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REVIEW ARTICLE

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Ultrasound of the elbow

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Abstract Ultrasonography (US) is an efficient alternative to magnetic resonance (MR) imaging for evaluation of soft tissues of the elbow. US is able to diagnose several abnormalities affecting tendons, muscles, ligaments and bursae around the elbow joint. In cubital tunnel syndrome, US identifies ulnar nerve abnormalities and extrinsic lesions that may cause nerve entrapment. Occult fractures, osteophytes and intra-articular loose bodies can also be imaged. In para-articular swelling, US is able to assess the presence of capsular and synovial processes and to differentiate them from soft tissue tumors. Key advantages of this technique include cost-effectiveness, availability and ability to perform a dynamic examination.

Keywords Elbow, ultrasound · Joints, ultrasound · Elbow, injuries · Tendon, injuries · Cubital tunnel syndrome

Introduction

Ultrasonography (US) is able to provide clinically useful information in assessing a wide range of pathologic conditions affecting synovial space and joint surfaces, tendon insertions and supporting soft tissues of the elbow joint. Although US of the elbow is an operator-dependent examination requiring experience and surgical feedback for reliable reporting and disease definition, it offers some advantages over magnetic resonance (MR) imaging, including time and cost-effectiveness, superior spatial resolution, dynamic study and the possibility of performing the examination in a comfortable position for the patient.

The purpose of this review article is to describe the normal US findings of the elbow and to familiarize radiologists with commonly encountered diseases of the elbow. The range of pathologic entities depicted with US is wide and heterogeneous in this field and, therefore, we have arbitrarily subdivided the elbow in a four-quadrant approach, consisting of its anterior, lateral, medial and posterior aspects.

Anterior elbow

US examination of the anterior aspect of the elbow may be performed with the patient facing the examiner with the elbow resting in an extension position on a table [1]. The main structures amenable to US examination are: the brachialis muscle, the distal biceps tendon (DBT), the brachial artery, the median nerve (MN) and radial

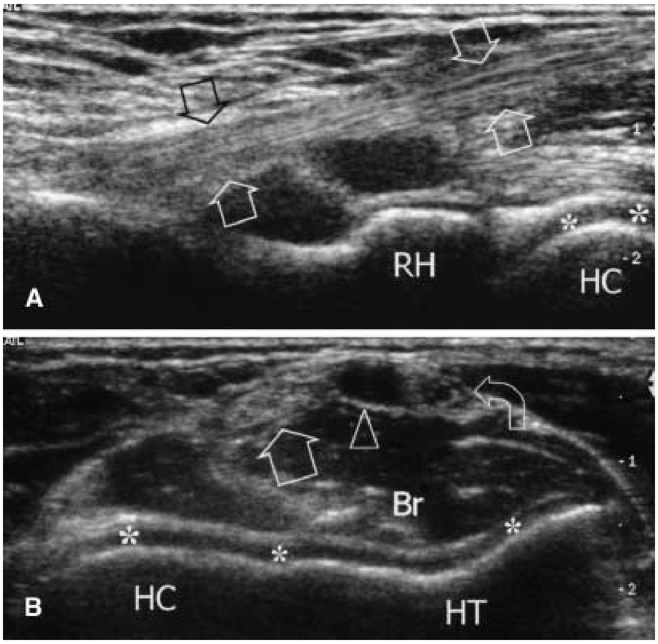


Fig. 1A, B Anterior elbow. **A** Longitudinal 12–5 MHz US scan of the normal elbow in a healthy subject shows the echogenic appearance of the distal biceps tendon (*arrows*) inserting on the bicipital tuberosity. Note the radial head (*RH*) and the humeral capitellum (*HC*), the latter covered by a band of hypoechoic cartilage (*asterisks*). **B** Transverse 12–5 MHz US scan over the brachialis muscle (*Br*) demonstrates the relation of the distal biceps tendon (*arrow*) with the brachial artery (*arrowhead*) and the median nerve (*curved arrow*). *HT* humeral trochlea

nerve (RN), the coronoid synovial recess with the anterior fat pad and the radiocapitellar and trochlea-ulna joints (Fig. 1).

One of the most common causes of acute anterior elbow pain is rupture of the DBT. This is a flattened tendon that derives from the union of the two muscle bellies, the long and short heads, of the biceps brachii muscle. It is approximately 7 cm long and curves laterally before inserting on the medial aspect of the radial tuberosity. The DBT also has a flattened aponeurotic attachment, commonly referred to as the lacertus fibrosus, that extends from the myotendinous junction to the medial deep fascia of the forearm, covering the MN and the brachial artery. Tears of the DBT account for less than 5% of all biceps tendon lesions, proximal injuries being far more common [2]. They typically occur after 40 years of age in weightlifters or those who attempt to lift a heavy object. Clinically, a complete tear of the DBT usually presents with pain and a palpable defect with a proximal lump in the anterior aspect of the arm related to the retracted muscle. In most cases, the clinical diagnosis is straightforward and does not need an imaging study; difficulties may arise either in the absence of significant muscle retraction because of an intact lacertus fibrosus, or when the retracted muscle is hidden from palpation by surrounding edema and hemorrhage. An early diagnosis of DBT rupture is important because surgical outcome is improved in patients treated in the first weeks after trauma. US features of a complete tear of the DBT include nonvisualization of the distal tendon, which appears retracted (up to more than 10 cm), and detection of hypoechoic fluid in the tendinous bed related to the hematoma [3, 4] (Fig. 2). The effusion is best recognized proximally, around the tendon stump. Even with high-resolution transducers, US is not sensitive enough either to depict the normal aponeurosis or to recognize direct signs of its rupture. When the lacertus fibrosus tears, more striking tendon retraction is common; however, there is no evidence that the degree of tendon retraction is in itself predictive of the status of the lacertus fibrosus [4]. Partial tears of the DBT are much less common than complete tears. Sonographically, they appear as hypoechoic thickening or thinning of the tendon and as contour irregularities or waviness without tendon discontinuity [4]. Distal lesions may be difficult to demonstrate due to anisotropy related to the oblique course of the tendon. In doubtful cases, MR imaging is an accurate means to confirm the diagnosis of partial tears [5, 6].

The DBT is not invested by a synovial sheath and, just proximal to the tendon insertion, it is in contact with the cubital bursa (CB). This bursa is located between the DBT and the radial tuberosity to reduce friction during pronation of the forearm [7]. Cubital bursitis can result from several causes (infection, inflammatory arthropathy, amyloidosis, etc.), but it is most commonly secondary to repetitive mechanical trauma. When the CB is only mildly distended, US may have difficulty in distinguishing it from the adjacent DBT that appears hypoechoic due to anisotropy [4]. Usually, transverse scans with the forearm supinated perform better in delineating the bursal shape. Sonographically, cubital bursitis appears as a hypoechoic mass located in proximity to the DBT [8]. The CB may have septations, thick walls and echogenic content. Rice bodies have also been described in this bursa with US [9]. In cases of abundant effusions, the CB can surround the distal DBT completely, mimicking a tenosynovitis (Fig. 3A). Cubital bursitis must be differentiated from synovial and ganglion cysts or other soft tissue masses. Ganglia commonly arise from the anterior capsule and may expand at variable distance from the joint dissecting the soft tissues of the forearm [10] (Fig. 3B). Visualization of a pedicle that connects the cyst with the elbow joint cavity may help the diagnosis. Tumors are distinguished from cystic lesions on the basis of their solid echotexture.

Both rupture of the DBT and cubital bursitis may cause irritation and impingement on the adjacent MN and RN. Entrapment of the MN is exceptional at the elbow and mainly results from anatomic variants, such as a supracondylar process with a ligament of Struthers, hypertrophy of the pronator teres muscle or an accessory

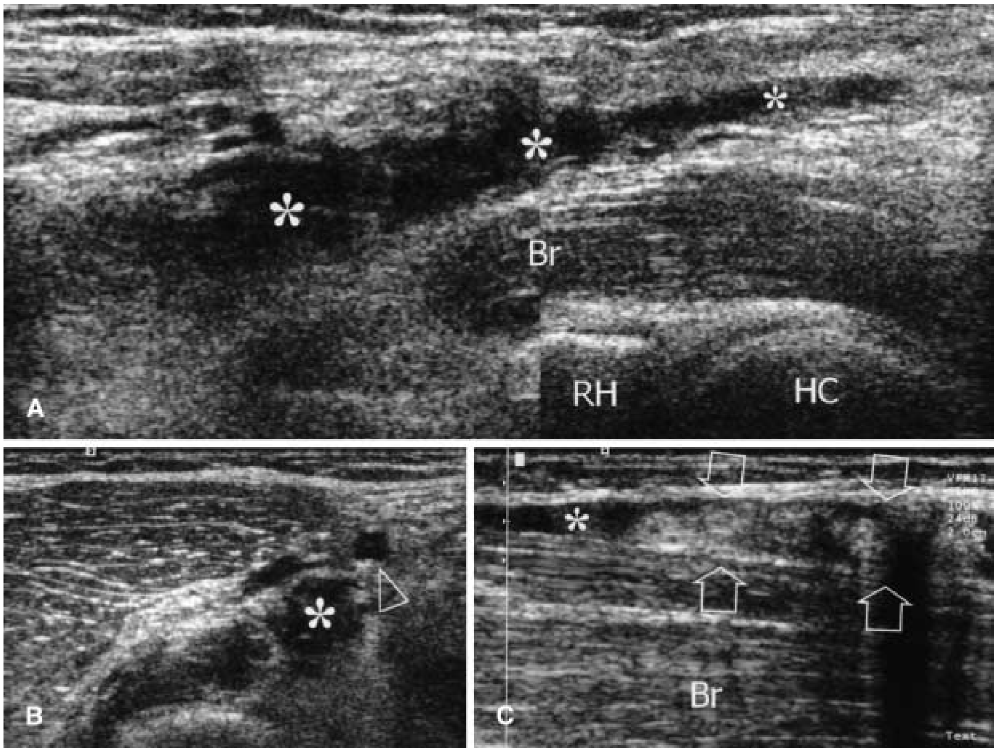


Fig. 2A–C Distal biceps tendon tear. **A, B** Longitudinal (**A**) and transverse (**B**) 5–12 MHz US scans over the brachialis muscle (*Br*) show hypoechoic fluid filling the bed (*asterisks*) of the retracted distal biceps tendon. Note the radial head (*RH*) and the humeral capitellum (*HC*). *Arrowhead* brachial artery. **C** Longitudinal US scan obtained proximal to the elbow joint demonstrates the torn and retracted tendon edge (*arrows*) surrounded by hypoechoic fluid (*asterisk*)

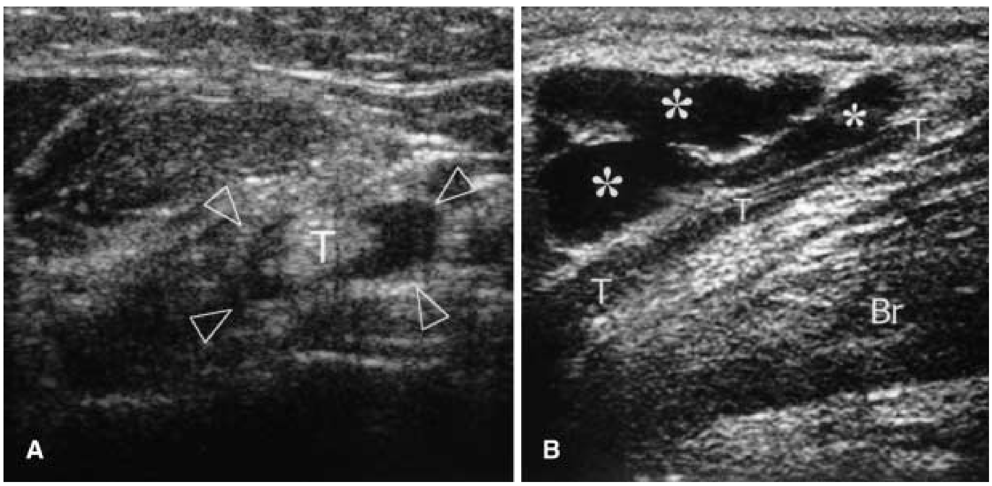


Fig. 3A, B Cystic lesions around the elbow joint. **A** Cubital bursitis. Transverse 5–12 MHz US scan at the anterior aspect of the elbow distal to the joint space shows an enlarged cubital bursa (*arrowheads*) which almost completely surrounds the distal biceps tendon (*T*), thus mimicking a tenosynovitis. **B** Ganglion cyst. Longitudinal 5–10 MHz US scan in the antecubital fossa reveals a lobulated anechoic fluid-filled mass (*asterisks*) superficial to the distal biceps tendon (*T*) and the brachialis muscle (*Br*), consistent with a ganglion

bicipital aponeurosis. Entrapment of the RN may result from thickening of the arcade of Fröhse along the proximal edge of the supinator. Although there are few reports in the literature on US imaging of these nerves at the elbow, both can be reliably visualized with this technique.

With the probe placed over the brachialis muscle, the anterior coronoid recess of the elbow joint can be examined by means of transverse and sagittal US scans (Fig. 4A). Anechoic effusion of more than 2 mm between the anterior aspect of the humerus and the joint capsule with elevation of the anterior fat pad indicates synovitis [11] (Fig. 4B). After the knee, the elbow is the second most common site of intra-articular loose bodies. The intra-articular location of a fragment can be established by showing it surrounded by fluid in a recess of the elbow joint [12, 13] (Fig. 5). In patients without a synovial effusion, the intra-articular injection of saline may enhance the conspicuity of small and radiographically occult loose bodies [14]. Moving the transducer radially, the annular recess around the proximal metaphysis of the radius is examined distal to the radiocapitellar joint space. Although rarely involved, this recess can readily

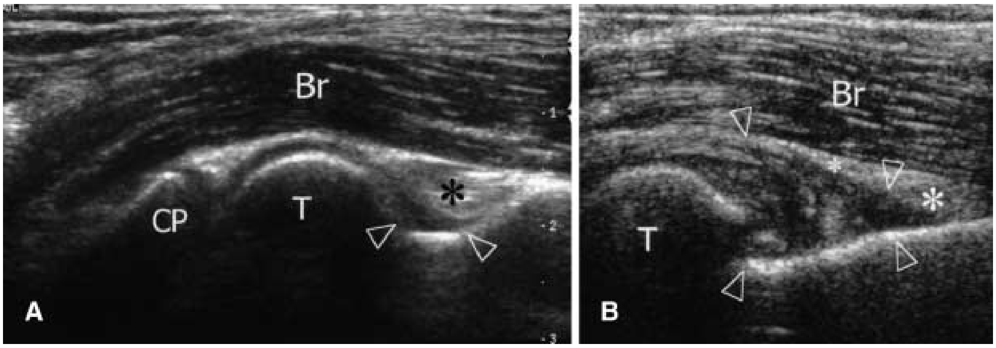
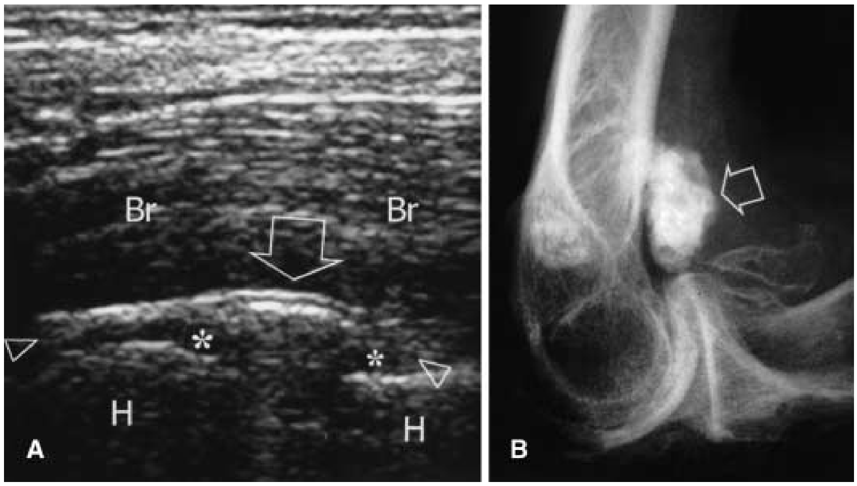


Fig. 4A, B Anterior joint recess. **A** Longitudinal 5–12 MHz US scan at the anterior aspect of the elbow in a healthy subject identifies the anterior joint recess (*arrowheads*) cranial to the hyperechoic bony surfaces of the coronoid process (*CP*) and the trochlea (*T*) and deep to the brachialis muscle (*Br*). Note the anterior fat pad (*asterisk*) visualized as a hyperechoic tissue delimiting this recess anteriorly. **B** Same US scan in a patient with rheumatoid arthritis shows a bulk of hypoechoic synovial pannus which fills this recess (*arrowheads*) and causes elevation of the anterior fat pad (*asterisks*)

Fig. 5A, B Intra-articular loose body. **A, B** Longitudinal 5–10 MHz US image (**A**) at the anterior aspect of the elbow joint with lateral radiographic correlation (**B**) shows a hyperechoic bony fragment (*arrow*) close to the anterior surface of the humerus (*H*). The intra-articular location of the fragment is suggested by a thin rim of surrounding hypoechoic fluid (*asterisks*) and slight displacement of the anterior fat pad (*arrowheads*)



be examined with US by asking the patient to alternate supination and pronation of the forearm with the elbow still extended. The radiocapitellar and trochlea-ulna joints can also be assessed. In normal states, the subchondral bone appears as a continuous and regular hyperechoic line covered by the hypoechoic band of the articular cartilage (Fig. 1). In patients with rheumatoid arthritis, the pannus is recognized as hypoechoic tissue associated with intra-articular anechoic effusion and joint erosions (Fig. 4B). Synovial cysts at the antecubital fossa and rheumatoid nodules can be depicted with US. Radiographically occult or equivocal fractures (e.g., radial head) may be detected by US as an interruption of the cortical line (Fig. 6). There are difficulties in assessing bony abnormalities about the elbow in skeletally immature patients using plain films because of the absence of the secondary centers of ossification. When a radiographic sign of a joint effusion is present but a fracture is not visualized, US may help in distinguishing the separation of the distal humeral epiphysis [15, 16] from elbow dislocation in neonates, as well as in detecting or excluding radial head [17] and supracondylar fractures [18, 19]. In adolescents, US is also able to recognize deformities of the capitellum and intra-articular loose bodies related to osteochondritis dissecans [20]. Similar abnormalities may be identified in Panner disease [21]. The US features of cellulitis [22] and osteomyelitis [23] in the infected elbow have also been described in children. In such cases, delay in the appropriate management of the patient can be avoided by an early US examination.

Lateral elbow

The lateral elbow may be examined with both elbows in extension, thumbs up, palms of the hands together [1]. When examining the radial collateral ligament (RCL) and the capsule, the elbow should be extended, keeping the hand pronated. At the lateral elbow, US can image the common extensor tendon (CET) and the RCL.

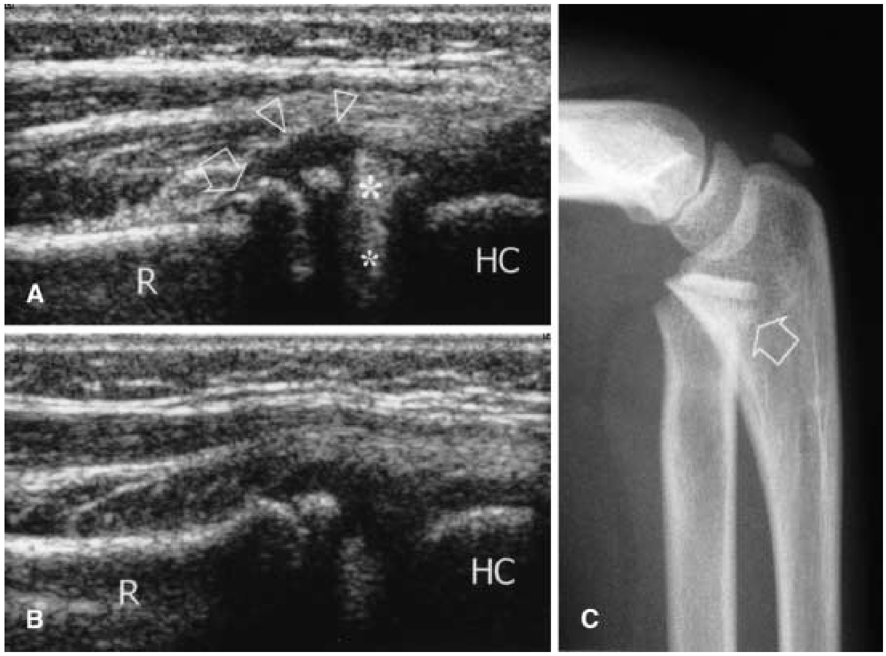


Fig. 6A–C Radial fracture. **A** Longitudinal 5–12 MHz US image at the anterolateral elbow in a 5-year-old child who presented with lateral elbow pain demonstrates increased distance between the humeral capitellum (*HC*) and the radial epiphysis (*arrowheads*) related to an intervening hyperechoic joint effusion (*asterisks*). Note the hyperechoic dot within the radial epiphysis representing the ossification center. At the radial metaphysis, US reveals a focal irregularity of the hyperechoic cortical line (*arrow*) suggesting a fracture. *R* radius. **B** Contralateral normal US scan. **C** Lateral radiograph confirmed the diagnosis of radial fracture (*arrow*)

The CET is a flattened tendon which originates from the anterolateral surface of the lateral epicondyle (LE). Sonographically, this tendon appears as a beak-shaped structure in which the individual contributions of fibers from the superficial extensor muscles (carpi radialis brevis, common digitorum, digiti minimi and carpi ulnaris) cannot be separated one from another into discrete components. However, the extensor radialis brevis makes up most of the deep articular fibers, whereas the extensor digitorum contributes to the superficial portion of the CET [24]. The extensor digiti minimi and carpi ulnaris provide only minor components. Deep to the CET, the LE appears as a smooth down-sloping hyperechoic image.

The most common disorder involving the lateral elbow is lateral epicondylitis, commonly known as "tennis elbow", caused by repetitive traction on the osteotendinous attachment [25]. US can be useful to confirm the clinical diagnosis in doubtful cases, reveal the extent and severity of the disease and monitor the response to therapy. The main US features of lateral epicondylitis include: preinsertional hypoechoic swelling of the tendon related to enthesopathy, focal or diffuse areas of decreased reflectivity in the tendon substance with loss of the fibrillar pattern related to tendinosis, discrete cleavage planes representing partial and complete tears, thickening of peritendinous soft tissues and a thin layer of fluid superficial to the tendon origin [24, 26] (Fig. 7). Although early tendon abnormalities may be confined to the superficial fibers, injury to the deep fibers of the extensor carpi radialis brevis component is more common and may even extend down to the joint capsule. Similarly, the anterolateral and mid-portion of the CET is more commonly involved, whereas the posterior portion usually remains unaffected [24]. In chronic disease, spurring at the CET insertion and cortical irregularities at the anterolateral surface of the LE may be recognized, although bony changes does not correlate with disease activity. A hypoechoic cleft through the tendon substance indicates a complete tear [27].

The RCL complex arises from the anterior aspect of the LE, immediately deep to the extensor carpi radialis brevis component of the CET, and blends down with the fibers of the annular ligament, which surrounds the radial head. Sonographically, it appears as a thin fibrillar structure with a slightly different course with respect to the CET origin and becomes more distinguishable when injured [24]. A torn RCL appears as a discontinuity of ligament fibers and local hematoma is usually found at the proximal margin of the capitellum. In the pulled elbow, a common injury among children due to slipping of the annular ligament over the radial head when the forearm is pronated, US is able to depict an increased distance between the radial head and the capitellum, probably due to the impingement of the annular ligament [28].

Medial elbow

The medial aspect of the elbow may be examined with the elbow in extension resting on a table, with the arm in forceful external rotation [1]. On the medial side of the elbow there are two main structures to be studied: the common flexor tendon (CFT) and the ulnar collateral ligament (UCL).

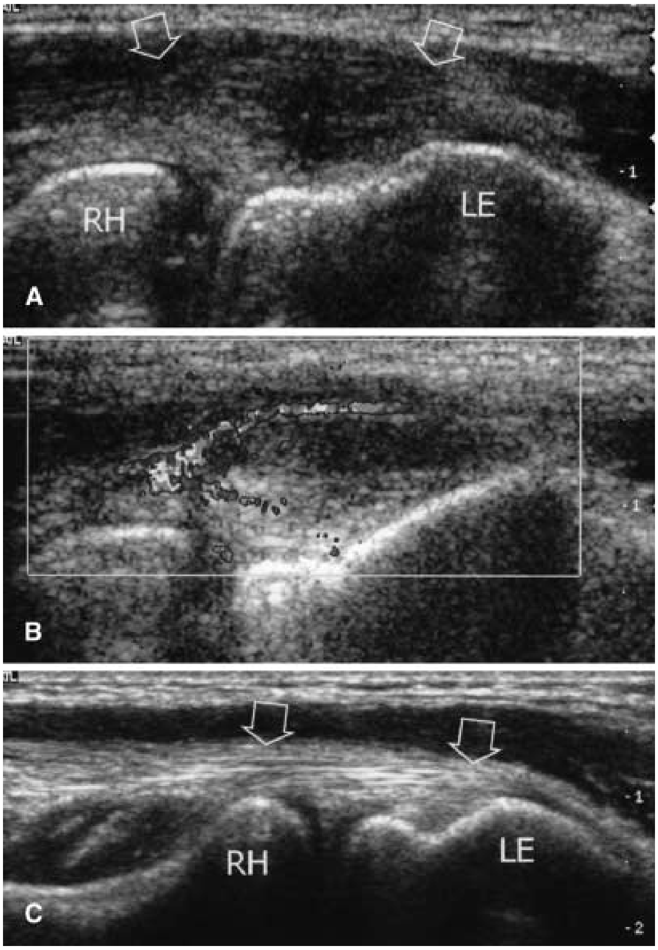


Fig. 7A–C Lateral epicondylitis. **A** Longitudinal 5–12 MHz US image at the lateral elbow in a tennis player with chronic elbow pain reveals a swollen common extensor tendon (*arrows*) with a full-thickness hypoechoic area compatible with tendinosis. *LE* lateral epicondyle; *RH* radial head. **B** The tendon appears hypervascular at color Doppler imaging. **C** Normal contralateral US scan

Similar to the extensor tendons, the flexor-pronator group arises by a common tendon from the medial epicondyle (ME). The CFT is shorter, thicker and more clearly separated from the capsule than the CET. Medial epicondylitis, also referred to as “golfer’s elbow”, is a degenerative tendinopathy that involves the attachment of the CFT. The US appearance of medial epicondylitis is similar to the more common lateral epicondylitis [29]. US can help in distinguishing tendinopathy from a lesion of the underlying UCL.

The UCL is much stronger than the RCL. Its degeneration and tearing with or without an injury of the adjacent CFT result from repeated overstretching in valgus stress during the acceleration phases of throwing or in the setting of posterior dislocation of the elbow. On longitudinal scans, the UCL appears as a thin hypoechoic band deep to the CFT. When the UCL is ruptured, US

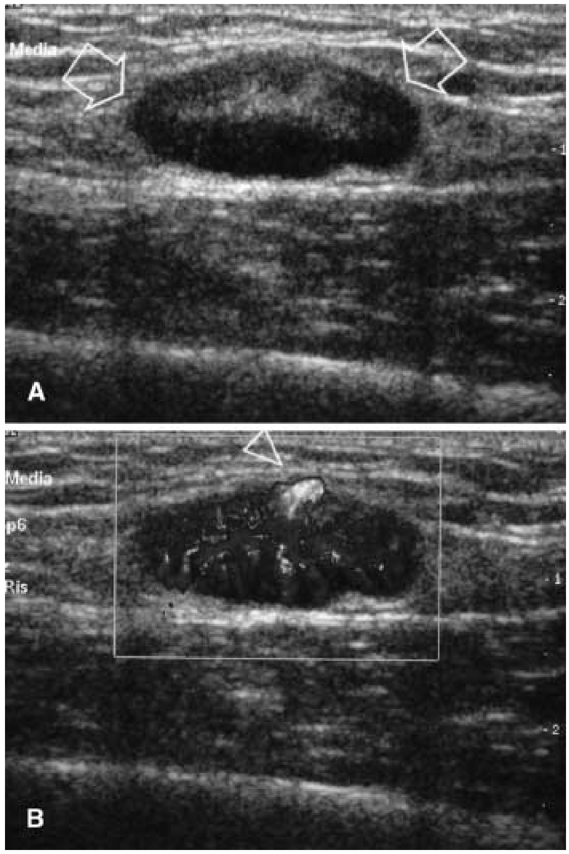


Fig. 8A, B Epitrochlear lymphadenitis. **A** Longitudinal 5–12 MHz US scan at the medial elbow in a patient with a palpable mass associated with the medial epicondyle. US identifies the typical appearance of a reactive lymph node (*arrows*). **B** The node is hypervascular at color Doppler imaging, with a vessel pedicle (*arrowhead*) entering the echogenic hilum and branching through the hypoechoic cortex

detects a hypoechoic torn ligament surrounded by fluid slightly posterior and deep to the ME [21, 27].

Close to the ME, small lymph nodes may enlarge as a consequence of reactive or septic inflammation [30] (Fig. 8).

Posterior elbow

The posterior aspect of the elbow may be examined by keeping the joint flexed 90° with the palm resting on the table [1]. In this position, rocking motion of patient’s elbow may be helpful in shifting the joint fluid and delineating small loose bodies [12]. The main structures of the posterior elbow to be examined are: the cubital tunnel and the ulnar nerve (UN), the triceps muscle and tendon, the olecranon recess and bursa.

The cubital tunnel is a long osteofibrous tunnel which extends throughout the elbow joint. It is delimited by the

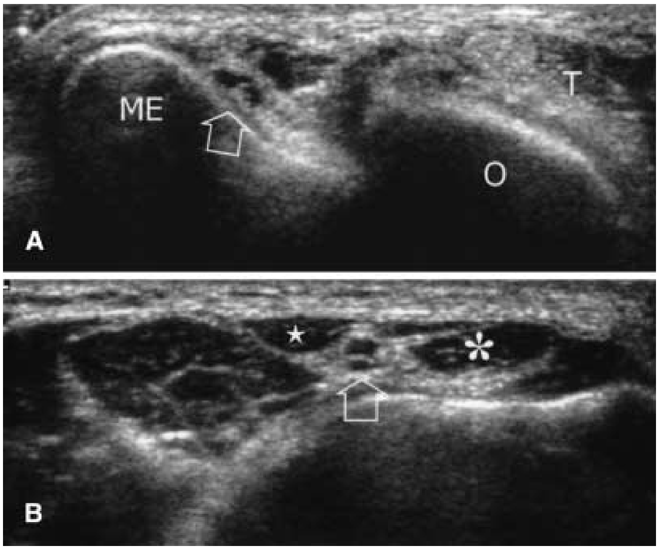


Fig. 9A, B Cubital tunnel. **A, B** Transverse 12–5MHz US scans at the proximal (**A**) and distal (**B**) cubital tunnel demonstrate the normal relationship of the ulnar nerve (*arrow*) with the medial epicondyle (*ME*) and, more distally, with the two heads (*asterisks*) of the flexor carpi ulnaris. Note the olecranon process (*O*) and the triceps tendon (*T*)

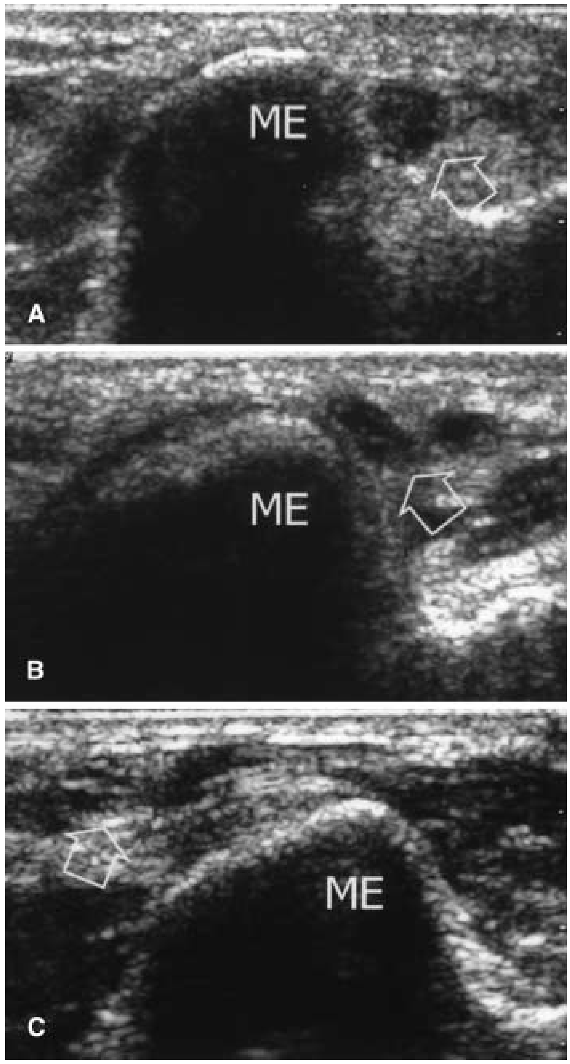


Fig. 10A–C Ulnar nerve dislocation. **A–C** Transverse 12–5MHz US scans of the cubital tunnel in a patient with palpable snapping at the medial elbow show the relation of the ulnar nerve (*arrow*) with the medial epicondyle (*ME*) while keeping the elbow extended (**A**) and during progressive degrees of elbow flexion (**B–C**). As the elbow flexes, the ulnar nerve is pushed against the tip of the medial epicondyle (**B**), until it snaps completely out of the tunnel (**C**)

olecranon, the ME, and a retinaculum – the Osborne fascia – which continues distally with the aponeurotic arch – the arcuate ligament – between the ulnar and humeral heads of the flexor carpi ulnaris muscle. It may be examined with the patient supine keeping the arm abducted, hanging over the table. Small footprint transducers may help to achieve full probe contact on the bony surfaces of the elbow. With larger transducers, thin, flexible stand-off pads may help scanning. The entrapment of the UN at the elbow presents with medial elbow pain and a spectrum of complaints ranging from sensory symptoms in the fourth and fifth fingers to weakness in the innervated hand muscles. The clinical diagnosis can be difficult, because the UN can be involved anywhere in the upper extremity. On transverse scans, the UN appears as an ovoid or bifid hypoechoic image close to the hyperechoic bony cortex of the ME (Fig. 9). Due to its arching course, the UN is less echogenic at the elbow than elsewhere in the upper limb as a result of anisotropy. Dynamic US scanning is ideal to depict the subluxation or even the intermittent anterior dislocation of the UN relative to the ME [27] (Fig. 10). During progressive elbow flexion, the UN can be seen pushing over the ME until snapping out of the groove. This condition is related to a short or absent retinaculum and is commonly encountered in asymptomatic healthy subjects. In some cases, however, the repeated contact of the UN against the ME can cause friction neuritis and functional deficit. UN entrapment may occur either at the condylar groove or at the edge of the arcuate ligament as a result of cubitus valgus, bone deformities or osteophytes in the condylar groove, heterotopic ossification, thickening of the UCL, accessory muscle, loose bodies and ganglion cysts [31]. US demonstrates the abrupt narrowing of the UN within the tunnel, often in association with a thickened retinaculum or a space-occupying lesion [32, 33, 34]. Proximal to the level of compression, the UN appears swollen and hypoechoic (Fig. 11). In cubital tunnel syndrome, the cross-sectional area of the UN may be significantly larger than in healthy subjects and in comparison with the contralateral nerve [34, 35].

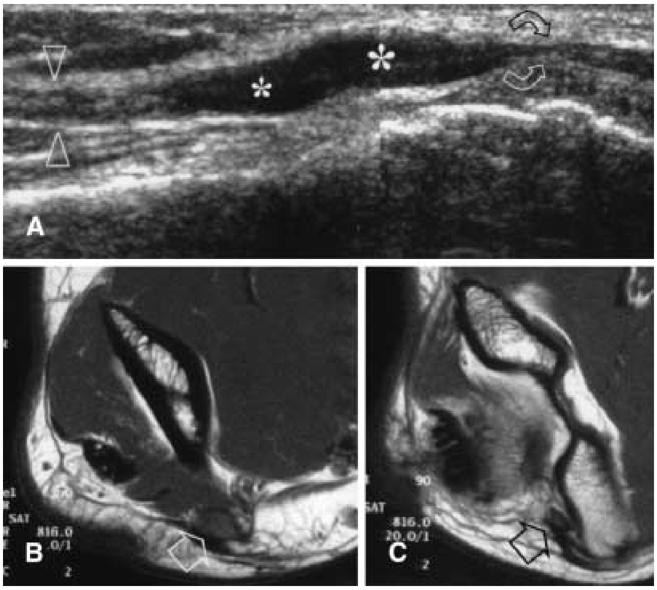


Fig. 11A–C Cubital tunnel syndrome. **A** Longitudinal 12–5MHz US scan of the cubital tunnel in a patient with cubitus valgus demonstrates the ulnar nerve (*arrowheads*) which appears increasingly swollen and hypoechoic (*asterisks*) as it progresses towards the compression point (*curved arrows*). **B**, **C** Transverse T1-weighted (TR/TE 816/20 ms) correlative MR images obtained at the distal arm (**B**) and within the cubital tunnel (**C**) show the abrupt change in the cross-sectional area of the nerve (*arrow*)

At the posterior elbow US can confirm the rupture of the distal triceps tendon (DTT). This tendon originates in the middle of the muscle and is composed of a superficial layer and a broader deep layer that combine to form the tendon that inserts on the posterosuperior aspect of the olecranon. An anomalous triceps insertion on the medial olecranon can cause clinical symptoms related to intermittent snapping of the medial triceps over the ME and UN neuropathy. Dynamic US scanning is able to demonstrate dislocation of both the UN and the triceps during progressive degrees of elbow flexion. The DTT typically tears with a fleck of bone attached to the retracted tendon. The mechanism involves flexion of the elbow against a contracting triceps, as it occurs during a fall on an outstretched arm. Local steroid injection in the olecranon bursa and pre-existing tendinosis may be implicated in the tendon rupture. At US examination, the torn DTT appears wavy, retracted and surrounded by fluid [36]. US is able to delineate the degree of tendon retraction and can help the diagnosis in partial ruptures, when swelling and pain may mask the clinical findings. Due to the close anatomic relation of the DTT to the ME and the cubital tunnel, an acute UN compression syndrome may occur secondary to a DTT tear [37].

The relatively common olecranon bursitis is secondary to repetitive local trauma. Sonographically, this condition may appear as a localized fluid collection within the subcutaneous tissue immediately superficial to the olecranon, associated with hyperemic flow signals on color Doppler imaging, typically in a rimlike fashion [38]. In hemorrhagic and septic bursitis, the fluid may contain internal echoes and the bursal wall may become thickened and echogenic (Fig. 12). Edema of surrounding soft tissues and cellulitis may be associated findings. However, these characteristics are too subtle to allow a definitive diagnosis based on US findings alone, and needle aspiration of fluid, possibly obtained under US guidance, is usually required for a specific diagnosis.

Deep to the DTT, the olecranon fossa is occupied by the hyperechoic posterior fat pad [11]. Displacement of this pad from the underlying humerus is a well-recognized sign of joint effusion and may best be seen with US keeping the elbow flexed [39] (Fig. 13). US is able to detect synovitis relatively easily and differences in echotexture can allow distinction between synovial hypertrophy and effusion. Gradual compression with the probe can help to distinguish effusion from synovial pannus. When there is clinical concern for septic arthritis, US-guided aspiration of the joint fluid can be performed [27, 40].

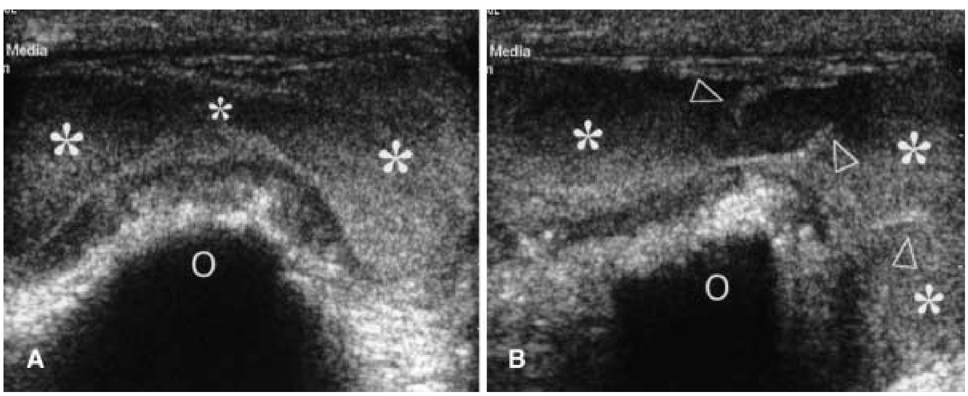


Fig. 12A, B Septic olecranon bursitis. Transverse (**A**) and longitudinal (**B**) 12–5MHz US scans of a painful soft-tissue mass over the olecranon process (*O*) show marked distention of the olecranon bursa, which exhibits thickened walls, septations (*arrowheads*) and highly echogenic effusion (*asterisks*)

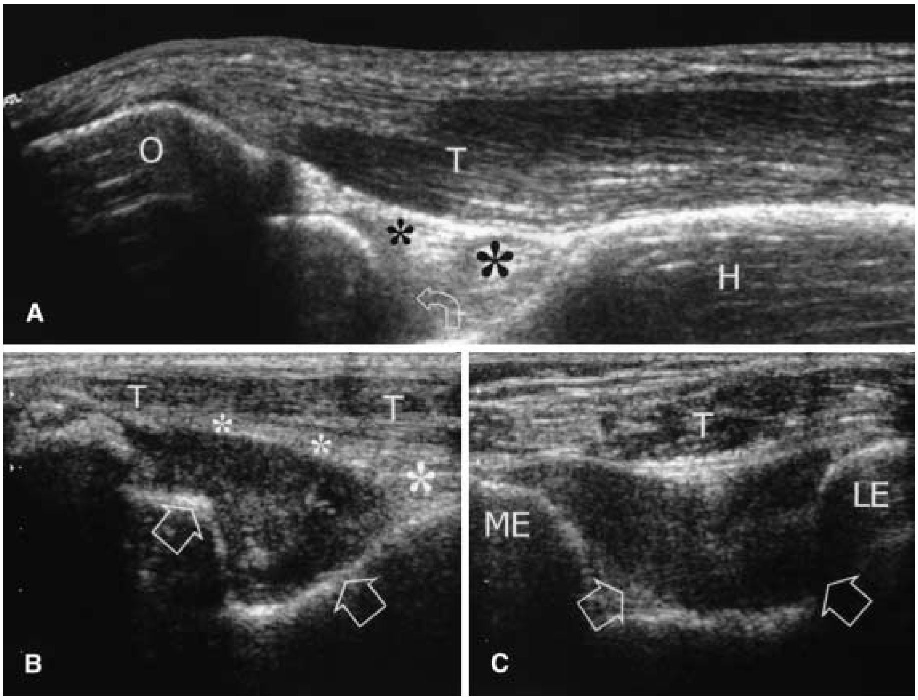


Fig. 13A–C Posterior joint recess. **A** Extended-field-of-view longitudinal 5–12 MHz US scan of the distal end of the humerus, obtained with the elbow flexed. In the olecranon fossa, the posterior joint recess (*curved arrow*) is delimited by the hyperechoic spoon-shaped contour of the humerus and by the echogenic posterior fat pad (*asterisks*) deep to the triceps muscle (*T*). **B, C** Longitudinal (**B**) and transverse (**C**) 5–12 MHz US scans of the olecranon fossa in a patient with rheumatoid arthritis demonstrate hypoechoic synovial pannus filling the posterior recess (*arrows*). The posterior fat pad (*asterisks*) is displaced by the pannus. *ME* medial epicondyle; *LE* lateral epicondyle

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