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Wrist Injuries in the Immature Athlete

Scott H. Kozin, MD,[*,†] and Joshua M. Abzug, MD[‡]

The pediatric skeleton has abundant cartilage and thick periosteum shield that protect the immature athlete. Injuries can still result from excessive overuse or overt high energy trauma. This article will focus on injuries about the pediatric wrist primarily distal radius physeal stress syndrome, ulnar abutment syndrome, scaphoid fractures, and distal radius growth arrest. The diagnosis of these entities along with treatment options will be discussed. Surgical techniques to remedy these difficult problems will be highlighted. Published outcomes after the various surgical procedures will also be reviewed.
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Introduction

The pediatric skeleton has unique anatomical qualities that protect the immature athlete. The abundant cartilage and thick periosteum shield the underlying bone from everyday stress. However, the increasing demands and activities of the modern day immature athlete test the boundaries of these defensive assets. Injuries result from excessive overuse or overt high-energy trauma or both. Upper extremity injury can affect the shoulder, elbow, forearm, wrist, or digits. Overuse is widespread in sporting activities that require upper extremity weight bearing such as gymnastics and competitive cheerleading. Trauma is prevalent in contact athletics and extreme sports such as mountain bike riding. This article focuses on injuries about the pediatric wrist with an emphasis on diagnosis, treatment, and outcome.

Pertinent Anatomy

The pediatric skeleton has many distinctive features compared with adults. Most important is the presence of the physis or growth plate that is divided into 4 distinct zones: germinal, proliferative, hypertrophic, and provisional calcification. Approximately 75%-80% of forearm growth and 40% of the entire upper extremity growth occurs at the distal radius and distal ulna physes.[1] The distal radial physis closes at approximately 16 years of age in girls and 17 years of age in boys.[2] As the hypertrophic and provisional calcification zones are relatively weaker when compared with the germinal and proliferative layers,[3,4] fracture lines tend to pass through these zones. However, high-energy athletic injuries may have fractures that undulate through all 4 zones and cause substantial growth plate damage.

The existence of secondary ossification centers is another distinctive feature. The distal radius epiphysis is absent at birth and appears at approximately 1 year of age. Precisely, the appearance is between 0.5 and 2.3 years in boys and between 0.4 and 1.7 in girls.[5] The configuration of the epiphysis also changes with age. The initial epiphysis is transverse in shape and becomes more triangular with time. When there is uncertainty about the normal appearance of the radial epiphysis and the presence of a fracture or growth plate abnormality, comparison x-rays, or consulting a skeletal atlas is essential.

The anatomy of the immature scaphoid warrants conversation. The scaphoid develops by endochondral ossification with the ossific nucleus first appearing in the distal pole, typically between 4 and 5 years of age. The bone ossifies from distal to proximal along the primary blood supply, which comes from a branch of the radial artery at the dorsal ridge. Ossification is usually complete between 13 and 15 years of age.[6] As the ossification front travels in a proximal direction, there is a relative weakness at the interface between the ossified and nonossified scaphoid.

*Department of Orthopaedic Surgery, Temple University, Philadelphia, PA.
†Shriners Hospitals for Children, Philadelphia, PA.
‡Department of Orthopaedics, University of Maryland Children's Hospital, University of Maryland, Timonium, MD.
Address reprint requests to Scott H. Kozin, MD, Department of Orthopaedic Surgery, Shriners Hospitals for Children, 3551 North Broad St, Philadelphia, PA 19140. E-mail: skozin@shrinenet.org

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Growth Plate Damage

Distal Radial Physeal Stress Syndrome

Persistent upper extremity weight bearing activities can directly damage the growth plate. The unrelenting stress across the physis produces destructive forces that damage the immature growth plate. The Heuter-Volkmann principle states that the rate of epiphyseal growth is affected by pressures applied to its axes.[7] Increased pressure inhibits growth, whereas a decreased pressure accelerates growth. Regarding the gymnast, the former predominates with supraphysiological loads inhibiting growth of the distal radial physis. Early symptoms and signs are pain during exercise and localized tenderness, which are often ignored given the stoic nature of these athletes. Persistent pain and inability to compete would ultimately lead to medical attention being pursued. In addition to the standard history of present illness questions, specifics regarding the number of practice hours performed during a typical week, which specific upper extremity weight bearing activities are being performed, the competition level, and upcoming competitions are important questions that should be asked. In the higher level competitors, the intensity and dedication are often astounding, with 20-30 hours of practice being common. The examination includes assessment of the entire upper extremity from the neck to the finger tips. Specifics regarding the wrist examination include palpation, assessing the range of motion when compared with the contralateral side, and provocative tests for instability. Tenderness about the growth plate is the classic finding with slight loss of wrist motion also typically being present. Frequently, the hands are calloused with normal digital range of motion and exceptional strength.

Posteroanterior (PA) and lateral radiographs should routinely be obtained. Classic radiographic findings include physeal wideninig with an irregular appearance because of the repetitive stress and overloading(Fig. 1).[8] Additionally, there may be Harris Growth arrest lines consistent with previous trauma.

Treatment requires immobilization, and the athlete needs to "shut down" from all upper extremity weight bearing activities to prevent permanent growth plate injury from occurring. Immobilization can be in the form of a short arm cast or removable splint depending on the perceived trustworthiness of the athlete. He or she can maintain his or her aerobic fitness, but must avoid strenuous load going across the wrist. The exact duration of immobilization and abstinence is unknown. Our practice is to treat physeal stress injuries similar to fractures with immobilization periods of 4-6 weeks dependent on the age of the athlete. Subsequently, return to upper extremity weight bearing activities is delayed until full range of motion has been regained. Afterward, graduated weight bearing is instituted with participation excluded following any recurrence of signs or symptoms.

Ulnar Abutment Syndrome

Chronic overloading of the distal radius can result is persistent inhibition of distal radial growth, thus leading to ulnar positive variance, and ultimately ulnar abutment syndrome. The pain about the distal ulna is exacerbated by ulnar deviation or shucking of the distal radioulnar joint or both. A concomitant triangular fibrocartilage complex (TFCC) tear can also be present. Plain PA x-rays of the wrist in neutral forearm rotation allow for assessment of the ulnar variance. Typically, apart from positive ulnar variance, Harris Growth arrest lines may be seen in the metaphysis of the radius. Initial management is nonoperative with rest and immobilization. A corticosteroid injection may be provided in case of persistent pain. Recalcitrant symptoms warrant a candid discussion regarding future sports participation and surgical options.

Surgical treatment should address any intra-articular pathology such as a TFCC tear. In child with some skeletal growth remaining, ulnar abutment can be addressed by performing a distal ulnar epiphysiodesis, allowing radial growth to result in an ulnar neutral or ulnar negative wrist. Although, the operation is straightforward, symptomatic relief is delayed until equalizing

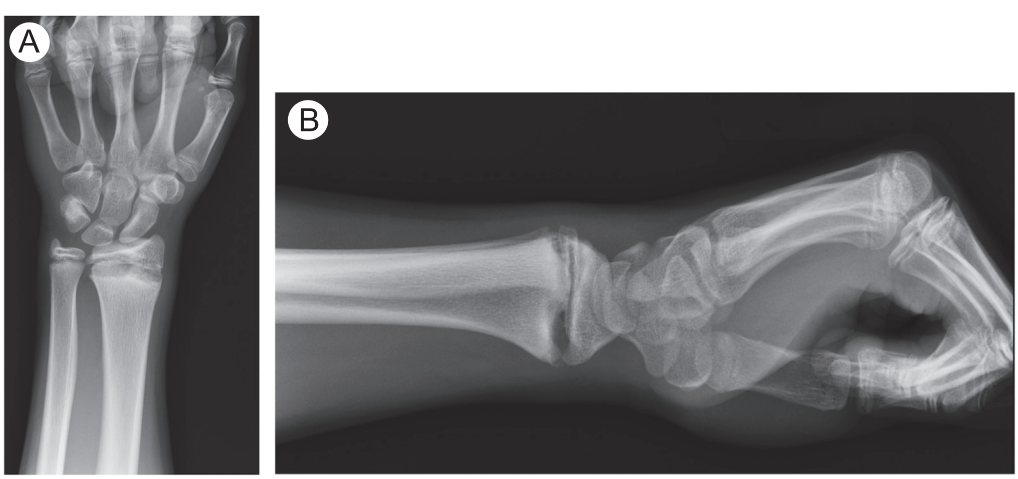

Figure 1 A 13-year-old female gymnast with increasing left wrist pain preventing competition. (A) Anteroposterior x-ray with widening and irregularity of the physis. (B) Lateral x-ray with widening more on the volar aspect. (*Courtesy*: Shriners Hospitals for Children, PA)