

Optimisation of Elbow MRI Technique and Normal Anatomy

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ANATOMY

- Trochoginglymoid joint
- 3 coupled articulations
 - Ulna-humeral
 - Radio-capitellar
 - Proximal radio-ulnar
- Normal motion
 - 0-140 degrees flexion / extension
 - 75 degrees pronation to 80 degrees supination
- Stabilizers
 - Highly conforming articular surfaces (static)
 - Capsulo-ligamentous structures (static)
 - Musculo-tendinous (dynamic)

1) OSSEOUS

a) Distal humerus

- Trochlea
 - Highly conforming articulation with greater sigmoid notch of ulna in all degrees of elbow flexion
 - Oriented approx 30 degrees anterior to humeral shaft
- Capitellum
 - Wider at volar / anterior margin c/w dorsal / posterior margin
 - Oriented approx 30 degrees anterior to humeral shaft
 - Capitellar pseudodefekt
 - Normal groove at the lateral, dorsal margin of the capitellum
- Carrying angle: 10-20 degrees valgus
- Epicondyles
- Supracondylar ridge
- Supracondylar process
- Radial fossa
- Coronoid fossa
- Olecranon fossa

b) Proximal ulna

- Olecranon process
 - Os supratrochleare dorsalis
- Coronoid process
- Trochlear (greater sigmoid) notch
- Trochlear ridge
 - Usually in midline
 - Not covered by articular cartilage
 - Can mimic a central osteophyte
- Trochlear groove (pseudo-defect)
 - At medial and lateral margins of trochlear notch
- Sublime tubercle (insertion ant bundle UCL)
- Supinator crest (LUCL insertion)
- Radial notch

c) Proximal radius

- Radial head
 - Little conformational stability with capitellum
 - Lateral pseudo-subluxation relative to radial head in extension
 - Provides 30 % of valgus stability
 - Highly conforming with lesser sigmoid notch of ulna
- Radial tuberosity
 - Biceps insertion

2) CAPSULE

- Deep synovial lining
- Superficial fibrous layer
- Attachments
- Fat pads (extrasynovial but intra-articular)
 - Anterior (capitellar & trochlear fossae)
 - Posterior (olecranon fossa)
- Recesses
 - Olecranon recess (3 sub-divisions)
 - Superior olecranon
 - Medial & lateral olecranon recesses
 - Anterior humeral recess (2 sub-divisions)
 - Coronoid fossa recess
 - Radial fossa recess
 - Collateral ligament recesses
 - Deep to collateral ligaments
 - Annular / peri-radial recess
- Synovial folds
 - Lateral synovial fold / fringe
 - Variable morphology
 - Normally <3mm thick and smooth margins

3) LIGAMENTS

a) Ulnar / medial collateral ligament

i) Anterior bundle

- Discrete structure separate to joint capsule
- Two layers
- Broad based origin at central 65% of the anterior / inferior surface medial humeral epicondyle
- Distal insertion sublime tubercle, variably flush with articular margin medial coronoid
- Length 2cm, width 0.8cm
- Primary stabilizer against valgus stress in extension (contributes 70 % of valgus stability)
- Functionally: anterior and posterior bands
 - Anterior band taut for the first 60° of flexion
 - Posterior band taut from 60° to 120° of flexion
- Best seen on coronal MR as uniformly low signal structure
 - In skeletally immature, high signal may be evident at prox and distal aspects of the normal UCL/ MCL

- Prox fibres may appear lax in extension
- Synovial invagination deep to humeral attachment
- ii) Posterior bundle**
 - Proximal insertion inferior margin medial humeral epicondyle
 - Distal insertion postero-medial margin trochlear notch
 - Fan shaped
 - Forms floor of cubital tunnel
 - Stabilizer to valgus stress in more than 90 degrees flexion
 - Best seen on transverse MR images with elbow in flexion
- iii) Transverse bundle**
 - Attaches to ulnar insertions of anterior and posterior bundles
 - No functional significance
- b) Radial / Lateral Collateral Ligament Complex**
 - i) Radial collateral ligament**
 - Proximal insertion lateral humeral epicondyle
 - Distal insertion broadly on annular ligament
 - Lies deep to common extensor origin
 - Best seen on coronal MR images
 - ii) Annular ligament**
 - Attachments at anterior / posterior margin radial notch
 - Stabilizes proximal radio-ulnar joint
 - Anterior component taut in supination
 - Posterior component taut in pronation
 - iii) Lateral ulnar collateral ligament**
 - Proximal insertion lateral humeral epicondyle
 - Distal insertion sublime tubercle prox ulnar
 - Variations:
 - cordlike (bilobed)
 - fanlike (conjoined)
 - “Cradles” postero-lateral radial head
 - Blends with annular ligament
 - Stops posterior & lateral translation of radial head in extension
 - Best seen on sequential coronal images due to oblique course
 - Some authors have advocated oblique coronal scan plane angled 20 degrees from coronal to assess LUCL, however this is not widely utilised

4) MUSCLES AND TENDONS

a) Common Extensor Origin

- Lateral humeral epicondylar common origin of:
 - extensor carpi radialis brevis (ECRB)
 - extensor digitorum
 - extensor digiti minimi
 - extensor carpi ulnaris
- ECRB is dominant component
- Immediately superficial to radial collateral ligament
- Radial humeral bursa
 - Lies deep to ECRB origin and superficial to radial collateral ligament

- EDC makes up most of superficial component of origin
- Best seen on coronal MR images as a uniformly hypointense structure
- ECRB, EDC not discernible as separate structures on MRI
- b) Extensor carpi radialis longus (ECRL)**
 - Arises from supracondylar ridge
- c) Supinator**
 - 2 heads originating from lateral humeral epicondyle and supinator crest of proximal ulna
 - Inserts on radial shaft
 - Posterior interosseous nerve passes between 2 heads of supinator
- d) Common flexor origin**
 - Medial humeral epicondylar origin of:
 - flexor carpi radialis
 - palmaris longus (absent in up to 13%)
 - flexor carpi ulnaris (humeral head but not ulnar head)
 - flexor digitorum superficialis (humero-ulnar head but not radial head)
 - Dynamic stabilizer to valgus stress
 - Best seen on coronal MR images as a uniformly hypointense structure
- e) Distal biceps brachii tendon**
 - Forms from union of tendons of the short and long heads 7 cm above insertion
 - Inserts on radial tuberosity at medial aspect of proximal radius
 - Bicipital aponeurosis / lacertus fibrosus arises from biceps tendon and inserts on investing fascia of flexor pronator muscle group
 - No tendon sheath
 - Bicipito-radial bursa surrounds distal biceps
 - Elbow flexor and supinator
 - Dynamic elbow stabilizer
 - On standard MR elbow studies, biceps best seen on axial and sagittal images
- f) Distal triceps tendon**
 - Lateral, long & medial heads have common tendinous insertion on olecranon
 - Non-tendinous, muscular component of triceps insertion deep to tendon insertion
 - Best seen on sagittal and axial MR images
 - Normal high signal striations on MR

5) NERVES

a) Ulnar nerve

- Formed by medial cord brachial plexus (C8 / T1)
- Courses medial to axillary / brachial artery in upper arm
- Pierces medial intermuscular septum at mid-arm to enter posterior compartment
- Courses medial to medial head triceps, usually within a fibrous tunnel created by a fibrous band joining medial intermuscular septum to tendon of medial head triceps
- Passes through **cubital tunnel** at medial humeral epicondylar level, borders formed by
 - medial humeral epicondyle

- medial edge of trochlea / olecranon
- ulnar collateral ligament
- arcuate / Osbourne's ligament
 - forms roof of tunnel
 - absent in 23 %
- Posterior recurrent ulnar artery and vein traverse cubital tunnel
 - High signal on fat sat PD images
 - May be misinterpreted as oedematous ulnar nerve fascicles
- Anconeus epitrochlearis is an anomalous muscle at superficial margin of cubital tunnel
 - Occurs in approx 1/3rd population
 - Occasionally may cause ulnar neuropathy
- Ulnar nerve subluxes anteriorly out of cubital tunnel in approximately 16 % of asymptomatic elbows
- Motor branches at elbow
 - Flexor carpi ulnaris
 - Flexor digitorum profundus (3 & 4)
- Then passes between 2 heads of flexor carpi ulnaris
- Traverses deep flexor pronator aponeurosis
- Deep motor branch in the hand supplies muscles of hypothenar eminence, deep head flexor pollicis brevis, adductor pollicis, interossei and lumbricals 3 & 4
- Best visualised on axial non fat suppressed MR images

b) Radial nerve

- Derived from posterior cord brachial plexus (C5-T1 nerve roots)
- Spirals posteriorly along mid-humeral shaft
- Pierces lateral intermuscular septum 10cm prox to lateral epicondyle
- Motor supply in arm
 - Triceps
 - Anconeus
- Passes between brachioradialis and brachialis
- Motor branches proximal to supinator tunnel
 - Brachioradialis
 - Extensor carpi radialis longus
 - Extensor carpi radialis brevis
 - Supinator
- Divides into superficial and deep branches at the elbow
 - Superficial branch (sensory) courses beneath brachioradialis, accompanying radial artery
 - Deep branch (posterior interosseous nerve) traverses the **radial tunnel** which extends from capitellar level to distal margin of supinator
- Distal radial tunnel passes between 2 heads of supinator
- Proximal radial tunnel formed by fibrous bands of adjacent muscles, including proximal border of superficial head of supinator and variably present (30-50 %) arcade of Frohse – fibrous adhesion between brachialis and brachioradialis muscles

- Recurrent radial arterial branches (leash of Henry) also demarcate radial tunnel
- Posterior interosseous nerve then passes along dorsal margin interosseous membrane
- Motor branches distal to supinator tunnel
 - Extensor digitorum
 - Extensor carpi ulnaris
 - Extensor digiti minimi
 - Abductor pollicis longus
 - Extensor pollicis brevis
 - Extensor pollicis longus
 - Extensor indicis
- Best visualised on axial non fat suppressed MR images

c) Median nerve

- Derived from medial and lateral cords brachial plexus (C6-8)
- Courses medial to brachial artery and distal biceps tendon
- Passes superficial to ulnar head of pronator teres and deep to humeral head (potential site of compression)
- Gives off anterior interosseous nerve branch which provides motor branches to
 - Flexor digitorum profundus (2 & 3)
 - Flexor pollicis longus
 - Pronator quadratus
- Then passes deep to the fibrous arch formed by the 2 heads of FDS and runs between FDS and FDP (potential site of compression)
- Often minimal perineural fat, limiting visualisation on MR
- Motor supply in forearm
 - Pronator teres
 - Flexor carpi radialis
 - Palmaris longus
 - Flexor digitorum superficialis
 - Motor supply in hand
 - Abductor pollicis brevis
 - Opponens pollicis
 - Superficial head flexor pollicis brevis
- Anatomic variants that can cause median nerve compression at the elbow
 - Supracondylar process and ligament of Struthers
 - High bifurcation brachial artery
 - High origin pronator teres
 - Anomalous insertion coracobrachialis

6) BURSAE

- Olecranon Bursa
- Bicipito-radial bursa
- Radial humeral bursa

MRI TECHNIQUE

1) FIELD STRENGTH

- Higher field strength MR scanners produce higher SNR images and facilitate reduced scan times and reduced motion artefact and or increased spatial resolution studies

2) PATIENT POSITIONING & COIL SELECTION

a) Patient supine, arm by side, forearm supinated

- Greater patient comfort, minimising motion artefact
- Require relatively low profile coil and good off isocenter gradient performance
- Coil options
 - Rigid planar coils (single or paired)
 - Flex coils (preferably phased array construct)
 - Low profile “bird cage” coils
- If flexion contracture, surface coil should be placed over flexed elbow, with the patient's arm at the side and the hand resting on the abdomen. Tangential axial views then may be prescribed from the sagittal images in flexion and “coronal” images along long axis of radius / ulna for best depiction of collateral ligaments and flexor pronator origin and extensor origin.

b) Superman position (arm above head)

- Facilitates use of phased array knee / extremity coil that cannot be used with arm by side, providing advantage of increased SNR
- Fixation of coil to table minimises motion artefact
- Rigid tubular construct allows use of pads to elevate the elbow and “wedge” the elbow in the coil, minimising motion artefact
- Positions elbow closer to isocenter
- On older MR units with limited gradient performance, this may be advantageous
- Newer MR units tend to have good isocentre gradient performance
- Patient position may vary from semi-decubitus to prone, depending on patient comfort
- Additional pads
 - in axilla
 - between head and coil
 - under hand
 - between knees if pt decubitus
- Strap on wrist / hand
- Sand bags may be placed on forearm – often poorly tolerated
- Supination often poorly tolerated (80 %)
- Poorly tolerated by patients with shoulder pathology (frozen shoulder, glenohumeral joint OA) or irritable brachial plexus
- Limited proximal coverage in the arm
 - May be an issue for imaging triceps injuries and distal humeral shaft pathology & rarely for distal biceps rupture

c) Pulse Sequences

- Pulse sequences should be optimized to provide high contrast and spatial resolution images of ligaments, tendons, and articular cartilage.
 - Articular cartilage in the elbow is thin and distributed over highly curved surfaces, making MR assessment difficult. There are no

published studies describing the accuracy of MRI in assessment of articular cartilage in the elbow.

- The commonly chronic, attritional nature of pathology in the ulnar collateral ligament often results in subtle abnormalities on MRI, sometimes consisting of subtle signal hyperintensity only appreciable on intermediate to short TE sequences, without macroscopic ligament fibres discontinuity.
- In addition to satisfactory in plane resolution as a result of a large acquisition matrix, spatial resolution is also achieved by use of a thin slice technique, 2mm or less for coronal sequences and 3mm or less for sagittal and axial sequences.
- Typical routine elbow MR protocols will involve a combination of proton density and fat suppressed proton density sequencing.
 - Magic angle artefact is rarely an issue in the elbow that might necessitate the use of more highly T2 weighted sequencing.
- If off isocentre frequency selective fat suppression on an MR unit is limited then STIR sequencing or the newer IDEAL sequence may be used
- Volumetric sequencing allows thinner slice thickness, by virtue of the inherently improved signal to noise.
 - 3D gradient echo sequencing, usually T2* weighted has been used by several centres to provide detailed elbow ligamentous assessment.
 - 3D proton density sequencing is a promising new MR technique that may provide improved assessment of articular cartilage and subtle ligamentous pathology.
- MR arthrography has been advocated as a means of improving assessment for ligamentous injury and loose bodies.
 - This converts a non-invasive test into an invasive one and increases the cost of the examination.
 - Many centres have found that use of a high spatial and contrast resolution MR technique provides satisfactory assessment of ligamentous and chondral pathology.
 - There are no rigorous published studies comparing MR arthrography with a high spatial and contrast resolution non-arthrographic technique.
- A routine elbow protocol will address most clinical scenarios.
- A tailored approach may be required for imaging the distal biceps, when clinically it is not clear whether there is a complete tear or partial tear.
 - In this setting, a large field of view sagittal fat suppressed PD sequence is performed and reviewed.
 - If there is clearly a complete rupture, then axial and coronal fat suppressed PD sequencing is performed and reviewed.
 - If no complete distal biceps tear is evident, then oblique axial 3mm PD and fat suppressed PD sequencing perpendicular to the distal biceps is performed, with additional thin section (2mm) oblique coronal PD sequencing plotted off a sagittal image along the distal biceps is performed. Finally an oblique thin section (2mm) sagittal PD sequence may be plotted along the distal biceps off the oblique coronal PD sequence.
 - The use of a sequence performed with the arm in the ABER position and elbow flexed to 90 degrees has been advocated as a means of

imaging the biceps tendon in an orientation that is perpendicular to its insertion on the radial tuberosity.

- If there is a specific clinical question as to the status of the posterior band of the ulnar collateral ligament, then imaging of the elbow in flexion is indicated, using transverse scans plotted perpendicular to the proximal ulna.
- Medial humeral epicondylar apophysis may be injured in the skeletally immature throwing athlete. MR assessment should include a fat suppressed T1 gradient echo sequence
- In the post-operative setting, artefact due to orthopaedic hardware may be minimised by increasing bandwidth, reducing TE and increasing the number of signal averages
- MR angiography may occasionally be used to assess for traumatic vascular injury, utilising either a contrast enhanced or time of flight technique.