

# UPPER EXTREMITY TRAUMA IN CHILDREN AND ADOLESCENTS: AN UPDATE FROM THE HAND AND UPPER EXTREMITY PROGRAM

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## INTRODUCTION

Children and adolescents use their upper extremities to explore their environment, assist in independent tasks of daily living, and participate in sports and play activities. For these reasons, traumatic injuries of the hand and upper extremity are extremely common in all age groups. As more information regarding the epidemiology, treatment, and outcomes of these injuries becomes available, treating physicians have become better equipped to manage upper extremity injuries. The purpose of this review is to provide a survey of recent research performed at Children's Hospital on upper extremity trauma in skeletally immature patients.

## WRIST

### DIAGNOSIS OF INSTABILITY

Carpal instability due to scapholunate ligament disruption has been well described within the adult orthopaedic literature. Typically, this injury results in a rotatory subluxation of the scaphoid and a dorsal intercalated segment instability (DISI) pattern. Patients will typically present with pain or symptoms of wrist instability following an acute traumatic injury. In adults, the diagnosis is often confirmed via plain radiographs of the wrist, with a scapholunate interval of greater than 2mm suggestive of scapholunate dissociation. Prompt recognition and appropriate surgical treatment is critical to restore normal wrist kinematics, alleviate symptoms, and prevent the long-term functional compromise and arthrosis.

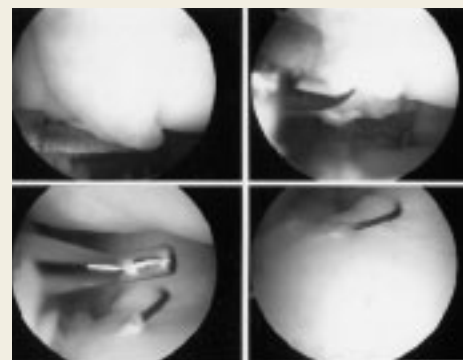
This radiographic diagnosis is more difficult to make in children and adolescents, due to the developing carpus. In particular, the lunate and scaphoid are usually not visible on plain radiographs until the age of four to five years. Furthermore, as there is often asymmetric carpal development, comparison radiographs of the contralateral wrist may be unreliable. For

these reasons, the diagnosis of scapholunate dissociation is a difficult one to make in the skeletally immature patient.

To address this problem, Kaawach, Ecklund, DiCanzio, Zurakowski and Waters determined the age- and gender-based normative values of scapholunate distances (SLD) as seen on posteroanterior (PA) wrist radiographs in children between the ages of 6 and 14 years.<sup>1</sup> The authors reviewed 119 PA wrist radiographs in 85 asymptomatic patients and measured SLD in each case. Repeated-measures analysis of variance revealed significant age and gender differences, and linear regression was used to determine normal SLD ranges for males and females in an age-appropriate fashion. Intra- and inter-observer agreement of these measurements was excellent. Interestingly, only 5 patients—all 12 years old or older—met the adult criterion of normal (less than 2mm) SLD. The authors conclude that by establishing normative values, orthopaedic surgeons and radiologists may better evaluate wrist radiographs for evidence of scapholunate injury.

### ARTHROSCOPIC TREATMENT OF INSTABILITY

The rising participation of children and adolescents in recreational and competitive sports has been paralleled by a rise in the incidence of acute and chronic wrist pain. At the 2003 Annual Meeting of the American Academy of Orthopaedic Surgeons, Earp, Waters, and Wyzykowski presented the outcomes of arthroscopic treatment of post-traumatic wrist instability in skeletally immature patients.<sup>2</sup> Twenty-nine patients with arthroscopically confirmed ligamentous wrist injuries were treated with arthroscopic synovectomy, ligamentous or chondral debridement, and/or ligament repair. (Figure 1) Wrist



**Figure 1:** Wrist arthroscopy images taken during arthroscopic evaluation (upper left) and debridement (upper right) of a traumatic peripheral TFCC tear from its ulnar insertion. Following suture repair, TFCC integrity is restored (lower right).

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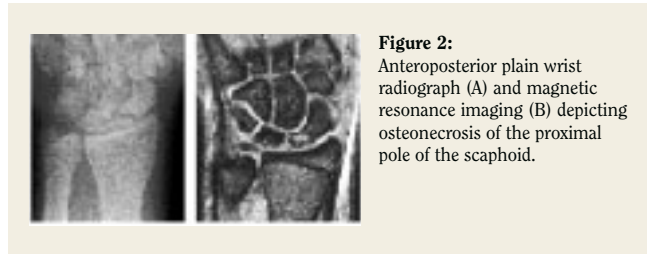
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symptoms and function as measured by the modified Mayo Wrist Score improved significantly in the short term. Though a very small number of patients required subsequent open reconstruction, the authors concluded that wrist arthroscopy is a valuable tool in the treatment of post-traumatic wrist instability in children and adolescents.

#### SCAPHOID FRACTURES

The scaphoid is the most commonly fractured bone of the developing carpus. Historically, the most common pattern of injury involved the distal pole, usually as a result of direct trauma; these injuries may be successfully treated with cast immobilization. Fractures through the scaphoid waist, however, are becoming more common in the skeletally immature. Currently, it is recommended that displaced fractures be treated with anatomic reduction and internal fixation. In cases of fracture nonunion, internal fixation with autologous bone grafting has been successfully utilized.

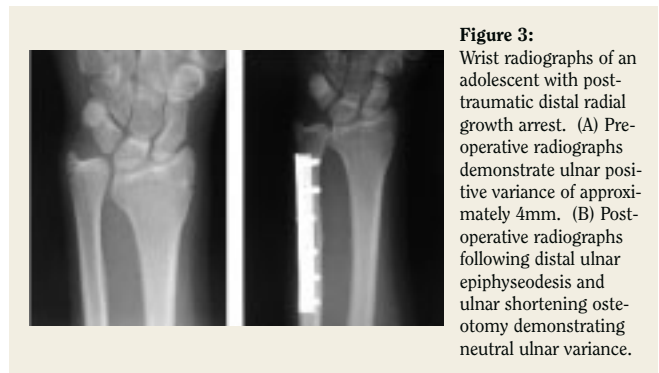


**Figure 2:** Anteroposterior plain wrist radiograph (A) and magnetic resonance imaging (B) depicting osteonecrosis of the proximal pole of the scaphoid.

Fractures of the proximal scaphoid are relatively rare injuries in the skeletally immature patient population, with nonunion and osteonecrosis being the most concerning potential complications. While there have been recent reports on the use of vascularized bone grafts to treat proximal scaphoid fracture nonunions in adults, little is known about the treatment of these entities in children and adolescents. Waters and Stewart have recently published the first case series of nonunion and osteonecrosis following proximal pole of scaphoid fractures in skeletally immature patients.<sup>3</sup> (Figure 2) Three patients were treated with vascularized bone grafting from the distal radius at an average of 18 months following their original injury. The diagnosis was confirmed via plain radiographs and computed tomography in all patients. At an average follow-up of 5.5 years, all attained clinical and radiographic union. The authors conclude that vascularized radial bone graft with internal fixation is effective for proximal pole nonunion and osteonecrosis in skeletally immature patients.

#### GROWTH ARREST OF THE DISTAL RADIUS

The distal radius is the most common site of fracture in the immature skeleton, comprising approximately 20-25% of all pediatric fractures. Approximately 15% of these fractures involve the distal radial physis, representing nearly 40% of all “growth plate” injuries in some series. Though unusual, growth disturbance of the distal radial physis does occur, with an estimated incidence of 1-7%. Growth arrest of the distal radial physis may have important clinical consequences, including pain, deformity, joint subluxation, and functional impairment. Often these complications are severe enough to warrant surgical correction.



**Figure 3:** Wrist radiographs of an adolescent with post-traumatic distal radial growth arrest. (A) Pre-operative radiographs demonstrate ulnar positive variance of approximately 4mm. (B) Post-operative radiographs following distal ulnar epiphyseodesis and ulnar shortening osteotomy demonstrating neutral ulnar variance.

Waters, Bae, and Montgomery have recently published the results of surgical treatment for post-traumatic distal radial growth arrest in children and adolescents.<sup>4</sup> Thirty patients with progressive deformity, wrist pain, and/or loss of motion secondary to distal radial growth arrest were treated with a combination of ulnar epiphyseodesis, ulnar shortening osteotomy, radial osteotomy, and/or radial epiphyseodesis procedures. (Figure 3) Treatment was predicated on the degree of deformity and amount of growth remaining. At average follow-up of 21 months, all patients had significant improvement in pain and function as assessed by the modified Mayo Wrist Score. Radiographically, ulnar variance was corrected from an average of 4.5mm positive to neutral and radial inclination was corrected from an average of 8.5 to 15.5 degrees. The authors conclude that surgery for post-traumatic distal radial growth arrest can improve pain and range of motion and prevent progressive deformity in skeletally immature patients.

## ELBOW

#### RADIAL NECK FRACTURES

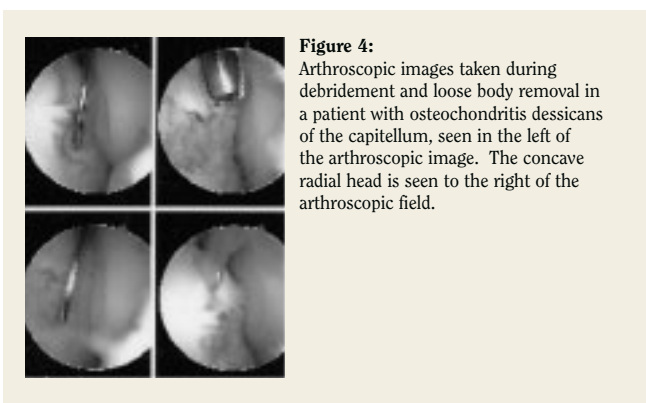
Fractures of the proximal radius in skeletally immature patients most commonly involve the physis and radial neck. This is partly due to the fact that the radial head is mostly comprised of cartilage. Radial neck fractures account for 8 percent of all pediatric elbow fractures, occurring most commonly in children between the ages of 9 and 12 years. Treatment is based upon degree of angulation. Most authorities agree that fractures with less than 30 degrees of angulation will remodel over time and do not require specific intervention. Fractures with greater than 30 degrees of angulation benefit from closed reduction. In cases of displaced fractures in which closed or percutaneous reduction is not successful or in which a stable reduction is not obtained, open reduction with internal fixation is indicated.

Radial neck fracture nonunion is a rare complication of displaced injuries in skeletally immature patients. To further identify risk factors and treatment options for this unusual complication, Waters and Stewart performed a retrospective review of nine cases of radial neck nonunion.<sup>5</sup> Patient age averaged 8 years, and all sustained Salter-Harris type II fractures with average angulation and displacement of over 80 degrees and 80 percent, respectively. The majority of cases underwent anatomic open reduction, but initial reduction was lost in all patients. Treatment was comprised of observation, radial head excision, or open reduction and internal fixation with bone

grafting depending on symptoms, deformity, and functional deficit. Interestingly, healing of the nonunion did not necessarily lead to improvement of clinical symptoms in all cases.

#### FLOATING ELBOWS

“Floating elbow” injuries refer to ipsilateral forearm and humerus fractures. As these injuries result from higher energy trauma with concomitant soft tissue injury, there may be significant swelling with the potential for compartment syndrome, particular if circumferential cast immobilization is utilized during treatment. Ring, Waters, Hotchkiss, and Kasser recently reviewed the treatment 16 pediatric patients with floating elbows treated at Children’s Hospital.<sup>6</sup> Of the 10 patients in whom casting was used to manage the forearm injury, two developed compartment syndrome and four patients required cast release due to symptoms of impending compartment syndrome. Six patients were treated with percutaneous wire fixation of both the humerus and forearm fractures without complications. The authors recommend percutaneous pin fixation of both the supracondylar and distal radius fractures in floating elbow injuries to prevent the need for circumferential casting and reduce the risk of compartment syndrome.



#### ELBOW ARTHROSCOPY

In a recent publication, Micheli, Luke, Mintzer and Waters described the techniques and results of elbow arthroscopy in pediatric and adolescent patients.<sup>7</sup> Forty-nine cases in 47 pediatric patients were reviewed with average follow-up of 4.7 years. The majority of procedures were performed for osteochondritis dissecans; less common indications included arthrofibrosis, synovitis, acute trauma, and posterior olecranon impingement. (Figure 4) Greater than 80% of patients had good or excellent results, with 90% of patients returning to sports without limitation. There were no neurovascular or infectious complications. The authors conclude that elbow arthroscopy has a safe and effective role in the treatment of selected elbow problems in children and adolescents.

#### ELBOW CONTRACTURE

Elbow joint contractures occur most commonly following traumatic injuries. In most cases, non-operative treatment consisting of stretching exercises, dynamic and static splinting, physical therapy, and manipulation provide adequate improve-

ment in elbow range of motion. The results of these treatment modalities may be limited, however, in cases of long-standing stiffness or those associated with intra-articular pathology. Patients with persistent functional impairments despite adequate trials of non-operative treatment may benefit from surgical release. While there have been many previous reports on the surgical treatment of post-traumatic elbow contracture in adults, little is known about the results of surgical treatment in pediatric patients.

Bae and Waters have recently published the results of operative treatment of post-traumatic elbow contractures in adolescents.<sup>8</sup> Thirteen patients were treated at an average age of 16 years. When possible, an extensile medial approach was utilized. Surgical releases involved excision of heterotopic ossification, hardware removal, extensive capsular excision, and when indicated, musculotendinous lengthenings of the brachialis and flexor-pronator mass. All patients were treated with continuous passive motion, physical therapy, and splinting post-operatively. At average follow-up of 29 months, average total arc of motion improved from 53 to 107 degrees. The authors conclude that in appropriately selected patients, surgical release combined with comprehensive post-operative therapy can provide improvements in range of motion in cases of post-traumatic elbow contracture.

#### BRACHIAL PLEXUS

##### EXAMINATION OF BRACHIAL PLEXUS BIRTH PALSY

Brachial plexus birth palsy refers to the paralysis of the upper extremity secondary to a traction or compression injury sustained to the brachial plexus during birth. The majority of infants will recover spontaneously and attain near normal upper extremity function; however, some will have persistent deficits and require surgical treatment. At present, physical examination findings are used to predict recovery and determine the need for surgical intervention. This practice highlights the critical role that classification systems based upon physical examination findings play in the evaluation and treatment of these patients.

Bae, Waters, and Zurakowski have reported on the reliability of three different classification systems measuring active upper extremity motion in patients with brachial plexus birth palsy.<sup>9</sup> Over 300 examinations were performed and findings were recorded according to the modified Mallet Classification, Toronto Test Score, and Hospital for Sick Children Active Movement Scale. Intra- and inter-observer reliability among examiners was determined to be fair to excellent using all classification systems. In general, intra-observer agreement was higher than inter-observer agreement. The authors concluded that these classification systems are reliable and may be utilized for future study of the natural history and results of surgical treatment of brachial plexus birth palsy.

#### COMPARTMENT SYNDROME

Compartment syndrome remains a concerning complication of upper extremity trauma. The diagnosis is often difficult to diagnose in children, and delays in treatment may lead to

disastrous complications. To further examine the current treatment of pediatric compartment syndrome, Bae, Kadiyala, and Waters reviewed 36 cases of compartment syndrome in 33 patients treated at Children's Hospital from January 1992 to December 1997.<sup>10</sup> The average patient age was 10 years, and 18 cases involved the upper extremity. Eleven of these cases occurred in the setting of acute fractures and three cases occurred following surgery (corrective upper extremity osteotomies or fracture fixation). Interestingly, pain, pallor, paresthesias, paralysis, and pulselessness were relatively unreli-

able clinical signs of compartment syndrome in these children. An increasing analgesia requirement in combination with other clinical signs, however, was a more sensitive indicator of compartment syndrome. Indeed, all ten patients with access to patient-controlled or nurse-administered analgesia during their initial evaluation demonstrated an increasing requirement of pain medication. With prompt recognition and expedient fasciotomy, over 90 percent of these patients had return to pre-injury levels of activity at an average of 2.5 months after surgery.

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