Distal Radioulnar Joint Instability and Associated Injuries: A Literature Review

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Abstract
The distal radioulnar joint (DRUJ) allows supination and pronation of the distal forearm and wrist, an integral motion in everyday human activity. DRUJ injury and chronic instability can be a significant source of morbidity in patients’ lives. Although often linked with distal radius fractures, DRUJ injury may occur in a variety of other upper extremity injuries, as well as an isolated pathology. Diagnosis of this injury requires the clinician to have a high index of suspicion and low threshold for clinical testing and further imaging of the DRUJ. The purpose of this article is to provide a review on DRUJ anatomy and biomechanics, to discuss common diagnostic and treatment modalities, and to identify common injuries associated with DRUJ instability.

Introduction
Distal radioulnar joint (DRUJ) instability is a potential sequela of fracture/dislocations of the upper extremity and can also present in isolation. As DRUJ instability is often secondary to other injuries, it can go unnoticed on initial presentation. The role of DRUJ instability in determining long-term functional outcomes in upper extremity injuries is still debated.1-3 However, chronic instability can be a source of morbidity in patients, leading to pain, dysfunction, and arthritis.4 Thus, DRUJ injury warrants a thorough clinical examination and when necessary, directed treatment modalities. The objective of this article is to review the literature on DRUJ instability and explore injuries of the upper extremity that are associated with DRUJ injury. We review relevant anatomy and biomechanics, common signs and symptoms in the evaluation, and diagnostic protocols including a discussion of relevant upper extremity fractures that should raise the clinicians’ index of suspicion of DRUJ injury. Lastly, we will discuss the various treatment options available to maximize patient outcomes.

DRUJ Anatomy and Biomechanics
The DRUJ is an incongruent diarthrodial, synovial articulation between the distal radius and ulna (►Fig. 1). It provides a pivot for pronation-supination of the distal forearm. The normal total arc of motion at the DRUJ is 150 to 180 degrees, with an additional 30 degrees through the radio-carpal joint. DRUJ motion is primarily rotational with components of axial and translational motion.5 In a normal wrist, the majority of the force at the wrist is transmitted through the radius (80%), with only 20% of the load transmitted through the ulna.6 However, these forces can vary with ulnar and radial deviation. At the extremes of pronation and supination, there may be only 2 mm of articular contact at the rims of the notch that correspond at less than 10% of the articular surface area of the joint.7 The shape of the sigmoid notch has important implications with respect to traumatic instability (►Fig. 2). Based on an anatomic study of 50 cadavers, Tolat et al observed four different sigmoid notch shapes: flat face (42%), ski slope (14%), “C” type (30%), and “S” type (14%).8 A flat sigmoid notch may be more prone to instability and less responsive to treatment by soft tissue repair alone.9

Bony architecture only accounts for approximately 20% of the DRUJ’s stability.9 The remainder of the stability is afforded by the surrounding soft tissue. These soft tissue restraints include the triangular fibrocartilage complex (TFCC), joint capsule, interosseous membrane (IOM), and musculotendinous units consisting of the extensor carpi ulnaris (ECU) and pronator quadratus.10,11 The TFCC is formed by the triangular...
fibrocartilage proper, ulnocarpal meniscal homologue, the ulnar collateral ligament, the superficial and deep dorsal and volar radioulnar ligaments, and the sheath of the ECU. The primary functions of the TFCC are to extend the articular surface of the distal radius to the ulnar head, transmit axial force across the ulnocarpal joint, provide a strong but flexible connection between the distal radius and ulna, and support the ulnar portion of the carpus.4

The radioulnar ligaments extend from the palmar and dorsal distal margins of the sigmoid notch and converge in a triangular configuration to attach to the ulna as the principal stabilizers of the DRUJ (►Fig. 3).9 It is generally agreed that the TFCC acts in concert with the rims of the sigmoid notch to constrain the joint.13 In the coronal plane they divide into two limbs: the deep (or proximal) limb attaches to the fovea and the superficial (or distal) limb attaches to the base and mid-portion of the ulnar styloid.4 When the radius rotates around the ulna in pronation, the dorsal superficial fibers tighten, as do the deep palmar fibers. Conversely, in supination the palmar superficial fibers as well as the deep dorsal fibers tighten to constrain DRUJ motion.9,11,13-15 The pronator quadratus is an important secondary stabilizer. The deep head of the pronator quadratus helps to stabilize the DRUJ by coapting the joint during active pronation and passive supination.16-18 Other secondary stabilizers include the IOM, ECU subsheath, and the ulnocarpal ligaments. The IOM contributes to the mechanical integrity of the forearm and serves as a conduit for force transfer from the radius to the ulna, origin for several flexor and extensor muscles, maintenance of longitudinal forearm stability, and support for the DRUJ.11,19,20
A complete radioulnar dissociation at the DRUJ cannot occur unless the IOM is incompetent. Furthermore, an isolated lesion of the TFCC will not lead to incomplete instability, as an intact or repaired DRUJ capsule leads to significant restoration of DRUJ kinematics.

Diagnosis

Physical Exam

Acute Dislocation

Diagnosing a DRUJ injury requires a high index of suspicion with recent wrist injuries and new findings such as limitation of pronation or supination. Acutely, a dorsal dislocation of the ulna presents with a dorsoulnar prominence and a block to supination, whereas a volar dislocation presents with a volar–ulnar prominence and block to pronation.

To assess the stability of the DRUJ, the patient’s elbow should be stabilized on a table or arm rest and the hand should be pointed toward the ceiling. With the patient’s forearm in neutral, the radius is stabilized and the distal ulna is shifted volar and dorsal to assess the amount of translation. Then in pronation and in supination the distal radius and distal ulna are stabilized, and the ulna is pushed toward the patient to check the firmness of the end point and whether that elicits pain. It is important to compare these findings to the contralateral side. An audible or palpable clink may occur with both active and passive pronation and supination. Obvious subluxation of the ulnar head indicates DRUJ instability.

Chronic Dislocation

A chronic dislocation may present similarly with either dorsal or volar prominences and block to supination or pronation. There are a variety of clinical exams the clinician can use to further illicit DRUJ injury and/or instability. Seo et al proposed a useful classification to grade chronic DRUJ instability patients using the anteroposterior stress test.

The ulnar fovea sign is an exam that can indicate a TFCC injury. It is performed with the patient’s elbow at 90 degrees flexion, with the wrist and forearm in neutral. One of the examiner’s hands supports the patient’s wrist radially, and the opposite hand’s thumb tip is pressed into the ulnar fovea. The fovea is the “soft spot” just distal to the ulnar head on the ulnar side of the wrist. A positive ulnar fovea sign indicates TFCC injury.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>Normal stability</td>
</tr>
<tr>
<td>1</td>
<td>Increased laxity, no clinical symptoms</td>
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<tr>
<td>2</td>
<td>Increased translation, symptoms evoked without a firm end point</td>
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<tr>
<td>3</td>
<td>Subluxation during active forearm rotation</td>
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The ulnocarpal stress test involves grinding the TFCC between the lunate/triquetrum and the distal ulna. With the patient’s arm at their side and the elbow flexed to 90 degrees, the examiner places one hand behind the distal humerus and the other hand in the patient’s palm as if to shake their hand. With the patient’s wrist in ulnar deviation, an axial stress is applied while the wrist is passively ranged through pronation and supination (Fig. 7). The presence of ulnar sided wrist pain signifies a positive exam.

The press test is a simple yet provocative test with a 100% sensitivity of TFCC tear detection in a study reported by Lester et al. The patient is asked to rise from a seated position by pushing their body weight off the chair with both hands, creating an axial ulnar load. Focal ulnar wrist pain represents a positive test. Furthermore, the piano key sign involves controlled dorsal–palmar radioulnar shucking. With the patient’s forearm in neutral, the palm on the exam table and pronated, and the wrist in 20 to 30 degrees of extension, the examiner uses one hand to stabilize the radius and the other to grip the ulna and apply a dorsal to volar load (Fig. 8). The test is positive if the patient experiences pain or there is ulnar laxity as compared with the opposite extremity.

Hahn et al developed a new clinical test called the bilateral test, which directly observes the ulnar head’s dynamic behavior and tests static DRUJ stability. The patient sits with the elbows flexed to 90 degrees and the shoulders adducted. The
The examiner bilaterally places the index finger on the DRUJ and the middle finger on the ulnar head, ranging the wrists from pronation to supination several times to provoke potential subluxation (Fig. 9). Using the bilateral test on their cohort of 20 patients, the authors had a sensitivity of 90% in confirming positive clinical exam with computed tomography (CT) imaging. 

Imaging

Initial radiographic evaluation should start with a true posteroanterior (PA) and lateral of the affected forearm, wrist, and elbow. The imaging of the wrist should be done with the arm abducted at 90 degrees with the wrist in neutral rotation to measure ulnar variance. A dorsal dislocation will show a widened DRUJ (as compared with the unaffected side) with divergence of the radius and ulna while a volar dislocation will show overlap of the radius and ulna at the level of the DRUJ due to the pull of the pronator quadratus. The authors suggest contralateral radiographs comparison if there is concern for DRUJ injury.

On lateral X-rays, a prominence of the ulnar head may indicate DRUJ instability. Poor lateral X-rays can be misleading. Mino et al determined that with just 10 degrees of supination or pronation of the lateral X-ray, a subluxed DRUJ appeared reduced and a dislocated DRUJ appeared subluxed. A reproducible way to determine a true lateral is to evaluate the scaphoid–pisiform–capitate relationship. The palmar surface of the pisiform is visualized midway between the palmar surfaces of the distal pole of the scaphoid and the capitate. Due to the challenge of obtaining a true lateral, the standard lateral X-ray remains imprecise for the diagnosis of DRUJ subluxation.

Evidence of DRUJ instability, however, can be exaggerated by utilizing a weighted lateral stress view. The patient sits with the elbow flexed at 90 degrees and forearm/wrist over the table, in full pronation. The patient is instructed to hold a 3 to 5-lb weight, keeping the arm off the table as a cross table lateral view is taken. Several other radiographic signs indicating a possible DRUJ disruption include a fracture at the base of ulnar styloid, ulnar styloid fractures displaced > 2 mm, > 20 degrees dorsal angulation of distal radius fracture (DRF), and avulsion fractures of the sigmoid notch.

CT scan is a useful tool in evaluating the congruity of the DRUJ and can be completed if there is clinical suspicion for a DRUJ injury. Several methods of evaluating DRUJ instability on CT scan have been described. Mino et al described a method in which CT scan of the DRUJ is done with the forearm in neutral rotation. Normal congruence is demonstrated when the ulnar head sits in the sigmoid notch of the radius (Fig. 10A). Lo et al found the radioulnar ratio superior to the Mino et al method, the epicenter method, and the congruency method in determining DRUJ instability (Fig. 10B). Park and Kim that the subluxation ratio method was the most reliable in regard to intra- and interobserver reliability (Fig. 10C).

Magnetic resonance imaging (MRI) is useful in evaluating the soft tissue restraints of the DRUJ, but its...
sensitivity and specificity vary. The radiology literature recommends a high-resolution 3-T MRI with intraarticular contrast.\textsuperscript{35} Recently, studies have suggested that performing wrist traction significantly improves the accuracy of MRI. In a prospective study of 40 wrists, the accuracy of tear detection improved after traction for the TFCC (98\% after traction vs. 83\% before traction), the lunotriquetral ligament (100 vs. 88\%), and the scapholunate ligament (100 vs. 95\%).\textsuperscript{36} Despite the usefulness of the aforementioned imaging studies, arthroscopy remains the gold standard for evaluating TFCC pathology. It has been shown to be more sensitive and accurate than imaging modalities.\textsuperscript{15}

**Pathology**

**Isolated Acute Dislocation of DRUJ**

Although rare, there are cases of isolated acute dislocations of the DRUJ without osseous involvement.\textsuperscript{37-40} These injuries usually occur dorsally, and are associated with hyper-pronation and extension injuries. The patient presents with the hand fixed in pronation, with the inability to supinate and a dorsal prominence of the ulnar head.\textsuperscript{40-42} A volar dislocation is often associated with hyper-supination with the inability to pronate.\textsuperscript{5} A volar prominence of the ulnar head may be palpable, with an associated dorsal cavity. Isolated DRUJ dislocations often result from an acute disruption of the TFCC with possible disruption of the secondary stabilizers of the DRUJ. The amount of TFCC injury required for a dislocation has not been described, although it is known that DRUJ dislocations may not require complete disruption of the TFCC.\textsuperscript{37,40}

Once diagnosed, an acute DRUJ dislocation can be closed reduced with local anesthesia with or without sedation. Digital pressure is placed on the distal part of the ulna and forceful supination/pronation is performed on the prominent ulna.\textsuperscript{37,43} Simple dislocations can be easily reduced, or may undergo spontaneous reduction after the injury. A complex dislocation may be due to entrapment of the ECU, extensor digitorum communis to the second digit, TFCC, and/or extensor digiti minimi (EDM).

After reduction, the joint should be ranged to assess the stable arc of motion. Generally speaking, a dorsal dislocation is most stable in supination while a volar dislocation is more stable in pronation. If the DRUJ is unstable after reduction, the radioulnar joint may be pinned in the position of greatest stability. Dual Kirschner wires are driven through just proximal to the joint and left slightly prominent on the ulnar and radial border that allows for easy retrieval if the wires break between the radius and ulna.\textsuperscript{4} Another option is to perform an open or arthroscopic TFCC repair. After the DRUJ is stabilized, immobilization is recommended. Many advocate cast immobilization of the forearm in the position of maximal stability for 4 weeks.\textsuperscript{4} These injuries should be followed closely with interval X-rays to ensure stable reduction. After 4 to 6 weeks, a removable splint is provided and a gradual, progressive, active range of motion program is begun.

**Distal Radius Fractures and DRUJ Instability**

DRF may be associated with DRUJ instability. Geissler et al examined 60 consecutive young patients who had failed closed reduction in the distal radius and had greater than 2 mm of articular step off. Of these 60 patients, 26 (43\%) of them were found to have an injury to the TFCC by arthroscopy.\textsuperscript{44} Lindau et al studied 51 young patients prospectively with displaced DRF with arthroscopy and found that 43 patients (84\%) had an injury of the TFCC.\textsuperscript{45} At median follow-up of 12 months, 19 patients (37\%) had DRUJ instability.\textsuperscript{45} In addition, May et al retrospectively investigated 130 DRFs and found that 14 (11\%) were complicated by either acute or chronic DRUJ instability.\textsuperscript{46} Although the incidence varies across studies, TFCC injuries and DRUJ instability are potentially associated with DRFs. Multiple studies have found that DRUJ instability is an independent worsening risk factor in DRF that is associated with poorer outcomes.\textsuperscript{2,47-50} Despite this, there is debate on the merit of DRUJ directed treatment and there is no widely accepted algorithm on how to treat potential instability with concomitant DRF.\textsuperscript{5}

Concurrent DRUJ disruption with DRF is best assessed intraoperatively after fixation has been performed. Initial wide displacement of the DRUJ and severe radial shortening
are the most important risk factors for persistent DRUJ instability.4 Chronic DRUJ instability after accurate reduction and fixation of the radius is uncommon. This may be due to the fact that the secondary stabilizers of the DRUJ confer enough stability that allow the TFCC to heal with proper immobilization or after sufficient stability has been conferred by locking plate fixation of the distal radius.5,31

It has been found that proper fracture reduction and alignment are the most important factors associated with stable healing of the disrupted DRUJ.4 If DRUJ instability persists despite adequate reduction and internal fixation of the DRF, treatment options include ulnar styloid repair, prolonged immobilization, arthroscopic or open repair of the TFCC, or any of these options with radioulnar pinning, or radioulnar pinning alone.5,51 Persistent instability may be due to mal-reduction and may necessitate fixation of the sigmoid notch or ulnar corner fractures. Volar locked plating can capture many larger dorsal ulnar fragments. Smaller volar or dorsal fragments may require fragment specific fixation, independently stabilizing each fracture fragment.

In one series, the results of closed reduction and long arm casting alone were equivalent to performing a TFCC repair or ulnar styloid fixation concurrently, providing a less invasive alternative.5 Kim et al performed a prospective analysis of 84 patients with DRF with 12 months follow-up.1 DRUJ laxity was assessed intraoperatively after fixation and those found to be lax were treated with an additional 4 weeks of immobilization in a postoperative sugar tong splint. No significant difference was observed between the two study groups in terms of overall wrist functional outcomes or subjective wrist pain.1 It is debated whether DRUJ instability in DRF merits invasive treatment, but authors have had successful outcomes with conservative immobilization in these patients postreduction and fixation.1,4

Ulnar styloid fractures can occur in isolation, or in conjunction with a DRF. Frykman found ulnar styloid fractures occurred in approximately 61% of DRF.52 Most of these fractures are not associated with DRUJ instability or long-term symptoms. However, fractures that occur specifically through the styloid base are associated with a higher risk of DRUJ instability.53,54 Like a DRF, it is important to evaluate an ulnar styloid fracture with a true PA and lateral. If on the lateral the ulnar styloid lies palmar to the axis of the ulnar shaft, suspect that the stability of the DRUJ is compromised.5 The treatment of ulnar styloid fractures hinges on the stability of the DRUJ. If the ulnar styloid fracture is associated with a DRF, the DRF should first be fixed and then the DRUJ can be tested for stability. If stable, the ulnar styloid fracture can be treated nonoperatively. If unstable, the ulnar styloid should be fixed. Treatment options include Kirschner wires, tension band wiring, compression screw fixation, mini-fragment plates, and suture anchors. If the DRUJ continues to be unstable, repair of the foveal attachment of the TFCC, which may be seen as a separate bony avulsion fragment adjacent to the styloid fracture and represents the foveal insertion of the radioulnar ligaments, should be performed arthroscopically or through an open approach.50,55

Galeazzi Fracture
Galeazzi published a series of 18 patients with diaphyseal radius fractures associated with dislocation of the DRUJ.64 The mechanism of injury of Galeazzi fractures is commonly a high-energy trauma such as a motor vehicle accident or a fall from height with the wrist in hyperextension and pronation. A class 1B TFCC injury is almost universally present. Not all diaphyseal radius fractures result in an injury to the DRUJ. The distance that the fracture is located from the articular surface can help predict the likelihood of an injury to the DRUJ. If the fracture is located within 7.5 cm from the mid-articular surface of the radius, it has been found to have a higher incidence of DRUJ injury.65 X-ray can be helpful in diagnosing DRUJ instability with diaphyseal radius fractures. This likely has to do with the high energy mechanism and the propensity of the DRUJ to completely displace, which makes it readily obvious on radiographic imaging.

The most common block to reduction in complex Galeazzi fractures is often the ECU tendon; however, other blocks have been described including the EDM tendon, extensor digitorum communis tendon to the second digit, as well as osseous blocks.57,58,62 A Galeazzi fracture is considered a “fracture of necessity” as nonsurgical treatment yields a poor result. Casting alone is associated with strong deformng forces acting on the distal fragment by the pronator quadratus, brachioradialis, thumb extensors, and abductors.57,63 At a minimum, the radius fracture should undergo an open reduction and internal fixation. After the radius has been fixed, the DRUJ should be stressed. If found stable, the patient can be immobilized and start early motion. If unstable, surgical stabilization should be achieved using the same protocol in the setting of the DRF with DRUJ instability (see previous section).

Essex-Lopresti Injury
In 1951, Essex-Lopresti described two cases of a dislocation injury of the DRUJ in combination with a comminuted radial head fracture.64 This injury pattern became known as an Essex-Lopresti injury. It is caused by an axial compression force through the forearm involving disruption of the primary and secondary constraints of the radius. As a result, the radius migrates proximally, and the ulna impacts the carpus. These injuries can be accompanied by other injuries including a DRF as well as a radial shaft fracture.55,56 Examination should include a thorough investigation of the elbow and the DRUJ. Inspection typically demonstrates a dorsally prominent ulna, tenderness along the IOM, limited wrist extension, and pronation and supination.

Radiographic evaluation should start with orthogonal X-rays of the elbow, forearm, and wrist. Special attention should be paid to the ulnar variance that can be calculated from a PA X-ray of the wrist.57 The radius pull test, where a 9.1 kg distraction force is pulled through the radius, can be helpful in determining longitudinal stability of the forearm.65 Smith et al found that proximal migration of at least 3 mm of the radius was achieved when the radial head and IOM were disrupted. Greater than 6 mm of proximal migration was visualized when the radial head, IOM, and TFCC were disrupted.48
DRUJ Instability and Associated Injuries  Qazi et al.

Treatment of an Essex-Lopresti injury starts with determining between ORIF versus replacement of the radial head. Internal fixation reestablishes the integrity of the radial head, whereas replacement acts as an internal splint while the IOM and TFCC heal. Timing of treatment plays an important role. Trousdale et al found that early treatment within a week with reconstruction of the radiohumeral joint and immobilization of the distal radioulnar dissociation are necessary to obtain satisfactory results. Nine out of 10 patients diagnosed and treated early had satisfactory results, while only 4 out of 14 patients treated more than a week after injury had satisfactory results. Once stabilization of the radial head has been completed, the DRUJ should be assessed for stability. If the DRUJ remains unstable, then one can similarly consider arthroscopic versus open repair of the TFCC. The forearm should be immobilized in a long arm splint or cast to prevent rotation for 4 to 6 weeks.

Conclusion

DRUJ injury can often be undetected on initial presentation of an upper extremity injury. Clinically, there are a variety of exam maneuvers that can help identify DRUJ instability. In addition to isolated acute injuries of the DRUJ, distal radial fractures, ulnar styloid base fractures, sigmoid notch and ulnar corner fractures, Galeazzi fractures, and Essex-Lopresti injuries were found to have a potential association with DRUJ injuries. It is important to have high clinical concern of DRUJ injury in these cases. Lateral X-ray imaging of the DRUJ is imprecise in determining injury, although sensitivity can be improved with a weighted lateral stress view. There are several methods of determining DRUJ congruity via CT imaging (Fig. 10). Arthroscopy remains the gold standard in visualizing tears of the TFCC. Although there is still debate on treatment options, the majority of studies reported no chronic instability or loss in functional outcomes with adequate upper extremity fracture reduction/alignment and conservative treatment (cast immobilization in a position of maximal stability for 4–6 weeks) for the DRUJ. In cases of persistent DRUJ instability, treatment options consist of, arthroscopic or open TFCC repair, fixation of ulnar styloid fractures when present and DRUJ pinning.

Conflict of Interest

None declared.

References

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