MRI of the Annular Ligament of the Elbow: Review of Anatomic Considerations and Pathologic Findings in Patients With Posterolateral Elbow Instability

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OBJECTIVE. The annular ligament is one of the major stabilizers of the proximal radioulnar joint. However, it is one of the least studied structures in the lateral elbow because of imaging challenges and low pathologic incidence. This article will examine the anatomy of the annular ligament, its biomechanics, and its functional importance. Eight surgically proven cases of annular ligament abnormality in patients with posterolateral and nursemaid elbow, along with the associated findings, are presented.

CONCLUSION. Adequate understanding of the anatomy and familiarity with the associated injuries that can be seen in annular ligament displacement or rupture will improve detection of annular ligament abnormality.

The annular ligament, a component of the lateral collateral ligament complex, is an important stabilizer of the proximal radioulnar joint. However, its clinical and functional significance has remained controversial, and it is the least-studied ligamentous structure in the lateral elbow in the radiologic and the orthopedic literature. Several of the earlier anatomic cadaveric studies of the annular ligament emphasized the variable anatomy of the lateral collateral ligament complex [1, 2]. This has presented a challenge to radiologists in identifying a normal annular ligament on MRI. Furthermore, abnormality of the annular ligament is relatively rare compared with its adjacent structures, thereby limiting its investigation.

Despite these challenges, the annular ligament has become an increasingly important structure to evaluate on MRI for patients presenting with chronic lateral elbow pain, posttraumatic dislocation, and posterolateral instability. It has also become a target in surgical reconstruction, especially in children with posttraumatic radial head dislocation due to the negative long-term sequelae of functional impairment and chronic subluxation of the distal radioulnar joint [3, 4].

This article reviews the anatomy of the lateral collateral ligament complex, its function, and various components with an emphasis on the annular ligament using MR arthrography images and dissection images in cadaveric elbows. Better understanding of annular ligament anatomy and its relationship with adjacent structures is necessary to improve detection abnormalities. We also present eight surgically proven cases of typical and atypical patterns of injury of the annular ligament in the setting of posterolateral elbow instability. Additionally, ancillary findings involving the lateral collateral ligament complex, common extensor supinator units, radiocapitellar joint, and associated osseous abnormality are discussed.

Anatomic and Functional Significance of the Annular Ligament

The lateral collateral ligament complex is composed of the lateral ulnar collateral ligament (LUCL), radial collateral ligament, and annular ligament. Variations in the anatomy of the lateral collateral ligament complex, including the accessory lateral ulnar collateral ligament, have been described [5].

The LUCL has traditionally been regarded as the major stabilizer of the lateral elbow [2]. Collectively, the lateral collateral ligament complex, albeit with some variability, is a Y-shaped structure that serves as restraint to varus stress, especially when the elbow is in flexion [6–8]. The LUCL arises from the lateral humeral epicondyle and extends along the lateral posterior aspect of the proximal radius to insert at the crista supinatoris of the proximal ulna. The radial collateral ligament arises from the lateral humer-

al epicondyle and inserts onto the annular ligament and fascia of the supinator muscle. Proximal to the annular ligament, the fibers of the lateral ulnar collateral ligament and the radial collateral ligament are often indistinguishable, blending with the overlying extensor tendons and muscular fascia [2, 9] (Figs. 1–3).

The annular ligament encircles the radial head and tapers distally as it extends over the proximal portion of the radial neck (Fig. 2). It originates from the anterior and posterior margins of the lesser sigmoid notch of the ulna and acts to stabilize the radial head to the ulna throughout the range of pronation and supination of the forearm (Fig. 2). The annular ligament is not a uniform ligamentous band and can be variable in its morphology. In a study by Cohen and Hastings [10] in 1997, it was shown that there is a broad conjoined insertion of the LUCL and annular ligament onto the proximal aspect of the ulna. This insertion was bilobed in 55% of the cadaveric specimens and broad in 45%. This finding was further characterized in a more recent study by Sanal et al. [11], who described the anterior attachment of the annular ligament as a single band, but the posterior band has been shown to be fenestrated, giving rise to a superior and an inferior band in some patients (Figs. 1C and 2E). Additional anatomic details that were discovered on histologic studies showed a variable synovial fold (Fig. 2E) at the superior edge of the annular ligament extending into the radiocapitellar joint [1]. The ligament also represented a thickening of the joint capsule around the radial head, with a thin synovial lining that was continuous with the elbow joint capsule superiorly and inferiorly [11].

The annular ligament exhibits low signal intensity on all MRI pulse sequences. Its anatomy is best seen on the axial and sagittal planes, whereas the coronal or coronal oblique planes are best for evaluation of the LUCL and radial collateral ligament. The axial plane enables identification of the annular ligament throughout its entire course around the radial head and its anterior and posterior attachments on the ulna. However, the lateral aspect of the annular ligament is often indiscernible from the remainder of the lateral ligamentous structures on MRI, which has been confirmed on cadaveric dissection studies [12, 13] (Figs 2 and 3). The sagittal plane shows a funnel-shaped ligament, with a wider and thicker proximal portion encircling the radial head and a narrow distal edge as

it wraps around the neck of the radius. Although the superior annular ligament forms a tight ring around the radial head, the inferior portion attaches loosely to the neck via a synovial membrane, thereby allowing normal rotation during pronation and supination of the proximal radioulnar joint [14, 15]. In children, it is suggested that damage to this distal synovial membrane is often the first process in nursemaid elbow [1, 16].

In addition to acting as a static stabilizer against varus stress across the elbow, the three components of the lateral collateral ligament contribute additional stability to the elbow. The LUCL acts as a lateral buttress to the radial head and prevents radial head subluxation. The radial collateral ligament stabilizes the annular ligament. The annular ligament itself serves as the primary stabilizer of the proximal radioulnar joint and enables normal rotation of the forearm [17, 18]. Transection of the annular ligament has been shown to increase the mediolateral and anteroposterior movement of the radial head by an average of 44% and 24%, respectively, suggesting its importance as a radial head stabilizer [19].

Although the lateral collateral ligament complex and osseous structures are the static stabilizers of the lateral elbow, the common extensor tendons work in concert with adjacent structures as dynamic stabilizers of the lateral elbow. The common extensor tendon originates from the lateral humeral epicondyle and lies just proximal and superficial to the insertion of the lateral collateral ligament complex. On imaging, cadaveric and histologic specimens, the fibers from the common extensor tendon and the lateral collateral complex are often indistinguishable. The common extensor tendon is composed of the extensor carpi digitorum brevis, extensor digiti minimi, extensor digitorum communis, and extensor carpi ulnaris. These are most commonly affected in lateral epicondylitis, or tennis elbow.

The key osseous articular structures contributing to stability at the elbow are the coronoid process of the ulna and the radiocapitellar joint. The coronoid process is recognized as an important structure in maintaining elbow stability, serving as a constraint to posterior ulnohumeral displacement [20]. Fractures of the coronoid process are most commonly the result of elbow dislocation. Therefore, visualization of a coronoid process fracture can be regarded as evidence of a previous subluxation or dislocation [7].

Patterns of Annular Ligament Injury

Injury to the lateral collateral ligament complex and its supporting structures can result in posterolateral elbow instability. Elbow dislocation is the most common cause of lateral collateral ligament injury, followed by iatrogenic injury during surgery for lateral epicondylitis and radial head fracture or dislocation. Chronic lateral epicondylitis, serial steroid injections, and chronic malalignment of the elbow can also give rise to posterolateral elbow instability. The classic presentation for patients with posterolateral instability includes pain as well as sensation of locking, clicking, or snapping when the arm is moving from a flexed position to extension. Ultimately, the diagnosis of posterolateral instability is based on history and physical examination using provocative maneuvers [21].

Posterolateral elbow instability classically refers to an injury to the LUCL that results in transient external rotatory subluxation of the ulna on the humerus, with posterior and varus displacement. In several cadaveric investigations, it was shown that the lateral ulnar collateral ligament was the primary lateral elbow stabilizer and any disruption to this ligament would produce posterolateral rotatory subluxation of the forearm with respect to the humerus [1, 2, 22]. However, recent kinematic studies refer to both the LUCL and radial collateral ligament working in concert to resist valgus stress. If both are injured, it can secondarily lead to subluxation or dislocation of the radiocapitellar joint even with an intact annular ligament, usually in the setting of chronic or repeated injury [8, 23].

In adults, sole injury to the annular ligament is rare because it is often associated with a larger injury to the lateral collateral ligament complex. However, in the pediatric population, due to immature radial head formation, dislocation and rupture of the annular ligament can be seen in the settings of nursemaid elbow and Monteggia fracture.

In children, a common injury occurs when there is a sudden axial traction on the hand or wrist resulting in subluxation or dislocation of the radial head out of the annular ligament sling, referred to as nursemaid elbow. Radiography is often normal after this injury. The distal annular ligament fibers surrounding the radial neck are often weaker in children, therefore predisposing them to ligamentous displacement. These patients often achieve complete recovery without intervention; however, in the setting of chronic pain and abnormal range of motion, MRI of the

elbow is often indicated to assess for continued displacement (Figs. 4 and 5). Similarly, in pediatric Monteggia fractures, the annular ligament is often interposed in the radiohumeral joint despite normal radiography, thereby necessitating surgical intervention to prevent long-term sequelae [24, 25] (Fig. 6). In pediatric patients, surgery is often indicated if there is ligamentous displacement or subluxation. Various techniques have been described in the orthopedics literature, including open reposition of the radial head, ulna osteotomy, and annular ligament repair among the major components yielding positive long-term outcomes, suggestive of its importance in radioulnar joint development [3, 4].

In adults, lateral elbow ligamentous injuries are most commonly associated with trauma, followed by iatrogenic or postreduction maneuvers. The severity of injuries to the lateral ligaments is usually not apparent on radiography and may not be fully appreciated on physical examination. MRI therefore has a key role in patients who have experienced severe trauma or continue to exhibit chronic pain and limited range of motion after reduction.

In the setting of radial head fractures, there are often associated ligamentous or osteochondral injuries (or both) that may alter prognosis and treatment. In a recent study of 24 patients with acute radial head fractures, MRI studies revealed associated injury of the LUCL in 80% of the cases, whereas the medial collateral ligament was injured in 55%, with involvement of both the LUCL and medial collateral ligament in 50%. Capitellar bone marrow edema was seen in 95% whereas osteochondral defects were discovered in 29% [26] (Figs. 7 and 8). However, the frequency and extent of annular ligament injury have not been addressed in the literature.

Other findings in the setting of lateral elbow trauma include ligamentous injury involving the common extensor tendons; annular ligament; and, less commonly, radial collateral ligament (Figs. 9 and 10). Furthermore, associated injuries in radial head dislocation often include displacement of the annular ligament into the radiocapitellar joint and increased T2 and STIR signal intensity within the annular ligament, consistent with sprain (Fig. 6). The interposed or impinged annular ligament fibers in the radiocapitellar joint have been known to cause painful snapping of the elbow joint on flexion. This can be misdiagnosed as lateral epicondylitis given the similarity in patient symptoms [27]. Cli-

nicians and radiologists should consider displaced annular ligament as a possible cause of symptoms in these patients.

Lateral collateral ligament abnormality resulting in late recurrent instability is rare but disabling. The diagnosis requires a high index of suspicion and careful physical examination. Often, conventional radiography of patients with posterolateral elbow instability shows normal findings. Therefore, different techniques and modalities have been used to assess for ligamentous structures of the elbow, including stress radiography, ultrasound, and MRI.

There are differing recommendations regarding the optimal MRI pulse sequences for detecting abnormalities of the lateral collateral complex in patients with posterolateral instability. One of the earliest studies by Potter et al. [28] in 1997 showed the detection of lateral collateral complex abnormality with coronal 3D gradient-echo and axial and sagittal fast spin-echo sequences. In 2001, Carrino et al. [29] evaluated different pulse sequences and planes with and without intraarticular gadolinium administration and concluded that intermediate-weighted fast spin-echo and MR arthrographic sequences gave the highest yield in terms of detection of LUCL abnormality. Several more recent studies reported that MRI and MR arthrography have been invaluable in evaluation of ligamentous injury and associated soft-tissue abnormalities, especially in the pediatric elbow [16, 30].

In terms of imaging of the annular ligament, the utility of MRI has remained controversial in recent literature because studies have shown that MRI underestimated the degree of annular ligament interposition within the radiocapitellar joint in symptomatic patients. However, the failure to diagnose might have been due to the lack of effusion, thereby limiting the evaluation of the annular ligament [31]. Regardless of the different recommendations, use of MRI has increased in patients with complicated posterolateral elbow injury or with worsening symptoms after clinical treatment because it plays a vital adjunctive role in surgical planning.

Summary

The annular ligament is a vital component of the lateral collateral ligament complex and can be injured in the setting of trauma and after closed reduction for elbow dislocation. A tear of one or more components of the lateral collateral ligament complex is often associated with intraarticular displacement of the an-

nular ligament. In the setting of elbow dislocation, the lateral collateral ligament complex is often injured, giving rise to posterolateral elbow instability. The functional importance of the annular ligament has been increasingly elucidated in various mechanical and functional studies and has been shown to be a major static and dynamic stabilizer of the proximal radioulnar joint. The annular ligament is best visualized on axial and sagittal MRI using standard sequences and field strength. Additionally, posttraumatic joint effusion helps to highlight pathologic changes of the annular ligament. Adequate understanding of the anatomy and familiarity with the associated injuries that can be seen in annular ligament displacement or rupture will therefore improve detection of annular ligament abnormality.

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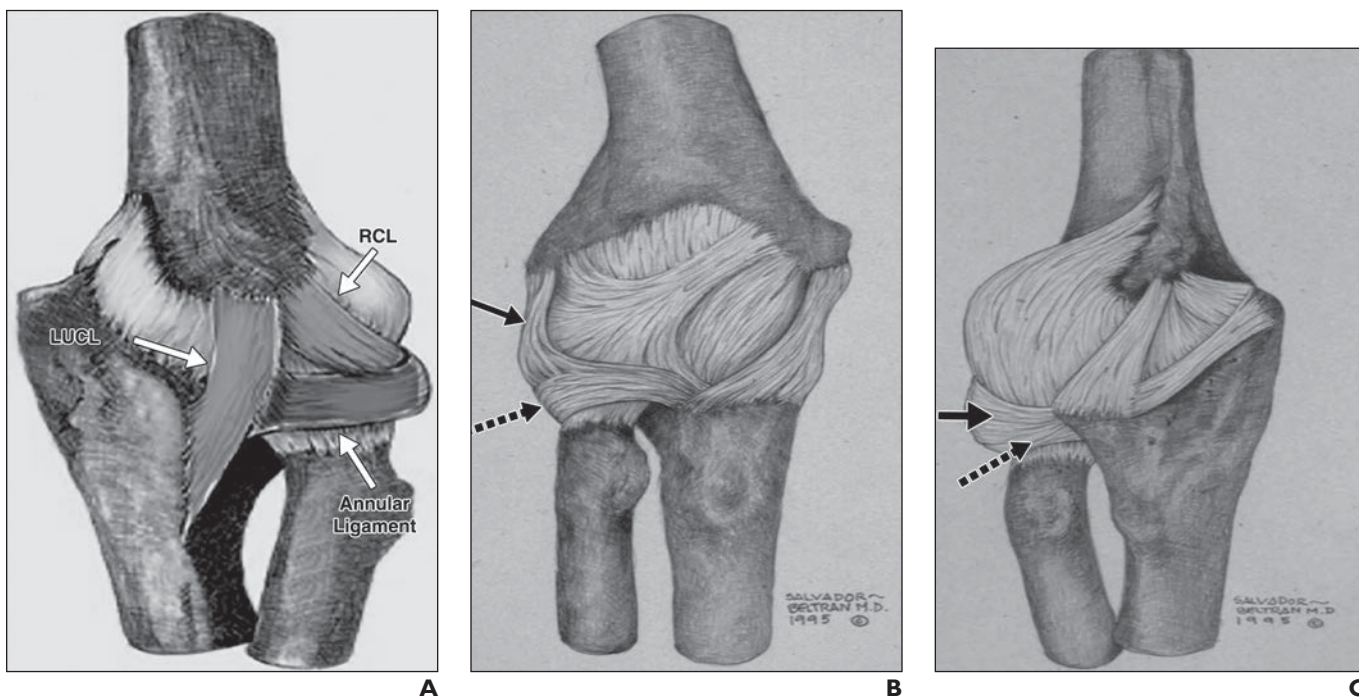
Fig. 1—Elbow ligaments. (Reprinted with permission from [32])
A, Drawing shows lateral collateral ligament complex from lateral perspective. LUCL = lateral ulnar collateral ligament, RCL = radial collateral ligament.
B, Drawing shows frontal perspective of RCL (*solid arrow*). Note relationship with annular ligament (*dotted arrow*).
C, Drawing of medial elbow shows superior (*solid arrow*) and inferior oblique (*dotted arrow*) bands of annular ligament.
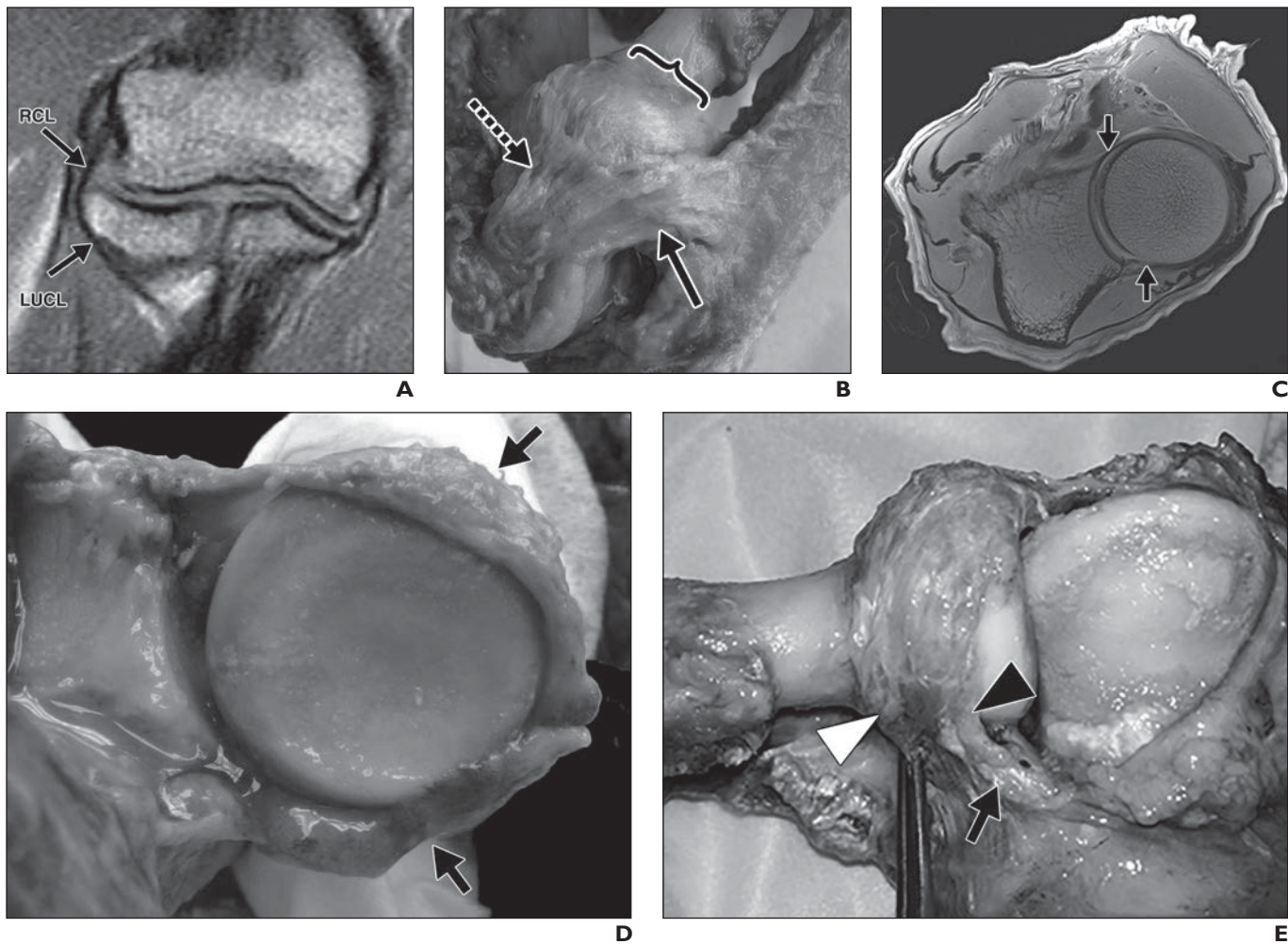
Fig. 2—MRI correlation with cadaveric dissection.
A, T1-weighted fat-saturated coronal image shows relationship between radial collateral ligament (RCL) and lateral ulnar collateral ligament (LUCL). Note that fibers of two ligaments are indistinguishable at proximal attachment onto lateral epicondyle. LUCL is seen to course medial and posterior to radial head and neck. (Reprinted with permission from [32])
B, Photograph of cadaveric dissection shows proximal fibers of RCL (*dotted arrow*) and LUCL (*solid arrow*) from lateral epicondyle. RCL fibers insert onto annular ligament distally (*bracket*). Annular ligament is smooth synovial thickening around radial head.
C, Axial proton density MR arthrogram in cadaveric specimen shows thin band of low signal intensity surrounding radial head, which is annular ligament (*arrows*).
D, Photograph of cadaveric dissection shows band of annular ligament circumferentially surrounding radial head (*arrows*). Note anterior and posterior medial attachments to ulna.
E, Photograph shows differentiation of superior (*black arrowhead*) and inferior (*white arrowhead*) bands of annular ligament. This was much better visualized in real time by applying traction on two bands using forceps. Part of medial synovial fold or capsule is also visualized (*arrow*) after disruption of joint capsule.
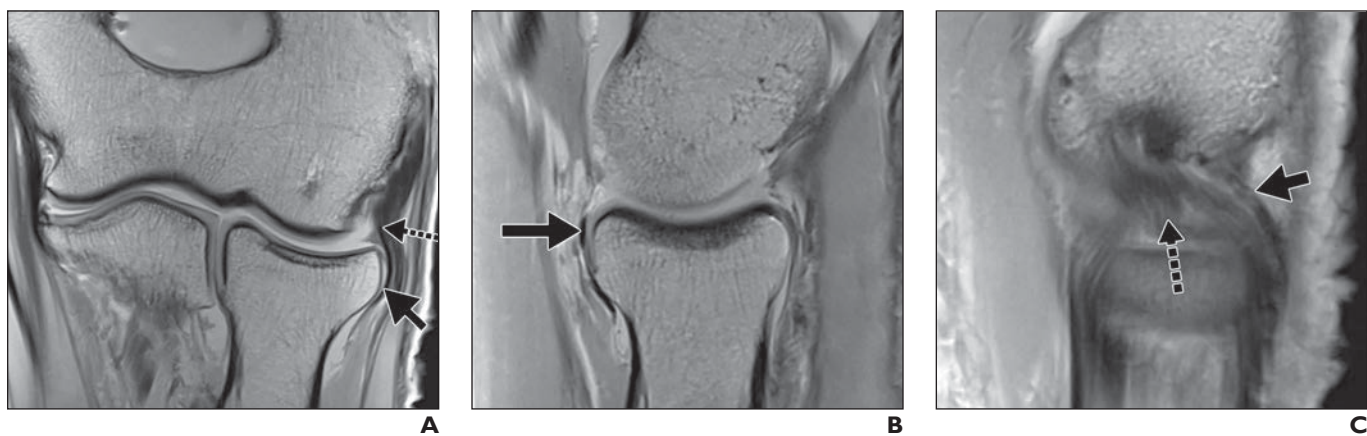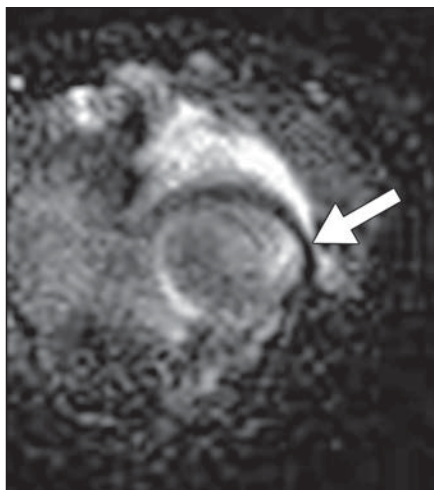

Fig. 3—Annular ligament.
A, Coronal proton density MR arthrogram in cadaveric specimen shows annular ligament (*solid arrow*) and its close relationship with radial collateral ligament (*dotted arrow*).
B and **C,** Sagittal proton density MR arthrogram images show anterior band of annular ligament (*arrow*, **B**) and its relationship (**C**) with radial collateral ligament (*dotted arrow*, **C**) and lateral ulnar collateral ligament (*solid arrow*, **C**).

Fig. 4—4-year-old boy with superior displacement of annular ligament in setting of nursemaid's elbow.
A, T2-weighted STIR sagittal image shows displaced annular ligament (*arrow*) superiorly above radial head and exhibiting wavy contour with associated elbow joint effusion.
B, T2-weighted STIR axial image shows intraarticular displacement of annular ligament (*arrow*).

A
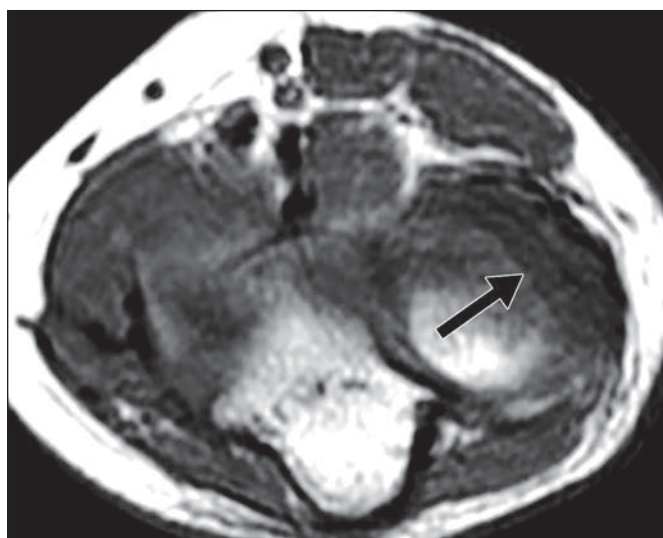
B

Fig. 5—2-year-old boy with congenital hypoplastic radial head with subluxation.
A, Coronal T2-weighted fat-saturated image shows hypoplastic radial head with incomplete articulation with capitellum, which is also hypoplastic due to lack of normal articulation during development. Annular ligament is wavy and displaced superiorly (*arrow*).
B, Axial T1-weighted image at level of radial head shows small radial head with irregular contour and laxity of annular ligament (*arrow*). Instead of surrounding radial head, it is displaced superiorly.
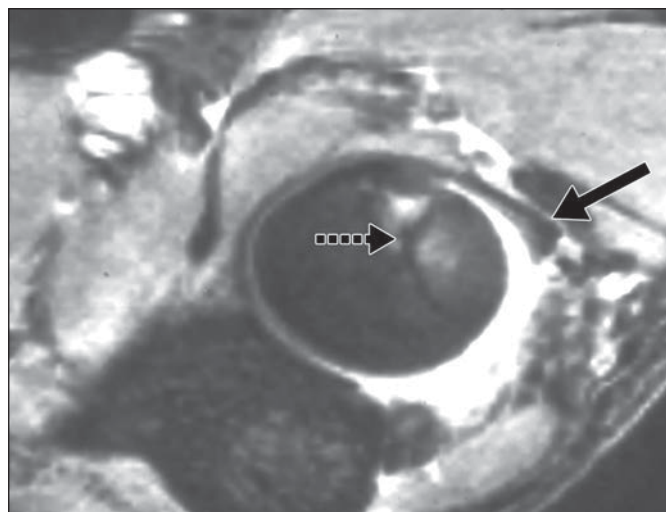
A

B

Fig. 6—Child with traumatic posterior elbow dislocation. Sagittal fluid-sensitive image shows posterior dislocation of radial head (R) in relation to capitellum (C) with displaced annular ligament (*arrow*) interposed between them. Note increased signal intensity within intact annular ligament suggestive of ligamentous sprain or strain.
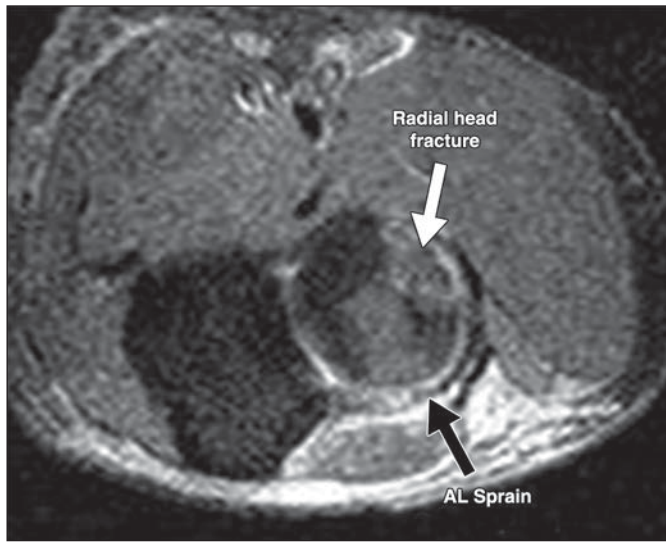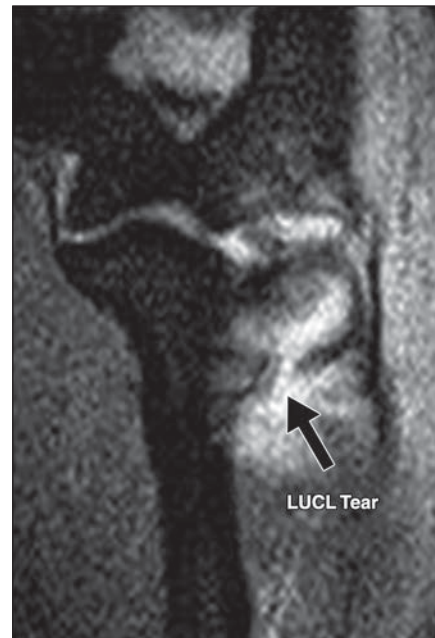
Fig. 7—Two patients with posttraumatic radial head fractures, with associated annular ligament and lateral ulnar collateral ligament (LUCL) injury.
A and **B,** Axial STIR image (**A**) shows increased signal intensity and thinning of annular ligament (AL) posteriorly, compatible with sprain or partial tear. Coronal fat-suppressed fluid sensitive image (**B**) shows complete rupture of LUCL more posteriorly. (Reprinted with permission from [32])
C, Axial STIR image at level of radial head shows nondisplaced fracture of radial head (*dotted arrow*), with complete posterior tear and retraction of annular ligament (*solid arrow*). Also note large associated joint effusion, which enabled better visualization of torn annular ligament.
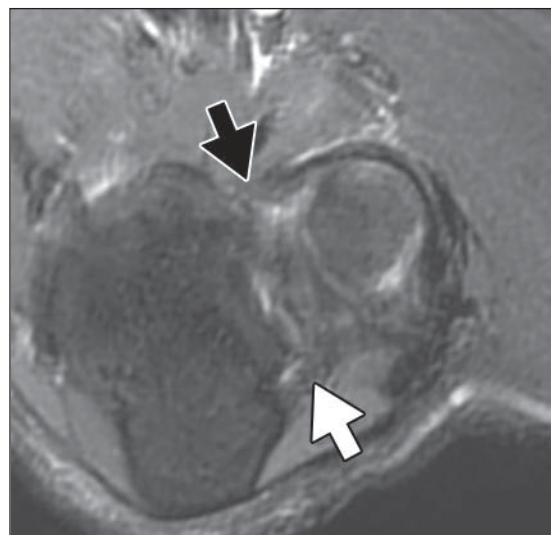
Fig. 8—Patient after closed reduction of traumatic posterior elbow dislocation.
A, Coronal STIR image shows superior displacement of annular ligament, which is interposed between radial head and capitellum (*arrow*), and complete tear of anterior attachment of annular ligament onto ulna (*arrowhead*).
B, Axial image better shows complete tear of anterior attachment of annular ligament, suggested by thinned and discontinuous fibers at crista supinatoris of ulna (*black arrow*). Posterior fiber appears thickened and irregular suggestive of likely partial tear (*white arrow*).
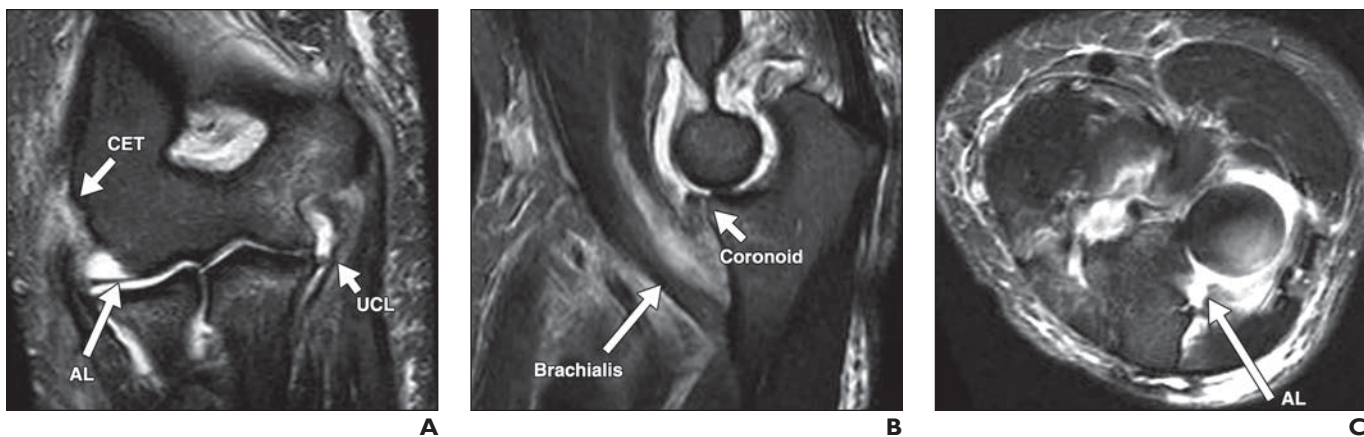
Fig. 9—Patient after closed reduction of traumatic posterior humeral dislocation with many associated findings, including complete displaced tear of annular ligament, common extensor tendon rupture, coronoid process fracture, and ulnar collateral ligament strain. (Reprinted with permission from [32])
A, Coronal STIR image shows superior displacement of annular ligament (AL), complete tear of proximal attachment of common extensor tendon (CET) at lateral epicondyle, with ulnar collateral ligament (UCL) strain exhibited by wavy contour and increased intraligamentous signal intensity proximally.
B, Sagittal image shows fracture of coronoid process with associated brachialis strain.
C, Axial fat-saturated fluid-sensitive image shows complete tear at posterior aspect of annular ligament (AL) with large effusion.
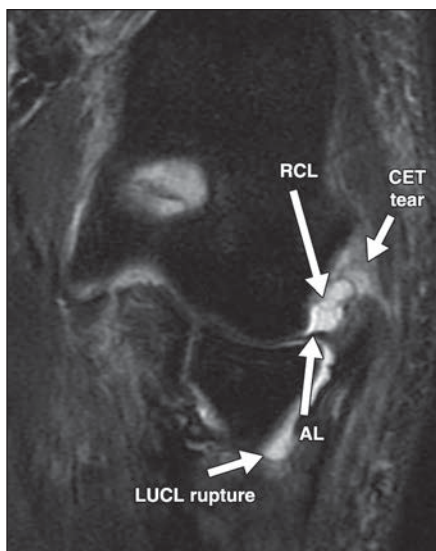

Fig. 10—Patient with posttraumatic displacement of annular ligament. Radial collateral ligament (RCL) and lateral ulnar collateral ligament (LUCL) rupture are associated with common extensor tendon tear. Coronal fluid-sensitive image of posterior elbow shows nonvisualization of common extensor tendon (CET) and RCL, which are torn at insertion site on lateral humeral epicondyle. There is laxity and wavy contour of LUCL, also suggestive of tear. Annular ligament (AL) is seen to be displaced superiorly and interposed between capitellum and radial head. (Reprinted with permission from [32])

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