MR of the adult elbow: what a resident needs to know

Poster No.: C-0423
Congress: ECR 2013
Type: Educational Exhibit
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Keywords: Athletic injuries, Pathology, Education, Technical aspects, MR, Extremities, Musculoskeletal bone, Musculoskeletal system
DOI: 10.1594/ecr2013/C-0423

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Learning objectives

1. To review of the normal anatomy of the adult elbow, with MR correlation.
2. To highlight important technical aspects that optimise visualisation of anatomic structures.
3. To review and illustrate the main pathologic groups affecting the elbow.
Background

This comprehensive review on magnetic resonance imaging of the elbow discusses normal elbow anatomy and the technical factors involved in obtaining high quality magnetic resonance images of the elbow, such as patient positioning and coil selection. Suggestions for sequence parameters and imaging planes are discussed for each of the pathologic entities.

The most common pathologies affecting the elbow are reviewed and illustrated: acute and chronic injuries to the collateral ligaments, medial and lateral epicondylitis, biceps and triceps tendinopathy (tendinosis, partial and complete tears, and anatomic variants such as bifurcated distal biceps brachii), osteochondral injuries and intraarticular bodies, inflammatory or infectious arthritis and bursitis, neuropathies of the median, radial and ulnar nerves and soft-tissue abnormalities.
1. NORMAL ANATOMY OF THE ELBOW

1.1 OSSEOUS STRUCTURES

The elbow joint consists of the ulnohumeral joint, the radiocapitellar joint, and the proximal radioulnar joint which are all located within a single synovium-lined joint capsule. The proximal articular surface of the humerus is divided into two components, the trochlea and the capitellum, which articulate with the ulna and radius respectively. The articular surfaces of the trochlea and capitellum are smooth and lined with articular cartilage. The capitellum and trochlea are oriented with 30 degrees of anterior angulation relative to the long axis of the humerus. The ulnohumeral articulation approximates a hinge (glymoid) joint, whereas the radiohumeral and radioulnar articulations allow for axial rotation, corresponding to a trochoid joint (Fig. 1 on page 24).

The elbow joint is best classified as a trochoginglymoid joint which allows for two types of motion: flexion-extension and axial rotation. The ulnohumeral joint is a hinge or ginglymoid joint which allows for approximately 150° of elbow flexion. The radiocapitellar and proximal radioulnar joints are trochoid joints which allow for approximately 75° of forearm pronation and 85° of forearm supination.

The ulnohumeral joint is a hinge joint formed by the articulation of the ulnar trochlear or greater sigmoid notch and the humeral trochlea and is one of the main stabilisers of the elbow (Fig. 2 on page 24). The humeral trochlea is a pulley-like central depression of the distal humerus and is covered by hyaline cartilage over an arc of 330°. The trochlear notch is formed by the articular surfaces of the olecranon and coronoid processes. Viewed en face, it has a figure-eight configuration with slight constriction midway between the coronoid and olecranon processes, traversed by a slight bony elevation called the trochlear ridge. This trochlear ridge lacks articular cartilage and is approximately 2 to 3 mm wide and 3 to 5 mm high. Because the height corresponds to that of adjacent articular cartilage, the articular surface remains smooth and congruent. In most cases, the trochlear ridge completely traverses the trochlear notch, but occasionally can be incomplete (traversing only the medial or lateral aspect of the notch). Sagittal MR images may reveal a central elevation of the trochlear articular surface corresponding to the trochlear ridge. The ridge has been reported in 81% of MR studies of normal volunteers, and may simulate either a central osteophyte or an olecranon stress fracture. Normal cortical irregularity may be seen at the peripheral margins of the trochlear ridge, termed "the trochlear groove". The contour change encountered at the peripheral margins of the trochlear ridge corresponds to the waist of the figure eight-shaped articular surface.
of the ulna. This normal variant can be distinguished from a true osteochondral lesion by recognition of its characteristic location.

The **radiocapitellar** joint is formed by the articulation of the convex, cartilage-covered capitellum of the humerus with the concave surface of the radial head (Fig. 3 on page 25). The capitellum or lateral humeral condyle is nearly spherical in configuration and allows for rotation of the radial head. The capitellum is separated from the trochlea by a groove which articulates with the rim of the radial head throughout the range of motion of the elbow joint. The capitellum approximates a sphere superiorly but narrows inferiorly with a distinct contour change where the anteriorly placed capitellum intersects the more posterior lateral epicondyle. The imaging appearance of the abrupt contour change at the posterolateral margin of the capitellum has been termed the "pseudodefect of the capitellum", which is most conspicuous on coronal images through the posterior aspect of the capitellum. In the sagittal imaging plane, the defect appears exaggerated on more lateral images (Fig. 4 on page 26). This normal variant can simulate an osteochondral lesion. True osteochondral defects, Panner disease, and even geodes from arthritis tend to be anterior. The proximal radius includes the discoid-shaped radial head and the tapered radial neck. The radial head articular surface has a central depression that accommodates the capitellum. The outer margin of the radial head articulates with the radial notch of the ulna. Hyaline cartilage of the articular surface of the radial head is contiguous with its outer margin, except for the anterolateral portion of the articular periphery.

The **proximal radioulnar joint** consists of the articulation of the radial head with the semilunar notch of the proximal ulna. The semilunar or lesser sigmoid notch is a depression within the proximal ulna located just distal to the lateral aspect of the coronoid process. The lesser sigmoid notch forms an arc of approximately 70° and is divided into medial and lateral portions by a small groove. Hyaline cartilage completely covers the semilunar notch. Hyaline cartilage also covers approximately 240° of the outside circumference of the radial head. It is this portion of the radial head which articulates with the semilunar notch of the proximal ulna throughout the range of pronation and supination of the elbow. The anterolateral third of the circumference of the radial head is not covered by articular cartilage (Fig. 5 on page 27).

Whereas the capitellum and trochlea have smooth surfaces lined by articular cartilage, the **epicondyles** are extraarticular structures with a rough, irregular contour. The prominent medial epicondyle is accentuated by the concave medial supracondylar ridge and serves as the origin of the anterior and posterior bands of the ulnar collateral ligament complex and, more superficially, the common flexor tendon. The less conspicuous lateral epicondyle is located just distal to the lateral supracondylar ridge and serves as the attachment site for portions of the lateral collateral ligament complex as well as the more superficial common extensor tendon.
The joint capsule invests the three articulations of the elbow forming a single contiguous joint space. It consists of two layers: a deep synovial lining and a more superficial fibrous layer. Three major fat pads are situated between the synovial and deep fibrous layers, making their location intraarticular but extrasynovial. Two anterior fat pads correspond to the capitellar and trochlear fossae, while a single posterior fat pad is concealed within the olecranon fossa.

Five principle recesses of the elbow joint are recognised, including the anterior humeral recess, the olecranon recess, the annular recess, and the recesses of the collateral ligaments.

The elbow has synovial folds or synovial plicae that are remnants of the embryologic formation of the joint, normally under 3 mm wide. Several synovial folds or plica have been described throughout the elbow joint and may be confused with intraarticular bodies or normal fat pads. According to their location they can be subdivided into posterosuperior (in the olecranon recess), plicae in the medial and lateral aspects of the olecranon recess or in the anterior humeral recess. The lateral synovial fold or synovial fringe is one of the most frequent and is seen between the radial head and capitellum, and it may be associated with chondromalacia of the radial head. Two distinct histologic types of the lateral synovial fold have been demonstrated: a) a true synovial fold described as a pliable structure composed of two layers of synovium and b) a rigid triangular fibrous structure lined by synovium. There is a considerable overlap in the size of symptomatic (normally joint blocking) and asymptomatic plica (Fig. 6 on page 28).

LIGAMENTOUS STRUCTURES OF THE ELBOW

The joint capsule is relatively loose in its anterior and posterior aspects, in order to allow for a wide range of motion during flexion and extension. Nevertheless, it is reinforced in their lateral aspects by the collateral ligaments.

Medial collateral ligament, or ulnar collateral ligament (MCL or UCL)

The MCL consists of three distinct components (Fig. 7 on page 29):

1. Anterior or oblique bundle: It originates from the central portion of the anterior inferior surface of the medial epicondyle, and consists of an anterior band and a posterior band which both insert on the sublime tubercle on the medial aspect of the base of the coronoid process of the ulna. The anterior band is taut between 0 and 60° of flexion, while the posterior band is taut between 60 and 120° of flexion. The anterior band and to a lesser extent the posterior band of the anterior bundle of the medial collateral ligament accounts for the vast majority of the stability of the elbow joint against valgus
and internal rotatory stress. On coronal images the anterior bundle of the UCL is seen as a uniformly low signal structure. Variations in attachment may occur in this region, so that an accessory articular recess distended with fluid should not be mistaken for a ligament tear.

2. Posterior bundle (ligament of Bardinet): It originates from the posterior surface of the medial epicondyle and inserts on the medial aspect of the olecranon process of the ulna. The posterior bundle is more of a fan-shaped thickening of the posterior capsule of the elbow joint than a distinct well-defined ligamentous structure. It is a secondary stabiliser of the elbow joint against valgus and internal rotatory stress but only at 120° of elbow flexion. It also acts as the floor of the cubital tunnel, so that MR imaging is most facile in the axial plane at the joint line.

3. Transverse bundle (ligament of Cooper): It consists of horizontal fibers running along the medial joint capsule from the coronoid process to the tip of the olecranon process of the ulna. The transverse bundle is variable in size and is often difficult to distinguish from the adjacent elbow joint capsule. It does not provide any stability to the elbow joint since the ligament both originates and inserts on the proximal ulna. It is not readily visualised on routine MR imaging.

**Lateral collateral ligament (LCL)**

The lateral collateral ligament consists of three distinct components (Fig. 8 on page 30):

1. The radial collateral ligament originates from the lateral epicondyle of the humerus and extends distally to blend into the fibers of the annular ligament.

2. The annular ligament is a thick band which completely encircles the radial head. The anterior portion of the annular ligament attaches to the anterior aspect of the sigmoid notch, while the posterior portion of the ligament expands and divides into several bands which attach to the posterior edge of the sigmoid notch. A common normal variant is a fenestration in the posterior radial insertion, in which two ligament bands are separated by a small fat pad.

3. The ulnar band of the lateral collateral ligament arises from the lateral epicondyle of the humerus and extends distally to insert on the tubercle of the supinator crest of the proximal ulna immediately distal to the insertion of the annular ligament. The proximal fibers of the ulnar band of the lateral collateral ligament cannot be distinguished from the proximal fibers of the radial collateral ligament. The distal fibers of the ulnar band of the lateral collateral ligament adhere closely to the intermuscular fascia of the extensor carpi ulnaris muscle and supinator muscle.

The ulnar band of the lateral collateral ligament and the annular ligament, which coalesce to insert broadly on the proximal aspect of the ulna, together account for the vast majority
of the stability of the elbow joint against varus and external rotatory stress. The annular ligament also functions to stabilize the proximal radioulnar joint.

Compared with the MCL, the LCL is not as well demonstrated on MR imaging because of the smaller size of the individual ligamentous structures and their oblique course.

MUSCULAR AND TENDONOUS STRUCTURES OF THE ELBOW

The musculature of the elbow is divided into anterior, posterior, medial, and lateral muscle compartments.

1. **Anterior muscle compartment:** The anterior muscle compartment is comprised of the brachialis muscle and biceps muscle which both function to flex the elbow. The brachialis muscle arises from the anterior surface of the distal humerus and inserts along the base of the coronoid process and into the tuberosity of the ulna. The biceps brachii muscle arises from long and short heads and is superficial to the brachialis muscle in the distal arm. Its tendon, formed from the muscle bellies of both heads, unite approximately 7 cm proximal to the elbow joint. passes through the cubital fossa to insert on the posterior aspect of the radial tuberosity. Like the Achilles tendon, the distal biceps tendon has no tendon sheath. The bicipital aponeurosis or lacertus fibrosis is the continuation of the anterior medial fascia surrounding the distal biceps muscle which courses over the median nerve and brachial artery to insert into the deep fascia of the forearm. This fibrous band may prevent proximal retraction of the complete biceps rupture, thereby masking the typical clinical findings of a balled-up muscular mass. The bicipitoradial bursa separates the distal biceps tendon from the anterior aspect of the radial tuberosity. The interosseous bursa is stated to occur in approximately 20% of individuals and is located along the medial aspect of the antecubital fossa adjacent to the biceps tendon and along the brachialis muscle. Both bursae may communicate in some cases.

2. **Posterior muscle group:** The anconeus and triceps form the posterior muscle group. The triceps arises from three heads, the lateral head from the posterolateral proximal humerus, the long head from the infraglenoid tubercle of the scapula, and the medial head from the posterior distal humerus. These form a common tendon that inserts at the olecranon, which normally may have a striated appearance. Rarely, a portion of the medial triceps may insert on the medial epicondyle and compress the ulnar nerve. The medial head of the triceps may subluxate, causing a snapping sensation similar to that of ulnar nerve subluxation. The olecranon bursa is made up by three bursae, a superficial olecranon bursa found in the subcutaneous tissue dorsal to the olecranon, a deep intratendinous bursa occurs within the substance of the triceps, and a deep subtendinous bursa found deep to the
triceps tendon near the tip of the olecranon. The anconeus arises from the posterior margin of the lateral epicondyle and courses medially to insert on the lateral margin of the olecranon. The role of the anconeus is somewhat controversial, although it is thought to help stabilize the elbow joint. The anconeus epitrochlearis is an anomalous muscle found to occur in 11% of anatomic specimens that may cause cubital tunnel syndrome. The anconeus epitrochlearis arises from the medial humeral condyle, passes superficial to the ulnar nerve, and inserts on the olecranon.

3. **Medial muscle compartment**: The medial compartment is comprised of the pronator teres muscle, flexor carpi radialis muscle, palmaris longus muscle, flexor carpi ulnaris muscle, and flexor digitorum superficialis muscle which function to flex the wrist and pronate the forearm. These muscles all originate from the medial epicondyle by way of the common flexor tendon (Fig. 7 on page 29).

4. **Lateral muscle compartment**: The consists of the brachioradialis muscle, extensor carpi radialis longus and brevis muscles, extensor digitorum muscle, extensor carpi ulnaris muscle, and supinator muscle which all function to extend the wrist and supinate the forearm. The brachioradialis and extensor carpi radialis longus muscles originate from the anterior lateral surface of the distal humerus. The extensor carpi radialis muscle, extensor digitorum muscle, and extensor carpi ulnaris muscle all arise from the lateral epicondyle by way of the common extensor tendon (Fig. 8 on page 30).

**NERVES OF THE ELBOW**

1. **RADIAL NERVE**: The radial nerve is a continuation of the posterior cord of the brachial plexus. Within the upper arm, the nerve courses distally and laterally within the spiral groove of the humerus. The nerve then penetrates the lateral intermuscular septum and enters into the anterior compartment of the arm, between the brachioradialis and brachialis muscles. At the proximal margin of the supinator muscle, just superficial to the radiohumeral joint, the nerve divides into the superficial and deep branches. The deep motor branch, commonly referred to as the posterior interosseous nerve, passes between the superficial and deep portions of the supinator muscle. The superficial branch of the radial nerve continues distally deep to the brachioradialis. The Arcade of Frohse is the fibrous arch formed by the proximal border of the superficial portion of the supinator, and is a the most common point of compression of the radial nerve (Fig. 9 on page 31).

2. **MEDIAN NERVE**: The nerve courses distally within the anterior compartment of the upper arm superficial to the brachialis muscle. The median nerve passes beneath the bicipital aponeurosis into the c where it lies medial to the biceps tendon and brachial artery (Fig. 10 on page 31). The nerve then passes between the humeral head and the ulnar head of the pronator teres muscle, and then passes deep to the fibrous arch formed by the two heads of the flexor digitorum superficialis. Impingement of the
median nerve, or pronator syndrome, usually occurs as it passes between the ulnar and humeral heads of the pronator teres. Less commonly the median nerve may be entrapped by a thickened lacertus fibrosis or fibrous arch of the flexor digitorum superficialis. In patients with a supracondylar process, the nerve may be impinged as it passes through the fibro-osseous tunnel created by the ligament of Struthers.

3. **ULNAR NERVE (Fig. 10 on page 31):** In the elbow, the ulnar nerve then passes through the cubital tunnel. The cubital tunnel is a fibro-osseous conduit along the posterior aspect of the medial epicondyke. The posterior bundle of the ulnar collateral ligament forms the floor of the cubital tunnel. The roof of the cubital tunnel is formed by the cubital tunnel retinaculum and the deep layer of the aponeurosis of the flexor carpi ulnaris muscle. The cubital retinaculum is also known as the arcuate ligament or ligament of Osborn. It originates from the tip of the medial epicondyke and inserts onto the olecranon process and into the margin of the triceps fascia. Complete absence of the cubital tunnel retinaculum results in hypermobility of the ulnar nerve and possible subluxation or dislocation of the nerve anterior to the medial epicondyke. Ulnar nerve subluxation or dislocation may be present in up to 15% of the general population and is commonly asymptomatic. The ulnar nerve continues distally traversing the flexor carpi ulnaris muscle and deep flexor pronator aponeurosis. After coursing through the cubital tunnel, the ulnar nerve passes between the humeral and ulnar heads of the flexor carpi ulnaris muscles. The nerve then courses distally through the anterior compartment of the forearm between the flexor carpi ulnaris muscle and the flexor digitorum profundus muscle. By far, the most common site of compression of the ulnar nerve is within the cubital tunnel. The ulnar nerve may be spontaneously compressed within the cubital tunnel during elbow flexion, although a variety of congenital (such as an anconeus epitrochlearis muscle (Fig. 11 on page 32), post-traumatic, sinovial cysts, osteoarthritis and rheumatoid arthritis, and neoplastic processes may also decrease the cross-sectional area of the cubital tunnel and lead to compression of the ulnar nerve at the elbow.

**MAGNETIC RESONANCE IMAGING OF THE ELBOW**

Magnetic resonance imaging of the elbow is best performed on a high field strength magnet. A surface coil is essential for obtaining high-quality images. A variety of coils may be used for imaging the elbow. A wrist coil can be used in small adults and children when a large field of view is not needed. Larger patients can be imaged with a flexible coil, anterior neck coil, shoulder coil, or knee coil. A larger coil, such as the shoulder or knee coil, is especially useful when the patient cannot fully extend the elbow or when the patient needs to be imaged in the prone position with the arm overhead.
Care should be taken to position the patient as comfortably as possible to minimize motion. Imaging is best performed with the patient supine in the anatomic position, with the arm at his or her side, the elbow fully extended, and the forearm in supination. This is the most comfortable position for the patient which decreases the likelihood of patient motion during the examination. This position also minimizes the rotation of the forearm and the proximal radioulnar joint with respect to the distal humerus which optimizes visualisation of the collateral ligaments and common flexor and extensor tendons in the coronal plane. However, positioning the elbow at the periphery of the magnetic field often results in a poor signal-tonoise ratio and may limit the effectiveness of spectral fat saturation techniques.

For large patients and for scanners which do not allow off-center imaging, the patient can be positioned in the prone position with the arm overhead. This position places the elbow joint close to the isocenter of the scanner and thereby improves image quality; however, the prone position is relatively uncomfortable for the patient which increases the likelihood of patient motion during the examination. This position also results in significant forearm pronation and radioulnar joint rotation which makes it more difficult to evaluate the collateral ligaments and common flexor and extensor tendons in the coronal plane. If complete extension cannot be achieved, or the elbow remains slightly flexed (20-25°), it may be preferable to perform the MR examination with the elbow flexed 90°, as images will be more anatomic.

A routine imaging protocol of the elbow should include sequences in the axial, coronal, and sagittal planes. Axial images should ideally be performed in a plane perpendicular to the long axis of the humerus, radius, and ulna with the elbow in a fully extended position. Axial images should extend from the level of the distal humeral metaphysis superiorly to the level of the radial tuberosity inferiorly. Coronal images are usually obtained parallel to a line bisecting both humeral epicondyles on an axial source image; however, the collateral ligaments of the elbow are optimally visualised in a 20° posterior oblique coronal plane in relation to the humeral diaphysis with the elbow extended and a coronal plane aligned with the humeral diaphysis with the elbow flexed 20-30°. These modified coronal planes are obtained using a sagittal scout image. Sagittal images should be obtained in a plane orthogonal to the coronal images.

The axial plane provides a nice visualisation of the course of both muscles and tendons, and is crucial in the evaluation of nervous entrapment and strains of the biceps brachii tendon.

At our institution, the routine elbow protocol consists of T1-weighted fast spin-echo sequences and fat-suppressed T2-weighted fast spin-echo sequences in the axial plane, T1-weighted fast spin-echo sequences and fat-suppressed PD weighted sequences in the coronal plane and fat-suppressed T2-weighted fast spin-echo sequences in the sagittal plane.
sequences in the sagittal plane. The employed FOV is 16-17 cm, with slice thickness 3 to 4 mm and an interslice gap of 10%. T1-weighted fast spin-echo sequences provide excellent anatomic detail of osseous structures as well as loose bodies. T2 and PD-weighted sequences are particularly useful for depicting collateral ligaments, tendons, osteochondral lesions and loose bodies. Fat suppression is especially useful for identifying subtle oedema within the osseous and soft tissue structures of the elbow. Some radiologists find gradient-echo sequences especially helpful in evaluating the collateral ligaments of the elbow. Nevertheless, these sequences are very sensitive to magnetic susceptibility changes and should not be routinely used in patients with a history of prior elbow surgery.

In our routine protocol, intravenous contrast material is not generally administered.

Traditionally, optimal MR imaging of the distal biceps tendon is performed in the axial plane, often with the patient's arm extended. Longitudinal views are difficult to obtain because of the oblique course of the tendon. For this purpose, the FABS position is particularly useful: the patient lies prone with the arm overhead, the elbow flexed to 90°, and the forearm supinated, so that the thumb points superiorly (FABS: flexed elbow, ab ducted shoulder, forearm supinated). In this way, a longitudinal view of the tendon, often in one section, is obtained, and partial volume averaging effects due to the oblique course of the tendon are minimised. Flexion of the elbow results in contraction of the biceps muscle belly; thus, the tendon is taut (Fig. 12 on page 33). FABS imaging provides a detailed view of the distal biceps tendon, including the difficult-to-assess region near its insertion on the radial tuberosity, and is often helpful in differentiating partial from complete tears. The FABS view is obtained in addition to conventional views specifically to evaluate disease of the distal biceps brachii tendon.

Direct MR arthrography of the elbow is very helpful in evaluating for intra-articular loose bodies, unstable osteochondral defects, and tears of the collateral ligaments. Anyhow, because of its invasiveness, it is seldom used at our institution.

Indirect MR arthrography may be an alternative imaging technique, although its diagnostic accuracy significantly decreases when no joint fluid is present.

PATHOLOGY GROUPS

LIGAMENT INJURIES

Injuries of the collateral ligaments may occur following an acute stress injury to the elbow or following acute traumatic elbow dislocation, however, tears are more commonly
caused by chronic repetitive stress to the elbow. The UCL is more commonly injured than the LCL

ULNAR COLLATERAL LIGAMENT TEARS

Tears of the ulnar collateral ligament may occur following an acute valgus stress injury to the elbow or following acute traumatic elbow dislocation; however, tears of the ulnar collateral ligament are more commonly caused by chronic repetitive stress to the elbow elicited by sports activities involving overhead throwing, such as those seen in baseball pitchers and javelin throwers. Chronic tensile overloading of the ulnar collateral ligament secondary to repetitive throwing activities causes inflammation and microscopic tears of the ligament. As a result, the ulnar collateral ligament becomes weakened and attenuated and may eventually rupture.

Most tears of the ulnar collateral ligament are full thickness tears which involve the anterior bundle of the ulnar collateral ligament. The vast majority of these full thickness tears occur in the midsubstance of the ligament. Complete soft tissue avulsions of the ulnar attachment and less commonly the humeral attachment of the anterior bundle of the ulnar collateral ligament can also occur.

The magnetic resonance imaging findings of a torn anterior bundle of the ulnar collateral ligament include redundancy, irregularity, poor definition of the ligament, and abnormal signal intensity within and adjacent to the ligament due to the presence of oedema and haemorrhage within the injured ligament. Reported sensitivity is as high as 100%, but this value drops to 57% when partial-thickness tears of the ligament occur, because these tears involve the deep intracapsular layer of the anterior bundle of the ulnar collateral ligament, which are obscured by the intact superficial fibers of the ligament and the adjacent medial capsule of the elbow joint.

Chronic pathology of the anterior bundle of the UCL is prevalent in throwing athletes. Imaging findings include diffuse increase in signal intensity and thickening of the ligament reflecting fibrosis- and microtears (Fig. 13 on page 34). Ulnar neuropathy and medial epicondylitis may also coexist. Associated findings include hypertrophic spurring at the coronoid attachment, capsular scarring, and loose bodies. This chronic injury often is associated with valgus extension overload or posteromedial impingement. In this syndrome, extreme repetitive valgus stresses create high contact pressures at the posterior medial margin of the humeral ulnar joint and cause osteophytes to form off the medial olecranon. During elbow extension, these osteophytes impinge on the olecranon fossa, causing reduced range of motion as well as pain, and they may become detached.
and form intraarticular loose bodies. Moreover, this syndrome may course with increased stress forces in the radiocapitellar joint and therefore it may be more prone to the development of osteochondral lesions.

LATERAL COLLATERAL LIGAMENT TEARS

Tears of the lateral collateral ligament lead to a condition referred to as posterolateral rotatory instability of the elbow. Posterolateral rotatory instability of the elbow is due to a tear of the ulnar bundle of the lateral collateral ligament, which is the primary stabilizer of the elbow joint against varus stress. This bundle may be difficult to visualize in its entirety on two-dimensional coronal magnetic resonance images of the elbow due to its oblique course. The insufficient ulnar bundle of the lateral collateral ligament allows posterior subluxation or dislocation of the radial head with secondary rotatory subluxation of the ulnohumeral joint when the elbow is extended and the forearm supinated. In this condition, the annular ligament remains intact. As a result, the radioulnar joint does not dislocate, and the proximal portions of the radius and ulna move as a unit.

Tears of the lateral collateral ligament in young individuals are usually the result of an elbow dislocation. Tears of the lateral collateral ligament in adults are most commonly caused by a varus extension stress injury to the elbow which does not result in elbow dislocation or following overaggressive release of the common extensor tendon origin for treatment of lateral epicondylitis. Most tears of the ulnar bundle of the lateral collateral ligament are full-thickness tears which involve the proximal attachment of the ligament to the lateral epicondyle of the humerus.

MR imaging findings of ulnar bundle of the lateral collateral ligament injury resemble those described for the UCL: hyperintensity, discontinuity, and surrounding soft tissue oedema in the injury is acute; or thickening, abnormally increased signal, and discontinuity in a chronically torn and remodeled ligament. Patients who have sustained an injury to the LUCL may have associated findings including cartilage loss, particularly over the medial humeralulnar joint, and intraarticular bodies. It also has been shown to be associated with lateral epicondylitis, particularly if the latter is severe (Fig. 14 on page 34).

TENDINOUS ABNORMALITIES

LATERAL EPICONDYLITIS (TENNIS ELBOW)
Lateral epicondylitis is a pathologic condition of the common extensor tendon at its origin from the lateral epicondyle of the humerus. Excessive use of the wrist extensor muscles is associated with its development. Lateral epicondylitis is also known as tennis elbow since over 50% of tennis players develop the condition at some time or another. However, lateral epicondylitis is far more common in nonathletes between 40 and 60 years of age and has an equal sex distribution. It is thought to represent an incomplete healing response to an initial microscopic or macroscopic avulsion injury of the common extensor tendon of the elbow, with mucoid degeneration and neovascularisation on histopathologic analysis.

Individuals with lateral epicondylitis usually present with chronic lateral elbow pain. The symptoms are usually exacerbated by activities that require resisted extension of the wrist. On physical examination, most individuals have point tenderness in the region of the common extensor tendon origin.

MR is rarely needed since most patients with lateral epicondylitis are easily diagnosed by clinical history and physical examination. In individuals who do not respond to conservative treatment, magnetic resonance imaging may be helpful to determine the extent of tissue damage to the common extensor tendon origin and to exclude other causes of lateral elbow pain. The common extensor tendon origin in individuals with lateral epicondylitis is usually thickened and shows increased signal intensity on both T1-weighted and T2-weighted images. The region of greatest signal abnormality is usually at the origin of the extensor carpi radialis brevis tendon from the lateral epicondyle of the humerus. When partial or complete tears occur, areas of intense fluid-like signal intensity on T2-weighted images are observed, corresponding to areas of significant disruption of collagen fibers (Fig. 15 on page 35).

Other associated findings include: bone marrow of the lateral epicondyle, anconeus muscle oedema, periostitis of the lateral epicondyle, fluid within the radial head bursa, dystrophic calcification adjacent to or osseous spurs projecting off the lateral epicondyle of the humerus and injuries to the ulnar bundle of the lateral collateral ligament.

MEDIAL EPICONDYLITIS (GOLFER'S ELBOW)

Medial epicondylitis is a pathologic condition of the common flexor tendon at its origin from the medial epicondyle of the humerus. It is much less common than lateral epicondylitis, and is thought to represent an incomplete healing response to an initial microscopic or macroscopic avulsion injury of the common flexor tendon of the elbow.

The pathologic condition most commonly involves the tendon origins of the flexor carpi radialis muscle and pronator teres muscle. Medial epicondylitis may be associated with ulnar nerve neuropathy and injuries to the medial collateral ligament of the elbow.
Unlike lateral epicondylitis, medial epicondylitis is mainly seen in athletes. The condition is associated with sports activities which generate repetitive valgus and flexion forces at the elbow. Medial epicondylitis usually involves the dominant elbow of golfers, racquetball and tennis players, swimmers, baseball pitchers, and javelin throwers. The symptoms are usually exacerbated by activities that require resisted flexion of the wrist and pronation of the forearm. On physical examination, most individuals have point tenderness in the region of the common flexor tendon origin.

Imaging findings are similar to those described previously for lateral epicondylitis (Fig. 16 on page 36).

BICEPS TENDON INJURIES

Rupture of the distal biceps tendon is relatively rare and accounts for less than 5% of all biceps tendon injuries. Distal biceps tendon rupture most commonly occurs in the dominant extremity of males between 40 and 60 years of age. Rupture of the distal biceps tendon may be partial or complete. All reported cases of complete rupture of the distal biceps tendon have occurred in males, while partial rupture of the distal biceps tendon is much less common and has been described in both males and females. Rupture of the distal biceps tendon is almost always the result of a single traumatic event in which a sudden extension force is applied to the arm with the elbow flexed 90º. Most tears of the distal biceps tendon occur at the insertion site of the tendon into the radial tuberosity. Intrasubstance tears and tears at the musculotendinous junction of the distal biceps tendon have been reported but are rare. The bicipital aponeurosis may or may not tear during rupture of the distal biceps tendon. If the bicipital aponeurosis is torn, the ruptured distal biceps tendon will retract proximally into the arm.

Both mechanical and degenerative factors are thought to play a major role in the pathogenesis of distal biceps tendon rupture. Most tears occur 1-2 cm above the radial tuberosity, where there is relative hypovascularity and a histologic structural transition point. Degeneration secondary to hypoxic tendinopathy occurs in this region. With increasing age, there is a progressive decrease in perfusion, elasticity, and hydration, and the processes of tendon repair slow further. Repetitive mechanical impingement of the distal biceps tendon against the anterior cortex of the radial tuberosity may occur during forearm rotation and may predispose the distal biceps tendon to rupture during acute trauma. Chronic inflammation of the bicipitoradial bursa may weaken the structural integrity of the distal biceps tendon and may make the tendon more susceptible to partial rupture.

The distal biceps tendon is best evaluated on axial magnetic resonance images. The longitudinal view of the tendon acquired with FABS imaging often best demonstrates tendon injuries.
Biceps tendinopathy presents the same radiologic signs as those described previously. Complete rupture of the distal biceps tendon is characterised by the absence of the low signal intensity biceps tendon at its insertion site on the radial tuberosity, soft tissue oedema and a mass-like area of fluid signal intensity is noted in the antecubital fossa in the region of the biceps tendon sheath. A variable amount of retraction of the distal biceps tendon is usually noted on sagittal images.

Partial rupture of the distal biceps tendon is characterised by the presence of increased signal intensity within an abnormally thickened or thinned distal biceps tendon. It may be difficult to distinguish between tendonopathy and partial rupture of the distal biceps tendon on MR. Secondary findings of a partially torn distal biceps tendon include the presence of bone marrow oedema within the radial tuberosity and the presence of fluid within the bicipitoradial bursa, which separates the distal biceps tendon from the anterior cortex of the radial tuberosity and serves to reduce friction between the tendon and the adjacent bone. Bifurcated distal biceps brachii tendon is an anatomic variant that arises from persistent division between the short head and long head of the distal biceps brachii tendon and can be characterised with MRI (Fig. 17 on page 37, Fig. 18 on page 38, Fig. 19 on page 39).

TRICEPS TENDON INJURY

Triceps tendinosis is an unusual cause of posterior elbow pain, but may be seen in association with sports that involve rapid or forceful extension of the triceps, such as javelin throwing, baseball, benchpressing in weight training, and gymnastics.

Abnormal signal intensity may be seen at the insertion of the triceps tendon, with or without thickening of the tendon. Triceps tendinosis is frequently associated with other chronic posterior elbow disorders, such as stress reaction of the olecranon process, olecranon osteophytes, loose bodies in the olecranon fossa, and olecranon bursitis.

Rupture of the triceps tendon is a very rare injury. Triceps tendon rupture occurs in both males and females and in individuals of all ages. Predisposing risk factors are occasionally present, such as renal insufficiency, hyperparathyroidism, Marfan's syndrome, osteogenesis imperfecta tarda, olecranon bursitis, local corticosteroid injection, and systemic anabolic steroids and corticosteroid use.

Rupture of the triceps tendon is almost always the result of a single traumatic event. The mechanisms of injury are usually a fall on an outstretched hand, a direct blow to the posterior elbow and a forceful eccentric contraction of the triceps muscle with the elbow flexed. Fractures of the radial head are commonly seen in association with triceps tendon rupture. Most tears of the triceps tendon occur at the insertion site of the
tendon into the olecranon process of the proximal. Intrasubstance tears and tears at the musculotendinous junction of the triceps tendon have been reported but are rare.

MR can distinguish between partial and complete rupture of the triceps tendon and can determine the amount of retraction of a completely torn tendon. The triceps tendon is best visualised on sagittal images. Partial rupture of the triceps tendon is characterised by a small fluid-filled defect within the distal triceps tendon with oedema in the surrounding subcutaneous tissue of the posterior elbow. Complete rupture of the triceps tendon is characterised by a large fluid-filled gap between the distal triceps tendon and the olecranon process with a large amount of oedema in the adjacent subcutaneous tissue. The distal edges of the torn triceps tendon are frayed and have heterogeneous signal intensity. A variable amount of retraction of the distal triceps tendon is usually present (Fig. 20 on page 40).

OSTEOCHONDRAI INJURIES AND INTRAARTICULAR BODIES

OSTEOCHONDRAI INJURIES

An acute valgus force to the elbow may result in osteochondral injury from impaction and shear forces applied to the articular surfaces. The capitellar articular surface impacts on the radius to produce a chondral or osteochondral injury. It usually occurs in men between the ages of 12 and 15 years when the capitellar epiphysis is almost completely ossified. On MR imaging, it is seen as irregularity of the chondral surface, disruption of the subchondral bone plate, or the presence of a fracture line. More severe lesions show a discrete fragment either in situ or loose in the joint. Both stable and unstable lesions demonstrate a hypointense rim on T1-weighted images with variable signal intensity centrally. An unstable fragment shows linear high signal on T2-weighted images along the interface between the fragment and the capitellum, which is believed to represent fluid or granulation tissue. If contrast-enhanced MR imaging is performed, a peripheral ring of enhancement at the interface between the fragment and adjacent subchondral bone is thought to represent enhancing granulation tissue and suggests instability of the lesion. This pattern of injury must be distinguished from the "pseudodefect" of the capitellum. The more anteroinferior location of the lesion, the presence of bone marrow oedema and a joint effusion helps confirm the true nature of the osteochondral injury (Fig. 21 on page 40, Fig. 22 on page 41).

Finally, osteochondrosis can affect the capitellum (Panner disease), which typically occurs in a younger patient population when compared with osteochondral injury and impaction type injuries. Osteochondrosis is a self-limiting disease of children aged between 5 and 12 years and occurs during periods of active ossification of the epiphyseal
centers of the elbow. Unlike in patients with osteochondral injuries, residual deformity or development of intraarticular loose bodies is rare in patients with osteochondrosis.

LOOSE BODIES

Loose bodies are most frequently found in the knee and elbow. The underlying cause may be an acute injury, but more often is related to chronic repetitive microtrauma. Such free fragments may continue to grow, so that they can adhere to the sinovial tissue or simply float in the joint fluid. Such free fragments tend to congregate in the coronoid and olecranon fossae (Fig. 21 on page 40). Care should be taken to distinguish osteophytes and hypertrophied synovium from intraarticular bodies by visualising the attachment sites of the former entities.

Small fragments, particularly those composed only of cartilage, are difficult to identify without the surrounding fluid of an effusion. For this reason, T2-weighted MR images are recommended for this purpose, especially those obtained in the sagittal and axial planes. Large osseous fragments may contain fatty marrow and therefore may be easily seen on T1-weighted MR images. In some cases, due to massive calcium content, they appear as low signal foci in every pulse sequence (Fig. 23 on page 42).

PRIMARY SYNOVIAL CHONDROMATOSIS

Primary synovial chondromatosis is a benign mono-articular disorder of unknown origin that is characterised by metaplastic formation of cartilaginous nodules in the synovium. Detachment of those nodules results in formation of free intra-articular bodies. In the inactive phase of the disease, resolution of synovial proliferation occurs, but loose bodies remain in the joint, and may increase in size obtaining nourishment from the joint fluid by diffusion. Occasionally, bursa or tendon sheaths may be involved. Imaging findings depend on the stage of disease and on the extent of calcification or ossification of the cartilaginous nodules. The most frequent pattern is one of predominantly unmineralised nodules which demonstrate typical chondroid signal characteristics (T1: intermediate to low signal, T2: high signal). Focal areas of signal void within these nodules represent areas of mineralisation. Gradient echo sequences will show signal voids more conspicuously. In some cases all the nodules are fully ossified with central fat intensity. Images obtained after administration of contrast material will show enhancement in thickened synovium, and can be helpful in differentiating thickened synovium from joint fluid. Secondary osteochondromatosis typically demonstrates associated and more prominent changes of the underlying degenerative disease of the joint. Any intraarticular bodies tend to be larger, less numerous, and more varied in size and shape than in primary synovial chondromatosis (Fig. 24 on page 43).
INFLAMMATORY OR INFECTIOUS ARTHRITIS AND BURSITIS

Elbow joints may be affected by rheumatoid arthritis in up to 20-50% of patients. MR is able to detect soft-tissue changes and damage to cartilage and bone even at earlier stages, particularly synovitis signs such as enhancement and thickening of the synovium. In chronic stages, destruction of cartilage, formation of pannus and scar tissue and fibrosis lead to joint space narrowing, which may manifest as low signal intensity sinovitis. Nevertheless, this appearance is more commonly found in chronic intraarticular haemorrhage, such as those occurring in hemophilia-related arthropathy and pigmented villonodular synovitis.

Pigmented villonodular synovitis is a member of a family of benign proliferative lesions of the synovium of the joint, bursa, and tendon sheath that are usually divided according to the site of origin (intraarticular or extraarticular) and pattern of growth (localised or diffuse). The term pigmented villonodular synovitis is generally used when diffuse intraarticular involvement is present. At MR, images typically show a synovial-based mass that affects most or all of the joint and that displays low signal intensity on T1- and T2-weighted pulse sequences. Magnetic susceptibility artifact (blooming) within the affected joint space on GRE images is also characteristic.

MRI is an important diagnostic tool for the evaluation of crystal deposition diseases. Gradient echo sequences will show chondral calcification foci more conspicuously. Chronic gout is often associated with the development of tophaceous deposits within cartilage, synovial membranes, bursae, and tendons. On the other hand, acute gout commonly presents as monoarticular arthritis, occurring in the first metatarsophalangeal joint, elbow, and fingers. Gouty tophi are mostly of low- or intermediate-signal intensity on T1W images and reveal an increase in signal intensity after intravenous administration of gadolinium. The imaging findings of tophi on T2W images are variable, but usually contain low-signal intensities. In the elbow, gout typically manifests as olecranon bursitis associated to bone erosion of the olecranon (Fig. 25 on page 44).

Septic or infectious arthritis is most commonly caused by Staphylococcus aureus, Streptococci, Haemophilus influenzae and Neisseria gonorrhoea. Bacterial seeding may be secondary to pneumonia, pyelonephritis, pyodermitis, intra-articular injection of corticosteroids, orthopedic surgery or penetrant injuries. The most commonly affected joints are, in decreasing order: knee, hip, ankle, elbow, wrist and shoulder. The response of sinovial tissue implies a certain degree of hyperplasia and purulent exudate, which can lead to a degradation of the underlying cartilage, as well as bony destruction. Associated myositis and/or bursitis foci are commonly found (Fig. 26 on page 45, Fig. 27 on page 46).
**Olecranon bursitis** generally results from trauma, although it may also be secondary to form infection, synovitis, rheumatoid arthritis, gout, crystal deposition diseases or hemodialysis. Infection caused by Staphylococcus aureus is found in up to 20% of the cases. MR is useful in the evaluation of associated anomalies such as osteomyelitis, although it is not frequent. The radiological appearance of olecranon bursitis depends on the stage of the disease and presence of chronic hemorrhagic foci. Hemorrhagic bursitis is characterised by hyperintense fluid on T1WI. Septic bursitis typically shows inflammatory changes in adjacent soft tissues, while chronic bursitis shows chronic synovitis, peripheral osteophytes and granulation tissue formation, which may present a complex aspect mimicking a solid mass (Fig. 26 on page 45, Fig. 27 on page 46).

**NEUROPATHIES OF THE MEDIAN, RADIAL AND ULNAR NERVES**

MR imaging is considered useful for the assessment of neuromuscular disorders. It provides high-resolution depiction of nerves and allows visualisation of primary abnormalities, such as a mass lesion compressing a nerve, as well as secondary abnormalities, such as nerve enlargement and enhancement due to neuritis. However, the primary nerve abnormality may not be visible in some cases. In such cases, the observation of signal intensity changes in the muscle that is innervated by the abnormal nerve may be used to diagnose and localize the nerve lesion. A normal nerve on T1-weighted images appears as a smooth round or ovoid structure with an MR signal that is isointense to that in adjacent muscle. A rim of hyperintense signal often surrounds peripheral nerves. Normal nerves do not appear enhanced after the intravenous administration of a gadolinium-based contrast agent. On T2-weighted images nerves appear isointense to mildly hyperintense, compared with the signal intensity in normal muscle. Nerve fascicles may have a signal intensity slightly higher than that in the perineurium and internal perineural tissue.

**Ulnar nerve**

Individuals with cubital tunnel syndrome usually complain of aching pain and discomfort on the medial aspect of the elbow and proximal forearm. Numbness and paresthesia in the distribution of the ulnar nerve is commonly present, which may be intermittent and related to daily activities which involve repetitive or constant elbow flexion posturing.

Cubital tunnel syndrome may be caused by compression of the ulnar nerve at several sites within the upper extremity. The ulnar nerve may be compressed as it passes from the anterior compartment to the posterior compartment of the upper arm through the arcade of Struthers. The ulnar nerve may be compressed just proximal to the elbow joint by the medial head of the triceps muscle. The ulnar nerve may also be compressed by fascial bands as it passes between the two heads of the flexor carpi ulnaris muscle and
by the deep flexor-pronator aponeurosis as it courses distally within the upper forearm; however, by far the most common site of compression of the ulnar nerve is within the cubital tunnel. The anatomy of this tunnel was previously described.

A variety of congenital, post-traumatic, degenerative, inflammatory, and neoplastic processes may decrease the cross-sectional area of the cubital tunnel and lead to compression of the ulnar nerve at the elbow, such as congenital hypoplasia of the trochlea, congenital cubitus valgus deformities, and post-traumatic cubitus valgus deformities following childhood elbow fractures, osteophytes or inflamed synovium may occur in patients with osteoarthritis and rheumatoid arthritis of the elbow joint, synovial cysts, distended bursae, and soft tissue tumours such as lipomas or haemangiomas within or adjacent to the cubital tunnel (Fig. 11 on page 32, Fig. 28 on page 47, Fig. 29 on page 47).

**Median nerve**

The most common cause of median nerve entrapment at the elbow is the pronator syndrome. This syndrome is commonly seen in recreational or occupational activities which require repetitive pronation and supination of the forearm. Individuals with this disorder usually complain of pain in the volar aspect of the forearm which worsens with exertional activities. Numbness and paresthesia in the distribution of the median nerve is occasionally present. The pronator syndrome may be due to compression of the median nerve at multiple sites within the upper extremity. The most proximal and least common site of potential compression of the median nerve is at a fibro-osseous tunnel formed by the supracondylar process of the humerus (an anomalous bony spur which arises from the anterior medial cortex of the distal humerus 5-7 cm proximal to the medial epicondyle). The roof of the fibro-osseous tunnel is formed by the ligament of Struther's which extends from the supracondylar process to the medial epicondyle. The next site of potential compression of the median nerve is at the bicipital aponeurosis. An unusually thick bicipital aponeurosis or an accessory fibrous bundle associated with a third head of the biceps muscle may compress the median nerve at this location. The third and most frequent site of potential compression of the median nerve is at the pronator teres muscle. The median nerve may be compressed by fibrous bands as it traverses between the superficial and deep heads of the pronator teres muscle (this is the most common point of compression). The fourth and second most common potential site of median nerve compression is at a fibrous arch formed by the proximal margin of the flexor digitorum superficialis muscle (this is the second most common point of compression).

**Radial nerve**
Compression of the radial nerve at the elbow may result in radial tunnel syndrome. This syndrome is commonly seen in professional cleaners, mechanics, construction workers, painters, and homemakers who are involved in occupational activities which require repetitive rotatory movements of the forearm. Individuals with radial tunnel syndrome usually complain of pain in the radial aspect of the forearm which worsens with exertional activities. Numbness and paresthesia in the distribution of the radial nerve is occasionally present. The symptoms of radial tunnel syndrome closely resemble those of lateral epicondylitis. In fact, many patients with radial tunnel syndrome are initially diagnosed as having chronic lateral epicondylitis which fails to improve with conservative therapy.

The radial tunnel is an anatomic space approximately 5 cm in length which begins proximally at the level of the capitellum and extends distally to the lower border of the supinator muscle. The tunnel is bounded medially by the brachialis muscle and anterolaterally by the brachioradialis muscle and the extensor carpi radialis longus muscle. The radial nerve and its branches may be compressed at multiple sites within the radial tunnel. In the proximal portion of the tunnel, the nerve may be compressed against the anterior capsule of the elbow joint by fibrous bands. More distally, the nerve may be compressed against the sharp medial edge of the tendinous origin of the extensor carpi radialis brevis muscle. The radial nerve and its branches may also be compressed between the radial neck and a fan-like vascular leash of vessels from the radial recurrent artery. In the distal portion of the radial tunnel, the nerve may be compressed as it passes through the arcade of Frohse (posterior interosseous nerve syndrome), the thick fibrous arch of the superficial head of the supinator muscle. The radial nerve and its branches may also be compressed by fibrous bands at the lower border of the supinator muscle. Compression of the posterior interosseous nerve has been associated with fractures of the proximal radius, dislocations of the radial head, masses such as ganglia, haemangiomias, and lipomas, and proliferative synovitis secondary to rheumatoid arthritis.

SOFT TISSUE PATHOLOGY AROUND THE ELBOW

This heterogeneous group includes the most commonly found benign or malignant masses affecting soft tissues around the elbow, such as lipomas (Fig. 30 on page 48), intramuscular haemangiomas (Fig. 31 on page 49), arteriovenous malformations (Fig. 32 on page 49), peripheral nerve tumours (Fig. 33 on page 50) and soft tissue sarcomas (Fig. 34 on page 50).
**Fig. 1:** The normal (right) elbow joint consists of the ulnohumeral (blue), radiocapitellar (orange), and proximal radioulnar (violet) joints located within a synovial-lined joint capsule.

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**Fig. 2:** Normal right ulnohumeral joint. Sagittal fat-suppressed T2 weighted image. The trochlear groove must be distinguished from a true osteochondral lesion.

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**Fig. 3:** Normal right radiocapitellar joint. Coronal fat-suppressed proton density-weighted MR image.

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**Fig. 4:** The imaging appearance of the abrupt contour change at the posterolateral margin of the capitellum has been termed the "pseudodefect of the capitellum", which is a normal variant. Coronal fat-suppressed proton density and sagittal T1 weighted MR images.

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**Fig. 5:** Normal right proximal radioulnar joint. Axial T1 weighted image.

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Fig. 6: Lateral synovial fold or synovial fringe of the radiocapitellar joint (solid white arrow), as compared with a coronal radiocapitellar joint (open white arrow), in coronal fat-suppressed proton density-weighted MR images. A radiohumeral meniscus is a normal variant, similar to the meniscal homologue of the wrist. A meniscus-like tissue can be observed interposed between the radial head and humeral capitellum (yellow arrow).

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**Fig. 7:** Normal right medial or ulnar collateral ligament (MCL or UCL). Color superimposed drawings on a volume rendered MDCT image shows the three bundles of the UCL: anterior (blue), posterior (orange) y transverse (violet). Coronal fat-suppressed proton density-weighted MR image on the right shows the anterior bundle, which runs deep to the common flexor tendon, both of which originate in the medial epicondyle.

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**Fig. 8:** Normal right lateral collateral ligament (LCL) Color superimposed drawings on a volume rendered MDCT image shows the three bundles of the LCL: The radial collateral
ligament (grey), the annular ligament (pink) and the ulnar band of the lateral collateral ligament (blue). Coronal fat-suppressed proton density-weighted MR image shows the radial collateral ligament (arrow), deep to the common extensor tendon, both of which originate in the lateral epicondyle. A pseudodefect of the capitellum (open arrow) and a small posterolateral plicae (arrowhead) are also observed.

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**Fig. 9:** Right radial nerve on axial T1-weighted images. Within the upper arm, the nerve (circle) runs between the brachioradialis (brm) and brachialis muscles (bm). Nerves are made more conspicuous by surrounding perineural fat. The biceps tendon (BT) and the extensor carpi radialis (ecrm) are also indicated. At the proximal margin of the supinator muscle, just superficial to the radiohumeral joint, the nerve divides into the superficial and deep (posterior interosseous nerve) branches

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**Fig. 10:** Right median and cubital nerves at the antecubital fossa on axial T1 (right) and T2 fat-suppressed (left) weighted images. Visualization of the median nerve can be difficult, particularly if there is little surrounding perineural fat. Normal nerves may be slightly brighter on T2-weighted images, and are made more conspicuous by surrounding perineural fat. This effect is most pronounced with the ulnar nerve as it passes through the cubital tunnel. The arcuate ligament, forming the roof of the tunnel, is seen as a slender hypointense band.

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**Fig. 11:** Left anconeus epitrochlearis muscle as a normal variant (solid arrow) on an axial T1-weighted image. This muscle replaces the arcuate ligament, which forms the
roof of the cubital tunnel. The arcuate ligament is indicated with an open arrow in the bottom image, in a different patient). On axial T2 fat-suppressed weighted image, a slight hyperintensity of the ulnar nerve is observed (arrowhead).

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**Fig. 12:** Normal distal biceps tendon. At conventional MR images, longitudinal views are difficult to obtain because of the oblique course of the tendon (arrows). MR images obtained with the patient in the FABS position shows a normal distal biceps tendon (open arrows), the musculotendinous junction (open arrowhead), and the radial tuberosity (solid arrowhead).

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Fig. 13: Medial collateral ligament injury in two different patients. Coronal fat-suppressed proton density-weighted MR images. Left image: partial tear (solid arrow). Right image: the anterior bundle of the UCL presents diffuse increase in signal intensity and thickening reflecting fibrosis and chronic pathology (open arrow).

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**Fig. 14:** LCL injury. Coronal fat-suppressed proton density-weighted MR images. Upper left image shows a normal LCL (solid white arrow). Upper right image shows a full-thickness tear of the ulnar bundle of the LCL (solid blue arrow), as well as injury to the adjacent common extensor tendon (solid yellow arrow). Bottom left image shows bone marrow edema in the medial epicondyle and trochlea (*), as well as a complete tear of the LCL (open blue arrow) and common extensor tendon (open yellow arrow). Bottom right image shows thickening of the LCL, indicative of a chronically torn and remodeled ligament.

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**Fig. 15:** Lateral epicondylitis. Coronal fat-suppressed proton density-weighted MR images. On the left image, a complete tear of the common extensor tendon at its origin from the lateral epicondyle of the humerus is observed (white arrow). On the right image, the common extensor tendon is torn (yellow arrow). Note the presence of an avulsed osseous fragment from the lateral epicondyle (blue arrow).

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Fig. 16: Medial epicondylitis. Coronal fat-suppressed proton density-weighted MR images. On the left image, a partial tear of the common flexor tendon (white arrow) is observed. On the right image, the common flexor tendon origin is usually thickened and shows increased signal intensity (yellow arrow). Note the presence of subtle bone marrow edema in the medial epicondyle (blue arrow).

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**Fig. 17:** Complete tear at the musculotendinous junction of the distal biceps tendon. Note the presence of hematoma (white arrows) adjacent to the ruptured distal biceps tendon (yellow arrows), which is retracted proximally into the arm.

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Fig. 18: Complete tear of the distal biceps and injury to the bicipital aponeurosis. Images obtained with the patient in the FABS position shows a thickened and retracted proximal part of the tendon (white arrows). Note the presence of fluid (yellow arrows) filling the gap and extending to the radial tuberosity.

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Fig. 19: Bifurcated distal biceps brachii tendon. Partial tear of the long head (yellow arrows) and complete rupture and proximal retraction of short head of biceps brachii.
tendon (blue arrows). A strain is also observed at the musculotendinous junction of the short head (white arrow). Note the presence of fluid signal filling the tendinous gaps. Findings are far more conspicuous in the FABS position.

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**Fig. 20:** Tendinopathy of the triceps tendon in two different patients. Upper row: subtle findings of triceps tendinosis, with slight hyperintensity at the insertion of the triceps tendon and musculotendinous junction (white arrows). Bottom arrow: severe triceps tendinosis and enthesitis, with dystrophic calcification of the tendon (yellow arrow), soft tissue edema (solid blue arrow) and bone marrow edema in the olecranon (open blue arrow). Subtle ulnar neuritis is also observed (circle).

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Fig. 21: Osteochondral injury affecting the posterior and medial aspect of the capitellar articular surface (white arrows). Note the presence of a loose body in the coronoid fossa (blue arrows). There is a superb correlation of CT and MR images.

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**Fig. 22:** Osteochondral injuries in two different patients. Upper row: stable osteochondral injury in the anterior and lateral aspect of the capitellum (white arrows), along with little sinovial fluid. Bottom row: Unstable osteochondral injury in the anterior aspect of the capitellum (blue arrows), which shows linear high signal on T2-weighted images along the interface between the fragment and the capitellum.

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**Fig. 23:** Calcified loose body in the coronoid fossa (arrows). It presents low signal intensity in both T1 and fat-suppressed PD sequences. No osteochondral lesion was found.

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Fig. 24: Synovial osteochondromatosis. Several intraarticular loose bodies (yellow arrows) are shown, particularly affecting the coronoid fossa. Moderate joint fluid is also present (white arrow). Degeneration of articular cartilage (blue arrow) and development of marginal osteophytes (not shown) were also found. These findings are typical for secondary osteochondromatosis.

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Fig. 25: Olecranian tophaceous gout. Note the presence of a distended superficial olecranian bursa, filled with a mass-like lesion isointense to muscle on T1WI (flechas blancas) and heterogeneous on T2WI (yellow arrows). Images obtained after administration of contrast material show enhancement of the thickened synovium (blue arrows).

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**Fig. 26:** Olecranon bursitis in three different patients. Left image: mild superficial olecranon bursitis (white arrow). Middle and right images: More severe olecranon bursitis in another patient (yellow arrows), with a fluid-filled bursa with peripheral enhancement and inflammatory changes in adjacent soft tissues, along with bone marrow edema in the olecranon (blue arrow).

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**Fig. 27:** Phlegmonous tricipital myositis (white arrows). Note the presence of bone marrow edema in the olecranon (yellow arrow), inflammatory changes in adjacent soft tissues, synovitis in the ulnohumeral joint (solid blue arrows) and mild olecranon bursitis (open blue arrow).
Fig. 28: Ulnar neuropathy. In the upper row, thickening and hyperintensity of the ulnar nerve along its course in the cubital tunnel is observed (white arrows). No cause was identified and it was thought to be secondary to hypermobility of the ulnar nerve and possible subluxation or dislocation. The patient underwent surgery, and postoperative MR was performed (bottom row). Ulnar nerve transposition is observed, now lying anterior and lateral to the cubital tunnel (yellow arrows). High signal intensity within the nerve is still depicted.
**Fig. 29:** Ulnar neuropathy. In the upper row, thickening and hyperintensity of the ulnar nerve along its course in the cubital tunnel is observed (white arrows). No cause was identified and it was thought to be secondary to hypermobility of the ulnar nerve and possible subluxation or dislocation. The patient underwent surgery, and postoperative MR was performed (bottom row). Ulnar nerve transposition is observed, now lying anterior and lateral to the cubital tunnel (yellow arrows). High signal intensity within the nerve is still depicted.

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**Fig. 30:** Elbow lipoma. Images show a well demarcated soft tissue mass located just lateral and superior to the medial epicondyle, posterior to the brachioradialis muscle and anterior to the triceps muscle. It is isointense to subcutaneous fat in both T1 WI (yellow arrows) and fat-suppressed T2 WI (blue arrow).

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**Fig. 31:** Intramuscular hemangioma. Note the presence of a lobulated mass in the brachioradialis muscle (arrows). The mass presents low signal on T1 WI, high signal on T2 WI and a progressive enhancement at contrast-enhanced MR imaging.

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**Fig. 32:** Subcutaneous AVM of the elbow. Note the presence of a vascular mass in the subcutaneous fat of the posterior aspect of the elbow, close to the olecranon (arrows). MR angiography (bottom arrow) shows the feeding arteries (originating from the superior and inferior ulnar collateral arteries) and venous drainage through the basilic vein.

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**Fig. 33:** Peripheral nerve sheath tumor. Note the presence of a small nodule within the lateral head of the triceps muscle. The lesion is well delineated, slightly hyperintense to muscle on T1 WI (white arrow), present cystic foci on T2WI (yellow arrow) and presents enhancement of the solid component (blue arrow).

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Fig. 34: Elbow leiomyosarcoma. A large ovoid and lobulated mass is observed in the subcutaneous fat of the medial aspect of the elbow. The mass presents heterogeneous high signal intensity foci on T1WI, related to hemorrhagic contents (white arrows), and heterogenous high signal intensity on T2WI (yellow arrows). Irregular enhancement of the mass is observed (solid blue arrows). Note the presence of intravascular invasion, as the lesion extends into the basilic vein (open blue arrow).

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Conclusion

MR imaging allows visualisation of elbow abnormalities not possible with other imaging modalities. The radiologist who specialises in MR imaging must have a thorough understanding of normal elbow anatomy and must pay close attention to positioning and imaging technique to optimize image quality.

The most common pathologies affecting the elbow have been reviewed and illustrated, including collateral ligamentous injuries, tendinopathy (lateral and medial epicondylitis, biceps and triceps tendon injuries), osteochondral injuries and intraarticular bodies, inflammatory or infectious arthritis and bursitis, neuropathies of the median, radial and ulnar nerves and soft-tissue abnormalities.
References


Personal Information

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Should you have any question, please do not hesitate and contact me: rcanoalonso@gmail.com