduced a simple yet easy to apply classification system in 1959 based on the degree of displacement, and although it has been modified over the years, current treatment recommendations by the American Academy of Orthopaedic Surgeons (AAOS) continue to be based on this classification system.[20,21] The Gartland classification system identifies the degree of posterior displacement in the sagittal plane, although coronal displacement is also common and can lead to malunion and residual deformity[17,20,22] (Fig. 3). A modified Gartland classification was introduced by

Table 1 Modified Gartland Classification of Supracondylar Humerus Fractures

| Type I	Nondisplaced, fat pad elevation can be only radiographic finding
Type II	Displaced with intact posterior cortex and posterior periosteal hinge, anterior humeral line is anterior to capitellum. IIA (with rotation) and IIB (without rotation)
Type III	Displaced, often in 2 or 3 planes
Type IV	Displaced with complete periosteal disruption. These fractures are unstable in flexion and extension[24]
Flexion type	
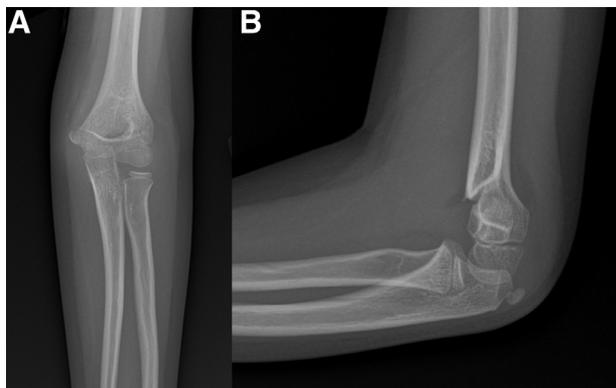
Figure 3 (A) AP radiograph of a type II supracondylar humerus fracture. (B) Lateral radiograph of a type II supracondylar humerus fracture.

Wilkins et al and further divided type II fractures into IIA, extension fractures without rotational abnormalities/translation and IIB, extension fractures with some rotational or translational component (Table 1).[23,49]

Treatment

The AAOS has developed Appropriate Use Criteria which is based on evidence-based information combined with clinical expertise as well as a Clinical Practice Guideline Summary which is based on the best current evidence and a systematic review of published studies.[7,21]

Nonoperative Treatment

Traditionally, children with nondisplaced supracondylar humerus fractures (Gartland type I) are treated in a long arm cast with 90° of flexion and neutral forearm rotation for 3-4 weeks. A recent study by Silva et al also evaluated the feasibility of a removable long arm cast and found that it can reliably maintain fracture alignment and result in similar outcomes. In addition, use of a removable soft cast could also result in a lower number of patient visits, decreased health care costs, and higher patient/parent satisfaction.[25]

Timing of Surgery

Although in the past the majority of surgeons considered pinning of type III supracondylar fractures an emergent procedure, more recent studies have shown that there is no significant difference with regard to conversion to open reduction, superficial pin tract infection, iatrogenic nerve injuries, or compartment syndrome if surgery was delayed up to 21 hours from injury.[26-28] At our institution, thorough evaluation in the emergency department is either performed by an orthopaedic resident, orthopaedic physician assistant, or orthopaedic attending and a long arm splint in 20°-40° of flexion is applied. The patient is then admitted and neurovascular checks are performed every 2 hours by the orthopaedic staff. The administration of narcotic pain

medication is kept to a minimum so that a potentially evolving compartment syndrome is not masked. On the other hand, open fractures, fractures in the setting of a pink pulseless, or dysvascular limb, evolving compartment syndrome, floating elbow, and median nerve compromise are considered emergent and require immediate surgical intervention.[13] The management of the pulseless but perfused supracondylar fractures remains controversial but there is consensus that timely reduction is required. Weller et al[29] concluded that the lack of a radial pulse after closed reduction and percutaneous pinning did not pose an absolute indication for vascular exploration as long as the limb was perfused; however, these patients require close postoperative monitoring in case of late-developing vascular compromise.

Operative Treatment

Displaced supracondylar humerus fractures are usually treated with closed reduction and percutaneous pinning. Some surgeons may choose to treat type IIA fractures with closed reduction and casting, as these fractures are technically considered stable; however, close observation is warranted. For closed reduction and percutaneous pinning, the upper extremity is prepped and draped in the usual sterile fashion; however, some authors prefer a semisterile technique.[30] Care is to be taken to cover gonads and thyroid with lead. A tourniquet can be applied if desired in the setting of an open fracture. The elbow is then hyperflexed and orthogonal fluoroscopy views are obtained. In stable fractures, a lateral view can be obtained by maximally externally rotating the extremity; however, in unstable fractures such as type IV, it is recommended to rotate the C-arm. Once anatomic alignment is restored, two to three 0.062 in. Kirschner wires are introduced laterally depending on the degree of displacement. Larger pins can be considered in older children. In type II fractures, the use of 2 pins is usually sufficient. In order to obtain sufficient fracture stability with lateral pining, it is important to maximize pin spread at the level of the fracture site and to engage sufficient bone in the fragments. In addition, both the medial and lateral columns have to be engaged. Kocher et al[31] found that lateral entry pin fixation is equally effective as medial and lateral entry pin fixation in completely displaced (type III) extension type supracondylar humerus fractures. A similar outcome was found by Foead et al[32] (Fig. 4). When using a cross pin technique, one has to keep in mind that iatrogenic injury to the ulnar nerve has to be avoided at all cost.[33-35] The reduction is then stressed under fluoroscopy and if deemed stable a felt is applied in order to prevent pin migration. The arm is splinted in 60°-80° of flexion and patients follow-up 1 week after surgery for repeat imaging and transition to a long arm cast; however, a recent study by Thompson et al has shown that radiographs in the early postoperative period in do not alter management or clinical outcome and recommend to weigh the theoretical benefits of an early visit with the associated cost.[36]
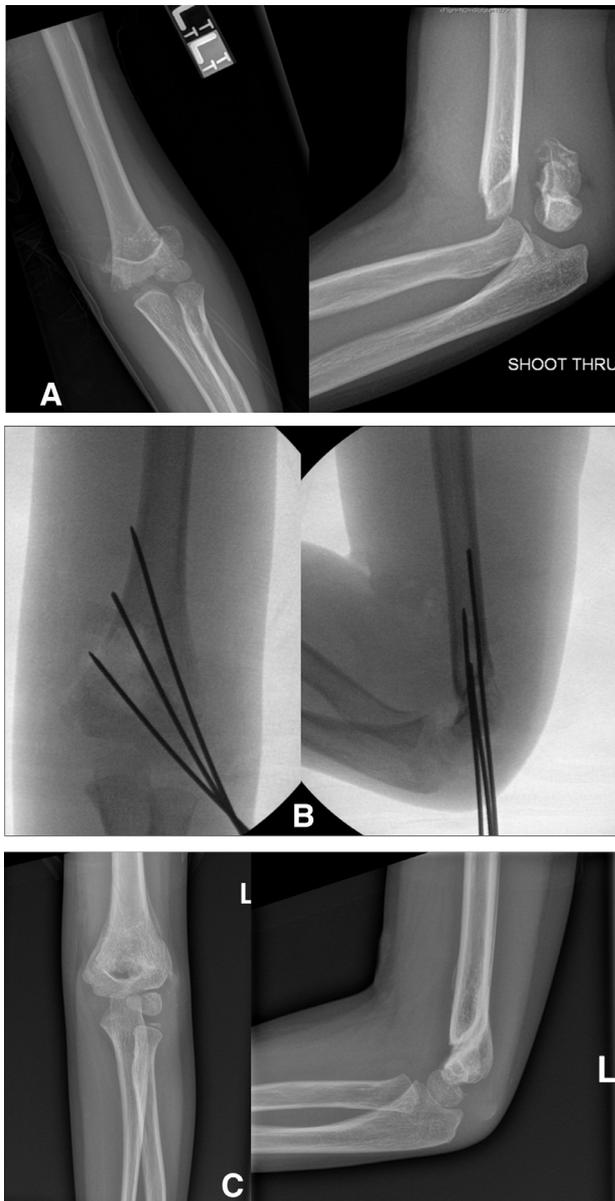
Figure 4 (A) AP and lateral radiograph of a type III supracondylar humerus fracture. (B) Intraoperative imaging s/p closed reduction and percutaneous pinning. (C) Healed fracture 3 months after surgery.

Open Reduction and Internal Fixation

Most supracondylar humerus fractures can be treated by closed means; however, open reduction and internal fixation is indicated when closed treatment fails which is usually caused by interposition of the brachialis muscle but can also be caused by periosteum or joint capsule. In addition, open reduction and internal fixation is warranted in the setting of open fractures, compartment syndrome, as well as neurologic and/or vascular compromise that require further exploration. This is usually the case when the brachial artery becomes entrapped.[37-41]

The anterior approach is most commonly utilized as it allows for exploration of the neurovascular bundle. For this approach, an incision is either made in a transverse or S-type fashion at the antecubital fossa. Blunt dissection is recommended given the proximity to the neurovascular bundle; however, in most cases, dissection has already been done by the trauma itself. It is of utmost importance to protect the neurovascular bundle at all times which is identified medial to the biceps tendon and belly, just proximal to the fracture site. After the fracture site has been cleaned reduction can usually be obtained manually or by using a freer elevator. In the setting of a vascular injury either direct repair or vein grafting is performed in combination with forearm and hand fasciotomies. We recommend that the availability of a surgeon trained in grafts and microanastomosis is taken into consideration.

Complications

Pin Tract Infection

Pin tract infection is considered the most common complication; however, most infections are superficial and can be managed with oral antibiotics and local wound care. More aggressive treatment in terms of surgical debridement and intravenous antibiotics is required in the setting of osteomyelitis and septic arthritis; however, satisfactory long-term outcome has been reported.[42]

Cubitus Varus

Cubitus varus is considered the most common complication after supracondylar humerus fractures and can occur in the setting of casting and pinning. Initially thought to be a purely cosmetic deformity, several studies found that it can lead to tardy posterolateral elbow instability, which often requires a valgus osteotomy in combination with ligament reconstruction.[43]

Compartment Syndrome

Although rare compartment syndrome can be a devastating complication and it is of utmost importance to evaluate every child presenting with a supracondylar humerus fracture. A recent study by Robertson et al showed that the incidence of compartment syndrome in pediatric supracondylar fractures is low; however, the risk increases significantly with increasing age, male sex, and the presence of concomitant forearm fracture or neurovascular injury or in those who underwent a vascular repair.[44,45] Evaluating a child for compartment syndrome can be a difficult task and in comparison to adults, the most sensitive indicator for pediatric compartment syndrome is an increasing need for narcotic pain medication.[46] Children who are at risk for compartment syndrome are admitted for at least 24 hours, are examined every 2-4 hours, and receive either low dose narcotic or non-narcotic analgesia. There is a low threshold to return to the operating room for fasciotomies if compartment syndrome is suspected.

Outcome

Previous studies have shown that supracondylar fractures with rotational and coronal plane deformities were more likely to have complications as well as the need for physical and occupational therapy and nerve injury; however, a more recent prospective study by Ernat et al concluded that Gartland classification and direction of displacement do not influence functional outcomes and that children who underwent surgical treatment of supracondylar fractures in general have excellent outcome.[47,48]

Summary

Supracondylar humerus fractures are one of the most common fractures in children. While nondisplaced fractures can be managed nonoperatively, both closed and open surgical reduction techniques are indicated when fractures are displaced or associated with neurovascular injury.

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