3 Examination Techniques and Ultrasound Appearance

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Ultrasound examination of the elbow may be performed with the patient seated and the elbow placed on the examination table/bed [1–4].

The exam is generally tailored to the clinical question, however a complete evaluation of the elbow should be considered; in these cases, a useful approach is to divide the elbow into anterior, lateral, posterior, and medial compartments (Table 3.1).

In general, examination of the anterior elbow may begin with the upper limb resting in an extended and supinated position on the examination table (Fig. 3.1). The key structures to be evaluated include the distal biceps muscle and tendon [5–8], the distal brachialis muscle and tendon [9, 10], the anterior joint recess [11] with the anterior fat pad, the median nerve, the radial nerve [12–14], the brachial artery, and the articular cartilage [1].

The biceps muscle is located superficial to the brachialis muscle and lateral to the brachial artery (Table 3.2) and median nerve [4]. Its tendon is long, approximately 7 cm, with an oblique course from the lateral to the medial and 90° rotation, to insert onto the radial tuberosity. It has been demonstrated that the distal biceps tendon is made of two separate tendons belonging to the short and long head of the biceps muscle. The distal portion of the biceps tendon is covered by an extrasynovial paratenon and by the bicipitoradial bursa.

Different approaches have been proposed to study the distal biceps tendon [1, 7]. The different approaches are complementary and may be performed together. In the anterior approach, the tendon may be found on the short-axis and evaluated from proximal to distal (Fig. 3.1); then, the probe is rotated by 90° so it is possible to place the transducer longitudinally to the insertion of the tendon (Fig. 3.2). Longitudinally, increasing the probe pressure over the tendon reduces the anisotropy. In

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Table 3.1 Checklist for elbow ultrasound evaluation

Lateral	Common extensor tendon
	Lateral collateral ligament
	Radial nerve
	Supinator muscle
	Posterior interosseous nerve
Anterior	Distal biceps tendon
	Bicipitoradial bursa
	Brachialis tendon
	Median nerve
	Brachial artery
	Joint recess
	Anterior fat pad
Medial	Common flexor tendon
	Medial collateral ligament
	Pronator teres
Posterior	Distal triceps tendon
	Olecranon bursa
	Ulnar nerve
	Joint recess
	Posterior fat pad

Fig. 3.1 Anterior elbow. Transducer placement is demonstrated on the upper limb resting in an extended and supinated position on the examination table (**a**). Sonography shows the distal biceps tendon (curved arrow) located superficial to the brachialis muscle, lateral to brachial artery (void arrow) and median nerve (arrow) (**b**)

Table 3.2 Landmark

Lateral	Common extensor tendon—lateral epicondyle
	Lateral collateral ligament—common extensor tendon
	Radial nerve—brachialis
	Posterior interosseous nerve—supinator muscle
Anterior	Distal biceps tendon—brachial artery
	Bicipitoradial bursa—distal biceps tendon
	Brachialis tendon—biceps muscle
	Median nerve—brachial artery
	Joint recess—brachialis, Brachioradialis
	Anterior fat pad—brachialis
Medial	Common flexor tendon—medial epicondyle
	Medial collateral ligament—common flexor tendon
	Pronator teres—median nerve
Posterior	Distal triceps tendon—olecranon
	Olecranon bursa—distal triceps tendon
	Ulnar nerve—medial epicondyle
	Joint recess—distal triceps tendon
	Posterior fat pad—distal triceps tendon

the medial approach, the elbow is flexed 90° and the forearm supinated (Fig. 3.3); the probe is placed longitudinally and medially over the distal arm. In this position, the brachial artery, medial to the biceps tendon, may be used as an acoustic window. In the posterior approach (Fig. 3.4), the elbow is flexed and the dorsum of the hand pointing toward the ceiling. The transducer is placed on a transverse plane over the proximal forearm at the level of the radial tuberosity. The insertion of the distal biceps is visible during pronation and supination movements.

From the lateral aspect of the tendon, an aponeurotic expansion, the lacertus fibrosus [15], extends to the medial deep fascia of the forearm [8]. It covers the median nerve and brachial artery and plays

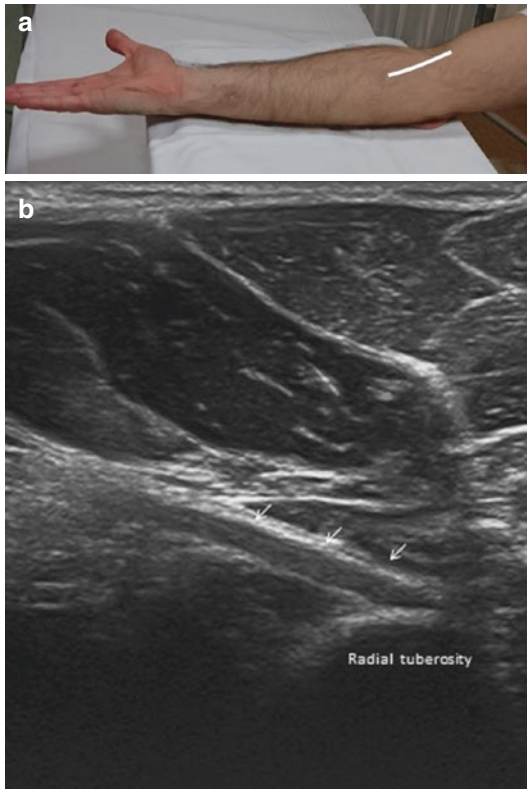

Fig. 3.2 Anterior approach for distal biceps tendon evaluation. Transducer placement (**a**). The distal biceps tendon is highlighted by arrows (**b**). In the anterior approach, the tendon may be found on short-axis and evaluated from proximal to distal; by rotating the probe by 90°, it is possible to place the transducer longitudinally to the insertion of the tendon. Increasing the probe pressure over the tendon reduces the anisotropy

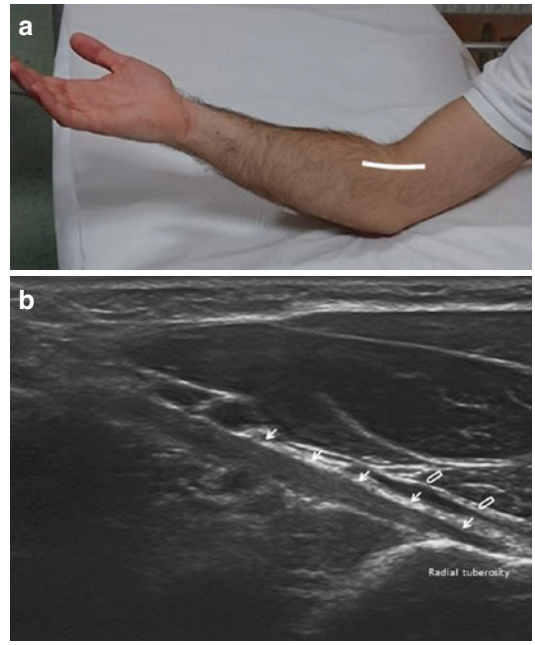

Fig. 3.3 Medial approach for distal biceps tendon evaluation. Transducer placement (**a**). The distal biceps tendon is highlighted by arrows (**a**). The probe is placed longitudinally and medially over the distal arm. In this position, the brachial artery, medial to the biceps tendon, may be used as an acoustic window

an important role in maintaining the distal biceps tendon in its appropriate position. An anterior approach with transverse planes is generally used to study the lacertus fibrosus. The patient is in a sitting position with the elbow lying on the table, and the lacertus fibrosus is scanned in two planes.

The brachialis muscle (Fig. 3.5) in the elbow is located deep in the biceps muscle. Its tendon inserts onto the ulnar tuberosity. The insertion of the brachialis may be muscular, tendinous, or mixed. Distal attachment of the brachialis is composed of a superficial and a deep head. An anterior approach with the upper limb resting in an extended and supinated position on the examination table is generally used. Transverse and longitudinal planes and pronosupination movements are useful to identify the two separate tendinous components [9, 10].

The median nerve [12–14], in the elbow, runs with the brachial artery, medial to the brachialis muscle. In the cubital fossa, both structures lie medial to the biceps brachii tendon (Fig. 3.1) and underneath the lacertus fibrosus [9]. At this level, the nerve lies medial to the artery and continues between the two heads of the pronator teres muscle. It gives off the anterior interosseous nerve approximately 2–5 cm distal to the medial epicondyle. The median nerve is easily evaluated with ultrasound (Fig. 3.6) on short-axis planes; with the patient in a sitting position and the elbow lying on the table, it has the typical honeycomb appearance.

The evaluation of articular cartilage [1] mainly relies on MR, but anterior transverse ultrasound images over the distal humeral extremity

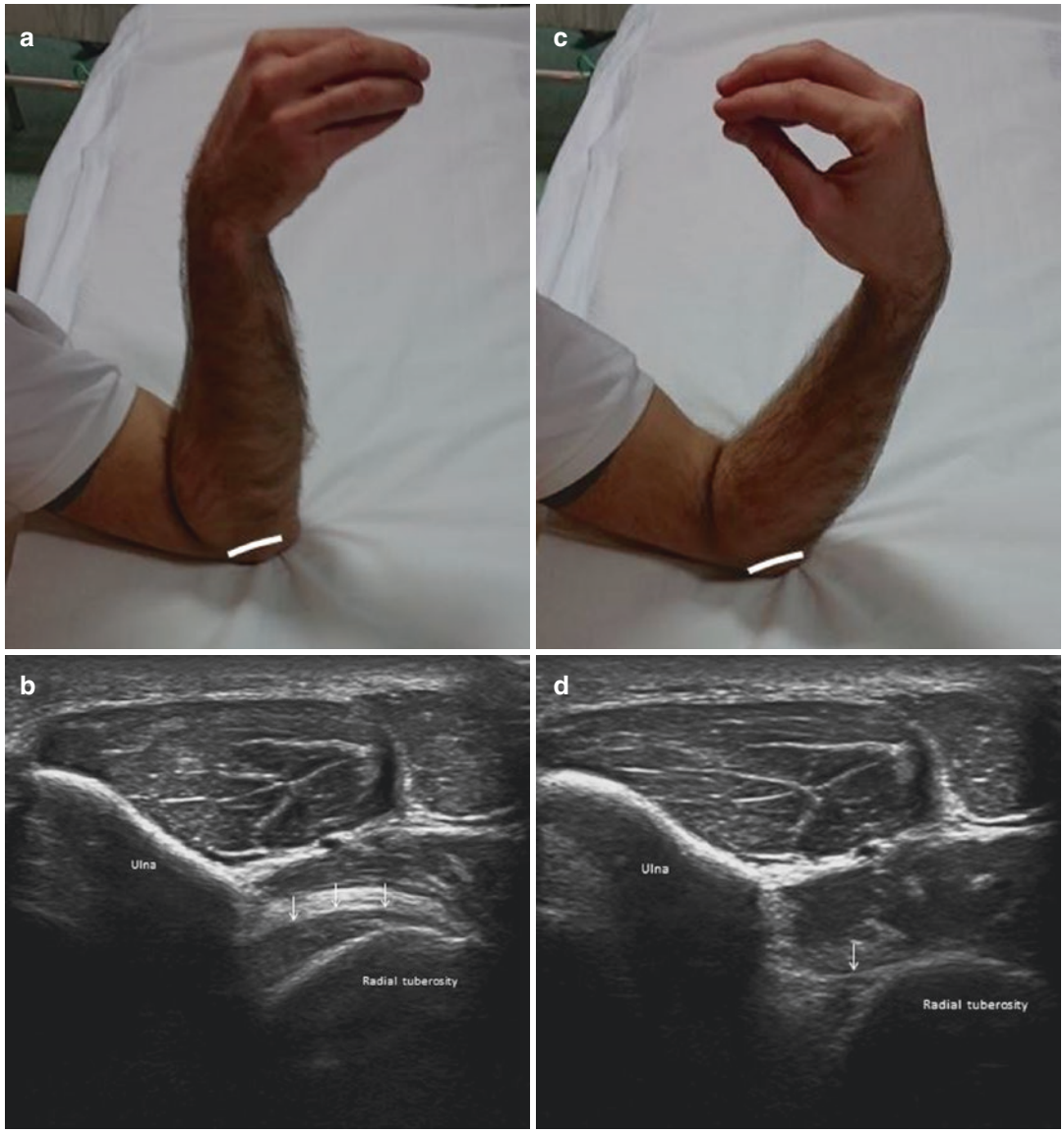

Fig. 3.4 Posterior approach for distal biceps tendon evaluation. Transducer placement (**a**, **c**). The distal biceps is highlighted by arrows (**b**, **d**). The elbow is flexed and the dorsum of the hand is pointing towards the ceiling, in the so-called cobra position. The transducer is placed on a transverse plane over the proximal forearm at the level of the radial tuberosity. The insertion of the distal biceps is visible during pronation and supination movements

(Fig. 3.7) are able to demonstrate the osteochondral surface of the capitellum and the trochlea. The articular cartilage appears as a hypoechoic band overlying the bone.

The radiocapitellar joint with the radial recess and the coronoid fossa with its respective coronoid recess are generally evaluated with anterior sagittal images (long-axis). The anterior fat pads are evaluated superficially to the recesses.

The lateral aspect of the elbow is generally examined with the elbow in flexion (Fig. 3.8a) or in the so-called crab position (elbow flexed 90° with the palm resting on the table) (Fig. 3.8b) [16, 17]. The radial head and the lateral epicon-

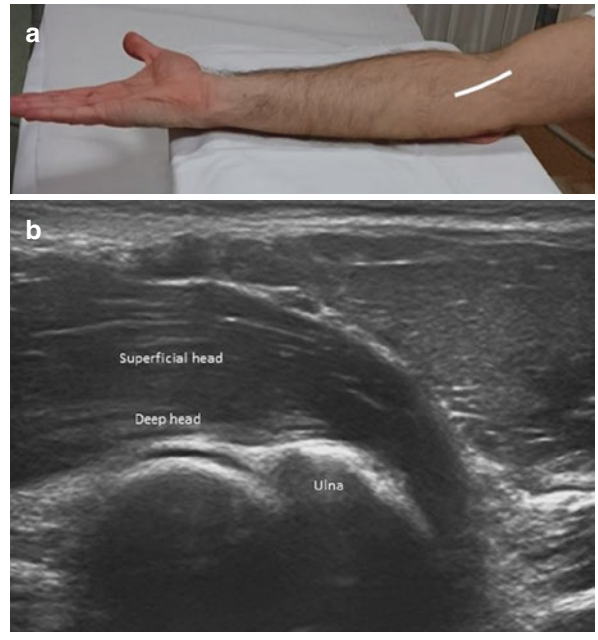

Fig. 3.5 Brachialis muscle and tendon. An anterior approach with the upper limb resting in an extended and supinated position on the examination table is generally used (**a**). The muscle and the tendon can be found on short-axis and evaluated from proximal to distal; then, by rotating the probe, it is possible to place the transducer longitudinally to the insertion of the tendon and the two separate tendinous components may be identified (**b**)

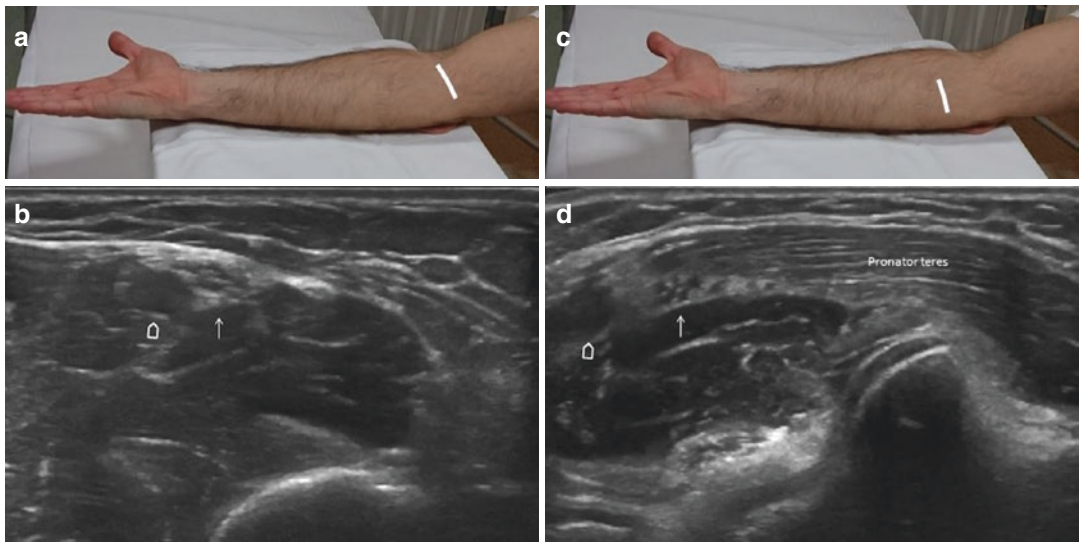

Fig. 3.6 Median nerve. The median nerve is easily evaluated with ultrasound on short-axis planes. In the elbow, it runs with the brachial artery (**a**) transducer placement, (**b**) sonographic image, void arrows—brachial artery, arrow—median nerve), then continues between the two heads of the pronator teres muscle (**c**) transducer placement, (**d**) sonographic image, void arrows—brachial artery, arrow—median nerve)

dyle may be used as landmarks. In the lateral aspect, the key structures to be evaluated are: the common extensor tendon, the lateral collateral ligament, the radial nerve and part of the radiocapitellar joint.

The common extensor tendon (Fig. 3.8c) arises from the lateral epicondyle. It consists of the tendons of four muscles: extensor carpi radialis brevis, extensor digitorum communis, extensor digiti minimi, and extensor carpi ulnaris. The

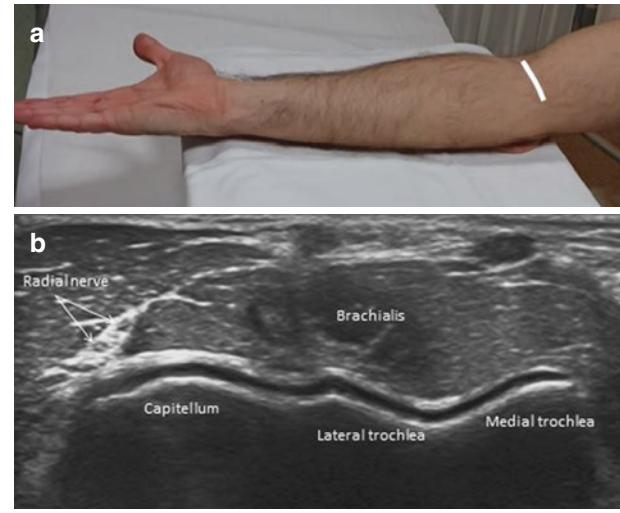

Fig. 3.7 Articular cartilage. Transducer placement (**a**). Ultrasound (**b**) demonstrates the osteochondral surface consisting of capitellum and trochlea. The articular cartilage appears as a uniform hypoechoic band overlying the subchondral bone

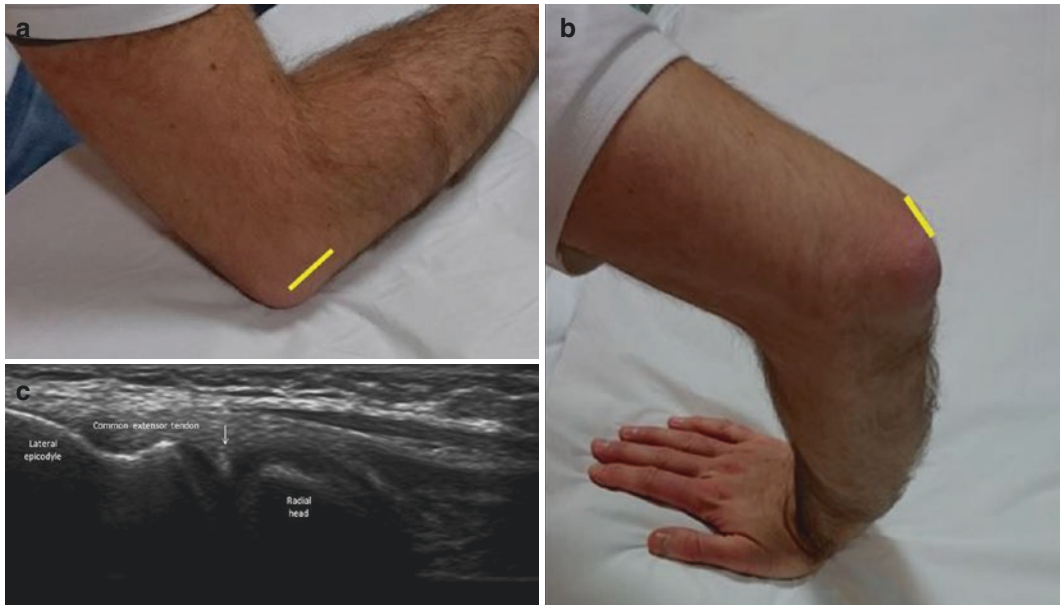

Fig. 3.8 Common extensor tendon. Transducer placement (**a**, **b**). Sonographic image (**c**). The lateral aspect of the elbow is generally examined with the elbow in flexion (**a**) or in the so-called crab position (elbow flexed 90° with the palm resting on the table) (**b**). The common extensor tendon must be evaluated in the long (**c**) and short axis: the lateral synovial fringe is depicted as a triangular hyperechoic structure between the capitellum and the radial head (arrow). Sonoelastographic image depicts the tendon in red, representing hard tissue (**d**)

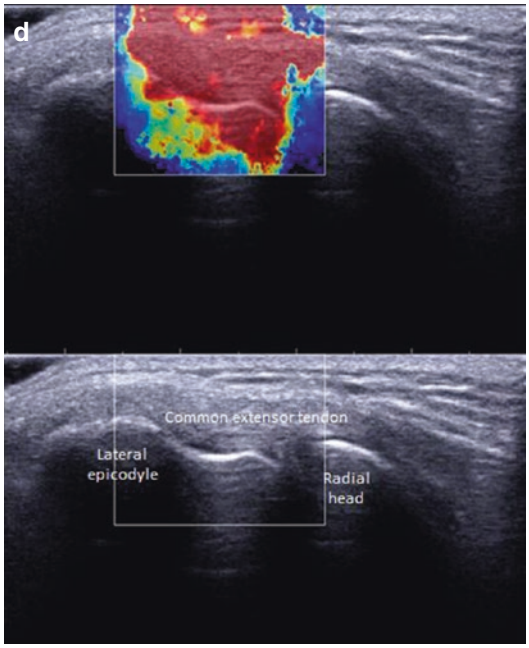

Fig. 3.8 (continued)

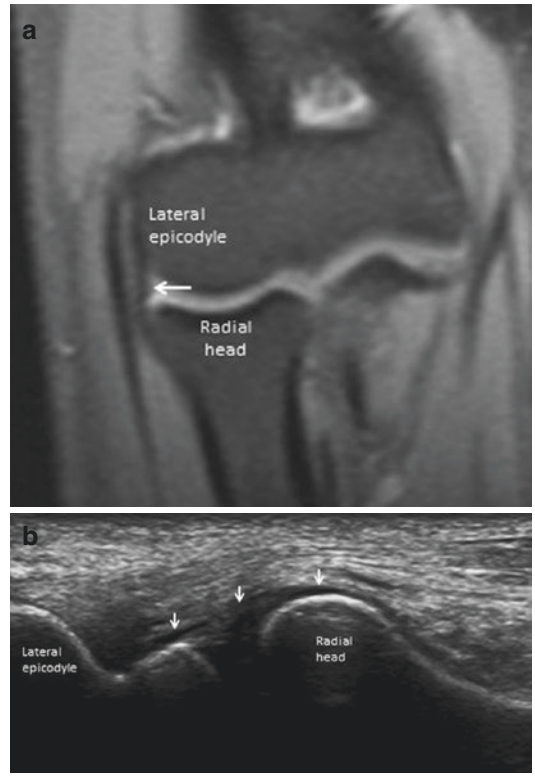

Fig. 3.9 Radial collateral ligament proper. MRI image (**a**) of the radial collateral ligament proper (arrow) extends from the antero-inferior aspect of the lateral epicondyle to insert into the annular ligament. It is generally examined in the same position as the common extensor tendon and appears hypoechoic (arrows) (**b**)

extensor carpi radialis brevis is the deepest, and the extensor digitorum is the most superficial. The single contributions from the extensor muscles to the common extensor tendon cannot be identified at ultrasound. The sonoelastographic image depicts the tendon in red, representing hard tissue (Fig. 3.8d).

The common extensor tendon is separated from the joint capsule by the lateral collateral ligamentous. The lateral collateral ligamentous complex consists of: the radial collateral ligament proper (Fig. 3.9), the lateral ulnar collateral ligament, the annular ligament, and sometimes the accessory radial collateral ligament [18–20]. No evidence and consensus exist to evaluate this ligamentous complex by ultrasound.

The lateral synovial fringe (a synovial plica) is depicted as a triangular hyperechoic structure intervening between the capitellum and the radial head (Fig. 3.8c).

The radial nerve is located between the brachialis and the brachioradialis muscles; more distally, the radial nerve divides into the superficial cutaneous sensory branch and the posterior interosseous nerve (Fig. 3.10). The posterior interosseous nerve enters the arcade of Frohse, passing between the superficial and deep parts of the supinator muscle [21–23]. Transverse ultrasound images are sufficient to demonstrate the nerve.

The posterior aspect of the elbow is generally examined in the so-called crab position (joint positioned in 90° of flexion, the forearm fully pronated (internally rotated)), and the palm resting on a table (Fig. 3.11). The posterior compartment of the elbow includes the triceps [24–26], the anconeus muscles [27, 28], the olecranon bursa [29–31], the olecranon fossa with the posterior recess [11], and the ulnar nerve [32, 33].

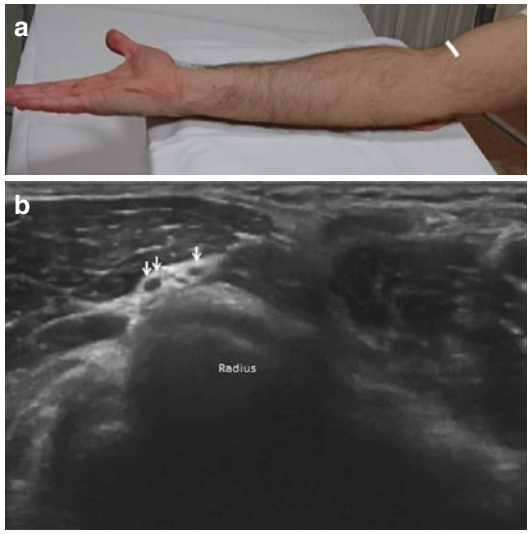

Fig. 3.10 Radial nerve. Transducer placement (**a**). In the anterior part of elbow (**b**), the cutaneous sensory branch (arrow) and the posterior interosseous nerve (double arrows), a result of bifurcation of the nerve, can be appreciated with sonography. The two branches are evaluated on short-axis planes

The triceps is made up of three heads, medial, lateral, and long, and is inserted onto the olecranon process of the ulna with a single thick tendon consisting of a superficial portion composed of the lateral and long heads, and a deep portion composed of the medial head [24–26]. Ultrasound examination of the triceps tendon can be performed on transverse and longitudinal planes moving the transducer from the myotendinous junction to the olecranon. Pre-insertional fibers of the tendon may appear hypoechoic owing to the anisotropy artifact.

The anconeus muscle is a small muscle located on the lateral side of the olecranon; it is depicted during the evaluation of the triceps [27, 28, 34]. In some individuals, it is possible to find an accessory muscle located between the posterior aspect of the medial condyle and the medial aspect of the olecranon: the anconeus epitrochlearis muscle. It is depicted during evaluation of the cubital tunnel (Fig. 3.12).

Deep in the triceps, the olecranon fossa and the posterior recess are visible in patients with effusions [11]. The olecranon fossa is identified as a concavity at the distal aspect of the humerus that is filled with the hyperechoic posterior elbow fat pad. The joint may be examined at 45° flexion to move the intra-articular fluid from the anterior synovial space to the olecranon recess.

The ulnar nerve in the elbow courses through the cubital tunnel, a retroepicondylar osseous groove at the postero-medial aspect of the elbow [32, 33]. The cubital tunnel is bordered by the posterior surface of the medial epicondyle and by the olecranon. The posterior bundle of the medial collateral ligament and the retinaculum (Osborne's ligament), respectively, form the floor and ceiling of the cubital tunnel. Stability: due to the particular anatomic location, the ulnar nerve at the elbow is prone to instability. The ultrasound technique to evaluate these conditions can vary; however, this consists initially of an evaluation of the ulnar nerve to look for signs of neuropathy; subsequently, the ulnar nerve is examined during active flexion and extension. The transducer is positioned transversely, with ends over the olecranon and the medial epicondyle.

The medial aspect of the elbow is generally examined with the elbow in extension or in the so-called crab position. The medial epicondyle may be used as a landmark. In the medial aspect, the key structures to be evaluated are: the common flexor tendon [35–37], the medial collateral ligament [19], and the pronator teres [38].

The common flexor tendon (Fig. 3.13) is made, from anterior to posterior, by the flexor carpi radialis, the palmaris longus, the flexor carpi ulnaris, and the flexor digitorum superficialis [35–37]. The tendon is evaluated with a probe placed longitudinally (long axis of the tendon). The tendon appears larger but shorter than the common extensor tendon.

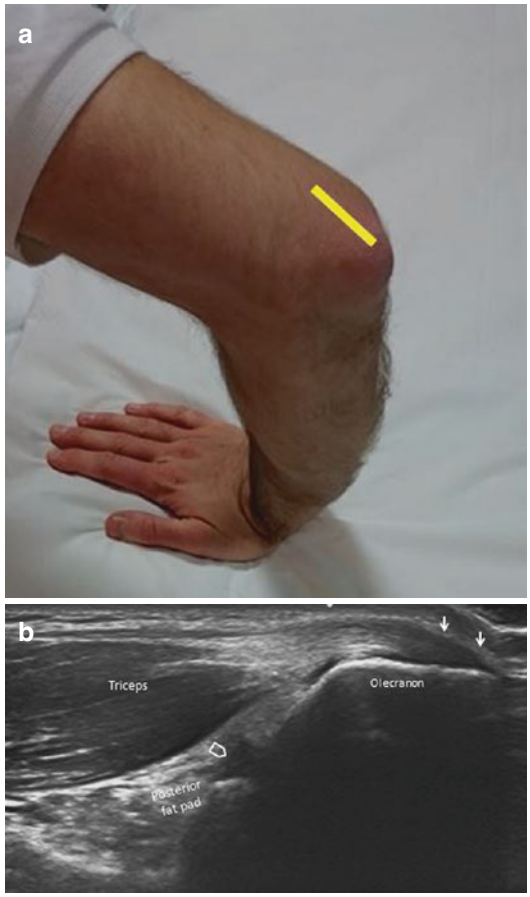

Fig. 3.11 Triceps tendon. Transducer placement (**a**). The distal triceps tendon (**b**) appears as a fibrillary echoic structure. Pre-insertional fibers appear hypoechoic owing to the anisotropy artifact (arrows). Ultrasound examination of the triceps tendon can be performed on transverse and longitudinal planes moving the transducer from myotendinous junction to the olecranon. Deep in the triceps, the olecranon fossa, the posterior recess (void arrow), and the posterior elbow fat pad may be evaluated

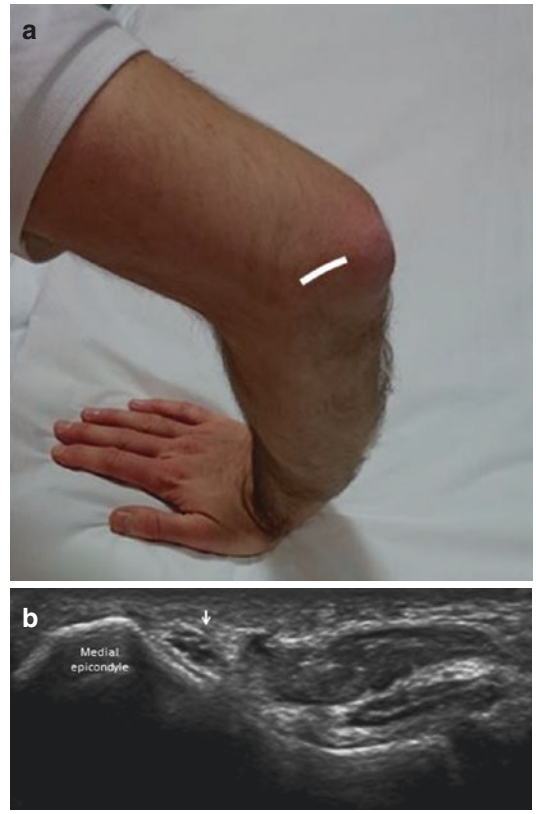

Fig. 3.12 Ulnar nerve. Transducer placement (**a**). Ulnar nerve (**b**) (arrow) in the elbow courses through the cubital tunnel, a retroepicondylar osseous groove at the postero-medial aspect of the elbow. It is evaluated using ultrasound on short-axis planes

The ulnar collateral ligament complex (Fig. 3.14) is composed of the anterior band, a posterior band, and a transverse band. The anterior and posterior bands arise from the inferior aspect of the media epicondyle. The anterior band inserts distally at the sublime tubercle of the ulna [19]. The posterior band inserts at the postero-medial margin of the trochlear notch of the ulna. The anterior band of the medial collateral ligament is depicted as an elongated structure crossing the trochlea-ulna joint deep to the flexor muscles. The ligament has a uniform thickness and echotexture. The posterior band is depicted during evaluation of the ulnar nerve.

The pronator teres is composed of a humeral head and an ulnar head. The larger humeral head is located superficially [38]. At the elbow, in more than 80% of individuals, the median nerve runs between the two bellies of the pronator teres. Sonographic evaluation of the pronator teres is performed with patient seated

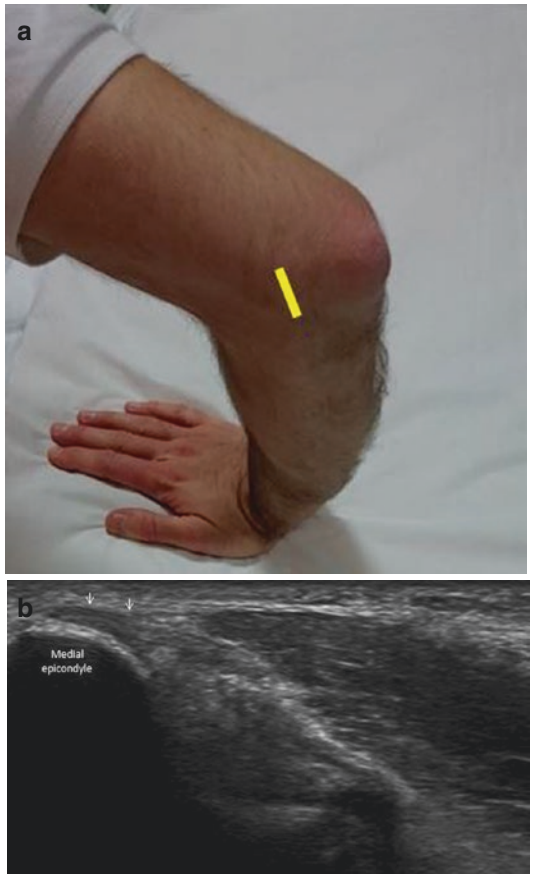

Fig. 3.13 Common flexor tendon. Transducer placement (**a**). The tendon (**b**) appears larger but shorter than the common extensor tendon (arrows). It is evaluated with probe place longitudinally (long axis of the tendon)

with the elbow extended and in supination on the examination bed. The examination may start with transverse sonograms, obtained at the level of the medial epicondyle and then moving the transducer caudally to the distal tendon.

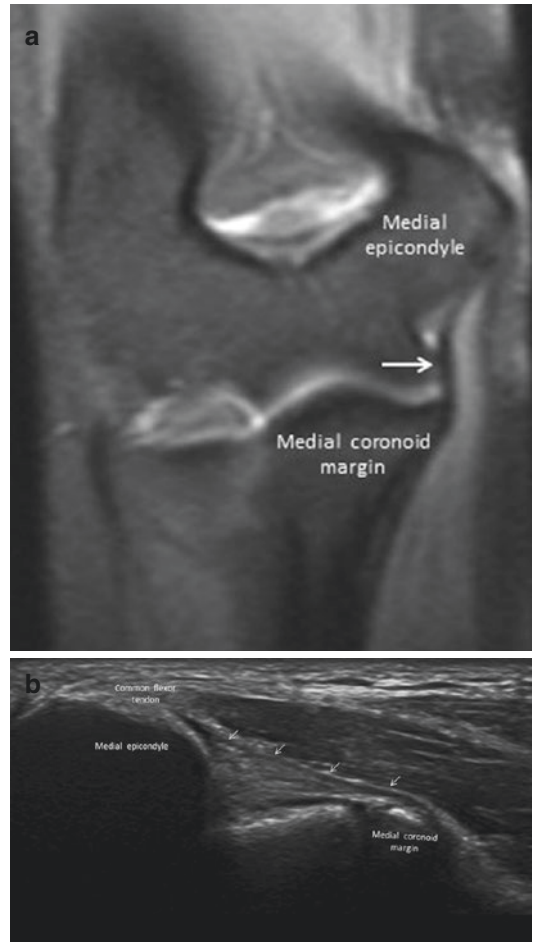

Fig. 3.14 Anterior band of the medial collateral ligament. The anterior band (arrow) arises from the inferior aspect of the media epicondyle and inserts distally at the sublime tubercle of the ulna (**a**: MRI image). It is generally examined in the same position as the common flexor tendon and appears hypoechoic (arrows) (**b**)

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