MRI of the Elbow – Update 2024

MRT des Ellenbogens – Update 2024

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ABSTRACT

Background Elbow pain can result in significant morbidity. MRI can help diagnosing the cause of elbow pain.

Methods Based on a systematic literature search as well as knowledge gained through frequent participation in conferences dedicated to advances in musculoskeletal imaging, this review aims to give a brief overview of normal anatomy and common pathologies of tendons and ligaments of the elbow on magnetic resonance imaging.

Results Stabilization of the elbow joint is provided by osseous structures and passive ligamentous and active muscular support. Loss of these important stabilizers, due to trauma and overuse, can result in elbow instability. Additional MR views or intra-articular contrast media can be useful for the detection of specific pathologies.

Conclusion MRI is frequently used to detect posttraumatic or chronic conditions, which can lead to posterolateral or posteromedial elbow instability. Knowledge of normal anatomy, variants, pathologies, as well as appropriate imaging is crucial to make the diagnosis.

Key Points

- Epicondylitis occurs due to chronic degeneration with tendinosis and partial tendon tearing and is not related to an acute inflammatory reaction.
- Posterolateral or posteromedial elbow instability can be the result of trauma with loss of passive ligamentous and active muscular stabilization.
- The most common elbow instability is posterolateral rotatory instability with the LUCL being the most important stabilizer affected by injury.

Citation Format

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ZUSAMMENFASSUNG

Hintergrund Ellbogenschmerzen können eine signifikante Morbidität hervorrufen. Die MRT kann helfen, den Grund der Ellbogenschmerzen zu diagnostizieren.

Methoden Basierend auf einer systematischen Literaturrecherche sowie Erkenntnissen, die durch eine häufige Teilnahme an Konferenzen zu Fortschritten in der muskuloskelettalen Bildgebung gewonnen wurden, soll dieser Review einen kurzen Überblick über die normale Anatomie und häufige Pathologien der Sehnen und Ligamente des Ellenbogens in der Magnetresonanztomografie geben.

Ergebnisse Die Stabilisierung des Ellenbogens wird durch knöcherne Strukturen, passive Ligamente und aktive muskuläre Unterstützung gewährleistet. Ein Verlust dieser wichtigen Stabilisatoren, durch Trauma oder Überbeanspruchung, kann in einer Ellbogeninstabilität resultieren. Zusätzliche MR-Ansichten oder intraartikulär appliziertes Kontrastmittel können in der Detektion spezifischer Pathologien nützlich sein.

Schlussfolgerung Die MRT dient zum Erkennen posttraumatischer und chronischer Pathologien, welche eine posterolaterale oder posteromediale Ellbogeninstabilität hervorrufen können. Kenntnis der normalen Anatomie, Varianten, Pathologien sowie der geeigneten Bildgebung ist entscheidend, um die Diagnose zu stellen.

Kernaussagen
- Eine Epikondylitis entsteht aufgrund einer chronischen Degeneration, Tendinose und Partialruptur der Sehnen und beruht nicht auf einer akuten inflammatorischen Reaktion.
- Die posterolaterale oder posteromediale Ellbogeninstabilität kann Resultat eines Traumas sein mit konsekutivem Verlust der passiven ligamentären und aktiven muskulären Stabilisatoren.
- Die häufigste Ellbogeninstabilität ist die posterolaterale Instabilität mit Verletzung des LUCL, welches der wichtigste Stabilisator ist.

Abbreviations

ALF	anterolateral facet of the coronoid process
AMF	anteromedial facet of the coronoid process
aUCL	anterior bundle of the ulnar collateral ligament
CT	computed tomography
FABS	flexion, abduction, and supination
FOOSH	fall on outstretched hand
LUCL	lateral ulnar collateral ligament
MR	magnetic resonance
MRI	magnetic resonance imaging
PLRI	posterolateral rotatory instability
PMRI	posteromedial rotatory instability
pUCL	posterior bundle of ulnar collateral ligament
RCL	radial collateral ligament
SMILE	symptomatic minor instability of the lateral elbow
UCL	ulnar collateral ligament

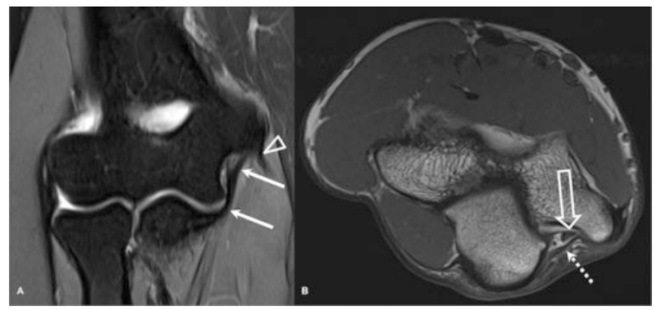
Introduction

Elbow pain encountered in clinical practice can result, particularly in athletes, in significant morbidity. Chronic degenerative damage and acute lesions of ligaments and tendons are primarily assessed clinically. Magnetic resonance imaging (MRI) is a frequent, supplementary diagnostic tool in unclear cases, for the detection of secondary findings and for preoperative planning due to its excellent soft tissue contrast. Anatomical knowledge of the supporting structures, which provide stability to the elbow joint, is essential to assess different anatomical characteristics in terms of morphology and signal behavior and to correctly diagnose pathological findings.

Medial Compartment

Medial ligaments

The ulnar collateral ligament (UCL) is the main stabilizer against valgus elbow stress and posteromedial rotatory instability [1]. The ulnar collateral ligament complex (▶ **Fig. 1**) consists of the anterior bundle (aUCL), the posterior bundle (pUCL), and the transverse bundle (Cooper's ligament) of the ulnar collateral ligament. The origin of the aUCL and pUCL is the anteroinferior surface of the medial epicondyle. Due to an origin posterior to the axis of the elbow, with increasing flexion the ligament tension increases. The aUCL inserts distal to the coronoid tip, at the sublime

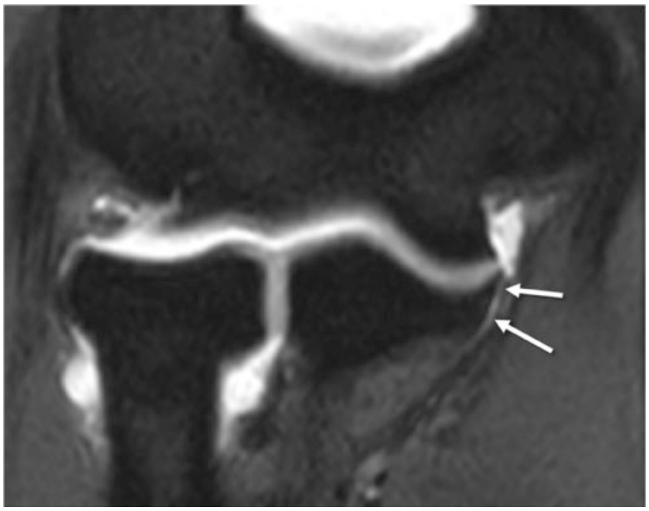


▶ **Fig. 1** Proton density (PD) fat-saturated coronal **A** and axial **B** T1-weighted MR images. Medial elbow anatomy. **A** shows the anterior bundle (aUCL; arrows) of the ulnar collateral ligament complex and the flexor tendon aponeurosis (arrowhead). **B** depicts the posterior bundle (pUCL; open arrow) of the ulnar collateral ligament complex and the arcuate ligament of Osborne (dashed arrow).

tubercle along the medial aspect of the coronoid tip [2]. The majority of the restraint to valgus and posteromedial rotatory instability is provided by the aUCL, which is composed of two portions [1]. These components are typically not seen as separate structures on MRI. On MRI the aUCL has a proximal hyperintense striped appearance which should not be misinterpreted as a pathologic finding (▶ **Fig. 1A**) [3]. The pUCL inserts along the midportion of the medial margin of the semilunar notch and forms the floor of the cubital canal, and is a fan-shaped thickening of the capsule (▶ **Fig. 1B**) [2]. The transverse ligament does not significantly contribute to joint stability, especially since its origin and insertion are located on the ulna and it does not connect two different bones like other ligaments. It runs from the olecranon to the posterior portions of the anteromedial facet of the coronoid process [4]. The transverse ligament cannot always be seen on MRI [5].

Injuries of the medial ligaments

The UCL, especially its anterior bundle (aUCL), is the most important stabilizer against valgus stress [6]. Athletes in overhead sports, e. g. baseball, commonly endure UCL injuries, which can result in valgus instability [7]. Due to repetitive valgus stress to the elbow, increased laxity and medial instability of the UCL can occur. The final tear can arise during a throwing motion when forces exceed the tensile strength of the anterior bundle [8]. Valgus extension overload syndrome forms the basic pathophysiologic model behind the most common elbow injuries in throwing athletes [9]. Ligament weakening or failure can occur when forces



▶ **Fig. 2** MR arthrography with T1 fat-saturated coronal MR image of a 27-year-old female shows a partial tear (arrows) of the anterior bundle of the ulnar collateral ligament with fluid between the ligament and the sublime tubercle, indicating a T sign.

near the rupturing point of the aUCL are applied during throwing [10]. Additionally, in severe cases of elbow dislocation alongside injuries of the lateral stabilizers, the UCL can also be torn, leading to valgus instability [11].

MRI has become the examination of choice in evaluating elbows with clinically suspected UCL injury [11]. MRI has been reported to have a sensitivity for partial-thickness tears of 14% only [8, 12]. In throwing athletes, the addition of a recently described flexed elbow valgus external rotation (FEVER) view resulted in increased diagnostic confidence and recognition of abnormal or torn UCL lesions, which were classified as normal on standard MR views [13]. Schwartz et al. showed in their study that intra-articular contrast agent can increase sensitivity for partial-thickness tears to 86%, with a 100% specificity [14]. The "T sign" indicates distal partial aUCL tearing and is seen especially on direct MR arthrography when injected contrast extends distally from the joint line along the cortical margin of the sublime tubercle of the ulna on coronal images (▶ **Fig. 2**) [15]. Of note, another indication for direct MR arthrography of the elbow is to assess chondral and osteochondral abnormalities [16].

Additionally, continued microtrauma may produce olecranon tip osteophytes, intraarticular loose bodies, and articular damage.

The concept of posteromedial rotatory instability will be discussed further below.

Medial muscles

The flexor-pronator muscle complex compresses the elbow joint, supports osseous stability, and provides dynamic stability to valgus stress [1, 2, 17]. The medial muscle group is divided into three layers. All muscles except for the flexor digitorum profundus muscle originate from the common flexor muscle origin with some fibers connecting to the UCL. The common flexor muscle origin forms an aponeurosis originating from the medial epicondyle (▶ **Fig. 1A**). The superficial layer consists of the pronator teres, flexor carpi radialis, palmaris longus, and flexor carpi ulnaris muscles. The middle and deep layer consist of the flexor digitorum superficialis and profundus muscles [18]. The roof of the cubital tunnel is formed by a band of fibrous tissue, which spans between the humeral and ulnar heads of the flexor carpi ulnaris muscle, i. e., Osborne's ligament also referred to as arcuate ligament of Osborne (▶ **Fig. 1B**). The ulnar nerve traverses in the cubital tunnel between the two heads of the flexor carpi ulnaris muscle [19].

Medial tendon pathologies

Abnormal morphology of the tendons, such as signal attenuation changes or thickening, is seen in tendinosis or tears, which can be best evaluated on coronal and axial sequences [5, 20]. A tear is characterized by interruption of tendon fibers. These defects are usually filled with fluid and thus are best visualized on fluid-sensitive sequences. Chronic stress to the common flexor tendons can cause medial epicondylitis, which is also known as golfer's elbow. The term epicondylitis is actually a misnomer because the underlying pathology is chronic degeneration with tendinosis and partial tendon tearing and is not related to an acute inflammatory reaction. The most probable hypothesis is that microscopic tears due to repetitive overload of the tendon cause an epicondylitis [20]. The most commonly affected muscles are the flexor carpi radialis, pronator teres, and palmaris longus muscles [18].

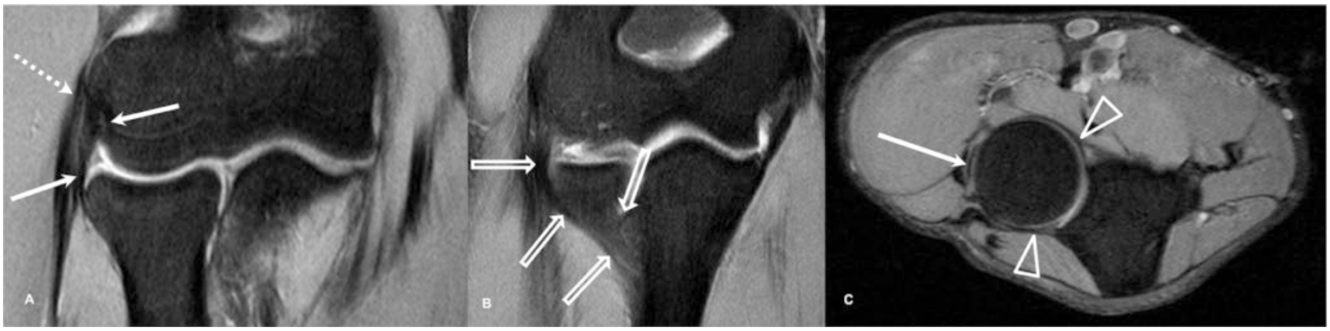
Lateral Compartment

Lateral ligaments

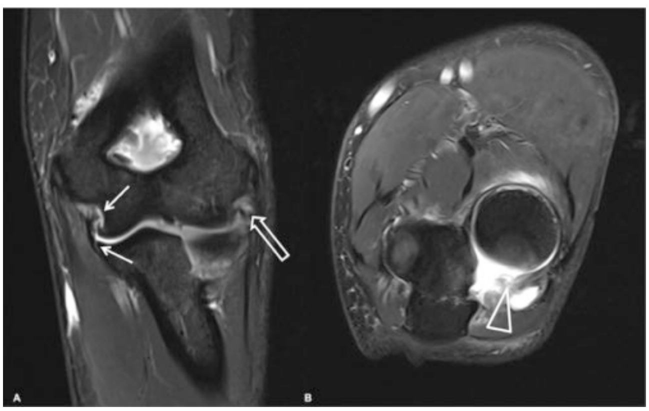
The lateral collateral ligament complex consists of three primary structures: the radial collateral ligament (RCL), the lateral ulnar collateral ligament (LUCL), and the annular ligament (▶ **Fig. 3**). The RCL arises from the inferior surface of the lateral epicondyle and has a wide insertion into the annular ligament [21]. The annular ligament surrounds the radial head, and thus maintains its contact with the ulna in the proximal radioulnar joint. It consists of a strong band of tissue originating and inserting at the anterior and posterior margins of the lesser sigmoid notch of the ulna [22]. The LUCL forms a posterior sling to support the radial head and functions as the primary stabilizer to varus stress. It arises from the lateral epicondyle, passes posterior to the radial head, and inserts into the supinator crest of the ulna [21]. The small fibers of the accessory lateral collateral ligament originate on the supinator crest of the ulna and blend with the inferior margin of the annular ligament. An additional accessory lateral collateral ligament was described in one-third of individuals [2, 23]. The function of the accessory collateral ligament is to stabilize the annular ligament during varus stress [24]. However, MR visibility of this accessory ligament has not been described in the literature to our knowledge yet.

Injuries of the lateral ligaments, posterolateral and posteromedial rotatory instability, symptomatic minor instability of the lateral elbow (SMILE)

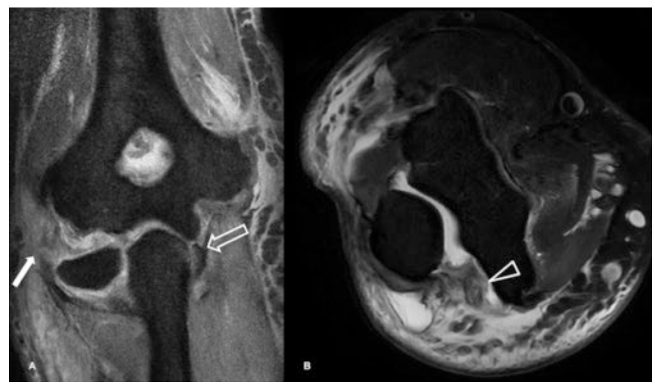
Loss of integrity of the LUCL, as an important element of the capsuloligamentous complex, contributes to posterolateral rotatory



▶ **Fig. 3** PD fat-saturated coronal **A**, **B** and axial **C** MR images. Lateral elbow anatomy with the lateral collateral ligaments of the elbow. **A** shows the extensor tendon aponeurosis (dashed arrow) and the radial collateral ligament (RCL; arrows). The lateral ulnar collateral ligament (LUCL; open arrows) is shown in **B**. **C** depicts the insertion of the RCL (arrow) at the annular ligament (AL; arrowheads).



▶ **Fig. 4** PD fat-saturated coronal **A** and axial **B** MR images of a 42 year-old female artist with posterolateral rotatory instability after an injury performing a handstand on one arm. **A** The arrows point at a partially disrupted anterior bundle of the ulnar collateral ligament proximally and distally (distally showing a T sign). The open arrow points at a partially torn lateral ulnar collateral ligament. **B** The arrowhead points at a completely torn and retracted posterior insertion of the annular ligament.



▶ **Fig. 5** PD fat-saturated coronal **A** and axial **B** MR images of a 64 year-old male with posteromedial rotatory instability. **A** The arrow points at a proximally ruptured and retracted LUCL. The open arrow shows a fracture at the anteromedial facet of the coronoid process, where the anterior band of the ulnar collateral ligament inserts. **B** The arrowhead points at a disrupted posterior bundle of the ulnar collateral ligament complex.

instability [25]. *Posterolateral rotatory instability (PLRI)* commonly occurs due to trauma (▶ **Fig. 4**). Most often patients suffered an elbow dislocation or a fall on an outstretched hand, i. e. "FOOSH injury", with a forceful valgus moment while the forearm was in supination [26]. This is the most common type of elbow dislocation and the most frequent cause of recurrent elbow instability [11]. A supination force coupled with valgus stress can result in rupture of the LUCL and the posterolateral parts of the capsule and thus in dislocation. The LUCL is considered the primary stabilizer of the elbow, especially against PLRI [11]. In cases of severe instability, additional lateral stabilizers such as the RCL, parts of the annular ligament, and common extensor tendons are often injured [27]. This disruption of some or all of the lateral-sided stabilizers is due to posterior displacement of the radial head relative to the capitellum of the humerus [28]. These can result in fractures of the coronoid process and radial head [29]. "Horii circle" describes that injuries tend to occur from lateral to medial with three stages of soft-tissue injuries according to O'Driscoll [30]:

1. In stage one, the LUCL is torn.
2. In stage two, the other lateral ligamentous structures, and the anterior and posterior capsule are disrupted.
3. In stage three, a disruption of the medial side, i. e. the ulnar collateral ligament complex occurs.

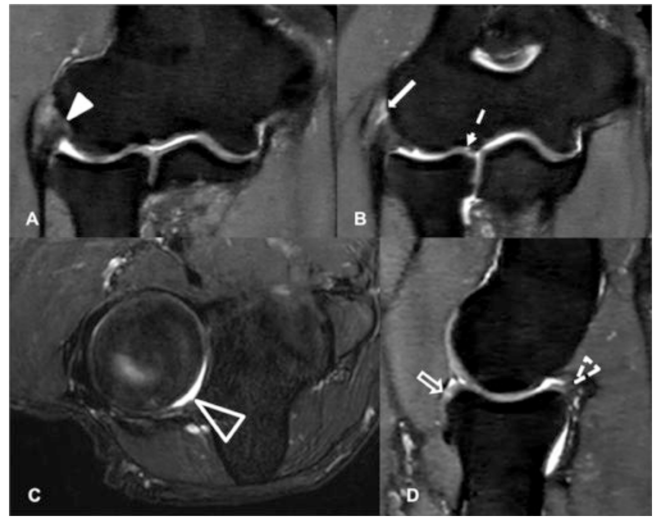
PLRI is often a clinical diagnosis. However, to evaluate fractures, subluxation, or dislocation, plain radiographs or computed tomography (CT) should be performed. A distance > 3 mm between the humerus and ulna (the "drop sign") can be a sign of PLRI and can also be noticed on sagittal CT and MR imaging. MRI is an excellent tool to diagnose ligament injuries due to PLRI. However, in chronic PLRI cases, injuries of the LUCL are not always easily identifiable on MRI [11, 31].

Posteromedial rotatory instability (PMRI) occurs after an axial and varus load with the forearm in pronation which causes a rupture of the RCL and a fracture to the anteromedial facet of the coronoid process (▶ **Fig. 5**). Additionally, the pUCL has to be disrupted for a gross subluxation of the elbow to occur [32, 33].

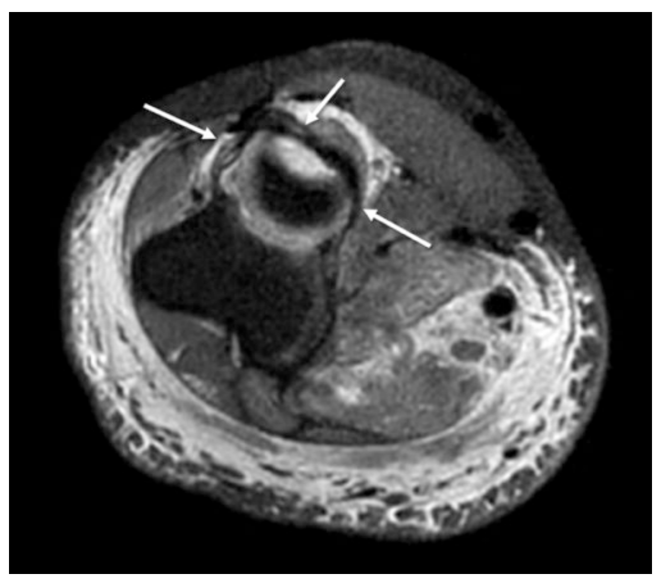
▶ Table 1 Comparison of typical injuries in posteromedial and posterolateral rotatory instabilities.

Finding	PLRI (posterolateral rotatory instability)	PMRI (posteromedial rotatory instability)
Radial head fracture	Commonly present	Commonly absent
Coronoid process fracture	Tip of the coronoid/ALF	AMF
Lateral ligamentous injury	LUCL most commonly	Disruption of the RCL and LUCL at the humeral origin
Medial ligamentous injury	aUCL is commonly involved in severe stages	pUCL is commonly involved in severe stages

Abbreviations: ALF (anterolateral facet of the coronoid process), AMF (anteromedial facet of the coronoid process), LUCL (lateral ulnar collateral ligament), RCL (radial collateral ligament), aUCL (anterior band of ulnar collateral ligament), pUCL (posterior band of ulnar collateral ligament).



▶ Fig. 6 PD fat-saturated MR images (coronal view in **A** and **B**, axial view in **C**, and sagittal view in **D**) of a 61-year-old male with chronic lateral epicondylitis, possibly due to symptomatic microinstability of the lateral elbow (SMILE). **A** The radial collateral ligament shows thickening and signal alterations (arrowhead). **B** A partial tear is present at the extensor tendon aponeurosis (arrow), consistent with lateral epicondylitis, and a cartilage fissure is present at the trochlear ridge (dashed arrow). **C** The annular ligament is elongated with widening of the proximal radioulnar joint (open arrowhead). **D** A deep cartilage fissure is present at the radial head (open arrow) and synovial thickening posterior to the radial head (dashed arrowhead). Of note to compare with normal anatomy see ▶ **Fig. 3**.



▶ Fig. 7 T2-weighted fat-saturated MR image of an 11-year-old boy with valgus trauma shows a luxation of the annular ligament into the humeroradial joint (arrows).

Similarities and differences between the two instability types are summarized in ▶ **Table 1**.

Iatrogenic causes of LUCL injuries can be multiple corticosteroid injections (e. g. for lateral epicondylitis), inadequate repair of the LUCL, or too extensive debridement of epicondylitis [27].

Lateral epicondylitis is generally considered an extra-articular condition [34]. However, Arrigoni et al. recently described a high incidence of intra-articular pathological findings due to an associated laxity of the RCL in patients with permanent lateral elbow pain [35]. They introduced a new concept of *symptomatic minor instability of the lateral elbow (SMILE)* showing that over 85 % of patients with lateral epicondylitis demonstrate at least one intra-articular pathology on arthroscopy, postulating the following cascade [34]:

1. Elongation of the RCL and annular ligament with relative hypermobility of the radial head.
2. Incongruence of the proximal radioulnar joint resulting in radial head impingement and chondropathy as well as joint inflammation leading to intra-articular synovitis.
3. Abrasion or shear of the stretched RCL/anterolateral capsule over the lateral portion of the capitellum in the elbow varus and pronation with a risk of capitellum lesion or capsular tears.

To date, only one radiological CT-arthrography-based study has described possible radiological findings [36], and there are no MR studies. The SMILE concept is still new in the orthopedic literature and until now has only been addressed by one study group. Thus, this pathological concept needs to be further validated in future studies. A possible MR case of SMILE is shown in ▶ **Fig. 6**.

In cases of pulled elbow (i. e., “nursemaid’s elbow”) and Monteggia fracture, which are typically seen in children, the annular ligament injury is primarily characterized as varying degrees of annular ligament displacement [37]. Usually, the clinical examination is sufficient for diagnosis and treatment of annular ligament displacement and no additional imaging is needed. ▶ **Fig. 7** shows a case of a displaced annular ligament onto the radial head.

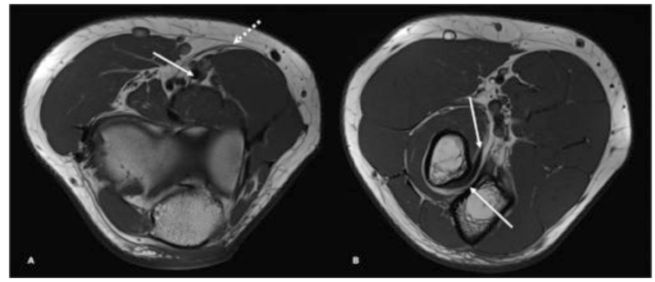
► **Fig. 8** PD fat-saturated MR image of a 56-year-old female with lateral epicondylitis. The arrow points at a partial rupture of the origin of the common extensor aponeurosis.

Lateral muscles

The muscles on the lateral aspect of the elbow are divided into three layers: the superficial layer, the extensor aponeurosis, and the supinator muscle [21]. The brachioradialis and extensor carpi radialis longus muscles form the superficial layer. The extensor carpi radialis brevis, extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris muscles form the aponeurosis [18, 38]. The brachioradialis and extensor carpi radialis longus muscles have their origin at the supracondylar ridge. The extensor carpi radialis brevis muscle arises from the common extensor tendon and radial collateral ligament. The origin of the common extensor group is the lateral humeral epicondyle superficial to the lateral collateral ligament complex (► **Fig. 3A**). The deepest of the lateral muscle group is the supinator muscle with its origin at the lateral epicondyle, lateral ligaments and supinator crest of the ulna and insertion into the lateral aspect of the proximal radial shaft [21].

Lateral tendon pathologies

The most common elbow disease in middle-aged patients is lateral epicondylitis, referred to as tennis elbow with a prevalence rate of 1 % to 3 % [39]. It is primarily a clinical diagnosis. Due to excessive use of the extensor muscles, microtrauma with small tears of the aponeurosis occur (► **Fig. 8**). Thus, the term epicondylitis is a misnomer on the lateral side as well. Incomplete healing can result in granulation tissue and mucoid degeneration. The most commonly affected muscle is the extensor carpi radialis brevis muscle [5, 40]. The role of MRI is to exclude tendon ruptures, bone stress reactions, and differential diagnosis of lateral elbow pain. Furthermore, it can be used for preoperative planning, especially if additional joint pathologies are present [5].



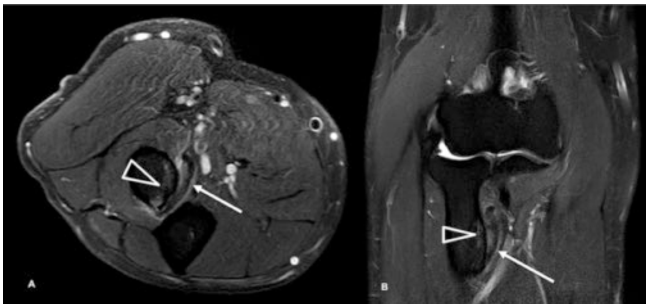
► **Fig. 9** T1-weighted axial **A**, **B** MR images. The biceps tendon courses distally through the antecubital fossa (arrows in **A** and **B**), is attached to the lacertus fibrosus (dashed arrow in **A**), and inserts at the radial tuberosity **B**.

► **Fig. 10** PD-weighted **A** and PD fat-saturated **B** MR image of an intact biceps tendon examined with the arm in flexion, abduction, and supination (FABS), enabling the visualization of the biceps tendon in one plane (arrows).

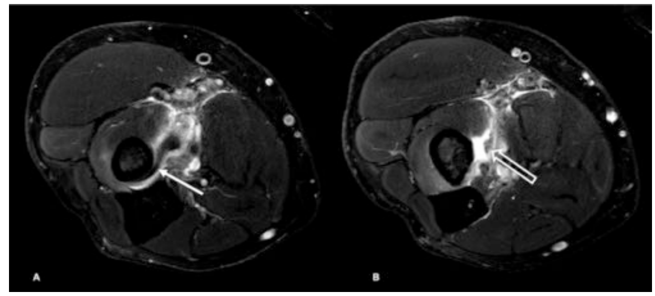
Anterior Compartment

Anterior tendons, muscles, and pathologies

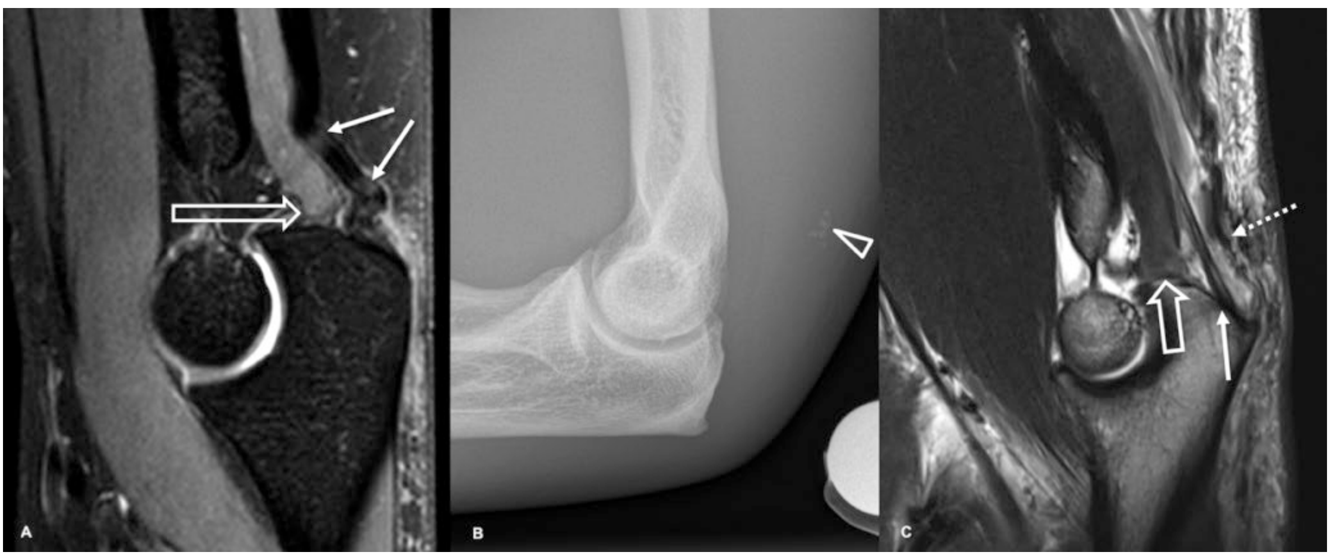
The anterior compartment contains two main flexors of the elbow, the biceps brachii and the brachialis muscle. The long and short heads of the biceps muscle arise proximally from the supraglenoid tubercle of the scapula and coracoid process. The biceps tendon passes distally through the antecubital fossa to insert at the radial tuberosity (► **Fig. 9**). The lacertus fibrosus or bicipital aponeurosis is formed by superficial tendon fibers running across the antecubital fossa and blending with the fascia of the flexor-pronator muscles (► **Fig. 9A**). This fibrous band prevents retraction of a torn biceps tendon to the upper arm [21]. By positioning the arm in flexion, abduction, and supination (FABS position) (► **Fig. 10**), the oblique biceps tendon can be visualized on one plane, and tendon retraction may be quantified easier compared to standard MR positioning [41]. MRI can differentiate complete tears from partial tears, and tendinopathies (► **Fig. 11**), as well as accompanying muscular injuries and hematomas [18]. Festa et al.



▶ **Fig. 11** 59-year-old man with elbow pain. Tendinopathy at the biceps tendon insertion with signal alteration of the tendon (arrows), perifocal edema, and bone marrow edema at the insertion site (arrowheads) is visible on axial **A** and coronal **B** PD fat-saturated MR images.



▶ **Fig. 12** 59-year-old man with partial biceps tendon rupture on axial PD fat-saturated MR images. Proximally at the radial tuberosity **A** the long head of the biceps tendon is intact, while distally the short head is torn and retracted from the insertion **B**. Note the perifocal soft tissue edema.



▶ **Fig. 13** Anatomy of the triceps tendon insertion on a sagittal PD fat-saturated MR image **A**. The arrows point at the conjoint insertion of the long and lateral head of the triceps tendon. The wavy contour and magic angle artifact are due to the examination in a relaxed extended position, and should not be mistaken for a pathology. The deep portion represents the muscular insertion of the medial head (open arrow) of the triceps muscle. Radiograph **B** and MR image **C** of a different patient: **B** Lateral radiograph of the elbow shows an avulsed entesophyte of the triceps tendon insertion (arrowhead). The correlating sagittal PD fat-saturated MR image **C** shows a partial rupture with retracted tendon portions (dashed arrow) of the common long and lateral head of the triceps tendon, while other portions of the common tendon (arrow) and the medial head (open arrow) insertion remain intact.

showed that the sensitivity and specificity of MRI for complete tears were 100 % and 82.8 %, respectively. In cases of partial tears, the sensitivity and specificity of MRI were 59.1 % and 100 %, respectively [42]. It is crucial to know that the distal biceps insertion has a specific anatomical feature. Although in most cases the two heads of the biceps tendon blend together to insert as a common tendon at the radial tuberosity, tendon fibers remain separated. Thus, the long head of the distal biceps tendon inserts at the proximal portion of the radial tuberosity and the short head at the distal portion [43]. Therefore, scrutiny needs to be given to the diagnosis of a distal biceps tendon tear, because only one portion/head of the tendon may be torn, while the other remains intact (▶ **Fig. 12**). In 25 % of cases, the distal biceps tendon remains bifurcated due to persistent division of the short and long head [44]. The distal biceps tendon does not have a tendon sheath. Fluid around the distal biceps tendon is usually located within the adjacent bicipitoradial bursa. The bursa has a U-shaped form surrounding the tendon. An abnormally distended bursa can mimic a soft-tissue tumor, but knowledge of the distinct anatomy of the bursa helps to correctly diagnose bursitis.

The brachialis muscle arises from the distal humerus and inserts into the ulnar tuberosity [21]. For assessing the musculotendinous junction, axial MRI sequences are suitable. Injuries to the brachialis muscle are referred to as “climber’s elbow”, because the muscle develops its greatest strength in 90° flexion and pronation. The brachialis muscle is a predilection site for the development of heterotopic ossifications after trauma [45].

▶ **Fig. 14** Axial PD fat-saturated image **A** of a 33-year-old female with acute ulnar paresis and claw hand for three weeks shows a hyperintense signal of the ulnar nerve (arrowhead) with surrounding soft-tissue edema (dashed arrow). Axial T1-weighted MR image **B** and axial PD fat-saturated image **C** of a 58-year-old male shows an anconeus epitrochlearis muscle (arrows). The anconeus epitrochlearis muscle originates from the medial epicondyle of the humerus, arches over the ulnar nerve (arrowheads), and inserts at the medial olecranon. This was an incidental finding in the examination, since the patient did not have any ulnar neuropathy symptoms, and did not show any thickening or signal alterations of the nerve (arrowheads). Of note: compare the unremarkable signal intensity of the ulnar nerve in **C** to the pathologic hyperintense signal in **A**.

Posterior Compartment

Posterior tendons, muscles, and pathologies

The posterior compartment consists of the triceps brachii muscle and the anconeus muscle. The triceps tendon consists of three heads arising from the infraglenoid tubercle of the scapula and proximal humerus [21]. The long and lateral head insert with a common tendon superficially at the tip of the olecranon, while the *m*edial head inserts with mostly *m*uscular fibers at the deep portion of the olecranon tip (▶ **Fig. 13A**). Thus, clinical evaluation might be harder, if some triceps function is still preserved due to just one of the triceps portions being torn. The triceps tendon may demonstrate a striated appearance on T2-weighted/proton density-weighted MRI sequences due to fibrovascular deposits. Similar to the biceps tendon, the most common location of a triceps tendon rupture is at the base [5, 21, 46]. The tendon can rupture with both deep and superficial portions or just one of those. Triceps tendon ruptures can be best assessed on sagittal MRI. Entesophytes at the triceps tendon can easily be seen on radiographs [46]. A retracted entesophyte should raise the suspicion of a tear of the triceps tendon (▶ **Fig. 13B**, **C**) [47].

Usually the elbow is examined in a relaxed extended position, giving the tendon a wavy contour on sagittal MR imaging, which should not be mistaken for a pathology (▶ **Fig. 13A**) [21]. Tendinopathies or ruptures of the triceps tendon are rare and often the result of overloading from throwing sports [48]. An uncommon cause of pain in the posterior elbow, sometimes complicated by injury of the ulnar nerve, is the “skipping/snapping elbow syndrome”. One of the reasons is luxation/snapping of the ulnar nerve over the medial epicondyle during flexion and extension movements. Additionally, an abnormal insertion of the medial triceps head with equivalent dislocation can cause the symptoms [49]. Recurrent subluxation of the nerve at the elbow can result in neuritis. Neuropathy of the ulnar nerve is the second most common peripheral nerve neuropathy after median nerve neuropathy [50]. However, the diagnosis of an ulnar nerve neuropathy on MRI needs to be correlated with symptoms (▶ **Fig. 14A**), especially with the knowledge that 60 % of asymptomatic volunteers show increased signal intensity of the ulnar nerve in the ulnar sulcus [51].

The anconeus muscle arises from the posterior aspect of the lateral humeral epicondyle, passing medially to insert along the lateral margin of the olecranon. The muscle tightens the joint capsule and plays a minor role in extension of the elbow [21]. Due to compensatory overload in the context of lateral epicondylitis, signal changes can occur in the anconeus muscle [18].

The anconeus epitrochlearis muscle is an anatomical variant that originates from the medial epicondyle of the humerus, arches over the ulnar nerve, and inserts at the medial olecranon (▶ **Fig. 14B**, **C**). Husarik et al. evaluated asymptomatic patients with MRI of their dominant elbow and found an anconeus epitrochlearis muscle to be present in 23 % of cases [51]. However, an anconeus epitrochlearis muscle can be associated with cubital tunnel syndrome. Depending on the volume, this muscle can cause compression of the ulnar nerve in the cubital tunnel [52].

Conclusion

Conventional MRI is an excellent imaging modality for the evaluation of elbow ligament and tendon injuries. Knowledge of normal MR anatomy of ligaments and tendons of the elbow is important to recognize pathologies. The most common elbow instability is posterolateral rotatory instability with the LUCL being the most important stabilizer. Recognition of injured ligaments is crucial to ensure appropriate therapy and restoration of elbow stability.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Karbach LE, Elfar J. Elbow Instability: Anatomy, Biomechanics, Diagnostic Maneuvers, and Testing. J Hand Surg Am 2017; 42: 118–126. doi:10.1016/j.jhsa.2016.11.025

[2] Safran MR, Baillargeon D. Soft-tissue stabilizers of the elbow. J Shoulder Elbow Surg 2005; 14: 179 s–185 s. doi:10.1016/j.jse.2004.09.032

[3] Husarik DB, Saupe N, Pfirrmann CW et al. Ligaments and plicae of the elbow: normal MR imaging variability in 60 asymptomatic subjects. Radiology 2010; 257: 185–194. doi:10.1148/radiol.10092163

[4] Floris S, Olsen BS, Dalstra M et al. The medial collateral ligament of the elbow joint: anatomy and kinematics. J Shoulder Elbow Surg 1998; 7: 345–351. doi:10.1016/s1058-2746(98)90021-0

[5] Janßen R, Falkowski AL, Hirschmann A. Assessment of ligament and tendon injuries of the elbow using magnetic resonance imaging. Radiologe 2018; 58: 996–1003. doi:10.1007/s00117-018-0441-1

[6] King GJ, Morrey BF, An KN. Stabilizers of the elbow. J Shoulder Elbow Surg 1993; 2: 165–174. doi:10.1016/s1058-2746(09)80053-0

[7] Mirowitz SA, London SL. Ulnar collateral ligament injury in baseball pitchers: MR imaging evaluation. Radiology 1992; 185: 573–576. doi:10.1148/radiology.185.2.1410375

[8] Joyner PW, Bruce J, Hess R et al. Magnetic resonance imaging-based classification for ulnar collateral ligament injuries of the elbow. J Shoulder Elbow Surg 2016; 25: 1710–1716. doi:10.1016/j.jse.2016.05.006

[9] Wilson FD, Andrews JR, Blackburn TA et al. Valgus extension overload in the pitching elbow. Am J Sports Med 1983; 11: 83–88. doi:10.1177/036354658301100206

[10] Cain EL Jr, Dugas JR, Wolf RS et al. Elbow injuries in throwing athletes: a current concepts review. Am J Sports Med 2003; 31: 621–635. doi:10.1177/03635465030310042601

[11] Graf DN, Fritz B, Bouaicha S et al. Elbow Instability. Semin Musculoskelet Radiol 2021; 25: 574–579. doi:10.1055/s-0041-1735467

[12] Timmerman LA, Andrews JR. Undersurface tear of the ulnar collateral ligament in baseball players. A newly recognized lesion. Am J Sports Med 1994; 22: 33–36. doi:10.1177/036354659402200106

[13] Lund P, Waslewski GL, Crenshaw K et al. FEVER: The Flexed Elbow Valgus External Rotation View for MRI Evaluation of the Ulnar Collateral Ligament in Throwing Athletes-A Pilot Study in Major League Baseball Pitchers. AJR Am J Roentgenol 2021; 217: 1176–1183. doi:10.2214/ajr.21.25608

[14] Schwartz ML, al-Zahrani S, Morwessel RM et al. Ulnar collateral ligament injury in the throwing athlete: evaluation with saline-enhanced MR arthrography. Radiology 1995; 197: 297–299. doi:10.1148/radiology.197.1.7568841

[15] Timmerman LA, Schwartz ML, Andrews JR. Preoperative evaluation of the ulnar collateral ligament by magnetic resonance imaging and computed tomography arthrography. Evaluation in 25 baseball players with surgical confirmation. Am J Sports Med 1994; 22: 26–31. doi:10.1177/036354659402200105

[16] Pazahr S, Sutter R, Zubler V. MRI of the Elbow: How to Do It. Semin Musculoskelet Radiol 2021; 25: 538–545. doi:10.1055/s-0041-1729884

[17] An KN, Hui FC, Morrey BF et al. Muscles across the elbow joint: a biomechanical analysis. J Biomech 1981; 14: 659–669. doi:10.1016/0021-9290(81)90048-8

[18] Chung CB, Chew FS, Steinbach L. MR imaging of tendon abnormalities of the elbow. Magn Reson Imaging Clin N Am 2004; 12: 233–245. doi:10.1016/j.mric.2004.02.007

[19] Granger A, Sardi JP, Iwanaga J et al. Osborne's Ligament: A Review of its History, Anatomy, and Surgical Importance. Cureus 2017; 9: e1080. doi:10.7759/cureus.1080

[20] Anderson MW, Chung CB. IDKD Springer Series Elbow Imaging with an Emphasis on MRI. In: Hodler J, Kubik-Huch RA, von Schulthess GK, Hrsg. Musculoskeletal Diseases 2021–2024: Diagnostic Imaging. Cham (CH) Springer Copyright; 2021: 23–39. doi:10.1007/978-3-030-71281-5_3

[21] Stevens KJ. Magnetic resonance imaging of the elbow. J Magn Reson Imaging 2010; 31: 1036–1053. doi:10.1002/jmri.22154

[22] Bozkurt M, Acar HI, Apaydin N et al. The annular ligament: an anatomical study. Am J Sports Med 2005; 33: 114–118. doi:10.1177/0363546504266070

[23] Stein JM, Cook TS, Simonson S et al. Normal and variant anatomy of the elbow on magnetic resonance imaging. Magn Reson Imaging Clin N Am 2011; 19: 609–619. doi:10.1016/j.mric.2011.05.002

[24] Cage DJ, Abrams RA, Callahan JJ et al. Soft tissue attachments of the ulnar coronoid process. An anatomic study with radiographic correlation. Clin Orthop Relat Res 1995: 154–158

[25] Terada N, Yamada H, Toyama Y. The appearance of the lateral ulnar collateral ligament on magnetic resonance imaging. J Shoulder Elbow Surg 2004; 13: 214–216. doi:10.1016/j.jse.2003.12.013

[26] O'Driscoll SW, Morrey BF, Korinek S et al. Elbow subluxation and dislocation. A spectrum of instability. Clin Orthop Relat Res 1992: 186–197

[27] Cohen MS, Hastings H 2nd. Rotatory instability of the elbow. The anatomy and role of the lateral stabilizers. J Bone Joint Surg Am 1997; 79: 225–233

[28] Conti Mica M, Caekebeke P, van Riet R. Lateral collateral ligament injuries of the elbow – chronic posterolateral rotatory instability (PLRI). EFORT Open Rev 2016; 1: 461–468. doi:10.1302/2058-5241.160033

[29] Al-Ani Z, Wright A, Ricks M et al. Posteromedial rotatory instability of the elbow: What the radiologist needs to know. Eur J Radiol 2021; 141: 109819. doi:10.1016/j.ejrad.2021.109819

[30] O'Driscoll SW. Classification and evaluation of recurrent instability of the elbow. Clin Orthop Relat Res 2000: 34–43. doi:10.1097/00003086-200001000-00005

[31] Fedorka CJ, Oh LS. Posterolateral rotatory instability of the elbow. Curr Rev Musculoskelet Med 2016; 9: 240–246. doi:10.1007/s12178-016-9345-8

[32] Ebrahimzadeh MH, Amadzadeh-Chabock H, Ring D. Traumatic elbow instability. J Hand Surg Am 2010; 35: 1220–1225. doi:10.1016/j.jhsa.2010.05.002

[33] Hwang JT, Shields MN, Berglund LJ et al. The role of the posterior bundle of the medial collateral ligament in posteromedial rotatory instability of the elbow. Bone Joint J 2018; 100-b: 1060–1065. doi:10.1302/0301-620x.100b8.Bjj-2017-0652.R2

[34] Arrigoni P, Cucchi D, D'Ambrosi R et al. Intra-articular findings in symptomatic minor instability of the lateral elbow (SMILE). Knee Surg Sports Traumatol Arthrosc 2017; 25: 2255–2263. doi:10.1007/s00167-017-4530-x

[35] Arrigoni P, Cucchi D, Luceri F et al. Lateral Elbow Laxity Is Affected by the Integrity of the Radial Band of the Lateral Collateral Ligament Complex: A Cadaveric Model With Sequential Releases and Varus Stress Simulating Everyday Activities. Am J Sports Med 2021; 49: 2332–2340. doi:10.1177/03635465211018208

[36] Zagarella A, Folco G, Monti CB et al. Semiquantitative index of symptomatic minor instability of the lateral elbow at CT arthrography (SMILE index): clinical applicability and reproducibility study. Eur Radiol 2024; 34: 2742–2750. doi:10.1007/s00330-023-10233-x

[37] Tan JW, Mu MZ, Liao GJ et al. Pathology of the annular ligament in paediatric Monteggia fractures. Injury 2008; 39: 451–455. doi:10.1016/j.injury.2007.07.010

[38] Fowler KA, Chung CB. Normal MR imaging anatomy of the elbow. Magn Reson Imaging Clin N Am 2004; 12: 191–206. doi:10.1016/j.mric.2004.02.004

[39] Savoie FH 3 rd, O'Brien MJ. Arthroscopic tennis elbow release. Instr Course Lect 2015; 64: 225–230

[40] Field LD, Savoie FH. Common elbow injuries in sport. Sports Med 1998; 26: 193–205. doi:10.2165/00007256-199826030-00005

[41] Giuffrè BM, Moss MJ. Optimal positioning for MRI of the distal biceps brachii tendon: flexed abducted supinated view. AJR Am J Roentgenol 2004; 182: 944–946. doi:10.2214/ajr.182.4.1820944

[42] Festa A, Mulieri PJ, Newman JS et al. Effectiveness of magnetic resonance imaging in detecting partial and complete distal biceps tendon rupture. J Hand Surg Am 2010; 35: 77–83. doi:10.1016/j.jhsa.2009.08.016

[43] Derias M, Phadnis J. Disorders of the distal biceps and triceps tendons. Orthopaedics and Trauma 2020; 34: 186–196. doi:10.1016/j.mporth.2020.05.001

[44] Dirim B, Brouha SS, Pretterklieber ML et al. Terminal bifurcation of the biceps brachii muscle and tendon: anatomic considerations and clinical implications. AJR Am J Roentgenol 2008; 191: W248–W255. doi:10.2214/ajr.08.1048

[45] Safran MR. Elbow injuries in athletes. A review. Clin Orthop Relat Res 1995: 257–277

[46] Kijowski R, Tuite M, Sanford M. Magnetic resonance imaging of the elbow. Part II: Abnormalities of the ligaments, tendons, and nerves. Skeletal Radiol 2005; 34: 1–18. doi:10.1007/s00256-004-0854-y

[47] Downey R, Jacobson JA, Fessell DP et al. Sonography of partial-thickness tears of the distal triceps brachii tendon. Journal of ultrasound in medicine : official journal of the American Institute of Ultrasound in Medicine 2011; 30: 1351–1356. doi:10.7863/jum.2011.30.10.1351

[48] Nocerino EA, Cucchi D, Arrigoni P et al. Acute and overuse elbow trauma: radio-orthopaedics overview. Acta Biomed 2018; 89: 124–137. doi:10.23750/abm.v89i1-S.7016

[49] Jacobson JA, Jebson PJ, Jeffers AW et al. Ulnar nerve dislocation and snapping triceps syndrome: diagnosis with dynamic sonography-report of three cases. Radiology 2001; 220: 601–605. doi:10.1148/radiol.2202001723

[50] Łasecki M, Olchowy C, Pawluś A et al. The Snapping Elbow Syndrome as a Reason for Chronic Elbow Neuralgia in a Tennis Player – MR, US and Sonoelastography Evaluation. Pol J Radiol 2014; 79: 467–471. doi:10.12659/pjr.891393

[51] Husarik DB, Saupe N, Pfirrmann CW et al. Elbow nerves: MR findings in 60 asymptomatic subjects–normal anatomy, variants, and pitfalls. Radiology 2009; 252: 148–156. doi:10.1148/radiol.2521081614

[52] Kim N, Stehr R, Matloub HS et al. Anconeus Epitrochlearis Muscle Associated With Cubital Tunnel Syndrome: A Case Series. Hand (N Y) 2019; 14: 477–482. doi:10.1177/1558944718762566