Wrist sprains and intracarpal lesions in the pediatric patient: Actual entities?

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Introduction

Compared to fractures of the digits and of the distal radius and/or ulna, with an actual prevalence 15% and 35% respectively (1), intracarpal ligamentous lesions are scarcely described the literature (2,3). One hypothesis could be that some authors consider the physiologic hyperlaxity in children and the cartilages covering the ossification centers of the carpal bones as protective factors. In fact, with a high modulus of elasticity, the cartilage can absorb a high amount of kinetic energy (4). Furthermore, since the physis is the more fragile area of the growing skeleton, trabeculae tend to pass through the physis but not carpal bones (5).

The terms “wrist sprains” or “occult bony lesion” are frequently used in daily practice but are non-specific. To this day, no precise description has been provided for the underlying pathology (6). The principal difficulty resides in the proper diagnosis of ligamentous injuries at the level of the wrist in children. This difficulty may be explained by two facts: 1) the clinical exam of an injured child is sometimes difficult, and 2) standard radiographs of an immature carpal bone in the emergency setting are difficult to interpret and may conceal osseocartilaginous or ligamentous lesions. In fact, carpal bones ossify late in life and present numerous radiographic pitfalls, both leading to over- and underdiagnosing bony lesions.

After providing a short summary of the process of carpal bone ossification and anatomical specificities inherent in their stability, we will detail indirect clinical and radiographic elements of a ligamentous injury of the carpal bones. We will then conduct a literature review of the different carpal lesions along with their treatment. Our review will be limited to patients with a still unfused radiocarpal physis.

Ossification of the carpal bones

The wrist of a fetus is originally constituted of a single cartilaginous mass. Around the tenth week of gestation, carpal bones are etched out from this mass and form eight distinct entities (4). These centers progressively ossify after birth with small anatomical variations and a small latency

between the two sexes. The chronology with which these ossification centers start to appear may be used as a tool to assess the proper age of the child.

The capitatum is the first bone to begin its ossification, generally around the first few months of life. Ossification then follows in a counterclockwise fashion. The hamatum appears around four months. The triquetrum is usually visible during the second year of life and the lunate begins its ossification during age four. The scaphoid slightly precedes the trapezium during age five. The trapezoid appears at the end of the fifth year or at the start of the sixth, and the pisiform concludes the ossification of the carpal bones around age nine.

Anatomical elements of carpal stability (7)

The carpal bones constitute a relay between the forearm and the hand. The carpal bones allow for two degrees of freedom: flexion/extension and ulnar/radial inclination. The normal functioning of the wrist is based on the relative mobility of the different bony pieces between each other, a mobility which itself is controlled by the ligaments and the morphology of these bony pieces.

Bony structure

The carpal bones are organized into two rows. The first row comprises the scaphoid, the lunate, the triquetrum, and the pisiform. The second row – hamatum, capitatum, trapezium, trapezoid – is characterized by the fact that the interosseous ligaments that unite the ossicles allow only a limited mobility of the different bones between each other.

The carpals are a system of variable geometry with the scaphoid having a natural tendency to go into flexion, while the triquetrum has a natural tendency to go into extension. The lunate balances and stabilizes the system. The carpal bones tend to spontaneously translate into ulnar and palmar deviation with the radial glenoid being open inwardly (25°) and to the front (10°).

Ligamentous structures

Intrinsic ligamentous system: this system unites the carpal bones without inserting on the skeleton of the forearm (5).

- The scapholunate ligament, the anterior and posterior thirds of which are thicker and are directly implicated in the stability of the scapholunate couple. The scapholunate ligament allows shearing movements with a rotation of 35° between the scaphoid and the lunate.
- The lunotriquetral ligament also contains three portions with a palmar portion that is more resistant, a middle fibrocartilaginous portion which is avascular and without biomechanical significance, and a dorsal portion which merges with the scaphotriquetral ligament. This ligament is more robust than the scapholunate interosseous ligament and limits the shearing movements between the lunate and the triquetrum.

A “V” deltoid ligament formed between two branches slung from the neck of the capitate. The lateral branch is the prolongation of the radioscaphocapitate ligament. The medial branch (triquetrohamatecapitate ligamentous complex) takes its origin on the ulnar border of the pisotriquetral joint. Its fundamental biomechanical importance lies in the coordination of movements of the first row and midcarpal stability.

Extrinsic ligamentous system

This is an intracapsular ligamentous system that is suspended between either the radius or the ulna and the carpal bones. The anterior ligamentous system is biomechanically stronger and includes the radioscaphoid, radioscaphocapitatae, radiolunotriquetral, radioscapholunar, ulnolunar, and ulnotriquetral ligaments.

The posterior ligamentous system is constituted of the dorsal radiocarpal, dorsal scaphotriquetral, and dorsal intercarpal ligaments.

Diagnostic elements

Mechanism of injury

Fracture-dislocations or isolated ligamentous injuries of the carpal bones are often due to high energy trauma (contact sports, bicycle accidents, etc…) with excessive dorsiflexion of the wrist (3).

Clinical signs

The clinical presentation of a carpal injury varies greatly. Classically, there is tenderness at the level of the injured bones, although the patient may also present with diffuse tenderness at the level of the carpal bones. Hemarthrosis may be present as discrete swelling of the wrist. Differential diagnoses involving the radial physis may be ruled out by absence of tenderness at the level of the distal radial physis. The clinical exam must also rule out associated complications, especially paresthesia in the territory of the median nerve. The clinical exam must be compared with the contralateral side.

Medical imaging

Standard anteroposterior and strict lateral radiographs must be obtained when faced with a suspected sprain of the wrist. Their interpretation may be difficult due to the uneven ossification of the different carpal bones, leading to varied interosseous spaces according to the subject’s age. Some authors suggest obtaining comparative contralateral radiographs (8). Radiographs in ulnar deviation or clenched fist views may be obtained to rule out a scapholunar lesion in adolescents with more specificity.

If the patient presents with persistent pain after sustaining trauma to the wrist with normal initial radiographs, an MRI should be obtained in young children with unfused carpal bones. The MRI should be obtained with gadolinium contrast and should include cartilage-specific sequences (gradient echo, associated with T1 fat saturation sequences). The MRI allows the visualization of cartilaginous fractures, bony edema, or even ligamentous ruptures. MRI may also rule out differential diagnoses such as lunate or scaphoid necrosis.

CT-scanning is indicated in older children in whom fine thin-slice images of the carpal bones may be diagnostic.

Traumatic injuries in young children

Isolated ligamentous injuries

Pure ligamentous injuries are unusual compared to bony injuries due to the ligamentous viscoelasticity.

The odd cases of isolated scapholunate disjunction which have been described in the literature usually involve pre-adolescents. Symptoms and complementary exams are similar to adults. Clinical signs include localized pain on the dorsum of the wrist which increases with radial deviation. Imaging may show a scapholunate diastasis with flexion of the scaphoid and a Dorsal Intercalated Scapholunate Instability (DISI, Figure 1). Initially, the surgical management is similar to the adult patient and consists of reducing the DISI, ligamentoplasty and capsulodesis through a dorsal approach (9).

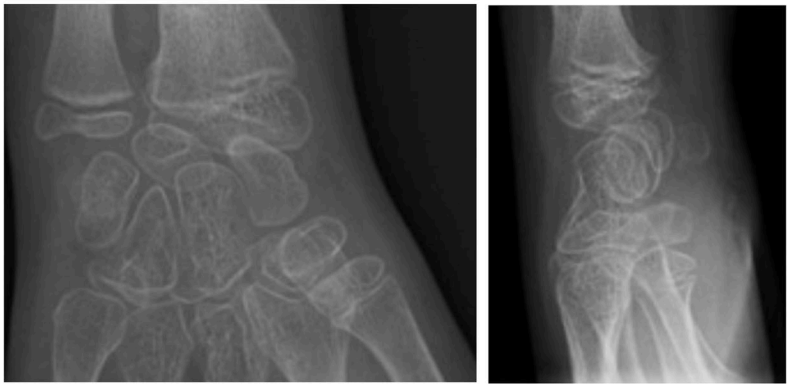

Figure 1 – Scapholunate diastasis and DISI in a 14 and a half-year-old boy diagnosed with a forearm fracture. The initial injury was missed.

Ligamentous injuries associated with perilunate dislocation

These injuries seem more frequent than isolated ligamentous injuries. A literature review shows that the symptoms are not specific and the mechanism of injury that is often unidentified.

Perilunate dislocations are serious injuries leading to carpal instability due to extended injury to the scapholunar and lunotriquetral ligaments. The diagnosis is difficult to make on patients with immature carpal bones and must be considered when there is disruption of radio-luno-capitate alignment on a strict lateral radiograph, and when there are modifications of the arcs of Gilula on anteroposterior radiographs (10). An MRI may confirm the diagnosis (Figure 2). Treatment is generally surgical and aims at reestablishing the congruency between the different carpal bones and repairing the ligaments which are protected by Kirschner wires (10,11).

In the absence of proper surgical management, the lesions lead to carpal instability with a risk of arthritis in the medium-term.

Figure 2 – Perilunate dislocation in a 3-year-old patient (11).

Figure 3 illustrates the case of a progressive dislocation over 3 years in an 8-year-old patient. The initial injury was a diaphyseal fracture of both bones of the forearm after sustaining a fall from a bicycle, which was initially treated conservatively. Clinically, there was pain and tenderness at the level of the wrist with a limited range of motion in extension (0°) and flexion (40°). The diagnosis was made on radiographs. Complementary imaging included an MRI and a CT-scan.

Figure 3 – An 8-year-old patient presenting with a perilunate dislocation which was initially missed (Col C. Klein)

Injuries to the triangular fibrocartilage complex (TFCC)

The TFCC participates in the stability of the distal radioulnar and ulnocarpal joints. Injuries to the TFCC are very rarely encountered in children (12) and are usually associated with distal fractures of both bones of the forearm, of the ulnar styloid, or Galeazzi fracture-dislocations. The mechanism of injury is high energy trauma involving axial rotational forces (e.g., sports accidents). In children with positive ulnar deviation, the TFCC is thinner and at higher risk of injury (13). The clinical presentation is dominated by tenderness of the ulnar compartment which increases during ulnar deviation of the wrist and during pronation-supination. The stability of the distal radioulnar joint must be compared to the contralateral side (14). Radiographs may show a fracture of the ulnar styloid, the presence of which must rule out an associated injury of the TFCC. The diagnosis is thus confirmed by MRI (8) or a CT-arthrogram. It should be noted that some authors have found a false-negative rate as high as 50% with an MRI (15). Injuries were classified by Palmer based on the location of the TFCC injury.

Most injuries of the TFCC associated with a fracture will heal spontaneously once the associated fracture has been properly treated. The soft tissues generally do not require any intervention (15). In isolated injuries, if there is a moderate tear, simple observation has sometimes been suggested as a treatment modality. If the lesion is central or paracentral, arthroscopic-guided debridement is indicated. If there is avulsion at the level of the fovea, reinsertion may be necessary (16). In most cases, these injuries are encountered in children at the end of their growth.

Extrinsic ligamentous injuries

Injuries of the dorsal extrinsic ligaments of the carpal area are encountered in patients sustaining a fall on the wrist in forced extension, or in sports which require repetitive dorsiflexion. The diagnosis is made with ligamentous hypersignal on MRI. Nevertheless, these injuries are rare. In fact, in a study on 91 patients with a painful wrist and a normal radiograph, Elvey et al. (6) found only one case of extrinsic ligamentous sprain.

Ligamentous injuries associated with fractures

- *Scaphoid fracture*

Scaphoid fractures represent up to 3% of fractures of the hand and wrist in the pediatric population and are the are the most frequently encountered carpal fractures in children (8,17). They are rarely found in children younger than 7 years of age and are more frequent in adolescents. These injuries may be associated with lesions of the scapholunar ligament.

Fractures of the proximal pole are unique; in that they may pass through the physis and may be missed on standard radiographs. When a displaced fracture of the proximal pole of the scaphoid is encountered, surgery becomes necessary. Open reduction and internal fixation of the scaphoid

with a screw along with direct repair of the scapholunar ligament is recommended in order not to disrupt the growth of the carpals as well the biomechanical stability of the wrist (15).

Fractures of the middle third of the scaphoid, an associated perilunate dislocation must be ruled out, as well as scapholunar injuries or Fenton syndrome when there is an associated proximal capital fracture.

Avulsion fractures of the distal pole of the scaphoid are often associated primarily with lesions of the scaphoradial and scaphotrapezial ligaments, the treatment of which is conservative (8).

Nonunion of the scaphoid in children is generally asymptomatic. The diagnosis may be made fortuitously during radiography of the wrist for a different reason. Many authors have shown that a large number of fractures of the scaphoid are diagnosed at nonunion (18,19). In our institution, a case of scaphoid nonunion was diagnosed 7 months after having sustained trauma of the left wrist without appropriate initial management. Imaging also found scapholunar disjunction and DISI (Figures 4 and 5). Management was surgical with pseudarthrosis treatment of the scaphoid involving an iliac bone graft, partial reduction of the DISI, and scapholunar ligamentoplasty (Figures 6 and 7).

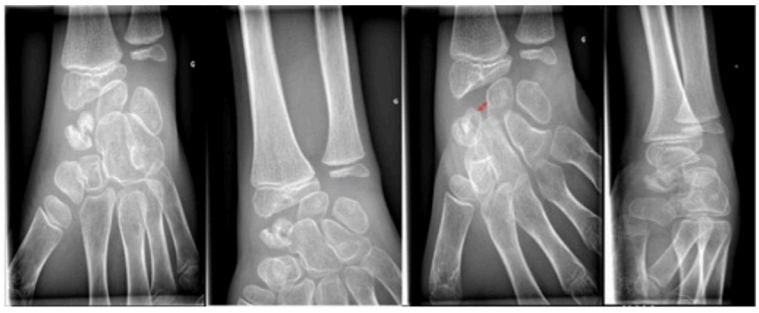

Figure 4 – Static and dynamic radiographs of a 10-year-old patient 7 months after having sustained trauma to the left wrist without initial management. Scaphoid nonunion, scapholunar disjunction, and DISI can be seen.

Figure 5 – T1-weighted MRI of a 10-year-old patient 7 months after having sustained trauma to the left wrist without initial management. Scaphoid nonunion and scapholunar disjunction can be seen.

Figure 6 – Perioperative fluoroscopy of the pseudarthrosis treatment of the scaphoid.

Figure 7 – Radiographs 3 months postoperatively

- Lunate fractures

Fractures of the lunate are rarely found in isolation (20). They can be associated with other carpal fractures (primarily scaphoid) and with perilunate dislocations.

- Capitate fractures

Injuries of capitate are rare in the pediatric population and are found in high energy trauma with excessive dorsiflexion of the wrist (e.g., fall from a bicycle) (21).

They may be associated with ligamentous injuries in Fenton's syndrome or scaphocapitate syndrome in which there is an association with a distal radial and scaphoid fracture, along with a fracture of the head of the capitate. Ligamentous injuries of the scaphocapitate and lunocapitate are found when there is rotational displacement of the proximal pole of the capitate. The high energy forces propagate around the lunate leading to injuries of the ligamentous attachments and lead to lunate or perilunate dislocations (Figure 8). Treatment is usually conservative in non-displaced fractures and surgical with reduction and pinning in displaced fractures and Fenton's syndrome. Surgical treatment allows the simultaneous treatment of any ligamentous injury.

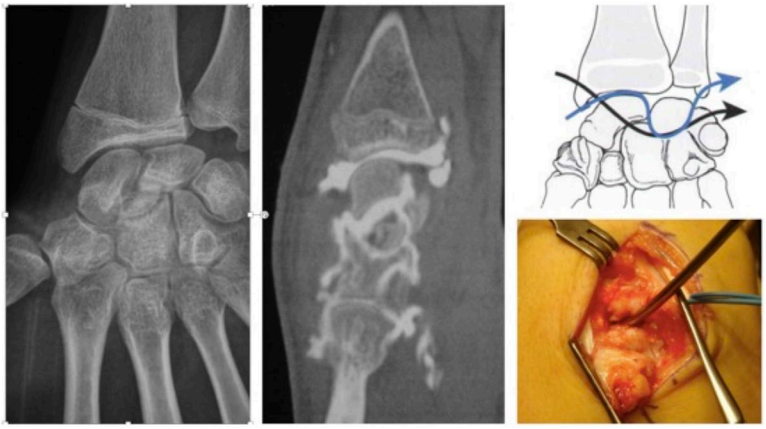

Figure 8 – Propagation of the forces throughout the carpal bones explaining the different associations of lesions. The forces drawn in black are associated with osseous lesions of the scaphoid, capitate, lunate, hamate, and triquetrum. The forces drawn in blue are associated with ligamentous lesions of the scaphoradial, scapholunate, lunocapitate, and lunotriquetral ligaments. Patient presenting an old Fenton lesion with rotational dislocation of the head of the capitate which is well visualized on a CT-arthrogram. Perioperative view of a fracture of the capitate.

Summary

Intracarpal ligamentous injuries in skeletally immature patients do exist but are rarely encountered, the initial diagnosis of which is painstaking, and treatment is often delayed. They must be ruled out in patients with persistent pain at the level of the wrist, especially after an overlying forearm fracture has healed. Clinical signs are often non-specific and poorly defined and must drive the clinician toward obtaining complementary examination, more specifically an MRI, since assessing radiographs of immature carpal bones is difficult. The shape of the different bones and the interosseous spaces vary according to the patient's age, thus making the diagnosis of ligamentous injuries delicate. Moreover, the mechanism of injury and its context should be considered when searching for carpal bone injuries. The literature on this subject is scarce with only a few cases of isolated intracarpal ligamentous lesions of the wrist having been found. Some authors showed that ligamentous lesions may be more frequently associated with a bony injury. Elvey et al. found that 70% of these injuries were associated with fractures on an MRI-based study (6). As a result, even simple fractures may be associated with complex carpal injuries that should be rules out. The prognosis is variable, ranging from simple residual stiffness to avascular necrosis of a carpal bone or a disorganized architecture of the carpal unit. The diagnosis of these injuries is rendered even more imperative when accounting for the fact that most cases require surgical management, as is the case with ligamentous injuries in adults.

In conclusion, intracarpal ligamentous injuries in children do exist, although they are uncommon. As a screening method, systematically undergoing an MRI in children presenting with wrist pain

after sustaining trauma to the upper limb that was resistant to a proper initial medical and conservative management may be prudent.

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