

## R E V I E W

## Acute and overuse elbow trauma: radio-orthopaedics overview

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**Summary.** The correct management of acute, subacute and overuse-related elbow pathologies represents a challenging diagnostic and therapeutic problem. While major trauma frequently requires a rapid surgical intervention, subluxation and minor trauma allow taking more time for diagnostics and planning the correct elective treatment after careful clinical and radiological investigation. In these conditions, communication between orthopaedic surgeon and radiologist allow to create a detailed radiology report, tailored to the patient's and surgeon's needs and optimal to plan proper management. Imaging technique as X-Ray, CT, US, MRI, CTA and MRA all belong to the radiologist's portfolio in elbow diagnostics. Detailed knowledge of elbow pathology and its classification and of the possibilities and limits of each imaging technique is of crucial importance to reach the correct diagnosis efficiently. The aim of this review is to present the most frequent elbow pathologies and suggest a suitable diagnostic approach for each of them. ([www.actabiomedica.it](http://www.actabiomedica.it))

**Key words:** elbow trauma, elbow instability, SMILE syndrome MRI, MR arthrography

### Introduction

Comprehension of the mechanisms that underlie the most common elbow injury patterns may improve the awareness and the detection of these injuries adopting an appropriate and early use of advanced imaging techniques. Elbow traumatic injuries of the elbow and post-traumatic sequelae are a frequently encountered pathology in emergency departments and outpatient care and imaging techniques are crucial to obtain a correct diagnosis (1-5).

The goals of this article are to review the elbow injuries describing the most common injury mechanisms, to present the clinically relevant imaging findings for each pathology and to propose a correct imaging protocol aimed at minimizing the potential for suboptimal or delayed patient care.

### *Acute Fractures*

Elbow fractures represent a frequent lesion in the emergency department. Correct diagnosis and classifi-

cation are a necessary premise to a successful treatment. Elbow fractures are grouped according to the bones involved; for each fracture pattern, several sub-classifications have been proposed to help in the decision-making algorithm or to provide prognostic information.

Capitellar fractures are divided into four groups according to the Bryan and Morrey classification (6-10). Type I (Hahn-Steinthal fracture) includes complete fractures of the capitellum, with involvement of a large osseous fragment of the lateral part of the trochlea, type II (Kocher-Lorenz fracture) includes frontal osteocartilaginous detachments resulting from shearing forces, type III (Broberg-Morrey fracture) includes comminuted fractures of the capitellum, type IV (McKee fracture) includes combined fractures of both capitellum and trochlea (11-15).

Radial head and neck fractures are divided into four groups according to the Mason classification, subsequently modified by Hotchkiss (16). Type I includes non-displaced or minimally (<2 mm) displaced fractures, type II includes displaced (>2 mm) fractures (angulated fractures), type III includes comminuted displaced fractures, type IV combines radial head fracture and elbow dislocation.

Coronoid fractures are divided into three groups according to the Regan-Morrey classification (17): type I includes avulsions of the tip of the coronoid process, type II includes fractures with fragments smaller than 50% of the height of the coronoid process, type III includes fractures with fragments bigger than 50% of the height of the coronoid process.

O'Driscoll introduced a more comprehensive coronoid fractures classification that emphasizes the importance of the anteromedial facet (18): tip (subtype 1 involving less than 2 mm of coronoid height and subtype 2 involving more than 2 mm of coronoid height), anteromedial facet (subtype 1 is a fracture of only the anteromedial rim, subtype 2 associates the rim and the tip, and subtype 3 associates anteromedial rim and sublime tubercle +/- the tip), basis (subtype 1 is a fracture of the coronoid body and base, subtype 2 is associated with an olecranon fracture). Fractures of the anteromedial facet are a commonly seen coronoid process fracture pattern, often with associated injuries of the medial collateral ligament (MCL, which inserts on the sublime tubercle of the medial coronoid base) that

lead to the development of varus and posteromedial rotatory instability.

Finally, the olecranon fractures are divided into three groups by the Morrey classification (19): type I includes non-displaced fractures (subtype A: simple fracture, subtype B: comminuted fractures), type II includes displaced fractures (subtype A: simple fracture, subtype B: comminuted fractures) and type III includes unstable fractures (subtype A: simple fracture, subtype B: comminuted fractures).

### Dislocations

Fractures can be accompanied by elbow dislocation: in this case, the term "complex elbow dislocation" is used. This condition is most frequently (44.5-75%) encountered in sportsmen after a fall on the outstretched hand (20-25) often in association to articular and ligamentous disruption, which may lead to permanent loss of function(26-30).

The most frequent patterns of complex elbow dislocation are: 1. Transolecranon fracture-dislocations, 2. Elbow dislocation with coronoid fracture (Figure 1), 3. Elbow dislocation with radial head fracture, 4. Elbow dislocation with both coronoid and radial head fracture ("terrible triad"). Prompt reduction is mandatory to avoid vascular or nervous damage.

The appropriate treatment (surgical or conservative) for elbow dislocation depends on the type and severity of associated fractures and soft-tissue injuries.



**Figure 1.** Lateral-lateral projection X-Ray elbow: Dislocation type 2

Consequentially, emphasis should be placed on identifying and classifying these associated injuries using correct imaging protocols.

### *Imaging Protocol*

Imaging plays a crucial role in the diagnosis and, therefore, in the management of the traumatic elbow. The elbow trauma mechanism (i.e. varus/valgus stress) also helps in defining the appropriate diagnostic plan.

Because the elbow stability is guaranteed primarily by osseous integrity (i.e. the presence of at least 50% of coronoid process and 30% of olecranon articular integrity) it is crucial to assess the presence of fractures. It is essential to exclude the presence of ligamentous damage, which can lead to chronic elbow instability.

The first step in the diagnostic algorithm is represented by the radiographic examinations. These exams have to perform according the international standards, considering that patient's pain could imply a limitation in meeting the correct criteria.

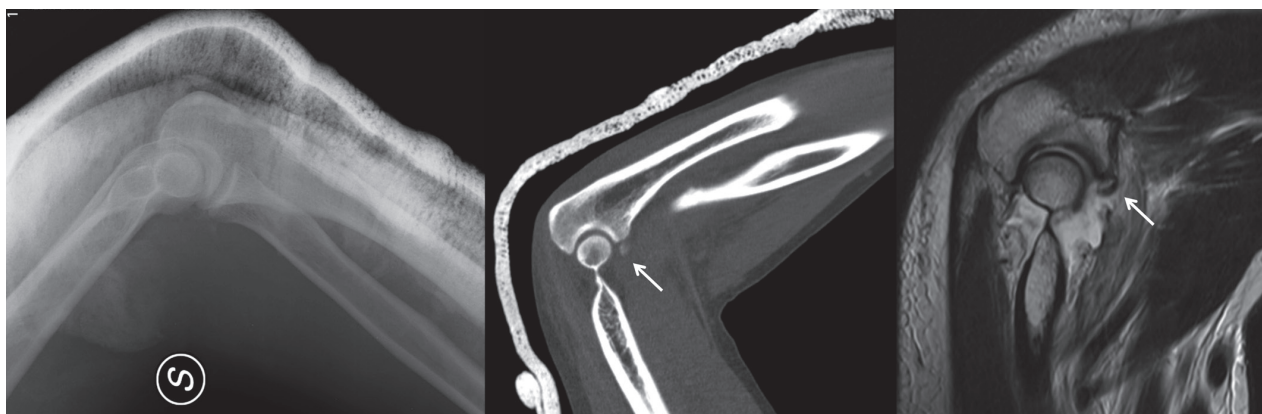
The two fundamental views for evaluating the elbow are the anteroposterior and the lateral views, obtained with projections 90° one from the other. To better assess the olecranon and coronoid, the study must be completed with a lateral projection, obtained by flexing the arm 90° with the hand in supination, leaning the ulnar side against the radiological cartridge and keeping the thumb upwards. There are also

oblique projections (medial and side view), targeted to study medial (e.g. ulnar coronoid) and lateral (e.g. radial head) joint bone structures.

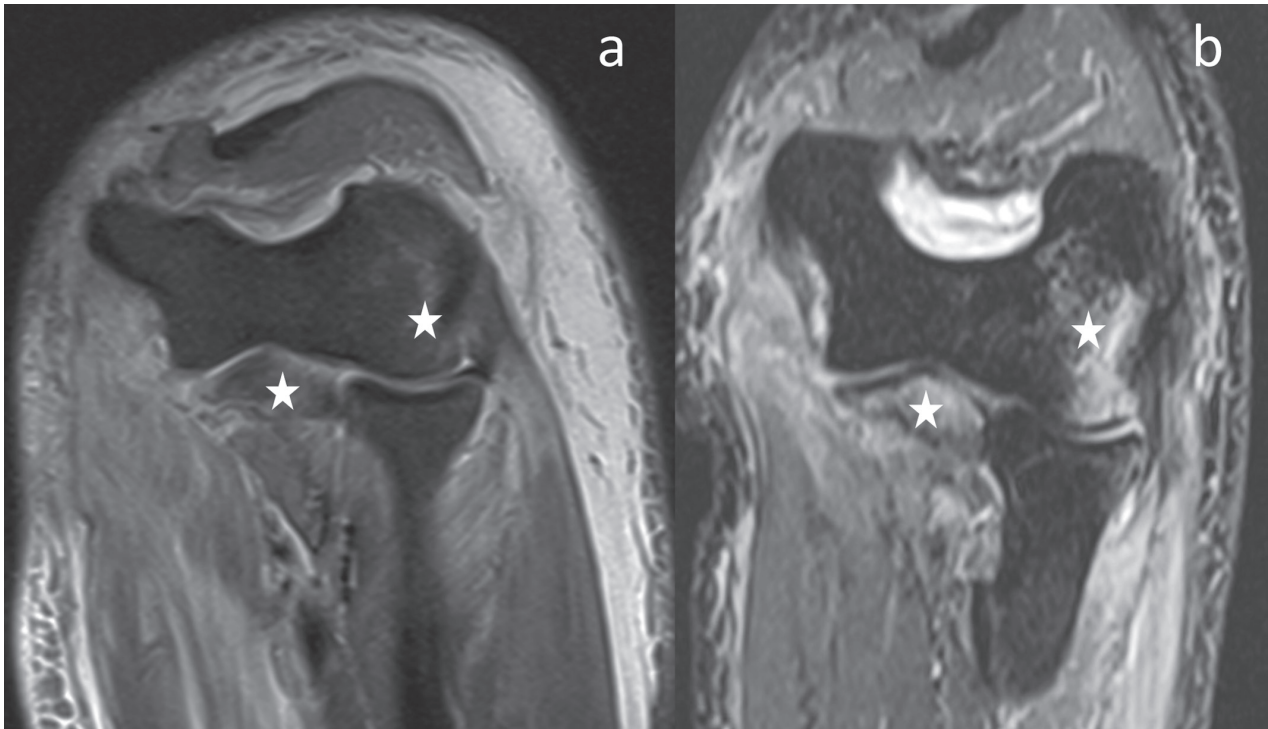
Even if the severity and the extension of elbow fractures could be evaluated with radiographs alone, the use of Computed Tomography (CT) imaging is recommended for a more detailed evaluation of comminuted fractures and for assessing the presence of occult fractures. For example, defining the morphologic characteristics and size of coronoid fractures is crucial in the management of the patient and, therefore, in this case the use of 3D CT reconstruction is strongly recommended to clearly define the injury degree (Figure 2).

The role of Magnetic Resonance (MR) imaging in the subacute stage is debated, as damage may be overestimated. Otherwise, the post-traumatic effusion could be used as a natural arthrographic effect to evaluate soft tissue injuries. Moreover the MR imaging high-spatial contrast resolution could be useful in the detection of occult fractures, bone marrow contusion (31-35), ligaments and tendons injuries, nerve damage and osteochondral detachments (Figure 3).

The correct evaluation of the elbow in MR begins in minimizing motion during examination. So in these painful patients MR can be performed with the arm 90° flexed without remove elbow cast or restraints. This makes the examination more comfortable and reduces the risk of a re-dislocation.



**Figure 2.** A sagittal X-Ray elbow after reduction: the CT and in MR T2w sagittal reconstruction show a coronoid tip fracture, not visualized on the X-Ray



**Figure 3.** a: subacute MR PD fat sat (72 hours after the injury): lateral epicondyle and radial head bone marrow oedema (white star). In the figure b after 3 weeks the oedema is much more evident

### Subacute/Overuse related

#### *Major elbow instability: PLRI*

Elbow instability may arise from high-energy trauma with elbow dislocation and acute gross instability or from ligamentous lesion, which may cause subacute patterns of elbow instability. Damaged to the lateral collateral ligament (LCL) complex, in particular to its ulnar band, can lead to posterolateral rotatory instability (PLRI) of the elbow. This condition, first described by O'Driscoll, results in the entire forearm rotating on the humerus, producing both radiocapitellar and ulnohumeral instability and can severely affect both sports performance and everyday activities. O'Driscoll also proposed a classification system for PLRI staging (36-40).

PLRI condition may follow acute dislocations or, more frequently, repetitive microtrauma and can result from proximal or distal LCL avulsions, midsubstance tears of the LCL or bony avulsions from the humeral epicondyle or from the crista supinatoris. PLRI can also

follow surgical or nonsurgical treatment of lateral elbow pathology, as iatrogenic injury after steroid injections or surgery in lateral epicondylitis (41-45). Treatment can be conservative (compressive sleeve, strengthening of the lateral musculature, topical non-steroidal anti-inflammatory drugs, physiotherapy) or surgical. Surgery is indicated for symptomatic patients, with objective instability or restrictions in everyday activities despite adequate non-operative treatment (46-50). In chronic PLRI, conservative treatment is likely to fail, since no anatomic healing of avulsed or torn ligaments is possible with immobilization alone. The diagnosis of PLRI is achieved through specific clinical tests.

#### *Imaging protocol*

Imaging plays a crucial role in identification of the damaged ligamentous structures, therefore indicating which patients could benefit from surgery and providing precious information to surgical planning.

MR imaging is effective for detecting bone, chondral and ligament injuries, usually correlated with



PLRI, but not for demonstrating of instability. The lateral complex, consisting of lateral collateral ligaments, annular ligament (AL) and lateral ulnar collateral ligament, is not easily seen on standard MR due to its small size. The ultrasound (US) guided administration of intra-articular gadolinium-based contrast material (5 to 10 mL of diluted gadolinium (1:250)) allows to distend the elbow capsule and to assess the ligament injuries and the detection of partial tears of the lateral complex. It is usually studied on coronal planes like a thin and hypointense structure. The AL encircles the radial head and stabilizes the proximal radio-ulnar joint and it is assuming an increasing importance in patients with chronic lateral elbow pain (see "Minor elbow posterolateral instability" paragraph below), post-traumatic dislocation, and posterolateral instability. The axial plane enables identification of the annular ligament throughout its entire course around the radial head and its anterior and posterior attachments on the ulna (51-55); the anterior portion of the annular ligament is taut during supination, whereas the posterior portion becomes taut during pronation. Another advantage of MRA is that it can show loose bodies, chondral or osteochondral fractures, and synovial abnormalities. Turbo Spin Echo (TSE) T1w or Proton Density (PD) weighted sequences with or without fat saturation are used in most cases in conjunction with gadolinium injection to better assess the abovementioned structures. In selected patients (with contraindications to do MR) CT arthrography (CTA) could be performed reaching good results. The use of dynamic ultrasonography could be considered if the diagnosis of PLRI is equivocal. This exam provides a unique view of the radial head subluxation or ulnohumeral widening as a supination torque is applied to the elbow. For dynamic ultrasound, the probe is placed in the anatomic axial plane connecting the lateral epicondyle to the olecranon and the ulnohumeral joint is visualized. Widening of the ulnohumeral joint is assessed as a posterolateral rotatory stress is applied, and ulnohumeral laxity (stressed distance e distance at rest) >4 mm may be indicative of PLRI(56-60).

### ***Major elbow instability***

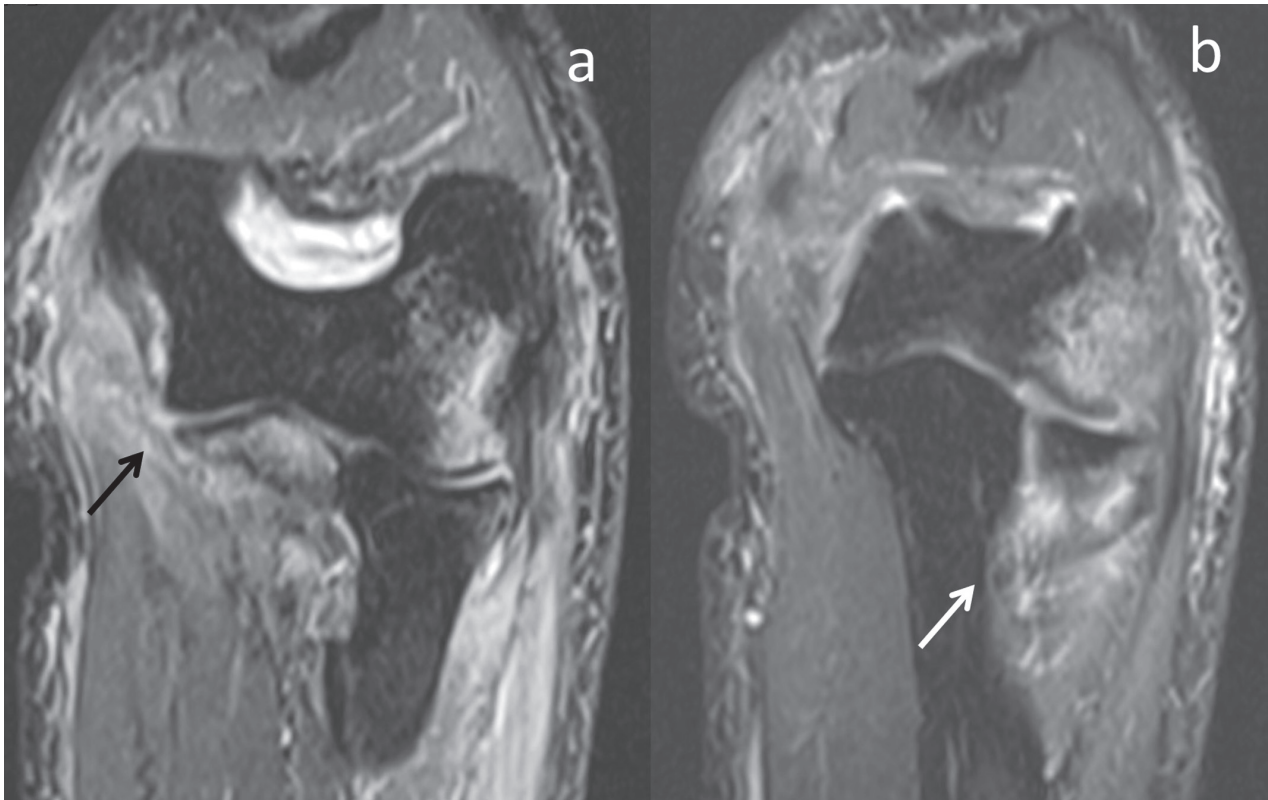
Medial instability usually affects patients involved in sport activities and is determined by acute

or chronic injuries to the medial ulnar collateral ligament (MUCL). The most frequent presentation is chronic elbow pain located on the medial side, which is worsened by overhead activities, like throwing. Pitchers affected by valgus instability frequently report decreased throwing velocity and arm fatigue. Rarely an acute rupture occurs during the gesture of throwing: this is accompanied by sharp pain in the medial side of the elbow, sometimes associated to a snap or pop. A combined valgus-extension overload may lead to posteromedial osteophytes formation and produce posterior elbow pain and ulnar nerve irritation symptoms. Medial ulnar collateral ligament injuries are usually well tolerated in everyday activities. However, throwing athlete's performance can be severely affected by medial or posteromedial instability. Inability to obtain previous performance level is considered a surgical indication for the professional athlete who has failed conservative treatment (61-65).

### ***Imaging protocol***

MR arthrography (MRA) is the study of choice to evaluate an MUCL injury. Notable findings are fluid signal in or around the ligament substance, ligamentous laxity or wavy fibres, fibre disruption, and adjacent marrow signal abnormality. The so called "T sign"(66) (Figure 4) is when the MUCL tears from its osseous attachment and allows for the extravasation of fluid along the humerus or ulna and is only appreciated on MRA or a CTA. The sign is present when injected contrast extends distally from the joint line along the cortical margin of the sublime tubercle, as seen on coronal images. As previously mentioned, CT is useful to classify coronoid fractures, especially in cases of small bone fragment detachments.

In literature is reported the "vacuum sign" visualized using stress radiography, and it is referred to the presence of hypodensity in the trochlear ulnar joint. Although this sign is uncommon patients with a vacuum sign had a high-grade partial tear or worse. Finally dynamic ultrasound imaging has been able to demonstrate increased thickness and hypoechoic calcifications as well as elbow valgus laxity showing changes in ulnohumeral joint gap (67-70).



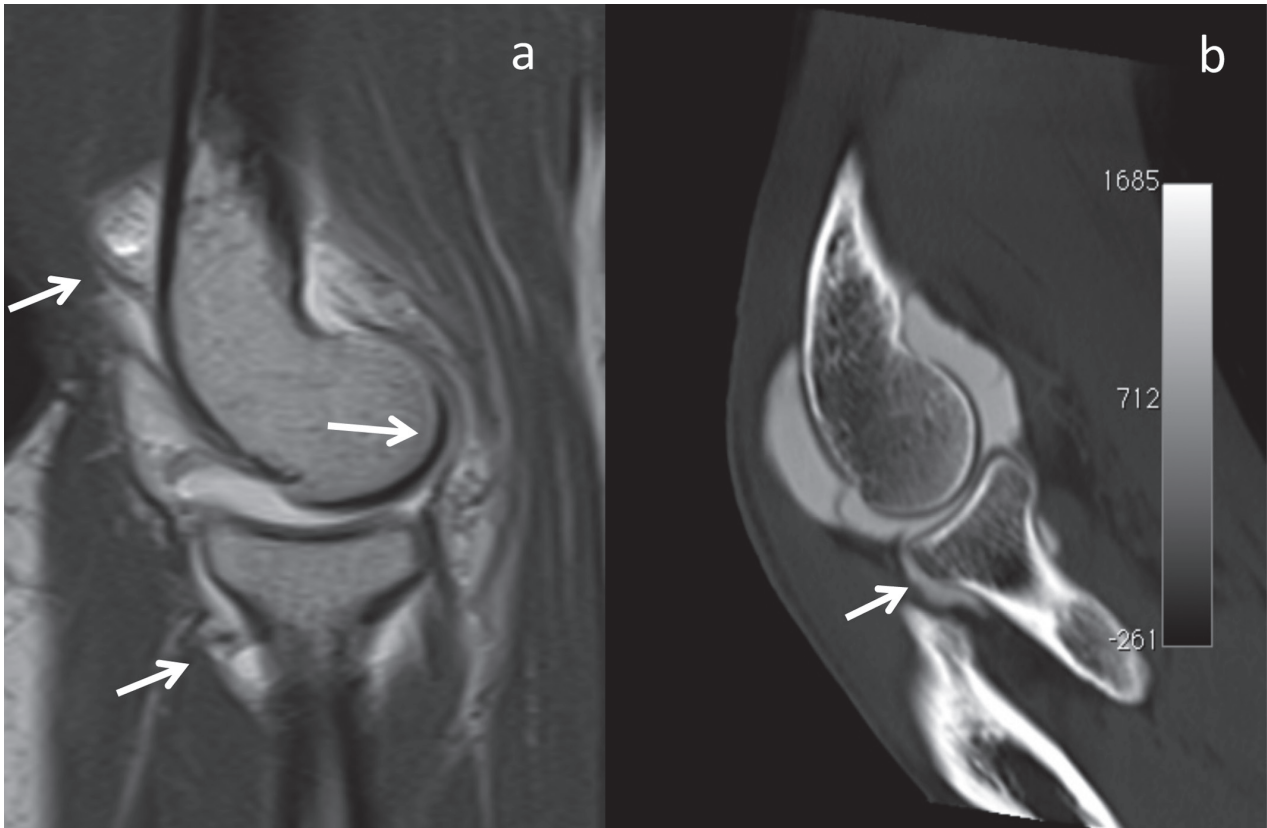
**Figure 4.** a: coronal MR PD fat saturation with 90° elbow flexion: T-sign (black arrow). b: ULCL elongation (white arrow)

#### ***Minor elbow posterolateral instability: SMILE and plica***

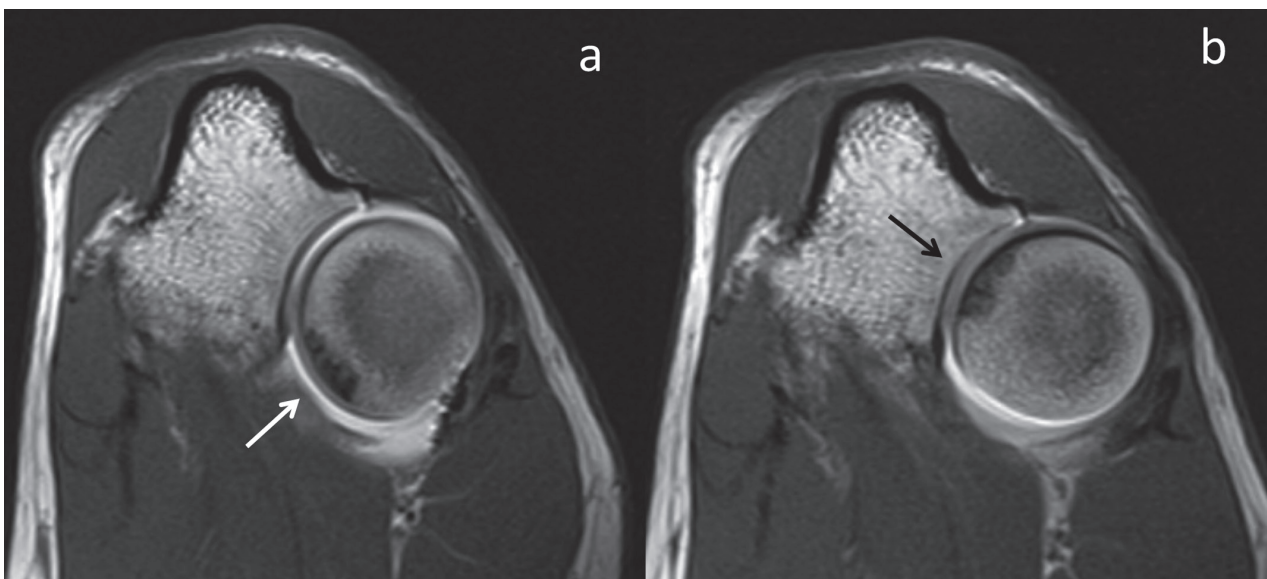
Recalcitrant lateral elbow pain is frequently associated with abnormal intra-articular findings, which could be related to a condition of patholaxity termed “symptomatic minor instability of the lateral elbow” (SMILE) (67). This condition may result from repetitive low-energy stress or shear as occurs in simple, repetitive or prolonged daily or working activities performed with the shoulder in moderate abduction, pronation of the hand and 50°-70° of elbow flexion, a position in which hand and the forearm create a varus/pronation moment on the lateral elbow. With time, this could result in progressive stretching and elongation of the radial component of the LCL (R-LCL) and of the annular ligament, with relative hypermobility of the radial head (Figure 5). Minor incongruence of the proximal radioulnar joint results in radial head impingement with the notch in pronation, and eventual radial head chondropathy (Figure 6), inflam-

mation and subsequent synovitis. Finally, abrasion of the stretched R-LCL and anterolateral capsule due to friction over the lateral portion of the capitellum can cause chondropathies of the lateral aspect of the capitellum and capsular tears. In this pathologic cascade, the extensor carpi radialis brevis (ECRB) is considered to act as a dynamic stabilizer, resisting varus forces in support of a deficient or lax R-LCL: ECRB tendinopathy could therefore be intended as the final consequence of repetitive loads and overuse on the R-LCL. Conservative treatment is indicated as first line approach in most patients affected by SMILE. With recalcitrant, symptomatic minor instability not responding to conservative treatment are amenable to arthroscopic synovectomy and, if intra-articular abnormal findings and associated signs of lateral ligamentous patholaxity are present, to plication of the elongated R-LCL(71-75).

A less frequent cause of painful impingement at the posterolateral side of the elbow can be a hypertrophic radiocapitellar plica.



**Figure 5.** a: the MR T2w image shows posterolateral capsular laxity in elbow SMILE syndrome MRA (sagittal plane). b: the CTA shows the capsular laxity in a normal elbow (sagittal plane)



**Figure 6.** MR axial TSE T1 w. Radial head chondropathy (white and black arrows). a: supinated b: pronated

This plica has a meniscal appearance and can extend anteriorly in the lateral elbow joint (76-81). Repetitive microtrauma can cause thickening and fibrosis of the plica, with eventual development of posterior elbow pain (82). Painful clicking, catching, effusions, and snapping with pronated elbow flexion greater than 90° are the typical manifestations of a symptomatic posterior plica (76-83).

Conservative is the first choice for symptomatic plicae. Arthroscopic resection is considered only when such measures have failed (76, 77, 84).

#### *Imaging protocol*

Image-based diagnosis and classification of intra-articular findings associated with lateral elbow pain is challenging. Ultrasound examination is still considered the imaging gold standard even if ultrasound is limited in the evaluation of joint cartilage and capsule (85-90). MR is limited by the need for different arm positions and reconstructions to fully investigate anomalies. MRA tridimensional reconstruction may help increase the accuracy of MR, showing indirect signs of SMILE, as radial head and capitellum chondropathy (Figure 6), posterolateral synovitis and, eventually, capsular tears (31, 91-94).

Finally, MR arthrography can also demonstrate synovial folds within the elbow joint (95) [42].

#### ***Medial and Lateral epicondylitis***

Lateral epicondylitis is defined as lateral elbow pain associated with tendinosis of the common extensor origin and is a frequent source of pain on the lateral side of the elbow (incidence of 1.3 % in the population between 30 and 64 years, with a peak between 45 and 54 (80). Repetitive microtrauma or forceful activity involving activation of the wrist extensors (both from sport activities and work-related) is the putative cause of this degenerative process, histologically characterized by angiofibroblastic hyperplasia at the common extensor origin with a final stage of fibrosis and calcification (96-100). Young athletes experience a typical acute onset of symptom, whereas older patients more frequently report chronic, recalcitrant symptoms. In most cases history and clinical examination are suf-

ficient to reach the diagnosis of lateral epicondylitis. Conservative treatment is the preferred approach to lateral epicondylitis, with success rate ranging 90%. Surgery is indicated for recalcitrant cases.

Medial epicondylitis, also known as golfer's elbow, is less frequent than medial-sided elbow pain. Golfers, athletes involved in racket sports, overhead throwing athletes and workers involved in repetitive flexion of the wrist are most frequently affected (101-105). Repetitive microtrauma to the tendon origin of the flexor-pronator of the wrist-forearm (which insert on the anterior aspect of the medial epicondyle of the humerus) leads to degeneration, tendinosis, and ultimately tearing of the tendinous insertion (98, 102, 106). Pain in flexion and pronation against is the typical complaint, sometimes associated with tenderness over the common flexor-pronator origin and decreased grip strength (107).

Conservative treatment is the preferred approach to medial epicondylitis; surgical treatment has been reported for recalcitrant medial epicondylitis (108).

#### *Imaging protocol*

Radiographs could show mineralization at the common flexor-pronator and extensor muscular origin but are in most of the cases negative (109).

On MR imaging, coronal images are most helpful to assess the common flexor-pronator and extensor tendon origin. MR imaging findings consist of increased tendon thickness and signal intensity in cases of tendinopathy. Partial thickness tears are seen as hyperintense fluid signal interrupting a portion of the tendon fibres with associated tendon thinning. Complete tears are seen as a complete interruption of the tendon on both T1- and T2-weighted images. On US imaging tendinosis commonly presents as tendon thickening with hypoechogenicity and loss of the typical compact fibrillar pattern (110).

Hyperemia representative of neovascularity may be seen on Doppler investigation (111). Other US findings occasionally seen in lateral epicondylitis include intratendinous calcification and bone irregularity in the adjacent lateral epicondyle (110). Tears appear as a focal anechoic or fluid-filled gap in the tendon with accompanying tendon discontinuity. Previous



studies have shown that US is accurate for the diagnosis of lateral tendinosis with a similar specificity (67%-100%) but slightly diminished sensitivity (64%-82%) as compared to MR imaging (90%-100% sensitivity) (64, 88, 112-115).

### ***Posteromedial Elbow Impingement***

Posteromedial elbow impingement is considered a part of the valgus extension overload syndrome, which was originally described in 1983 by Wilson (116).

This is characterized by pain, swelling, presence of posteromedial osteophytes and loose bodies (derived from osteophyte fracture). Athletes involved in overhead sports, in which the elbow is demanded with extremes forces and accelerations/decelerations over many repetitions, are most frequently affected category. Baseball players are most frequently diagnosed with this syndrome, which has however been described also in football, volleyball and tennis players, boxers, weightlifters and gymnasts (117, 118).

During throwing, medial shear, lateral compression, torsion and valgus stress are applied to the elbow, especially to the posterior compartment. Repetitive hyperextension, valgus and supination are believed to be the initial factor in the development of this syndrome (119, 120).

Non-operative treatment, consisting in medical therapy and correction of poor throwing technique, is indicated as first line of treatment. Persistent symptoms may require surgical treatment.

### ***Imaging protocol***

Imaging plays a key role in treatment decision, since medial collateral ligament integrity must be evaluated, in order to consider its reconstruction after removal of posteromedial osteophytes or loose bodies (121).

The MR and MRA could evaluate the chondropathy at the articular surfaces of the posterior trochlea and the anterior, medial olecranon. The findings ranged from abnormal oedema-like signal in the hyaline cartilage to cartilage defects and subjacent, subchondral bone marrow oedema and posteromedial synovitis, olecranon spurring in and loose bodies (122). In a re-

cent study C.C Ko et al, showed that CT is superior to MRI in identifying joint space loss and number and location of loose bodies (123, 124).

### ***Biceps Tendon Pathology***

Acute complete rupture of the distal biceps at the elbow is a rare injury, caused by eccentric biceps contraction against resistance (125, 126). Males, smokers weight lifters and anabolic steroid abusers are the categories at risk (125-128). Partial tears are less common and more frequently undiagnosed (129).

Chronic tears are complicated by tendon retraction and scar formation and can result in permanent flexion and supination strength deficit (130). Pain on the anterior elbow, exacerbated by activity and strength reduction are a common presentation. A palpable gap and a positive "Popeye sign" may be present.

Surgical treatment is recommended to restore function and strength: different techniques have been described, including open and endoscopic approaches and fixation with cortical buttons, suture anchors, trans-osseous tunnels and interference screws.

### ***Imaging Protocol***

Using the US examination the tendon can be difficult to visualize, because of the local anisotropy due to its deep course and inclination at the point of its insertion (59, 70, 131). The biceps tendon has also an aponeurotic attachment on lacertus fibrosus, which is in close relation to the median nerve and brachial artery. The complete tear can be imaged as total absence of the tendon, which is almost always markedly retracted, often more than 10 cm from the distal insertion. Partial tears and tendinosis of the biceps are very uncommon. The MR in 90° elbow flexion could be useful to the correct evaluation of the radial footprint and the lacertus fibrosus. Proton density, fat saturation and T2-weighted TSE echo are the most frequently used sequence for their ability to distinguish muscle and tendon fibres.

### ***Triceps Tendon Pathology***

Triceps tendon ruptures are a rare condition, most frequently caused by sport-related overuse (132, 133).

Skeletally immature athletes, wheelchair athletes, weight lifters and anabolic steroid abusers are the categories at risk. Acute ruptures from eccentric loading on the triceps have been described in cyclists and motorcycle riders after falls on the outstretched hand (134).

Conservative treatment with elbow immobilization in a splint at 30° of flexion can be chosen for in low-demand patients with partial ruptures up to 50% of the tendon without extension lag or severe functional impairment (135-137). Surgical repair is recommended for tears involving more than 50% of the tendon and if an extension lag is present (132, 138-141).

Imaging studies increase the diagnostic accuracy and may help reduce the number of misdiagnosed cases

### *Imaging Protocol*

Radiographs could show mineralization at the triceps tendon. On MR imaging, sagittal images are most helpful to assess the triceps tendon. MR imaging findings could demonstrate tendinopathy, partial or complete tears. US is able to depict a retracted and wavy tendon with various degrees of local effusion (142). Acute tear of the distal triceps tendon can constitute a cause of ulnar nerve compression syndrome. Dynamic US is able to evaluate the snapping of the medial triceps belly and identify the ulnar nerve around the epicondyle.

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