Musculoskeletal ultrasound: Anatomy and technique

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The Shoulder

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The shoulder joint is the commonest joint examined sonographically, and is often the first joint on which most imagers are introduced to musculoskeletal ultrasound. The shoulder is superficial and readily accessible to ultrasound assessment and is excellent for assessing the normal anatomy and pathology of the shoulder joint; it has sensitivities and specificities in assessment of the rotator cuff that are comparable to magnetic resonance imaging (MRI). Ultrasound offers excellent resolution, is multiplanar, accessible, and cost efficient. One of ultrasound's main strengths is its ability to image in real time the normal dynamic motion of joints and surrounding soft tissues. This dynamic component of the study may expose pathologies not apparent in a static examination. This feature is particularly important in assessing for subluxation of the biceps tendon or impingement syndromes, e.g., supraspinatus or subcoracoid impingement. In addition, ultrasound allows for a more complete functional assessment of the structure. This chapter will outline the clinical indications for shoulder ultrasound, discuss the transducers suited to the examination, and then review the normal anatomy of this region. Anatomy will include a brief overview of surface anatomy, which will allow the imager to identify key landmarks that can then be used to formulate a structured and reproducible approach to the study as detailed in the section on ultrasound technique.

Clinical Indications

The commonest indication is in the assessment of rotator cuff and biceps tendon pathology, including tendinosis, partial and full thickness tears, and impingement syndromes. Rheumatology referrals for joint effusion, synovial thickening, and erosions are increasing in number. Subtle nondisplaced fractures, particularly of the greater tuberosity, and Hill–Sachs defects, which may not be identified on plain radiographs, may be identified in a patient with persistent posttraumatic pain. Ultrasound can identify etiologies of nerve impingement, e.g., suprascapular nerve impingement and potential secondary findings such as atrophy and fatty infiltration of the supplied muscles. Labral injuries, particularly posterior labral tears with paralabral cyst formation, can be identified, although a full evaluation of the labrum requires MRI. Ultrasound is an important imaging modality in the primary imaging assessment of soft tissue masses, and is beneficial in assessing for solid/cystic components, internal and adjacent vascularity, and dynamic and functional components.

Interventional procedures include ultrasound-guided biopsy of soft tissue masses, arthrograms (e.g., in patients requiring MRI but who are allergic to iodine used in fluoroscopically guided injections), direct joint or tendon injections, joint aspiration, aspiration and dissolution of calcific tendinosis, and aspiration and injection of bursae and paralabral cysts.

The acromioclavicular joint can also be assessed at the same time for a wide range of local pathology including degeneration, inflammatory arthropathy, trauma, and joint sepsis. Interventional procedures include joint aspiration and injection.

Technical Equipment

High-resolution linear array transducers with a broad-bandwidth frequency between 7.5 and 12 MHz are generally preferred, with frequencies lower and higher required for deep and superficial structures, respectively. Linear array transducers lack divergent beam geometry, which accentuates anisotropy. Color and power Doppler are valuable in assessing hyperemia in inflammatory or reparative tissue and the vascularity of soft tissue masses, as well as in differentiating cystic lesions from vascular structures. Evaluation of deeper structures, depending on the patient's habitus, including the anterior labrum, may require a low-frequency curved array transducer.

Anatomy

Surface Anatomy

The clavicle is palpable, throughout its length, at the root of the neck. At its distal end it forms the articulation with the acromion, the acromioclavicular joint, which is felt as a change in the smooth contour of the clavicle. The acromion is the superolateral bony projection from the scapula directly over the glenohumeral joint. Anterior, lateral, and posterior to the acromion is the smooth soft tissue contour of the deltoid muscle that covers the glenohumeral joint and the humeral tuberosities. Anteriorly, a triangular depression is formed between the medial border of the deltoid and the pectoralis major: the deltopectoral angle. Within the lateral aspect of this triangle, a bony prominence can be felt on deep palpation: the coracoid process of the scapula (Figure 2.1). The anterior and posterior axillary folds are formed by the pectoralis major and latissimus dorsi muscles, respectively.[1] Posteriorly, extending from the acromion, a palpable bony ridge—the scapular spine—separates the supraspinatus and infraspinatus fossae. The soft tissue contour of the posterior aspect of the joint is formed in part by the supraspinatus and infraspinatus muscles as well as the overlying musculature, which includes the deltoid, trapezius, and latissimus dorsi muscles. Patients with atrophy of these muscles may have a visible loss of mass in this region when compared with a normal contralateral side (Figure 2.1).

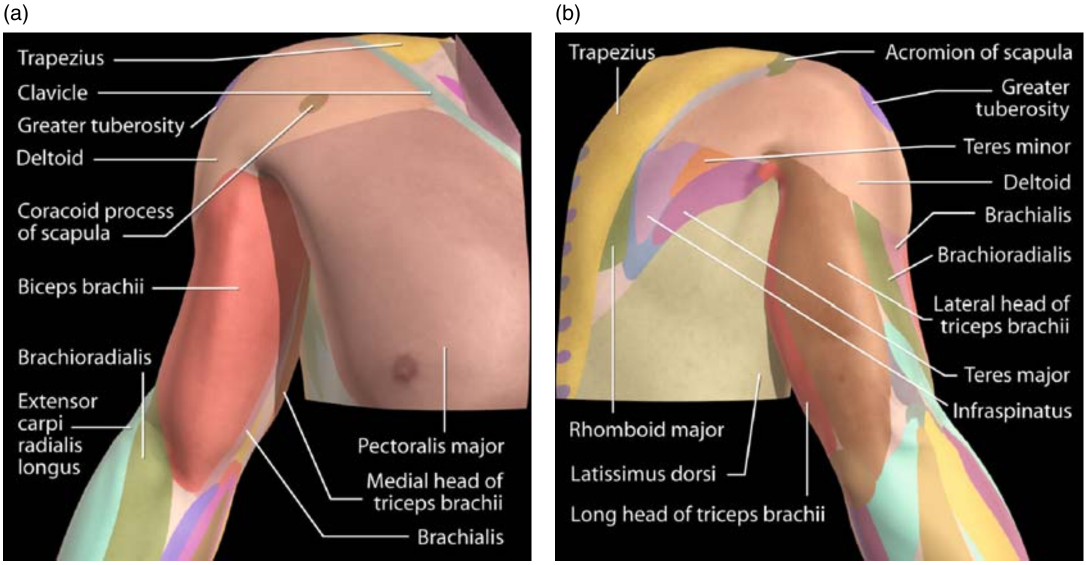


Figure 2.1. The surface anatomy of the shoulder: **(a)** anterior and **(b)** posterior views.

Bones

The glenohumeral joint is an enarthrodial, or ball-and-socket, joint with multidirectional capabilities (Figure 2.2).[2] This wide range of motion is facilitated by the shallow glenoid fossa of the scapula articulating with the significantly larger humeral head. This anatomical arrangement, however, predisposes the joint to dislocation, which in turn is counteracted by the support mechanism of the glenohumeral ligaments, the rotator cuff tendons (Table 2.1), and the glenoid labrum. The articulating surfaces of the humerus and glenoid are covered by articular cartilage, which is thin at the center of

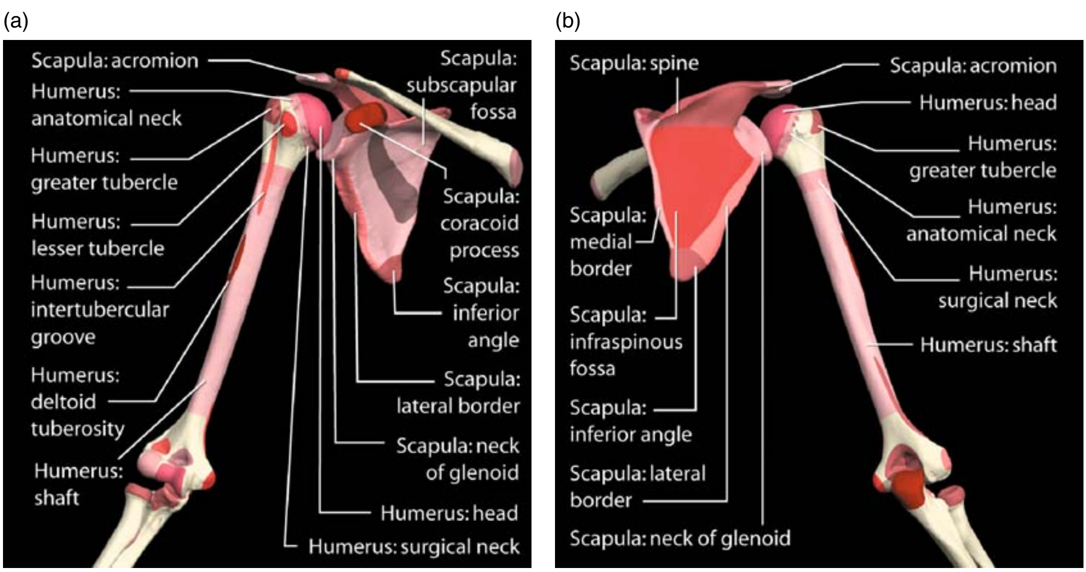


Figure 2.2. The important shoulder bony landmarks: **(a)** anterior and **(b)** posterior views.

Table 2.1. Rotator Cuff Muscles.

Supraspinatus
Infraspinatus
Teter minor
Subscapularis

the glenoid and thick peripherally; the opposite holds true for the humeral head. The cartilage is continuous except for a focal spot on the posterosuperior aspect of the humeral head, known as the bare area. On ultrasound, the peripheral aspect of the humeral articular cartilage is identifiable as a continuous thin hypoechoic covering of uniform thickness with the deeper cortical bone visualized as a smooth uninterrupted hyperechoic line with posterior acoustic shadowing.

The rounded greater tuberosity is lateral to the humeral head and has three facets. The anterior and middle facets serve as sites of attachment for the supraspinatus tendon; the infraspinatus tendon also attaches to the middle facet and the teres minor tendon to the posterior facet and adjacent humeral shaft (Figure 2.3). The lesser tuberosity is smaller, anteromedial, and separated from the greater tuberosity by the bicipital groove. The subscapularis tendon attaches to the lesser tuberosity and the adjacent humerus (Figures 2.2 and 2.3).

The acromion, meaning shoulder summit, is the termination of the scapular spine. It may be oblong or triangular in shape and has a smooth concave undersurface. It has three centers of ossification that usually unite by 22 years.[3] If nonunion persists, it is termed os acromiale, and is important to identify when present. Os acromiale occurs in approximately 5% of the population and is bilateral in up to 20% of cases. The fibrous capsule of the joint is lax, which allows for the wide range of motion, and is lined by a synovial

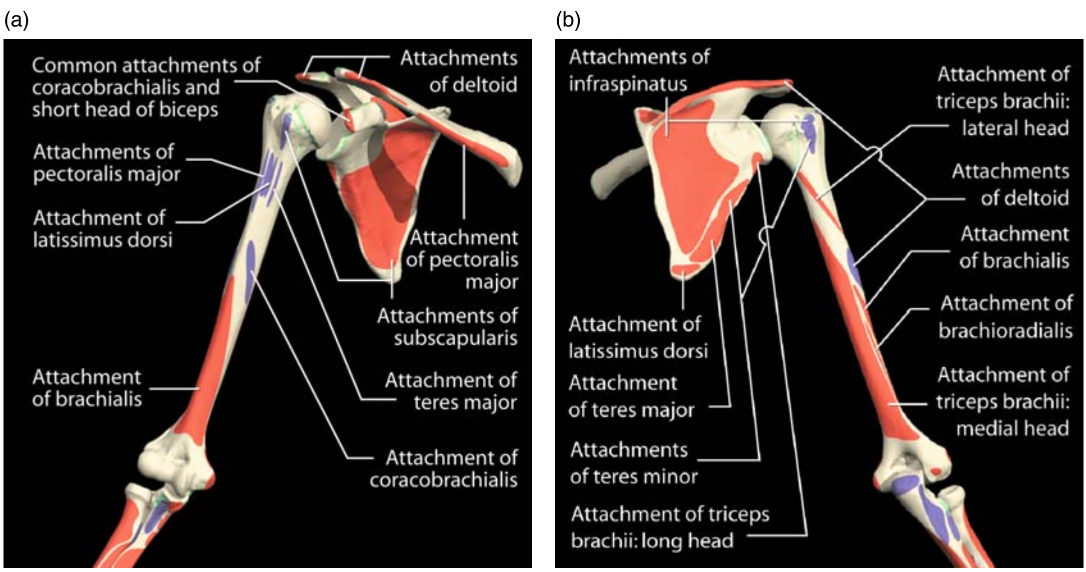


Figure 2.3. The muscle origin (red) and insertion (blue) points of the shoulder girdle muscles: **(a)** anterior and **(b)** posterior views.

membrane. The capsule attaches to the anatomical neck of the humerus and the circumference of the glenoid, posterior to the glenohumeral ligaments. It is strengthened by these ligaments, which are not usually identifiable on ultrasound, and by surrounding tendons including the subscapularis, the long head of the biceps, supraspinatus, infraspinatus, teres minor, long head triceps, and the coracohumeral ligament. Three main capsular openings may exist. The first is for the transmission of the long head of the biceps; the second is anterior and subcoracoid and communicates with the subscapularis bursa; the third, if present, lies posteriorly and communicates with the infraspinatus bursa.

Muscles and Tendons

The supraspinatus, infraspinatus, subscapularis, and teres minor muscles form the rotator cuff. Their origin, insertion, and actions are outlined in Table 2.2.[4] The supraspinatus, infraspinatus, and teres minor insert onto the greater tuberosity, from anterior to posterior, forming a continuous layer separating the subacromial bursa from the glenohumeral joint space and forming an important supporting mechanism for the joint capsule. In addition, they act as dynamic stabilizers of the glenohumeral joint and counteract the upward translation induced by the deltoid.[3] The muscles of the shoulder are shown in Figure 2.4.

Table 2.2. Shoulder Muscles.

Muscle	Origin	Insertion	Main action
Supraspinatus	Supraspinous fossa scapula	Greater tuberosity—anterior and middle facets	Shoulder/arm abduction
Infraspinatus	Infraspinous fossa scapula	Greater tuberosity—middle facet	External rotation, stabilizer
Subscapularis	Subscapular fossa scapula	Lesser tuberosity	Internal rotation, stabilizer
Teres minor	Dorsal surface axillary border scapula	Greater tuberosity—posterior facet and adjacent humeral shaft	External rotation, stabilizer
Biceps Long head	Supraglenoid tubercle scapula	Radial tuberosity and bicipital aponeurosis	Flexion and supination forearm
Short head	Apex coracoid process	Unites with long head to form a single tendon that inserts onto the radial tuberosity, bicipital aponeurosis	Flexion and supination forearm
Pectoralis major	Anteromedial aspect clavicle, sternum, and upper six costal cartilages	Lateral ridge of the bicipital groove	Adductor, medial rotator, and flexor arm
Pectoralis minor	Third to fifth ribs	Medial border; coracoid process	Protracts scapula
Deltoid	Anterolateral third clavicle, the acromion, and the spine of the scapula	Deltoid tuberosity (mid humerus)	Abducts arm to horizontal (anterior fibers); flexes and extends arm (posterior fibers)

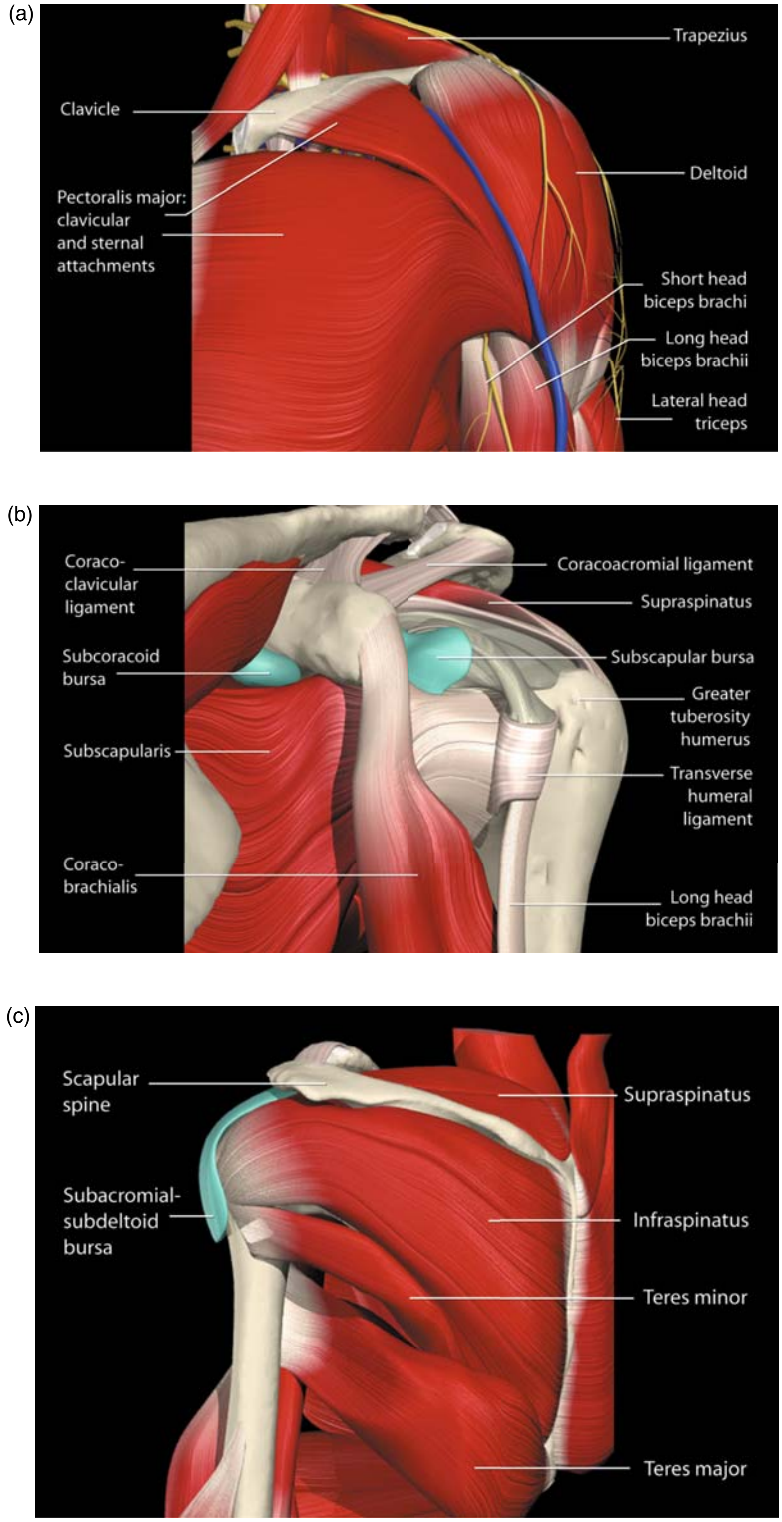
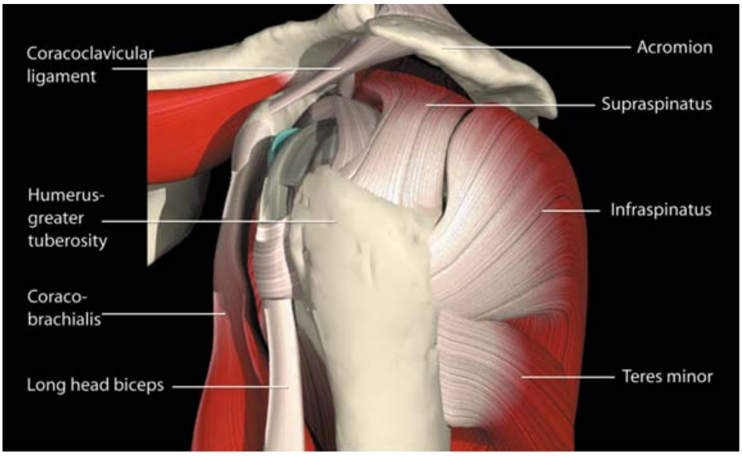


Figure 2.4. The muscles of the shoulder: **(a)** anterior c, **(b)** anterior with pectoralis and deltoid muscles removed, **(c)** posterior with deltoid and trapezius muscles removed.

(d)



(e)

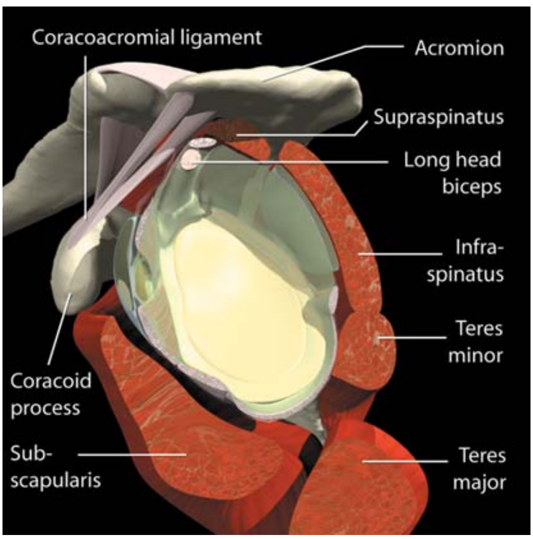


Figure 2.4. (*Continued*) The muscles of the shoulder: **(d)** lateral view with deltoid muscle removed, and **(e)** sagittal through shoulder joint with humerus removed.

The supraspinatus originates from the supraspinatus fossa of the scapula and adjacent scapular spine. The tendon has two components, ventral and dorsal, arising from the muscle and extending obliquely anteriorly, approximately 50° to the coronal plane, over the superior aspect of the humeral head to insert predominantly on the anterior and middle facets of the greater tuberosity.[5–7] The infraspinatus muscle arises from the internal two-thirds of the infraspinous fossa of the scapula and fascia. The tendon may be single or multipennate, and extends obliquely anterosuperiorly to insert onto the middle facet of the greater tuberosity. Occasionally a bursa, which can communicate with the glenohumeral joint, is present between the tendon and joint capsule. The teres minor is a smaller, elongated muscle that is in close contact with the infraspinatus, arising from the infraspinatus fascia and the axillary border of the scapula. It has a short tendon, which helps distinguish it from the infraspinatus, inserting onto the posterior facet of the greater tuberosity and adjacent humerus.

The subscapularis muscle is a large triangular muscle arising from and occupying the subscapularis fossa of the scapula. The tendon is multipennate and merges into a single tendon to insert onto the lesser tuberosity. It is separated from the neck of the scapula by the subscapularis bursa and from the supraspinatus, which lies laterally, by the rotator cuff interval. Passing through this interval is the long head of the biceps tendon, which arises from the supraglenoid tubercle. As the long head of the biceps courses distally within the intertubercular groove it is surrounded proximally by the bicipital sheath, a synovial recess of the glenohumeral joint.

Within the bicipital groove, the long head of the biceps tendon is held in place by the transverse humeral ligament superiorly and by a fibrous extension of the pectoralis major inferiorly. The transverse humeral ligament is not a true ligament, but rather a continuation of fibers from the subscapularis tendon.[8] Superficial fibers of the subscapularis tendon pass over the lesser tuberosity, across the bicipital groove, to insert onto the anterior aspect of the greater tuberosity. In addition, deep fibers of the subscapularis extend into and form a superficial layer to the floor of the bicipital groove, creating a sling of tissue around the biceps tendon. The supraspinatus tendon and coracohumeral ligament lend fibers, deep to the superficial band of the subscapularis, which help to form the roof of the bicipital groove. This anatomy accounts for the pattern of biceps dislocation. Inferiorly, the roof of the groove is maintained by the pectoralis major tendon.

Insider Information 2.1
The subscapularis tendon contributes fibers to the floor and roof of the bicipital groove. This anatomy accounts for the different positions of the dislocated biceps tendon, superficial, within or deep to the subscapularis tendon and muscle.

The coracohumeral ligament is composed of two bands extending from the base of the coracoid process to the lesser and greater humeral tuberosities. It reinforces the joint capsule and rotator interval and helps form the roof of the bicipital groove.[3]

The following muscles and tendons are included for completeness, as pathology within them may present with shoulder symptoms. The short head of the biceps is extraarticular, arising from the apex of the coracoid process in union with the coracobrachialis tendon. The short and long heads of the biceps continue into adjacent but separate muscle bellies that unite only in the distal arm as the distal biceps tendon. The pectoralis major muscle arises from a broad attachment from the anteromedial aspect of the clavicle, sternum, and upper six costal cartilages to insert onto the lateral ridge of the bicipital groove. The tendon is broad and bilaminar. The pectoralis minor lies deep to the pectoralis major, arises from the third through fifth ribs, and inserts on the medial border of the coracoid process.

The deltoid is a large muscle that covers the anterior, lateral, and posterior aspect of the shoulder and imparts a rounded appearance to it. It receives its name from its resemblance to the inverted Greek letter delta: Δ. It has an extensive origin from the anterolateral third clavicle, the acromion, and the spine of the scapula, and inserts as a thick tendon onto the deltoid tuberosity in the mid humerus. It abducts the arm to a horizontal position. The anterior fibers flex and the posterior fibers extend the arm.[4]

The ultrasound appearance of muscle and tendons is reviewed in detail in Chapter 1. The normal size of the above muscles and tendons is related to the patient's age and physical activity. Correlation with the contralateral shoulder is advised. In general, the rotator cuff tendons measure between 5 and 10 mm in thickness and the biceps less than 5 mm.

Bursae

The subacromial-subdeltoid (SASD) bursa is the largest bursa in the body. It lies deep to the deltoid muscle and the acromion process, being attached to the periosteal undersurface of the acromion. It extends laterally beyond the attachment of the rotator cuff by up to 3 cm, medially to the acromioclavicular joint, anteriorly to overlie the bicipital groove, and posteriorly over the rotator cuff. It does not normally communicate with the shoulder joint. The normal ultrasound appearance is of two opposing hyperechoic layers formed by fibroadipose tissue and capsule with an intervening hypoechoic layer representing the viscous fluid within the bursa. The bursa normally measures less than 2 mm in thickness.[7]

Insider Information 2.2
The subcoracoid bursa may communicate with the SASD bursa.

The subcoracoid bursa lies between the subscapularis and coracoid process. It may communicate with the SASD bursa but does not normally communicate with the shoulder joint. The subscapularis bursa lies between the subscapularis tendon and joint capsule and normally communicates with the shoulder joint; it may be better described as a recess.

Multiple other bursae are seen around the shoulder joint (Table 2.3). These include the infraspinatus bursa, between the infraspinatus and joint capsule, which may communicate with the joint. The supraacromial bursa lies within the subcutaneous tissues superficial to the acromion. The teres major bursa lies between the teres major and humerus. Two latissimus dorsi bursae are present, one lying anterior and the other posterior to its tendon.

Table 2.3. Bursae around the Shoulder.

Subacromial-subdeltoid
Subcoracoid
Subscapularis[a]
Infraspinatus[a]
Supraacromial
Teres major
Coracobrachialis
Anterior latissimus dorsi
Posterior latissimus dorsi

[a]Indicates bursae that normally communicate with the glenohumeral joint.

Rotator Cuff Interval

The rotator cuff interval is a triangular space between the subscapularis and the supraspinatus tendons. The base is formed by the coracoid process and the apex by the transverse humeral ligament. It is a dynamic space whose area decreases significantly in internal rotation, less so in external rotation, and is maximal in the neutral position.[9] The long head of the biceps passes through the interval, separated from the supraspinatus and subscapularis by up to 3 mm. Overlying the interval, from superficial to deep, is skin, subcutaneous tissue, the deltoid muscle, a fibrofatty layer, the coracohumeral ligament, the joint capsule, the superior glenohumeral ligament, and the long head of the biceps tendon.

Coracoacromial Arch

This arch is formed by the coracoid process, the acromion, and the connecting coracoacromial ligament (Figure 2.5). This ligament is triangular with the base attached to the lateral coracoid margin and the apex attached to the anterior margin of the acromion. It may consist of two bands and an intermediate band that may in turn be absent as a normal variant with the pectoralis minor inserting onto the joint capsule. Deep to the coracoacromial ligament lie the supraspinatus, the superior aspect of the subscapularis tendon, and the anterior fibers of the infraspinatus tendon. Supraspinatus impingement between the acromion and greater tuberosity can occur, due to the restricted space of the coracoacromial arch. Impingement is most prevalent in 60° forward flexion, abduction, and internal rotation.[10]

Acromioclavicular Joint

The acromioclavicular joint (ACJ) is a diarthrodial joint between the distal end of the clavicle and the medial aspect of the acromion. The articular surfaces are covered by fibrocartilage. An articular fibrocartilage disc is usually present, although it may often be incomplete. Degeneration of both disc and joint occurs early and may be seen as early as the second decade of life.[11–13] A lax capsule,

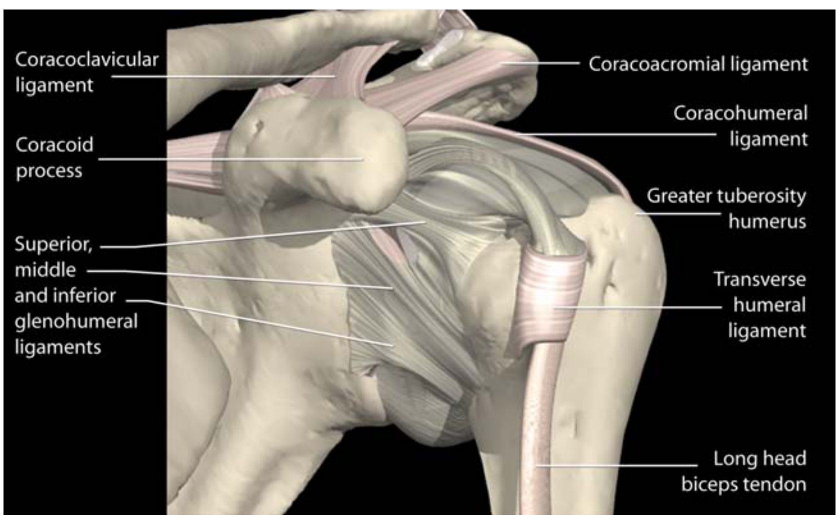


Figure 2.5. The ligaments around the anterior shoulder joint.

lined by synovium, is supported by the acromioclavicular (AC) ligaments: anterior, posterior, inferior, and superior. The strong superior AC ligament interlaces with fibers from the overlying deltoid and trapezius. The weaker inferior ligament and joint are in direct contact inferiorly with the SASD bursa.

This joint is further supported by two additional ligaments, the coraco-clavicular and the coracoacromial ligaments, which do not belong to the AC articulation but form an additional support mechanism for the joint (Figure 2.5). The former is in turn composed of two ligaments, the conoid and the trapezoid, which extend between the lateral aspect of the clavicle and the coracoid process of the scapula. The trapezoid attaches to the oblique line on the inferior aspect of the clavicle. The conoid component extends from the base of the coracoid to the conoid tubercle on the clavicular undersurface. The coracoacromial ligament is detailed in the previous section.

Labrum

The glenohumeral joint has the widest range of motion of all joints and combined with an articulating humeral head almost four times the size of the glenoid cavity is predisposed to instability. This instability is counteracted in part by the glenoid labrum. The labrum is composed of fibrous tissue, hyaline cartilage, and fibrocartilage and forms a rim around the glenoid (Figure 2.6).[14] It serves as a site of attachment for the glenohumeral ligaments, and the resulting labral-ligamentous complex is an important component in stabilizing the joint. The labrum is subject to many anatomical variations in size and shape, particularly anteriorly. It has a triangular appearance and is most commonly hyperechoic and homogeneous on ultrasound with the base attaching to the glenoid rim.[15–17] The shape of the posterior labrum changes from a triangular structure in internal rotation of the shoulder to a slightly buckled appearance in external rotation.[18] The same maneuver gives the anterior labrum a more pointed form.[19] It can be divided into 12 segments, extending in a clockwise fashion from the 12 o'clock position at the biceps anchor. Alternatively, it can also be divided into four quadrants: anterosuperior (1-3), anteroinferior (3-6), posteroinferior (6-7), and posterosuperior (9-12), with the equivalent 12-segment classification given in parentheses.

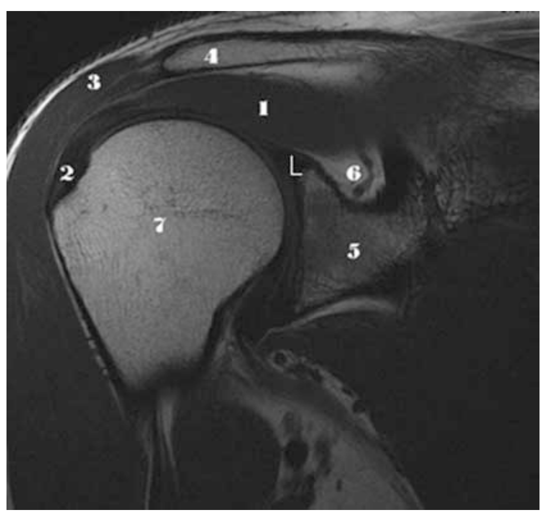


Figure 2.6. Coronal T1-weighted magnetic resonance (MRI) anatomy mid-shoulder joint: 1–supraspinatus muscle, 2–supraspinatus tendon, 3–deltoid muscle, 4–acromion, 5–glenoid, 6–spinoglenoid notch, 7–humerus, L-labrum.

> **Insider Information 2.3**
> The shape of the posterior labrum changes from triangular in internal rotation to a more buckled appearance in external rotation.

Scapular Notches and the Suprascapular Nerve

The suprascapular nerve arises from the upper trunk of the brachial plexus, C5–6. It contains motor and sensory fibers and supplies both the supraspinatus and infraspinatus muscles with articular branches to the glenohumeral joint and acromioclavicular joints. From its origin, it passes posterior to the trapezius and omohyoid to enter the supraspinous fossa via the suprascapular notch. The suprascapular notch is converted into a fibroosseous tunnel by the transverse or suprascapular ligament. This ligament attaches to the base of the coracoid process and to the inner aspect of the scapular notch. The suprascapular vessels pass over this foramen. The suprascapular nerve passes on the scapular aspect of the supraspinatus muscle, which it supplies, and courses inferiorly through the spinoglenoid notch.[20] The spinoglenoid notch connects the supraspinous and infraspinous fossae between the lateral margin of the scapular spine and the medial margin of the glenoid (Figure 2.7). It is bounded posteriorly by the spinoglenoid ligament and transmits the suprascapular nerve and vessels. Inferiorly, it supplies the infraspinatus. Knowledge of the different levels of innervation will allow an understanding of entrapment neuropathies and their subsequent imaging findings. Pathology affecting the suprascapular nerve above the spinoglenoid notch involves the innervation to both the supraspinatus and infraspinatus and, at or below this level, the infraspinatus. The teres minor is supplied by the axillary nerve.

> **Insider Information 2.4**
> Pathology of the suprascapular nerve at or below the spinoglenoid notch affects the infraspinatus muscle. More proximal pathology will also affect the supraspinatus muscle. The teres minor muscle is supplied by the axillary nerve.

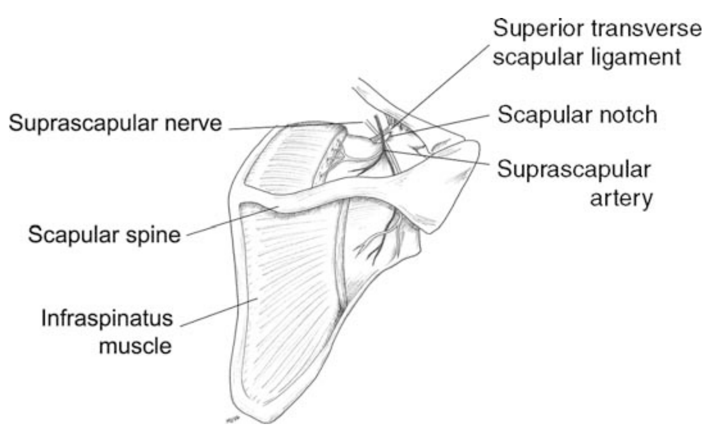


Figure 2.7. The posterior surface of the scapula demonstrating the suprascapular nerve and the spinoglenoid notch.

Technique

The patient sits on a revolving stool with the shoulder exposed; this allows for easy access to the anterior and posterior aspects of the shoulder and for the required positional changes. A pertinent history should be obtained from the patient, especially as symptoms may have changed since clinical referral. The examiner can either sit or stand in front or behind the patient. I prefer to perform the examination while standing behind the patient. This allows me to directly face the monitor and keep the transducer below the level of my own shoulder. This puts less stress on my own rotator cuff, particularly if I need to perform multiple similar examinations in the same session. The examination can be focused on a specific pathology or require a full routine evaluation, which will be described here. All tendons are assessed in their orthogonal planes. A summary of positions in which the individual tendons are evaluated is provided in Table 2.4. "Longitudinal" and "axial" refer to the axis of the structure being imaged.

Long Head Biceps

The long head of the biceps tendon and sheath are evaluated in a neutral position with the arm in supination resting on the ipsilateral thigh (Figure 2.8a). This position places the bicipital groove anteriorly. Transverse and longitudinal views are obtained from the proximal aspect of the bicipital groove distally to the musculotendinous junction (Figures 2.8b and c and 2.9). On the longitudinal view, the fibrillar pattern of the biceps tendon may appear hypoechoic in part, but by gently pressing on the inferior aspect of the transducer the fibrillar pattern will, in normal tendons, become homogeneous. This is termed the heel–toe effect (Figure 2.9).

Table 2.4. Ultrasound Evaluation: Position of the Shoulder Muscles.

Muscle	Position examined	Muscle	Position examined
Supraspinatus	Crass position Middleton position	Long head biceps	Elbow flexed to 90º, arm supinated and hand resting on ipsilateral thigh
Infraspinatus	Ipsilateral hand on contralateral arm/shoulder	Short head biceps	Elbow flexed to 90º, arm supinated and hand resting on ipsilateral thigh
Subscapularis	Elbow flexed to 90º, arm supinated resting on ipsilateral thigh, dynamic with internal and external rotation	Pectoralis major	Elbow flexed to 90º, arm supinated and hand resting on ipsilateral thigh
Teres minor	Ipsilateral hand on contralateral arm/shoulder	Pectoralis minor	Arm adducted in relaxed state
Deltoid	Arm adducted in relaxed state		

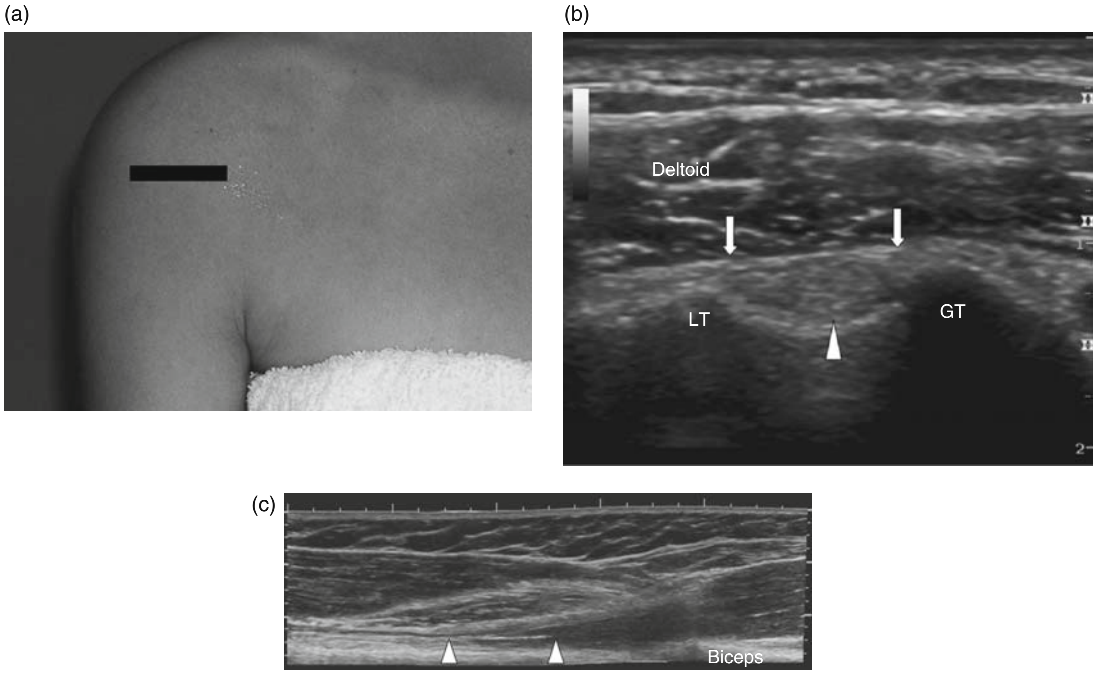


Figure 2.8. Long head biceps tendon (LHBT): **(a)** transducer position and corresponding **(b)** transverse ultrasound image of the hyperechoic oval LHBT (arrowhead) within the bicipital groove. **(c)** Longitudinal ultrasound image of the LHBT at its musculotendinous junction (curved arrow). LT, lesser tuberosity; GT, greater tuberosity; arrows, transverse humeral ligament.

Insider Information 2.5
Perform the heel–toe effect in the longitudinal assessment of the long head of the biceps tendon. The intraarticular portion of the biceps tendon can be evaluated with the arm in external rotation.

The hyperechoic transverse humeral ligament (THL), essentially a continuation of fibers from the coracohumeral ligament, the subscapularis, and supraspinatus tendons, is seen spanning the intertubercular groove (Figure 2.8b). A dynamic examination should then be performed with internal and external rotation of the shoulder, maintaining the elbow by the side, to assess the integrity of the transverse humeral ligament and for biceps tendon subluxation. The biceps tendon should normally be maintained within the groove (Figure 2.10). Subluxation and dislocation may become apparent only on this dynamic component of the study.[21]

The superior intraarticular portion of the long head of the biceps, within the rotator interval, can be further evaluated by externally rotating the shoulder, keeping the elbow by the side, and maintaining the transducer in a longitudinal plane to the biceps within the bicipital groove. Moving the transducer superiorly, in the longitudinal axis of the biceps, allows visualization of its proximal component and occasionally the bicipital anchor (Figure 2.11).

The bicipital groove, between the greater and lesser tuberosities, is deep and narrow superiorly, becoming wider and shallower inferiorly (Figure 2.8b).[22] It contains the biceps tendon and a branch of the anterior circumflex artery.

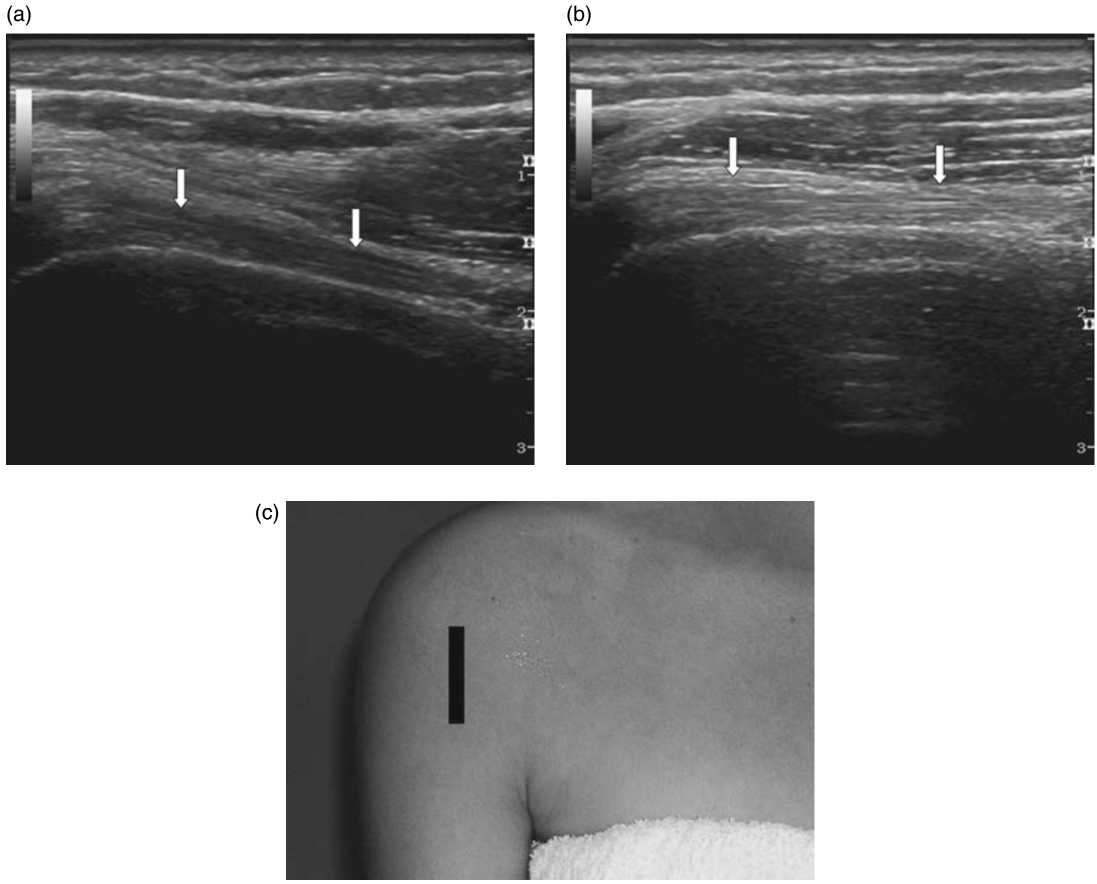


Figure 2.9. Long head of the biceps tendon: longitudinal ultrasound image demonstrating the “heel–toe” effect. **(a)** Pre heel–toe the fibrillar pattern of the tendon is not clearly discerned. **(b)** Post heel–toe. By gently depressing the distal margin of the transducer the fibrillar pattern of the normal tendon is clearly seen. **(c)** Corresponding photograph of the transducer position.

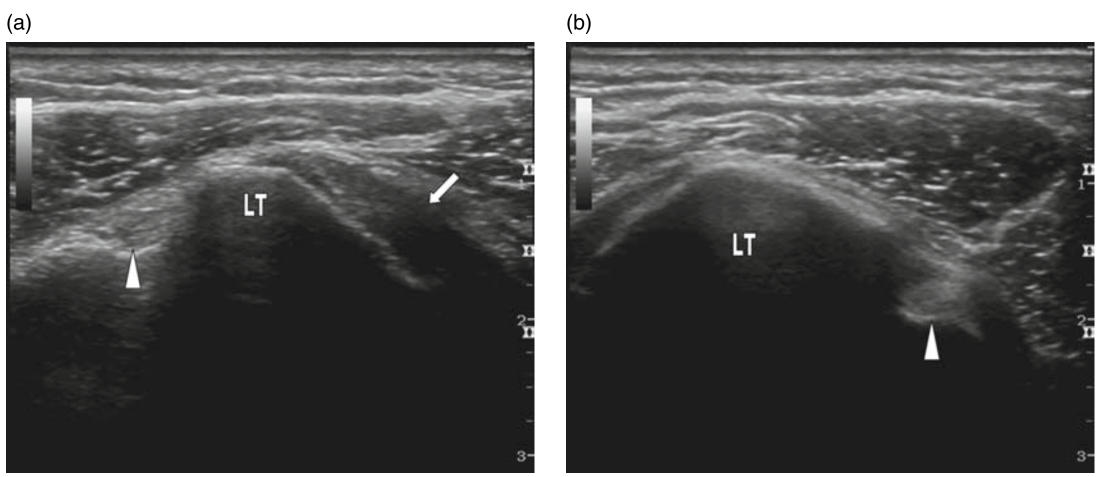


Figure 2.10. Transverse ultrasound image of the hyperechoic long head biceps tendon (arrowhead) within the bicipital groove on **(a)** internal rotation and **(b)** external rotation. LT, lesser tuberosity; arrow, subscapularis tendon.

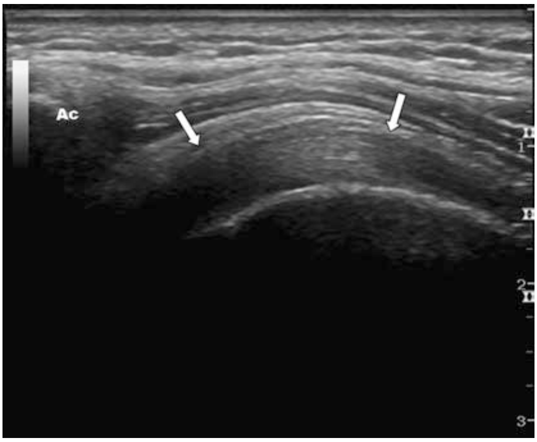


Figure 2.11. Longitudinal ultrasound image of the intraarticular portion long head biceps tendon (arrows). Ac, acromion.

The smooth, continuous, hyperechoic bony contour of the groove is best seen in the axial plane as in the assessment of the long head biceps. The groove has a width of approximately 10 mm and a length of 5 cm. A shallow groove and medial wall are predispositions to subluxation.[15] There is normally a minimal amount of fluid within the bicipital sheath. Proximally within the groove, the bicipital sheath is encompassed by a synovial sheath. This should be evaluated for thickening or internal flow on Doppler, as may occur in cases of synovial proliferation. The bicipital sheath should be evaluated to its distal aspect. Due to gravity, this is the point of accumulation of joint fluid and, occasionally, intraarticular bodies. The evaluation of the short head of the biceps is detailed in Chapter 3.

Insider Information 2.6
Evaluate the bicipital sheath to its inferior-most extent; this is a common location for intraarticular bodies to gravitate.

Subscapularis

The subscapularis tendon is assessed with the arm both in neutral and in external rotation positions. Longitudinal assessment in the plane of the tendon demonstrates its subcoracoid position and attachment onto the lesser tuberosity (Figure 2.12). The transducer should be moved superiorly and inferiorly to encompass the full extent of the tendon. The axial scan best demonstrates its multipennate structure with the multiple proximal tendon slips seen as hyperechoic foci surrounded by the hypoechoic muscle (Figure 2.12c).[7] Maintaining the elbow by the side and abducting and adducting the forearm allows for a dynamic assessment. This is an important component of the study that can help discriminate anisotropy, focal tendinosis, and partial tears. Reposition the transducer medially so that it overlies the coracoid process and repeat the above dynamic study (Figure 2.13). This may reveal subcoracoid impingement of the subscapularis tendon or the subcoracoid bursa. In addition, the subcoracoid bursa may lie medial to the coracoid process on a static study and extend to the lateral aspect of the coracoid only when assessed dynamically.

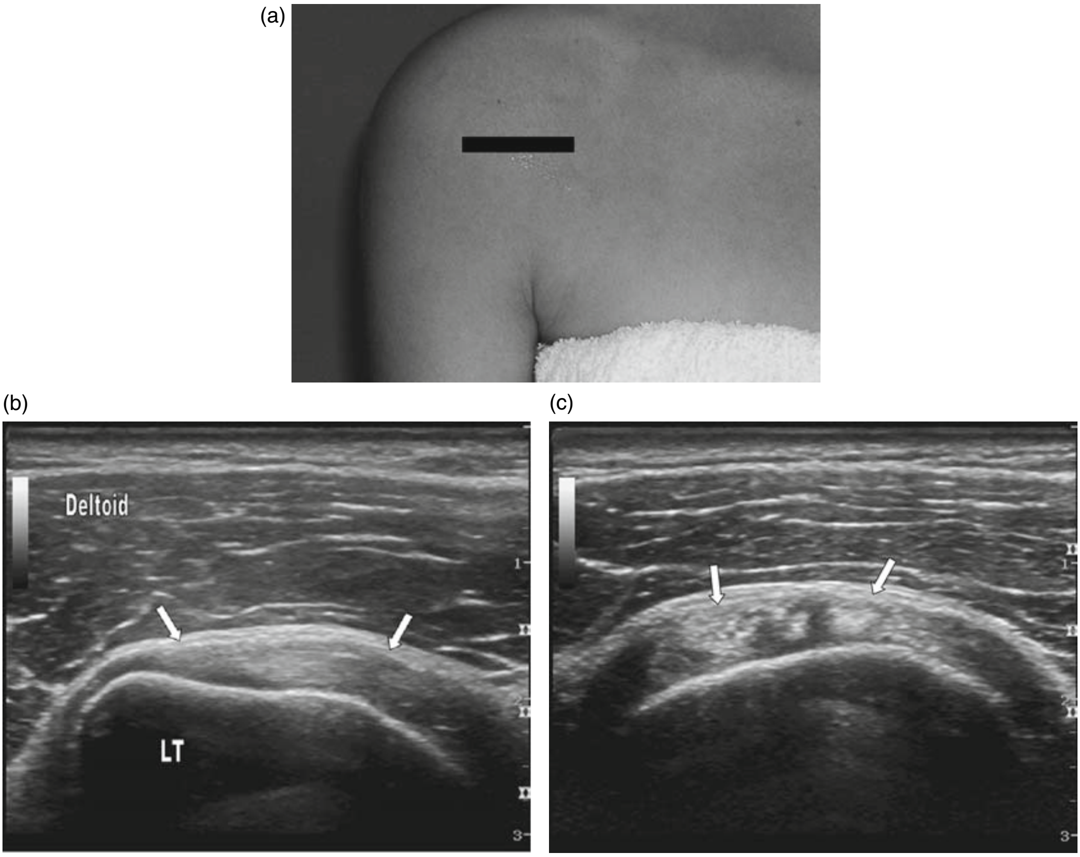


Figure 2.12. Subscapularis tendon (arrows). **(a)** Transducer position and corresponding **(b)** longitudinal ultrasound image. **(c)** Subscapularis in the transverse plane demonstrating the normal appearance of the multipennate hyperechoic tendons. LT, lesser tuberosity.

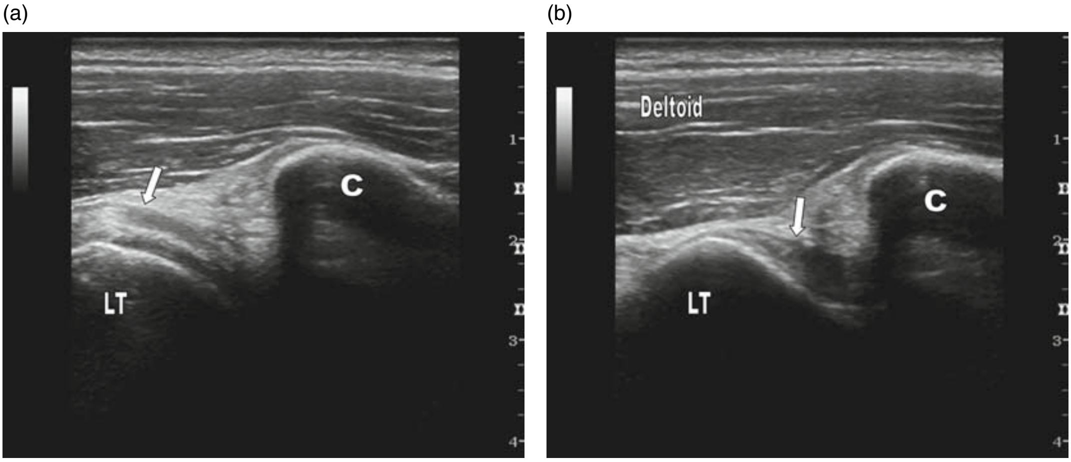


Figure 2.13. Longitudinal ultrasound image of the subscapularis tendon (arrow) at the level of the coracoid process (C). **(a)** External rotation and **(b)** internal rotation. LT, lesser tuberosity.

> **Insider Information 2.7**
> Insertional measurements of the rotator cuff: subscapularis 40 × 20 mm, supraspinatus 23 × 16 mm, infraspinatus 29 × 19 mm, teres minor 29 × 21 mm [anterior to posterior (length) × medial to lateral (width)].[24]

Supraspinatus

The supraspinatus is the commonest tendon involved in rotator cuff pathology. It is clearly separated from the subscapularis anteriorly by the rotator interval through which the biceps passes. Posteriorly, there is no clear anatomical plane between it and the infraspinatus; however, there is an extensive interdigitation of fibers between the tendons.[23] On ultrasound, this region is seen as a change from the hyperechoic fibrillar pattern of the supraspinatus tendon to the lower echogenicity of the infraspinatus. The supraspinatus tendon extends for approximately 2.5 cm in the anteroposterior direction.[5,24]

The supraspinatus tendon is normally partially obscured by the overlying acromion process. To overcome this, the supraspinatus tendon should be viewed in full internal rotation and hyperextension with the forearm behind the back, palm facing posteriorly, overlapping the scapular tip while maintaining the elbow by the side, the Crass position (Figure 2.14a). This places the tendon under stress and hence accentuates tears.[25] Examination is repeated in the modified Crass/Middleton position with the upper arm extended and the shoulder in a neutral position, elbow flexed and pointing directly posteriorly, and the palm of the hand placed forward against the ipsilateral back pocket (Figure 2.14b). This position allows for visualization of the supraspinatus tendon immediately adjacent to the bicipital interval, an area often obscured by the acromion in the Crass position. This anterior region, just proximal to the distal fiber insertion, is known as the "critical zone." It is important to keep the elbow adducted.[26]

The supraspinatus tendon has two visible main components, as described in the anatomy section. On ultrasound they appear as a cone of tendinous bundles anteriorly and a flatter posterior tendon. A hypoechoic band of intervening muscle may be present medially, but fades as one extends laterally toward the greater tuberosity.[27] In the modified Crass position, longitudinal images are obtained first by visualizing the intraarticular portion of the long head of the biceps tendon in the longitudinal plane (Figure 2.15a); this is equivalent to the longitudinal plane of the supraspinatus. The transducer is then slowly moved posteriorly in the plane of the supraspinatus, 45° to 50° to the coronal oblique plane (Figure 2.15b). This plane can be better understood by visualizing the supraspinatus fossa and mentally drawing a line from the fossa to the point of insertion, i.e., along the plane of the muscle fibers. In the longitudinal plane, the tendon fibers have a smooth convex upper border, which is noncompressible, and insert into the raised cortical surface of the greater tuberosity, which appears like a shelf. The insertional tendon fibers are also known as the tendon footprint, or footplate. Note that the articular cartilage extends only to the base of the shelf of the greater tuberosity (Figure 2.15b). The transducer is rotated 90° counterclockwise to assess the tendon in the axial plane commencing anteriorly (Figure 2.16). In this position, the coracoid process can be identified medially, but the subscapularis is poorly visualized as it is now subcoracoid. The biceps tendon

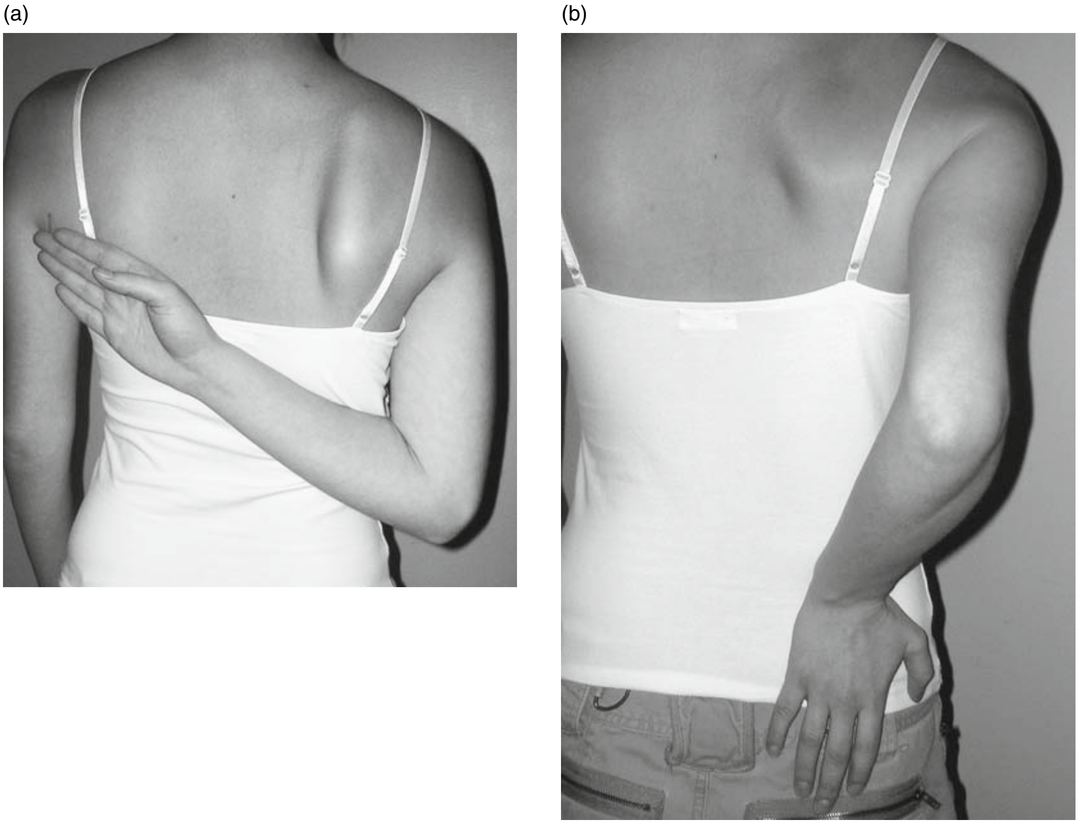


Figure 2.14. Supraspinatus tendon: positions for ultrasound evaluation: **(a)** Crass and **(b)** Middleton (modified Crass).

is noted as a hyperechoic oval structure. Lying just lateral to the biceps is the anterior aspect of the supraspinatus. The transducer is maintained in this plane and moved posteriorly to encompass the whole of the supraspinatus tendon. In the Crass position, the subscapularis and occasionally the biceps may not be identified as they are in a subcoracoid position. The transducer is positioned in the plane of the longitudinal axis of the supraspinatus tendon as described above and placed over the coracoid process. This is now used as our anterior marker if we do not identify the long head of the biceps tendon e.g., in a complete biceps rupture (Figure 2.17). The transducer is then slowly moved posteriorly, carefully maintaining it in the longitudinal axis of the supraspinatus tendon, and then evaluated in the transverse plane. It is important to use both the Crass and modified positions for a complete study.

Where there is limited range of movement, the supraspinatus tendon is examined in as much internal rotation and hyperextension as possible. It may occasionally be easier for the patient and the examiner if the examiner moves the arm back and forth in this position to unroof as much of the supraspinatus tendon from under the acromion as possible, while also assessing the dynamic motion of the fibers. The layers of structures, from deep to superficial in the longitudinal plane, are the hyperechoic humeral cortex, hypoechoic thin

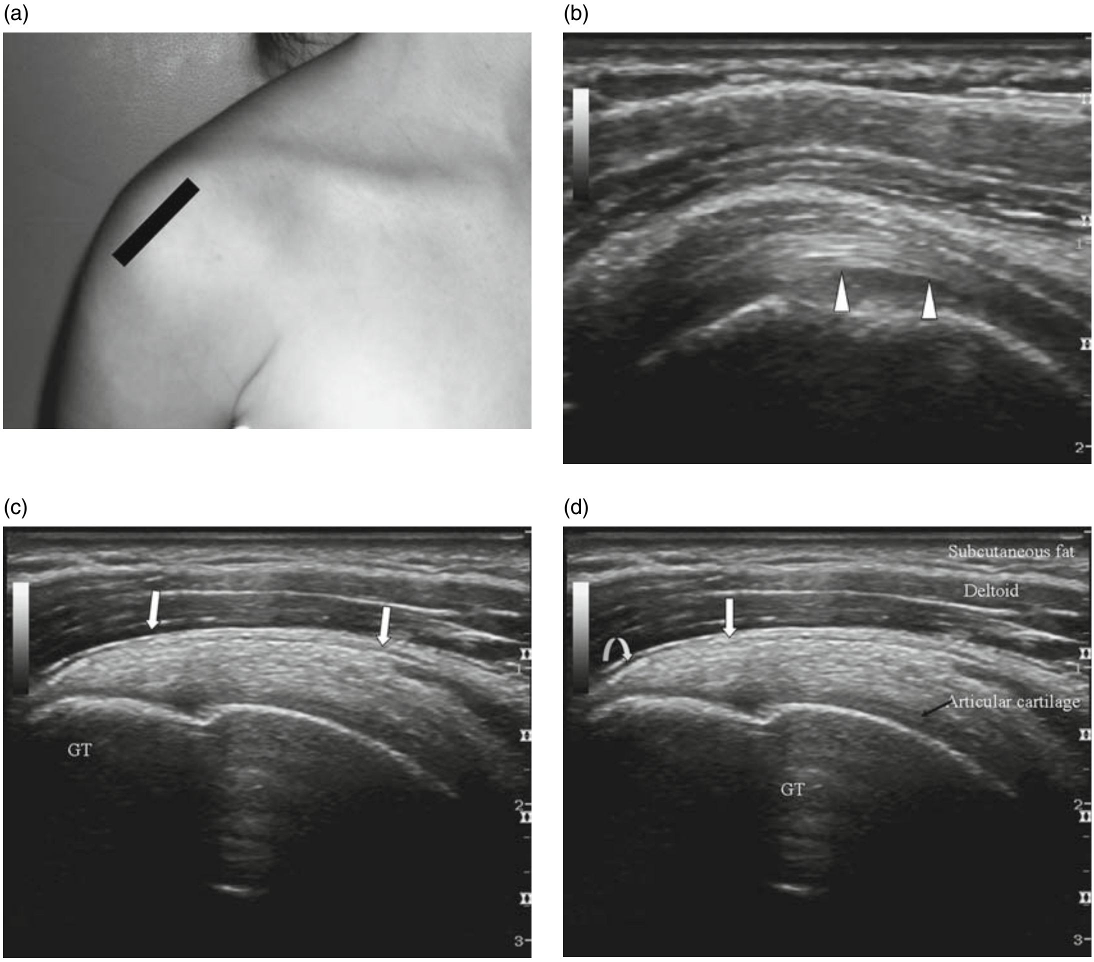


Figure 2.15. Supraspinatus tendon (arrows): **(a)** transducer position and corresponding **(b)** longitudinal ultrasound image of the intraarticular portion long head of the biceps tendon (arrowheads) at the rotator cuff interval. **(c)** The longitudinal ultrasound image demonstrating the hyperechoic fibrillar pattern of the supraspinatus is achieved by slowly moving the transducer posteriorly in the same plane. **(d)** Surrounding structures. GT, greater tuberosity; black arrow, articular cartilage; curved arrow, hypoechoic SASD bursa and adjacent hyperechoic capsule and peribursal fat.

rim articular cartilage, hyperechoic supraspinatus tendon, peribursal hyperechoic fat and bursal capsule layers with intervening hypoechoic fluid within the SASD bursa, the hypoechoic deltoid muscle, subcutaneous fat, and skin (Figure 2.15). Once the SASD bursa is identified, it should be followed in the anterior, posterior, medial, and lateral direction. This is important as significant distention with fluid may be visualized in only one region; this is usually lateral to the greater tuberosity as this is a low pressure zone. An alternative position for examination of the supraspinatus has been described whereby the patient lies supine with the shoulder at the edge of the bed, arm and elbow extended with the forearm pronated.[27]

The supraspinatus muscle is evaluated in the suprascapular fossa (Figure 2.18). This is performed to assess muscle mass and fatty infiltration. The transducer is aligned with the muscle fibers, perpendicular to

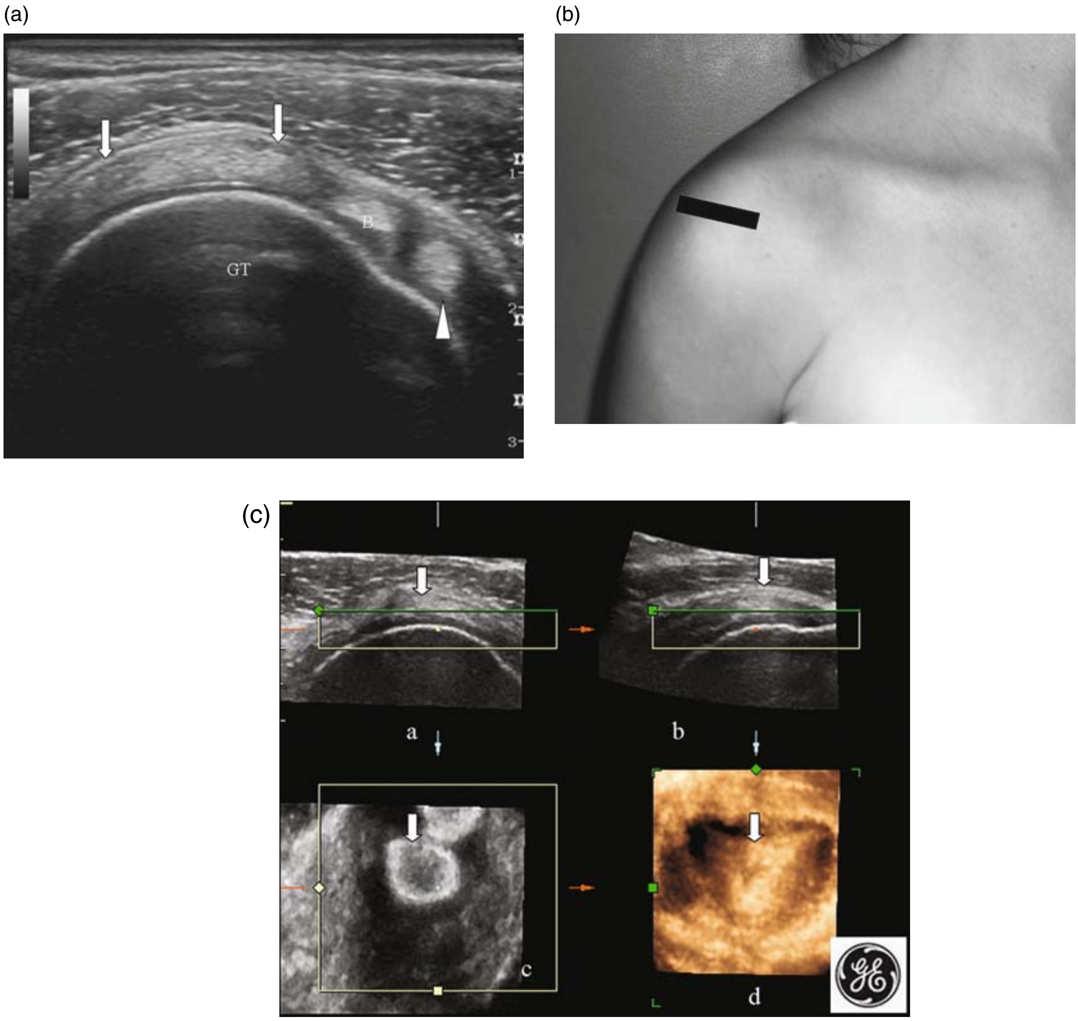


Figure 2.16. Supraspinatus: (**a**) transverse ultrasound image demonstrating the rotator cuff interval and (**b**) corresponding transducer position. (**c**) Ultrasound of the supraspinatus tendon using 4-D transducer: a, axial, b, sagittal, c, coronal, and d, 3-D reconstruction. Arrows, supraspinatus tendon; GT, greater tuberosity; B, long head biceps tendon; arrowhead, subscapularis.

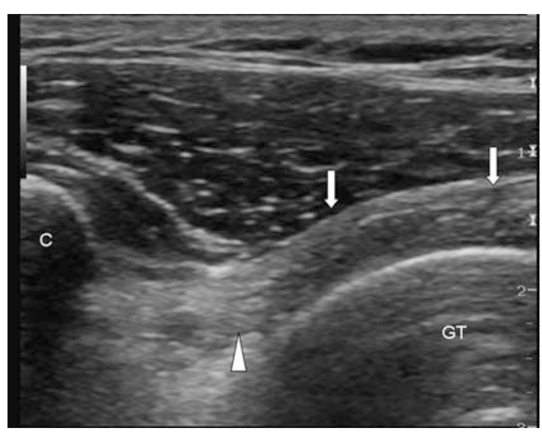


Figure 2.17. Ultrasound image of the transverse plane supraspinatus tendon in a modified Crass (Middleton) position. Arrows, supraspinatus tendon; arrowhead, long head biceps tendon; GT, greater tuberosity; C, coracoid process.

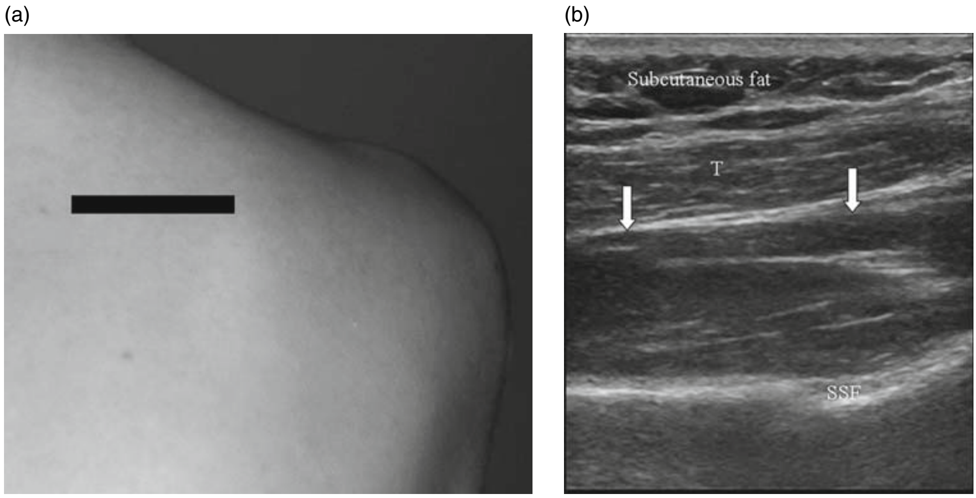


Figure 2.18. Supraspinatus muscle (arrows): **(a)** transducer position and **(b)** corresponding longitudinal ultrasound image. SSF, suprascapular fossa; T, trapezius.

the skin. The trapezius muscle is superficial, and the continuous hyperechoic cortical line of the scapula is deep to the supraspinatus muscle. Abnormal fatty infiltration is noted as increased echogenicity when compared with the contralateral side. Assessment should be performed in the relaxed state of the muscle being investigated. Contraction decreases echotexture and increases the apparent mass. New studies of dynamic evaluation during active muscle contraction have been performed to assess the contraction patterns of the supraspinatus and infraspinatus in normal and abnormal states. Abnormal contraction patterns may explain different functional capabilities in patients with similar pathology.[28] Further clinical studies are required to assess these contraction patterns and clinical significance.

Anisotropy

This is the commonest artifact in musculoskeletal ultrasound and it is essential to be able to recognize both its presence and its remedy. Anisotropy is the different ultrasound echogenicity of normal tissue when the angle of insonation is not 90° to the plane of the structure being imaged. It is most pronounced in tendons, but can be seen in other soft tissues such as ligaments and nerves. A common site of occurrence is within the supraspinatus tendon due to its coronal oblique course and angulation. To separate anisotropy from pathology, the transducer is held in the same position but is angled until it is perpendicular to the tissue of interest. When this position is achieved, the apparent hypoechoic region will resolve and the tissue, if normal, will be of homogeneous echogenicity (Figure 2.19). The tissue will remain hypoechoic if pathology is present.

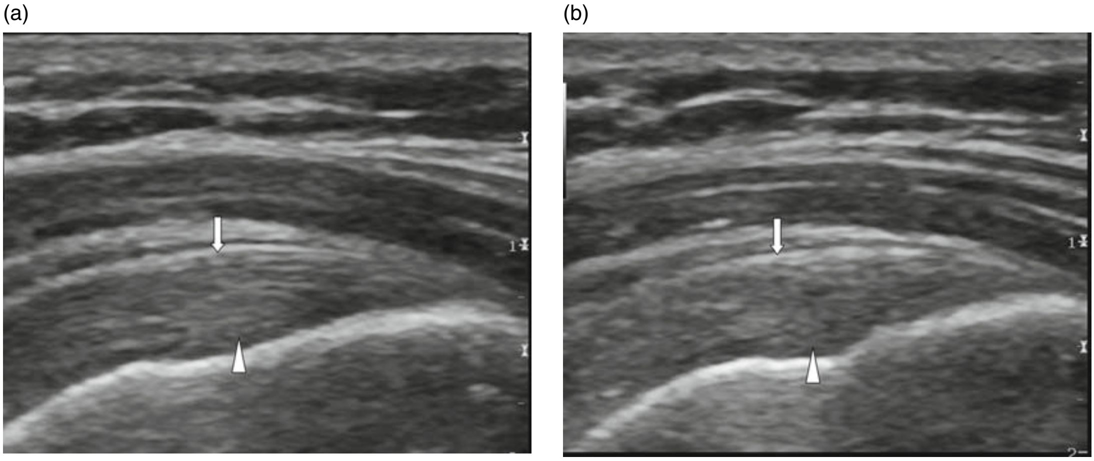


Figure 2.19. Anisotropy: supraspinatus (SS) tendon. **(a)** Normal longitudinal hyperechoic ultrasound appearance of the SS tendon. **(b)** Same position as **(a)** with transducer angled 5–10°. Hypoechoic areas appear when the transducer is no longer perpendicular to the tendon fibers and simulate pathology. Arrowhead depicts hyperechoic fibers perpendicular to the supraspinatus consistent with the rotator cable.

Insider Information 2.8
Anisotropy is the different ultrasound echogenicity of normal tissue when the angle of insonation is not 90° to the plane of the structure being imaged.

Infraspinatus and Teres Minor

The infraspinatus and teres minor tendons are evaluated with the forearm placed across the chest and the palm of the hand placed against the contralateral shoulder (Figure 2.20a). The infraspinatus is larger and lies superior to the teres minor (Figure 2.20b). Differentiation is easily achieved at

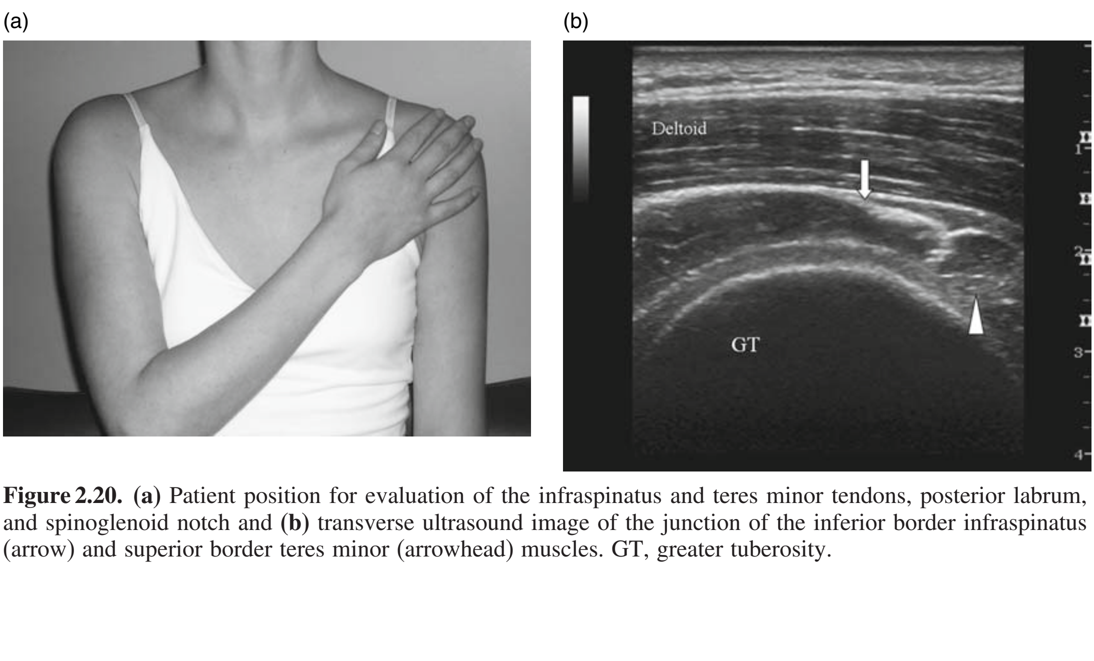


Figure 2.20. **(a)** Patient position for evaluation of the infraspinatus and teres minor tendons, posterior labrum, and spinoglenoid notch and **(b)** transverse ultrasound image of the junction of the inferior border infraspinatus (arrow) and superior border teres minor (arrowhead) muscles. GT, greater tuberosity.

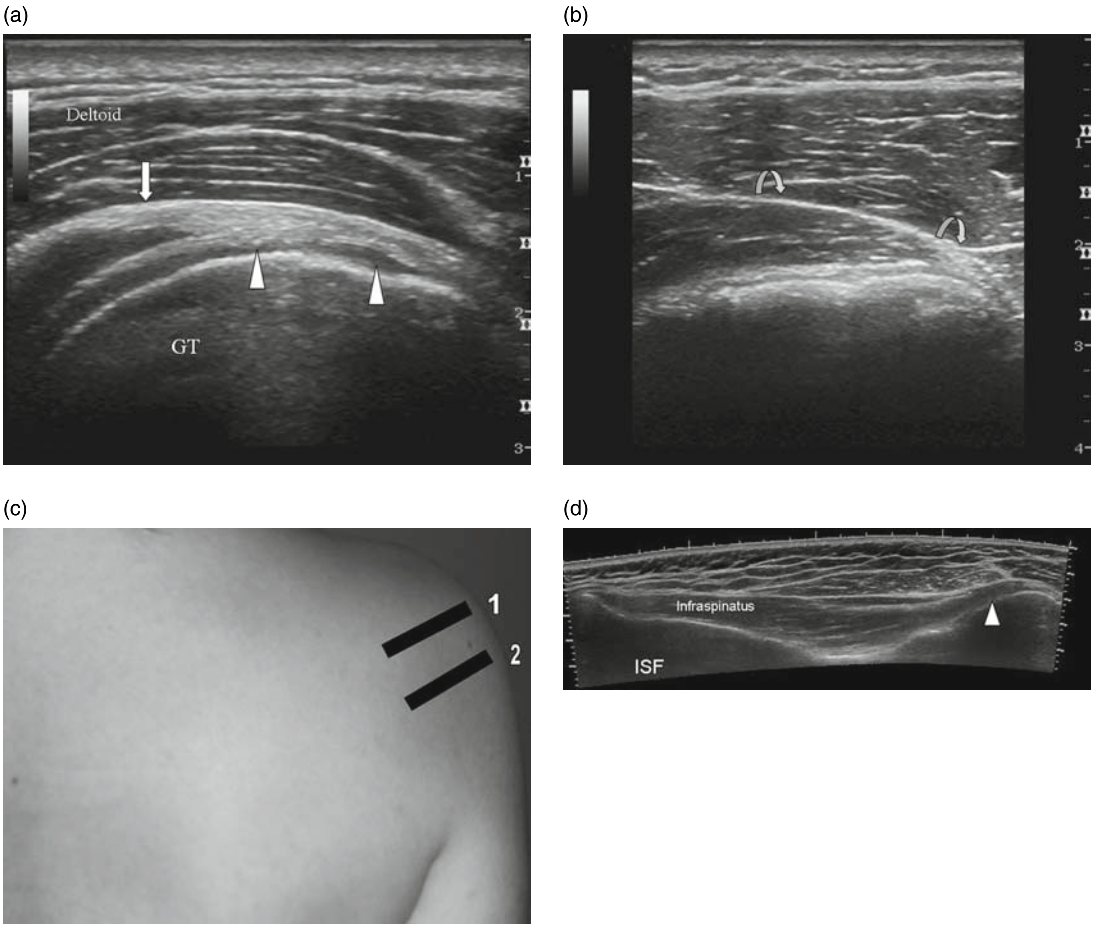


Figure 2.21. Longitudinal ultrasound of **(a)** infraspinatus tendon (arrowheads) and musculotendinous junction (arrow) and **(b)** teres minor (curved arrows). Note the short hyperechoic tendon of the teres minor, which can be used to differentiate from the infraspinatus. **(c)** Transducer positions. **(d)** Extended field of view ultrasound of the infraspinatus. 1, infraspinatus; 2, teres minor; GT, greater tuberosity; ISF, infraspinous fossa scapula.

their site of insertion onto the greater tuberosity as the infraspinatus has a long tendon (Figure 2.21a), whereas the teres minor has a short tendon, measuring only 1–2 cm (Figure 2.21b). The separation between the supraspinatus and infraspinatus tendons is described previously in the ultrasound evaluation of the supraspinatus tendon. Both tendons are evaluated in their longitudinal and transverse planes from musculotendinous junctions to insertion points.

Insider Information 2.9
The teres minor has a short tendon, allowing it to be differentiated from the infraspinatus, which has a longer tendon.

Posterior Labrum and Spinoglenoid Notch

The posterior labrum and spinoglenoid notch are viewed with the arm maintained in the same position as that for the infraspinatus. The transducer is moved transversely, perpendicular to the glenoid, and medially to overlie the

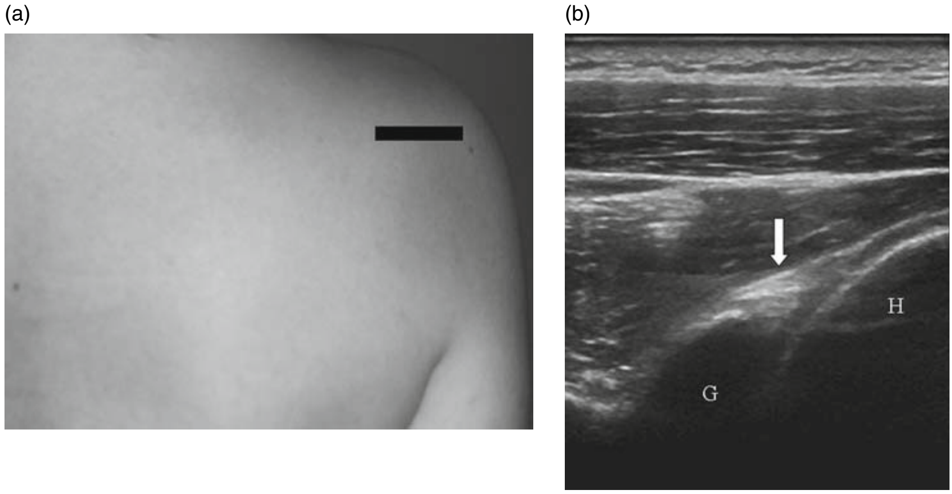


Figure 2.22. Posterior labrum: **(a)** transducer position for evaluation of the posterior labrum and **(b)** corresponding ultrasound image demonstrating the hyperechoic triangular labrum (arrow) between the humeral head (H) and glenoid (G).

posterior aspect of the glenohumeral joint (Figure 2.22a). The hyperechoic triangular labrum, the commonest morphology, lies between the hyperechoic cortical surfaces of the humeral head and the bony glenoid (Figure 2.22b).[15,16] Ask the patient to gently tap the ipsilateral hand on the contralateral shoulder. This movement will allow easier identification of joint fluid within the posterior recess as it extends between the labrum and humeral head. No fluid should normally extend through the labrum; if present, this would indicate a tear of the labrum. If fluid is identified, adjacent and posterior to the labrum, this may represent a paralabral cyst and as such will not change configuration on the dynamic motion described above. Moving the transducer medially, in the same plane, the spinoglenoid notch can be identified as a focal bony depression outlined by a continuous hyperechoic cortical line (Figure 2.23).

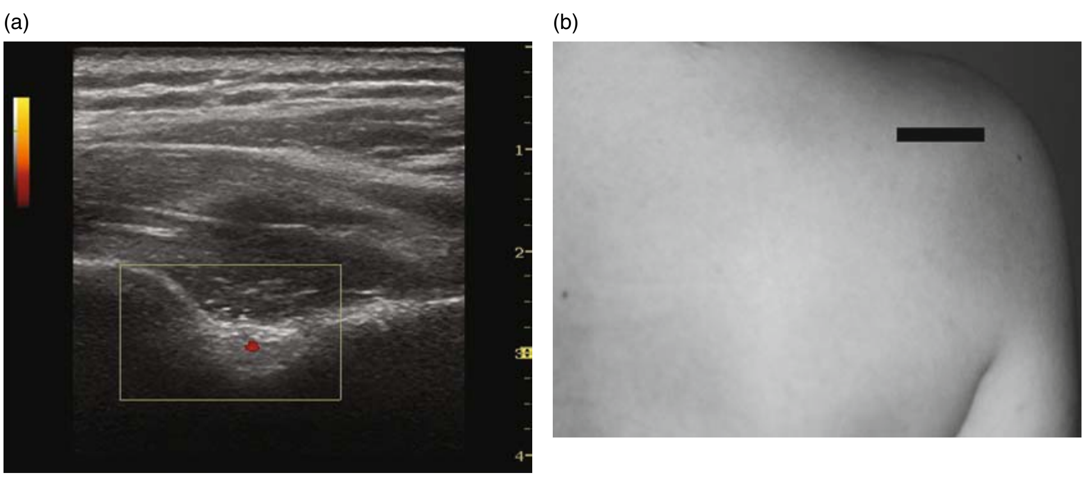


Figure 2.23. Spinoglenoid notch: **(a)** transverse ultrasound image of the spinoglenoid notch with color Doppler demonstrating the suprascapular artery and **(b)** the corresponding transducer position.

The transducer should be moved superiorly and inferiorly in a transverse plane to evaluate the full extent of the notch, which contains the suprascapular nerve, artery, and vein. With power Doppler, the suprascapular vessels can be identified and distinguished from the adjacent suprascapular nerve.

Anterior Labrum

The anterior labrum is more difficult to evaluate than the posterior labrum, particularly in patients of large habitus, and usually requires a low-frequency curved array transducer. Once the coracoid process is identified in the deltopectoral angle, place the transducer in a plane parallel to the subscapularis and move the transducer laterally until the glenoid and adjacent anteromedial humeral head are seen at the glenohumeral joint. Projecting from the hyperechoic margin of the glenoid is a triangular hyperechoic body, the anterior labrum (Figure 2.24). There may be a hypoechoic line seen at the base of the labrum; this line should normally measure less than 2 mm. A hypoechoic line wider than 2 mm has been reported to be diagnostic of a labral tear.[29] The transducer is then moved inferiorly to evaluate the remainder of the labrum. The arm is then moved in internal and external rotation.

On external rotation, the labrum is partly compressed by the humeral head and adapts a more rounded appearance.[30] The overlying capsule may be seen as a thin echogenic line interposed between the more superficial subscapularis and deeper labrum. As in the posterior labral study, this will contribute to the evaluation of the anterior recess and for joint effusion. Evaluation of the anterosuperior labrum is limited due to the overlying coracoid process. We do not normally perform an assessment of the anterior labrum as part of our standard study of the shoulder.

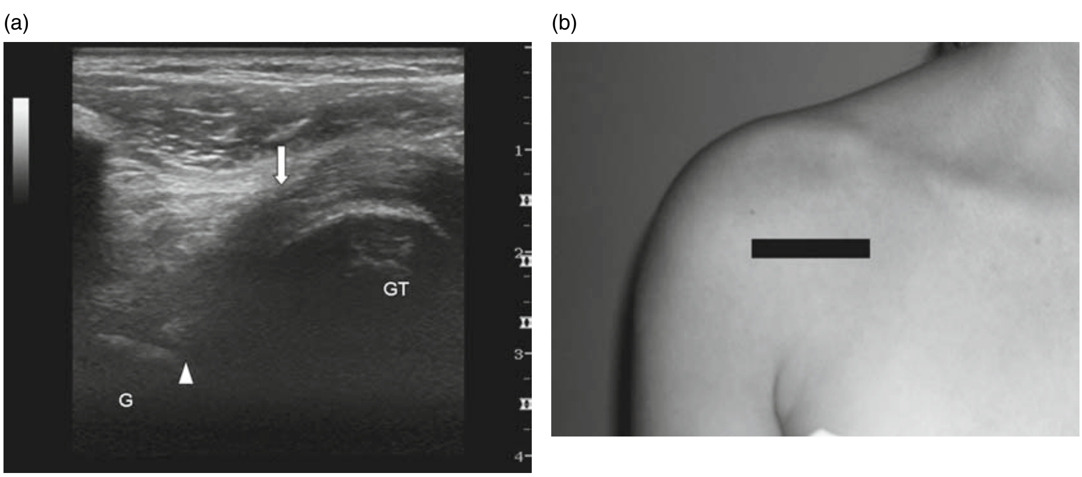


Figure 2.24. Anterior labrum: **(a)** ultrasound image in the long axis of the subscapularis muscle demonstrating the anterior labrum (arrowhead) deep to the subscapularis tendon and **(b)** the corresponding transducer position. LT, lesser tuberosity; G, glenoid.

Acromioclavicular Joint and Acromion

The acromioclavicular joint is assessed in the sagittal and coronal planes, with the arm in a neutral position by the patient's side (Figure 2.25). In the coronal position, the clavicle usually lies at a slightly higher position than the acromion. The capsule is convex at, or just above, the hyperechoic cortical line of the adjacent clavicle. The transducer is then moved from anterior to posterior, noting that the joint space is wider anteriorly. Joint width is compared with the contralateral side. Dynamic assessment can be performed by abducting and adducting the arm.[12] If acromioclavicular instability is suspected clinically, measurement of acromioclavicular separation before and after attachment of weights to each wrist or hand, with contralateral comparison, has been shown to correlate with radiographic measurements.[31]

Coracoclavicular distance can be assessed by placing the base of the transducer in a coronal plane on the tip of the coracoid process and the tip on the clavicle. Measurements are taken from the superior border of each; these measurements have also been shown to be accurate and reliable when compared to radiographic evaluation.[32] The acromion is evaluated initially in a coronal plane, anterior to posterior. It is necessary to assess for the presence of an os acromiale, which can be identified as a break in the linear cortical line (Figure 2.26), presuming there is no history of acromial fracture. The patient's age should be noted because the acromion fuses late, around the 22nd year. The subacromial space can be measured, though we do not routinely perform this component of the study, by aligning the transducer in a coronal plane to the acromion with the upper margin of the transducer on the acromion and the lower margin overlying the humeral head.[33]

Ligaments

The ultrasound appearance of ligaments is outlined in detail in Chapter 1. Ligaments have a homogeneous hyperechoic appearance with a fibrillar pattern. The ligaments of the shoulder and acromioclavicular joints are summarized in Table 2.5. The transverse humeral ligament is assessed

(a) (b)

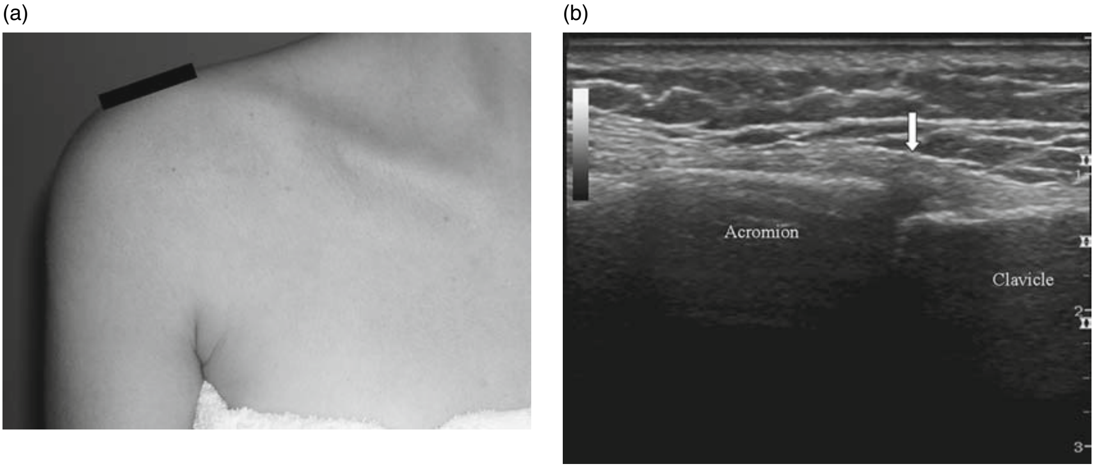


Figure 2.25. Acromioclavicular joint: (**a**) transducer position and (**b**) corresponding ultrasound image in the coronal axis. Arrow, joint capsule and superior acromioclavicular ligament.

Figure 2.26. Acromion: coronal ultrasound with the transducer maintained in the same plane as Figure 2.25a, but moved slightly laterally from the acromioclavicular joint (arrowhead).

when evaluating the biceps tendon as described previously. The remaining ligaments, which are not routinely assessed, include the coracohumeral (C-H) ligament, which is visualized with the arm in the neutral position, as described in the assessment of the long head biceps tendon, with the medial aspect transducer on the coracoid process and the lateral aspect on the greater tuberosity (Figure 2.27). Rotating the transducer superiorly so the lateral edge lies on the acromion brings the coracoacromial ligament into view (Figure 2.28). Occasionally the rotator cable, a fibrous sheath that extends from the coracoacromial ligament to envelop the supraspinatus and infraspinatus, can be identified. Its fibers pass perpendicular to those of the supraspinatus and can be seen as a thin hyperechoic fibrillar structure medial to the greater tuberosity. The fibers are prone to anisotropy and it is important not to misinterpret this appearance as pathology of the articular fibers of the supraspinatus (Figure 2.19a).[34] The glenohumeral ligaments are not routinely identifiable with ultrasonography.

Subacromial Impingement

Dynamic assessment of possible subacromial impingement has become an additional component to the shoulder ultrasound examination. Up to eight different clinical tests are used in the assessment of supraspinatus impingement.[35] The shoulder is adducted in internal rotation, and the transducer is placed over the lateral margin of the acromion in a coronal plane (Figure 2.29a). Movement of the supraspinatus tendon and overlying bursa is

Table 2.5. Ligaments of the Shoulder and Acromioclavicular Joints.

Transverse humeral[a]
Coracohumeral[a]
Coracoacromial[a]
Coracoclavicular
Glenohumeral (3)
Acromioclavicular (superior[a]) (4)
Suprascapular

[a]Can normally be visualized on ultrasound.

(a) (b)

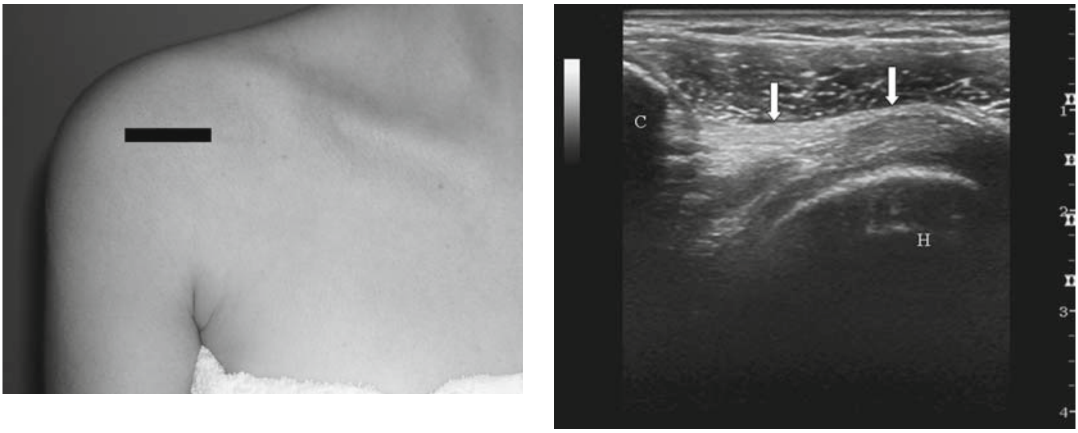


Figure 2.27. Coracohumeral ligament (arrow): **(a)** transducer position and **(b)** corresponding ultrasound image. C, coracoid process; H, humerus.

assessed during abduction (Figure 2.29b). The tendon may be better visualized with the transducer in an oblique coronal plane anterior to the acromion and acromioclavicular joint. The transducer is then placed in a sagittal plane with its posterior margin upon the anterior aspect of the acromion, and the arm is then flexed in internal rotation. The supraspinatus tendon and the SASD bursa normally move smoothly under the acromion, without bunching of the fibers of the tendon or lateral distention of the bursa. The patient should not have limitation of motion or pain.[36] Alternative etiologies, if the SASD bursa is significantly distended and impinges on dynamic assessment, need to be excluded, e.g., inflammatory arthropathy.[37] In these alternate pathologies, the supraspinatus tendon should not impinge.

(a) (b)

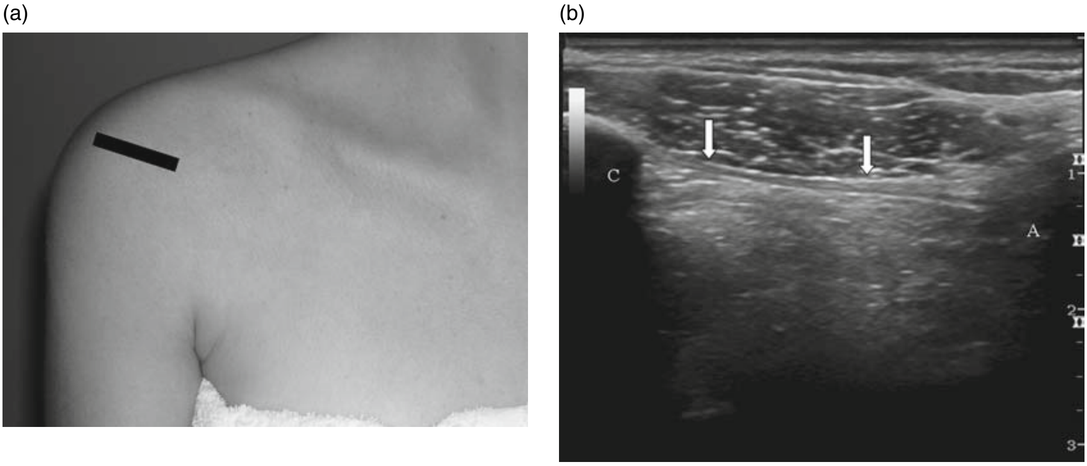


Figure 2.28. Coracoacromial ligament (arrow): **(a)** transducer position and **(b)** corresponding ultrasound image. C, coracoid; A, acromion.

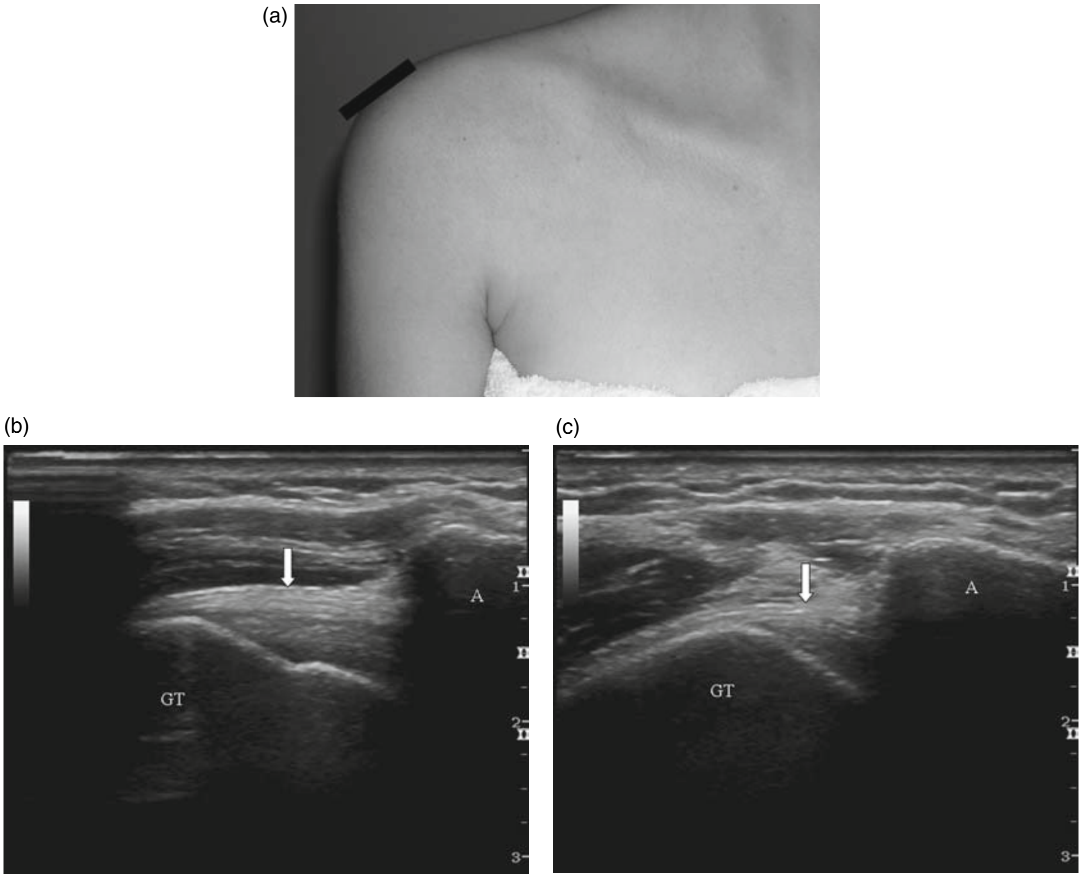


Figure 2.29. Supraspinatus dynamic impingement test: **(a)** transducer position and **(b)** corresponding ultrasound image in the longitudinal plane of the tendon in the neutral position and **(c)** in abduction. The supraspinatus tendon should move smoothly under the acromion without bunching of its fibers, lateral distention of the overlying SASD bursa, or superior translation of the humeral head. A, acromion; GT, greater tuberosity.

Miscellaneous Observations

The cortical surface of the humeral head normally appears as a smooth, hyperechoic, continuous line and is evaluated initially with the arm by the side in a neutral position followed by internal and external rotation. The bare area, on the posterosuperior humeral head, is identified as a small focal depression and lies directly deep to the infraspinatus (Figure 2.30). It should not be mistaken for early erosion or a small Hill–Sachs defect; if there is concern, correlation with the contralateral side can be performed.

The deltoid is not routinely evaluated, but is imaged if the patient is symptomatic in this region or if there is a history of trauma including postsurgical dehiscence and contracture. The three anatomical components of the deltoid—anterior, intermediate, and posterior—are evaluated separately in a transverse plane from origin to insertion onto the deltoid tuberosity. Fiber orientation is posterior oblique, vertical, and anterior oblique, respectively.

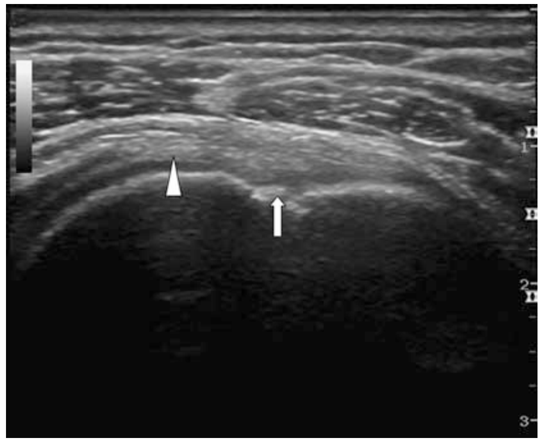


Figure 2.30. Ultrasound image: "bare area" demonstrated as focal cortical irregularity on the posterosuperior aspect greater tuberosity (arrow), with overlying infraspinatus tendon (arrowhead).

Occasionally, pathology within the pectoralis major may present with shoulder symptoms. The patient is examined in the long head of the biceps position with the transducer in the axial plane to the body, longitudinal to tendon, overlying the mid and distal bicipital groove (Figures 2.31). The muscle has an extensive origin, and it is important to evaluate the tendon from its superior to inferior border. In addition, we perform a dynamic test by externally rotating the arm, keeping the elbow by the side. Anterior shoulder instability, which accounts for 95% of shoulder instability, can be assessed on ultrasound.[30] Ultrasound examination is often limited, however, in the assessment of the anterior labrum, the underlying bony glenoid, and anterior capsule, but can usually clearly visualize a Hill–Sachs defect of the humeral head. The glenohumeral ligaments are not normally visible on ultrasound.

Sonoarthrography, wherein a standard shoulder arthrogram is performed and then evaluated with ultrasound, has been studied.[38] In the study, sonoarthrography exhibited similar sensitivity and specificity to standard ultrasound in the diagnosis of rotator cuff tears. It is our practice that patients

(a) (b)

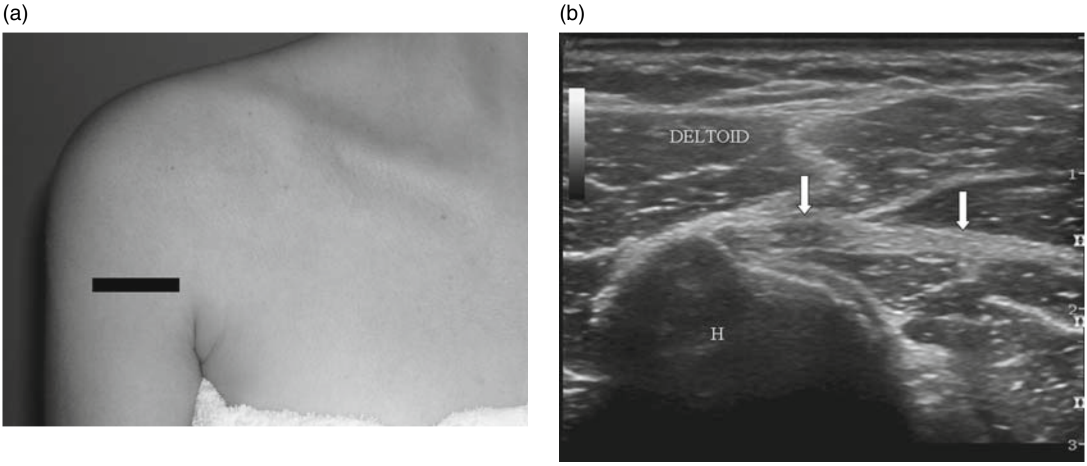


Figure 2.31. Pectoralis major: **(a)** transducer position and **(b)** corresponding ultrasound image of the longitudinal plane tendon at the humeral insertion. H, humerus.

proceed to an MRI arthrogram, the imaging gold standard for rotator cuff pathology, if a standard ultrasound examination is inconclusive in the appropriate clinical setting. Patients who fail to complete MRI arthrogram, e.g., those with claustrophobia or for whom it is contraindicated, would normally proceed to a computed tomography (CT) arthrogram in our institution. Anterior shoulder translation measurements can be performed in patients with anterior instability,[39] but in the author's opinion, this adds little to information that already has been obtained by clinical examination. Underlying pathology, such as disruption of the labrum and bony defects such as a Bankart lesion or a Hill–Sachs deformity, can be evaluated as described above.

Imaging Protocols

Imaging protocols are tailored to the clinical question. We will routinely include any new area of symptoms that have developed in the region of the shoulder since the previous clinical review. All patients with a clinical question of pathology related to a single or all components of the rotator cuff or proximal biceps will undergo a standard study of the shoulder as outlined in the Appendix. Assessments for joint effusion or synovitis receive a dedicated study of the joint space, recesses, and bursae, including Doppler, and an examination of the visible glenoid and humeral cortex for erosions. Posttraumatic patients are evaluated as per standard protocol, in addition to the area of symptoms. Patients suspected of neural impingement, e.g., within the spinoglenoid notch, will receive a standard study with special focus on the nerve in question and its region of innervation.

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