Ultrasonography and Ultrasound-guided Interventions of the Shoulder

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Nowadays shoulder ultrasound is commonly used in the assessment of shoulder diseases and is as accurate as magnetic resonance imaging in the detection of several pathologies. Operator dependence is the main disadvantage of shoulder ultrasound. After adhering to a strict examination protocol, good knowledge of normal anatomy and pathologic processes and an awareness of common pitfalls, it can be used as a focused examination providing rapid, real-time diagnosis, and treatment by ultrasound-guided interventions in desired clinical situations. Also shoulder ultrasound can help the surgeon decide whether treatment will be surgical or nonsurgical. If arthroscopy is planned, sonographic findings help to counsel patients regarding surgical and functional outcomes. If a nonsurgical approach is indicated, ultrasound can be used to follow patients. This review article presents the examination techniques, the normal sonographic appearances and the main pathologic conditions found in shoulder ultrasound. And also addresses a simplified approach to scanning and ultrasound-guided intervention. Knowledge of optimal techniques, normal anatomy, dynamic maneuvers, and pathologic conditions is essential for optimal performance and interpretation of images.

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Introduction

One of the primary roles of orthopedic surgeons comprises treating patients who present with pain in the shoulder. Shoulder pain is the second leading cause of musculoskeletal pain after spinal pain. Primary diagnosis of shoulder lesions is made using plain radiography, but results from this cannot discern neither signs of inflammation nor tears of the rotator cuff and other structures—which are key concerns. Magnetic resonance imaging (MRI) can detect these findings but MRI necessitate space and cost, and MRI-guided intervention is nearly impossible. Fluoroscopic-guided intervention is possible but the patient will be exposed to radiation and the surgeon can not be guided during the intervention with spatial orientations and positions of nerves and tendons. Compared to fluoroscopic-guided intervention devices, ultrasound is compact, applicable to the outpatient setting, radiation exposure free, and is a real-time imaging tool for nerves, muscles, vasculatures and tendons. de Jesus et al. compared the diagnostic accuracy of MRI and ultrasound for the diagnosis of rotator cuff tears through a meta-analysis of the studies in the literature and concluded that ultrasound and MRI are comparable in both sensitivity and specificity. Technical advancement of ultrasound device and improvement of interventional knowledge and skill have enable to be included as a primary imaging investigation among the battery of available diagnostic modalities. Limitations to ultrasounds exist such as low resolution, in comparison to the resolution that can be achieved with either computed tomography or MRI, and learning curve is long and steep, and results are operator dependent. Nevertheless, with the development of musculoskeletal ultrasonography, based on advanced ultrasound capabilities in the future, we believe that shoulder ultrasonography may receive greater attention and become a standardized method for diagnosis and intervention for shoulder pathologies. This review article aims to illustrate the technical performance, normal sonoanatomy and main pathological conditions found in shoulder ultrasonography,
as well as ultrasound-guided interventional techniques.

**Surface Anatomy of the Shoulder for Ultrasonography**

Understanding the surface anatomy of the shoulder is important for ultrasonography. A good understanding of the spatial orientation and position of key structures and their effect on the image increases diagnostic competency, understanding of images and accuracy of the intervention. By knowing the shoulder surface anatomy inside out, an orthopedic surgeon understands how the probe should be positioned to obtain the desired views. The examination of the shoulder using sonography begins by marking the bony structures that are definable by palpation, such as the superior facet of greater tubercle, and then by inferring the positions of other structures, such as the supraspinatus tendon, from these markers.

At the midline base of neck, an U-shaped indentation can be palpated, the jugular notch. It is the first structure to be defined and the portion of uppermost sternum. On either side of the jugular notch is the clavicular notch, the boundary of which forms the sternoclavicular joint and the point where the clavicle begins. The palpation of the superior and the inferior borders of the clavicle into the lateral end of the clavicle lead to the large, round acromion, and the acromio-clavicular joint forms at the junction (Fig. 1A). The acromion is the most palpable structure of the lateral shoulder. It is a large bony structure that can also be found through palpation from the scapular spine of the posterior shoulder towards the lateral spine where the acromion is found in continuity. At the lateral acromion from the posterior aspect, an anterior, perpendicular fall in the acromial structure can be felt and is denoted the posterior angle, and in front of the posterior angle is a straight, lateral border, which if you follow anteriorly you end up at a medial, smooth turn, which is the anterior angle. The anterior angle is found around 2 cm away from the acromio-clavicular joint (Fig. 1B).

Scapular is a triangular-shaped bone found at the posterior part of the thorax. To locate the scapula, the medial border of the scapula is palpated, which is situated around 6 cm lateral to the vertebral spinous processes and at the level between the 2nd and the 7th thoracic spinous processes. In general, the medial end of the scapular spine levels with the 3rd thoracic spinous process whereas the inferior angle of the scapula levels with the 7th thoracic spinous process. Medial border of the scapula may not be easily palpable, for example, because the superior angle is masked by trapezius muscle, in which case the scapular should be made to be protruded by placing the humerus in adduction, extension, and internal rotation (Fig. 1C).

The superior boundaries of the scapular spine and the clavicle meet at their lateral ends and form a V-shaped posterior indentation, which is the region where they are met with the acromion. In other aspects, when you follow the inferior boundary of the clavicle in the lateral direction, you end up at an anterior indentation which is the junction of the clavicle and the antero-

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**Fig. 1.** (A) Surface anatomy of anterior shoulder region. At the midline base of neck, an 'U' shaped indentation can be palpated, the jugular notch (black arrow). After tracing laterally from the medial aspect of the clavicle until reaching a bony prominence marking the lateral end of the clavicle, a ridge between the clavicle and the anterior shoulder region. Black arrow indicates posterior aspect of shoulder region. Black arrow indicates posterior indentation. Arrowheads indicate acromio-clavicular joint. White arrow indicates posterior angle of acromion. (B) Superior aspect of shoulder region. Black arrow indicates posterior indentation. Arrowheads indicate acromio-clavicular joint. White arrow indicates posterior angle of acromion. (C) Posterior aspect of shoulder region. Black arrow indicates inferior angle of scapula. White arrow indicates superior angle. (D) Lateral aspect of shoulder region. Black arrow indicates anterior angle of acromion. White arrow indicates coracoid process.
medial acromion. Where the two indentations connect is the acromio-clavicular joint. However, because the outeredge of the clavicle forms a large and round shape, the actual boundary of the joint encompasses a larger area than the boundary formed by only the two indentations combined; this can be confirmed by palpation as the clavicle protrudes further out than the acromion (Fig. 1B).

The coracoid process can be palpated 2 finger breadth below and medially from the acromio-clavicular joint. The coracoid process bulges out from the anterosuperior face of the scapular glenoid and at its lateral end bends in the shape of a beak; the surface that can be felt from palpation is just the lateral tip. There are 3 main ligaments related to the coracoid process: coracocromial ligament, coracoclavicular ligament, and coracohumeral ligament. It is also the place where the attachments of tendons are found, for example, the pectoralis minor, the coracobrachialis, and the short head of biceps tendon.

The greater tubercle is palpable on the line from the lateral epicondyle of the distal humerus in the direction of the humeral longitudinal axis and just below the acromion (Fig. 1D). This relationship between the lateral epicondyle and the greater tubercle is retained however the shoulder is rotated. The greater tubercle is normally covered by the deltoid, so palpation of the accurate contour of the greater tubercle is difficult. To make it easier, the Crass position is employed for which the patient places his or her hand on the contralateral back pocket with the palm facing away from the gluteal; this causes the humerus to go into adduction, extension, and internal rotation and allows the greater tubercle to position at the front of the shoulders. In this Crass position, the greater tubercle is shifted anteroinferior to the acromioclavicular joint which in turn allows the maximal exposure of the supraspinatus tendon from the acromion.

Palpation of the immediate inferior region of the acromioclavicular joint reveals a flat superior facet of the greater tubercle, which is also the insertion site of the supraspinatus tendon. The total width of the supraspinatus tendon is around 23 mm; only the anterior 13 mm of the tendon inserts at the superior facet of the greater tubercle whereas the posterior 10 mm inserts at the middle facet. So at the middle facet of the greater tubercle, the insertion of both the infraspinatus tendon and the supraspinatus tendon occurs. This middle facet which forms an angulation can be palpated by moving laterally from the superior facet. Below the middle facet is the flat inferior facet, which is where the teres minor muscle inserts (Fig. 2).

The lesser tubercle can be palpated by first working from the greater tubercle towards the medial end, pass the intertubercular groove, which accommodates the long head of biceps tendon, and finally to the lesser tubercle, the insertion site of the subscapularis tendon (Fig. 1D).

Familiarization with the surface anatomy of the shoulder is crucial in order for the examiner to know where the probes should be placed during shoulder ultrasonography.

**Shoulder Ultrasonography**

Compared to other parts of the body, shoulder joints are found relatively close to the skin surface, which is why linear probes are recommended over convex probes. Although authors prefer facing the patients, ultrasonographic evaluation of the patient can be made either facing the patient or standing behind. But either way, to reduce strain, the examiner should ideally be positioned so that his or her shoulder is higher than the patient’s shoulder, and the elbow should be close to the body rather than extending the arm toward the patient. To allow fine motor control during the scanning and also reduce strain on the shoulder, the probe should also be held at its base, stabilizing the probe by resting either the edge of the hand or the little finger on the patient. To obtain accurate views of tendons, the direction of the running tendon fiber must be perpendicular to the sound beam. If the sound beam does not hit the target surface at a perpendicular angle, anisotropy that can be misinterpreted as tears occurs; thus, an ultrasonographer must be able to differentiate between anisotropy and a tear (Fig. 3). A systematic approach for ultrasound scanning is recommended (Table 1).
The long head of biceps tendon is usually the first structure to be examined by ultrasonography. First, the arm is slightly externally rotated with the forearm in supinated position resting on the thigh (Fig. 4). We obtain initially a view of the long head of biceps tendon in the transverse plane by placing the probe about 3 cm inferior to the acromioclavicular joint on the anterior shoulder and then the tendon is totally examined in a transverse plane from the level where it emerges beneath the acromion to the musculotendinous junction (Fig. 5). The reason why the transverse plane is examined before the longitudinal plane is because it is much easier to locate the biceps tendon within the humerus. In the transverse scan, the echogenicity of the biceps tendon is readily identifiable as a round, hyperechoic area in the intertubercular groove between the medial, pointed lesser tubercle and the lateral, flat greater tubercle. Running over the biceps tendon in a parallel fashion is the transverse humeral ligament (Fig. 5). Because an extension of the synovial lining of the glenohumeral joint invests the biceps tendon down to approximately 3 to 4 cm beyond the distal end of the groove, intra-articular fluid can spread even to this region. So if tenosynovitis or secondary effusion resulting from intra-articular lesions is developed, hypoechoic peritendinous doughnut-shaped fluid accumulation may be shown. Small amounts of fluid can normally be seen surrounding the tendon especially when the fluid does not completely surround the tendon but partially (Fig. 5F). The ascending branch of the anterior circumflex humeral artery runs laterally to the tendon, and can be found by pulsation or Doppler scan (Fig. 5E).

Immediately underneath the acromion lies the entrance of intra-articular space where tubercles disappear, the intertubercular groove becomes shallow, and the long head of biceps tendon flattens and tilts here. There are two essential ligaments that support and stabilize the intra-articular portion of the long head biceps tendon: The thin hyperechoic coracohumeral ligament can be identified superficial to the long head of the biceps tendon, which contributes to the biceps pulley along with the

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**Table 1. Protocol of Shoulder Ultrasound Examination**

| Step | Anatomical site of scan |
|------|-------------------------|
| 1    | Biceps transverse and longitudinal scan |
| 2    | Subscapularis longitudinal & transverse scan |
| 3    | Supraspinatus longitudinal & transverse scan |
| 4    | Infraspinatus longitudinal & transverse scan, teres minor transverse scan, glenohumeral joint, posterior labrum, spinoglenoid notch |
| 5    | Acromioclavicular joint, dynamic view of subacromial impingement |

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**Fig. 3.** (A) Ultrasound image shows hypoechoic appearance of biceps tendon due to anisotropy when not imaged perpendicular to the sound beam. (B) After correction of probe tilting, normal echogenicity can be recovered from anisotropy.

**Fig. 4.** The patient is asked to place patient’s hand palm up on the lap for the examination of biceps brachii tendon, long head.
thin and hyperechoic superior glenohumeral ligament deep and medial to the biceps tendon (Fig. 5). The tendon undergoes an abrupt angulation so during the scanning the probe must be tilted accordingly to maintain an accurate view, and as this is also a region for tendinopathies and partial tears, it should be examined without miss. To obtain better images of this region, the shoulder might be extended so that the humeral head moves anteriorly; this motion widens the rotator interval, stretches the biceps tendon, and places tension on the coracohumeral ligament. Distally the transverse scan should include up to the level of the pectoralis major tendon (arrowheads), which is identified coursing over the biceps tendon (closed arrow) to insert on the lateral aspect of the bicipital groove. (E) Doppler imaging reveals the ascending branch of anterior circumflex artery, which is usually on the lateral side of tendon. (F) Biceps brachii tenosynovitis. Transverse scan of the biceps tendon shows fluid and synovial thickening surrounding the biceps tendon sheath.

Sb: subscapularis, H: humerus shaft.

Fig. 5. (A) Long head of the biceps brachii tendon (transverse scan). Transverse humeral ligament (arrowheads) appears as a very thin hyperechoic band over the sulcus. Biceps tendon appears as an oval hyperechoic structure within the intertubercular sulcus between lesser tubercle (opened arrow) and greater tubercle (closed arrow). (B) The position of probe (black bar) on the intertubercular sulcus over the anterior shoulder. (C) By moving the probe more proximally along the orientation of biceps tendon, the rotator interval including biceps tendon (between the supraspinatus tendon laterally and subscapularis tendon medially) can be shown. Hyperechoic tendon at this level is sandwiched between the coracohumeral ligament superiorly (arrowheads) and superior glenohumeral ligament (closed arrow) inferomedially. (D) The biceps tendon is followed distally to the level of the pectoralis major tendon (arrowheads), which is identified coursing over the biceps tendon (closed arrow) to insert on the lateral aspect of the bicipital groove. (E) Doppler imaging reveals the ascending branch of anterior circumflex artery, which is usually on the lateral side of tendon. (F) Biceps brachii tenosynovitis. Transverse scan of the biceps tendon shows fluid and synovial thickening surrounding the biceps tendon sheath.
90° to obtain a scan of the tendon in the longitudinal plane. The scan stretches from the proximal intra-articular portion of the tendon to the distal musculotendinous junction. It is important to orient the ultrasound beam perpendicular to the long axis of the tendon to visualize the normal echogenic, fibrillar pattern but the tendon deepens towards the distal portion leading to anisotropy. Therefore this process may require gently pushing the inferior aspect of the probe against the patient’s arm to ensure that the tendon fibers are oriented perpendicular to the ultrasound beam (Fig. 6). Complete tears of the biceps tendon results in a Popeyes sign and areas of deficit are seen especially with acute tears, but with time the accumulation of fibrous tissue in the interturbecular groove emulates an intact hyperechoic tendon. To differentiate complete tears to an intact tendon, one can check whether fibrillar pattern which should be seen in normal tendon is present.

Fig. 6. (A) The transducer is then rotated 90° to examine the tendon in a longitudinal plane. Long axis image shows the fine fibrillar structure of the tendon. (B) Probe placement (black bar). (C) Proximal longitudinal scan of tendon (arrowheads) which runs deeply into glenohumeral joint under the acromion. (D) Distal longitudinal scan at the level of musculotendinous junction (arrowheads). H: humerus.

Fig. 7. Biceps medially subluxation (arrow) from the intertubercular groove of the right side comparing normal left side.
Examiners should look out for intrasubstance tears of the tendon or whether the biceps tendon undergoes a medial subluxation or dislocation from the intertubecular groove during external rotation (Fig. 7).

**Subscapularis Tendon**

The patient’s arm may need to be externally rotated to optimally visualize the tendon. The probe is initially placed in a transverse orientation at the level of the lesser tubercle and moved medially along the long axis of the tendon (Fig. 8). Externally rotating the shoulder pulls out the subscapularis muscle, which is normally hidden deep to the coracoid process, in the lateral direction thereby exposing it for ultrasound. The scanning of the subscapularis tendon usually begins from the cranial portion of the tendon, where tears often occur, towards the caudal portion. Because the subscapularis muscle is rhombus shaped, the size of the muscle decreases as you go towards the lateral insertion site; thus, to view the cranial portion the medial end of the probe should be tilted superiorly and to view the caudal portion, inferiorly. By doing so the direction of the muscle fiber is made as parallel as possible to the longitudinal plane of the probe. The subscapularis tendon may show anisotropy at the point where the tendon passes over the articular cartilage which is located at the medial portion from lesser tubercle, but this anisotropy seen here is anatomically normal and may falsely indicate a tear (Fig. 9).

Care must be taken to adequately visualize the most superior aspect of the subscapularis, as most subscapularis tears associated with supraspinatus tears will involve this area. At first, the probe moves to the upper part where lesser tubercle can no longer be seen. And then moves down slowly to find the lesser tubercle, and we can defined the cranial portion of the subscapularis tendon in the longitudinal plane as the region where the lesser tubercle begins to come into view. As well as the longitudinal plane, we examine the subscapularis tendon in the transverse plane by rotating the probe 90°. During the scanning of the transverse view, the probe must be slightly rotated laterally on its cranial side so that it is perpendicular to the tendon, that is, from the front, the probe on the right shoulder is rotated in the 11 o’clock direction whereas the probe on the left shoulder is rotated in the 1 o’clock direction (Fig. 10). The subscapularis tendon in the transverse plane appears as 4 to 6 bundles of hyperechoic tendons intertwined with hypoechoic muscle; the cranial portion is mostly tendinous and appears hyperechoic, and the caudal portion is mostly muscular and appears hypoechoic.

**Supraspinatus Tendon**

In the neutral position, the supraspinatus muscle is hidden under the acromion and from ultrasonographic range. Structures blocked by bony elements cannot be reached by ultrasound leading to the formation of posterior acoustic shadowing; these structures resting inside a shadowy dark area cannot be imaged. Thus, methods to expose the supraspinatus tendon from behind the acromion have been devised. The Crass position, this hyperextended and internally rotated position pulls the supraspinatus tendon out from under the acromion. In this position, the greater tubercle is located directly anterior; to obtain a longitudinal view of the supraspinatus, the probe is simply placed in the sag-
ittal plane over the anterior shoulder inferior from acromioclavicular joint and to obtain a transverse view, the probe is turned 90°. On the transverse plane, the infraspinatus inserts onto the middle facet of the greater tuberosity superficially overlapping the supraspinatus tendon. But because the directions of the tendinous fibers differ, a difference in anisotropy that distinguishes them can be seen (Fig. 11). Transverse scan over the smooth, round echogenic surface of the humeral head shows thin layer of hypoechoic hyaline cartilage with a uniform thickness of the overlying rotator cuff are seen. Moving the probe distally toward the insertional site at greater tubercle, the superior facet and the middle facet which meet forming an angulation will be visualized (Fig. 11). However, the Crass position cannot be executed by patients with shoulder lesions that limit their ability to internally rotate or extend the shoulders, and excessive internal rotation actually causes the rotator interval to excessively rotate and slip below the coracoid process sometimes. This excessive rotation makes poor visualization of the rotator interval but actually, many supraspinatus tears occur anterior near the rotator interval. For patients who cannot faithfully execute a Crass position and improving the visualization of rotator interval effectively, they are asked to place the palm of their hands on the ipsilateral back pocket. In this position, the greater tuberosity is now located more upward and lateral than with the Crass position as the degree of internal rotation is decreased to allow easy visualization of the rotator interval with little patient discomfort. In this modified Crass position, the supraspinatus tendon does not run vertically below the acromioclavicular joint any more but 45° in a plane inferior and lateral from the acromioclavicular joint (Fig. 12). It is important to place the probe in parallel to this 45° axis to obtain a longitudinal scan of the supraspinatus, and to obtain a transverse plane, the probe is simply rotated 90° from here. Of further note, when the elbow points posterior while in the modified Crass position, the internal rotation is reduced, which allows the rotator interval to be seen more clearly. Physically, extremely elderly patients may not be able to perform even these little shoulder motions. In these patients, the elbow should be flexed and shoulder extended so that the supraspinatus tendon moves just anteriorly from the acromion. This simple position sufficiently exposes the anterior portion of the supraspinatus tendon (Fig. 13, 14).

On the longitudinal plane of the supraspinatus tendon, the
tendon has a beak-shaped configuration because the tendon parallels the curved contour of the humeral head, flattening out as it inserts into the greater tuberosity. As the probe is moved posterior over the middle facet of the greater tubercle, the angle between the round articular surface of the humeral head and the curved tubercle surface becomes nearly flat (Fig. 15). Because the tendon fibers are curving away from the sound beam, the insertion site of the greater tubercle is a common area for anisotropy and one should continually angle the probe and ultrasound beam to eliminate anisotropy. The supraspinatus tendon runs parallel to the longitudinal plane of the biceps tendon, thus it is ideal to begin just anterior to the supraspinatus over the rotator interval and the long head of the biceps brachii tendon. This ensures that the most anterior aspect of the supraspinatus has been included so as to not overlook a tear. In addition, once the long axis of the biceps tendon is in plane, this establishes

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**Fig. 12.** (A) Modified Crass position, the patient is asked to extend his or her arm posteriorly and place the palmar side of the hand on the superior aspect of the iliac wing with the elbow flexed. (B) The long-axis plane of the supraspinatus is approximately 45° in a plane inferior and lateral from Crass position. Therefore, probe placement for longitudinal (left) and transverse (right) scans should be adjusted to this plane. (C) Transverse scan distal to articular surface of modified Crass position shows more upward and lateral migration of rotator interval (arrow). (D) Comparison of the position of rotator interval (arrows) between Crass position (left) and modified Crass position (right). In modified Crass position, anterior portion of supraspinatus near the rotator interval can be evaluated more clearly. Many supraspinatus tears occur within this area. SF: superior facet, MF: middle facet.

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**Fig. 13.** (A) The hyperextended position with elbow flexion. (B) Although lack of internal rotation, the image can show the anterior portion of supraspinatus near the rotator interval (arrow).
Fig. 14. (A) Schematic comparison of three positions. Normal superior view of shoulder. Black bar indicates supraspinatus tendon. (B) In hyperextended position, supraspinatus tendon moves just anteriorly from acromion. (C) In modified Crass position, supraspinatus tendon rotates more internally than hyperextended position. (D) In Crass position, supraspinatus tendon rotates extremely internally and deeply below the coracoid process. Ac: acromion, P: coracoid process, C: clavicle.

Fig. 15. (A) Probe placement for supraspinatus tendon (longitudinal scan). (B) Longitudinal image over rotator interval shows long head of biceps brachii tendon (closed arrow). (C) Supraspinatus tendon has a homogeneous pattern of medium-level echoes and a convex beak-like shape. From superficial to deep, note the echogenic fat stripe (closed arrow) under hypoechoic deltoid, the hypoechoic line of subacromial-subdeltoid bursa and the echogenic fat stripe over supraspinatus tendon (opened arrow). Deeply, the hypoechoic cartilage of the humeral head covered the echogenic cortex of the humeral head and the greater tuberosity. (D) After moving the probe laterally, image shows the middle facet where the angle is nearly flat.
the long axis plane of the supraspinatus so that the probe is then simply moved posterior over the tubercle in the same imaging plane to complete evaluation of the supraspinatus tendon and then finally the infraspinatus tendon. Several images are obtained sequentially from anterior to posterior over the greater tuberosity, focusing not only distally at the facets but also more proximally as well before make an informed decision of the tendon condition (Fig. 15).

Tendinosis of the supraspinatus tendon is diagnosed if there is swelling of the tendon with a heterogeneous hypoechoic tendon texture and a loss in fibrillar pattern in spite of the absence of an intrasubstance tear (Fig. 16). Also, we can diagnose a partial thickness tear of the supraspinatus tendon when a partial thickness hypoechoic area of deficit with partial discontinuity is seen. van Holsbeeck et al. defined ultrasound criteria for identification of partial-thickness tear of the rotator cuff. The criteria were a mixed hyper and hypoechoic focus in the crucial zone of the supraspinatus tendon and a hypoechoic lesion visualized in two orthogonal imaging planes with either articular or bursal extension. They reported the sensitivity of ultrasound in depiction of partial-thickness tears was 93%, and specificity was 94%. The positive predictive value was 82%, and the negative predictive value was 94%.

![Fig. 16. Rotator cuff tendinosis. The image reveals supraspinatus tendon degeneration as tendon swelling with internal echostructure heterogeneity.](image16)

![Fig. 17. (A) Articular partial-thickness tear. The image shows the tear at the articular side of the supraspinatus tendon as a hypoechoic defect with echogenic boundary (arrows). The defect is persistent on all longitudinal (A) and transverse (B) imaging planes. Asterisk indicates biceps long head tendon.](image17)

![Fig. 18. Full-thickness tear of supraspinatus tendon (arrows) that reaches from the bursal to the articular margin with sagging of the overlying bursa. Longitudinal (A) and transverse (B) view. Asterisk indicates secondary subdeltoid bursitis. (C) Corresponding magnetic resonance imaging. Arrow indicates full-thickness tear of supraspinatus tendon. (D) Another full-thickness tear of supraspinatus tendon (asterisk and arrow) in ultrasound (left) and magnetic resonance imaging (right). SF: superior facet, MF: middle facet.](image18)
value was 98% using these diagnostic criteria (Fig. 17). For full-thickness tear of the supraspinatus tendon, the images show a sonolucent defect extending across the width of the supraspinatus tendon. The edges of the torn tendon may be retracted and visualized on both sides of the tear. This area of deficit may become filled with fluid or occupied by the deltoid muscle and peribursal fat which can oppose the overlying humeral head cartilage (Fig. 18).

Middleton et al. suggested three sonographic criteria indicative rotator cuff tear. These criteria were (1) discontinuity in the normally homogeneous echogenicity of the rotator cuff; (2) replacement of the normal homogeneous echogenicity by a central echogenic band; and (3) nonvisualization of the cuff. The diagnostic value of these criteria were a sensitivity of 93% and a negative predictive value of 95%. Supplementing this criteria, secondary changes that are rotator cuff tear dependent can aid diagnosis of rotator cuff tears; for example, irregularity of the greater tubercle cortical surface, cartilage interface sign which refers to the sonographic presence of a thin markedly hyperechoic line (loss of supraspinatus coverage makes this line visible) at the interface between the hyaline articular cartilage of the humeral head and an abnormally torn hypoechoic supraspinatus tendon, subacromial-subdeltoid bursal fluid accumulation or bursal collapse towards the humeral head cartilage, superior migration of the humeral head, fluid accumulation around the biceps tendon (Fig. 19).

When analyzing ultrasonographic findings of rotator cuff, it is important to differentiate anisotropy with partial tears; the boundary of anisotropy produces a much less well-defined, uniformly hypoechoic region and can be corrected by adjustment of the angle of the probe whereas that of a partial tear is well-defined region and remains so irrespective of the probe angle.

Calcific tendinitis combined with posterior acoustic shadowing is commonly seen in the supraspinatus tendon (Fig. 20). The degree of posterior acoustic shadowing depends on the degree of calcification. Those examining the ultrasonography must be aware that the more ductile the calcification becomes, the lower the extent of posterior acoustic shadowing that appears at the supraspinatus tendon.

**Posterior Structures: The Infraspinatus, the Teres Minor, the Glenohumeral Joint, the Posterior Labrum, and the Spinoglenoid Notch**

We can examine from behind the patient the infraspinatus muscle in the longitudinal plane by positioning the probe inferior and parallel to the scapular spine. A better scan of the infraspinatus muscle can be achieved with the arm in flexed and adducted position. This can be done by asking the patient to place his or her arm across the front of his or her body. The subsequent adduction and internal rotation of the shoulder in this maneuver causes an anterior pull of the distal insertion of the infraspinatus tendon and makes it easier to visualize (Fig. 21). To obtain a comprehensive view of the infraspinatus tendon across the humeral head, the probe must be moved along the tendon following an imaginary curved contour because the tendon is curved as it wraps around the posterior humerus head to the
relatively anteriorly located greater tuberosity in this maneuver.

We can examine the infraspinatus muscle in the transverse plane by rotating the probe 90° and moving it medially; the infraspinatus muscle contains a hyperechoic central tendon, which is characteristic in the infraspinatus fossa. Below the infraspinatus muscle is the teres minor muscle but without the hyperechoic central tendon (Fig. 22). Lesions of the teres minor muscle are rare. When the probe is moved laterally in this transverse scan, we can examine the insertion of the infraspinatus tendon at the middle facet of the greater tuberosity.

Further, we can examine the humeral head and the glenoid if the probe is shifted medially and in parallel with respect to the longitudinal plane of the infraspinatus tendon when the patient’s arm is either in adduction and internal rotation or in neutral position. In this longitudinal scan, we can see an articular joint between the humeral head and the glenoid and a triangular-shaped posterior labrum situated at superolateral corner of the glenoid (Fig. 23). The cleft between the posterior labrum and the superior glenoid is in general no more than a 2-mm width; however, a cleft larger than this may be indicative of a tear, and if along this tear there is a concomitant infraspinatus articular sided partial tear, these findings are suggestive of a posterior impingement syndrome. When we examine more medial to the posterior labrum, a stair-shaped spinoglenoid notch where are known to form ganglion cysts and possibly cause suprascapular nerve entrapment syndrome can be seen (Fig. 24).

**Acromioclavicular Joint, Dynamic Views of the Subacromial Impingement**

The acromioclavicular joint is palpated and its surface anatomy is marked. By positioning the probe on this mark in the plane that is parallel to the long axis of the lateral clavicle,
we can examine the clavicle, the acromion, joint capsule, the fibrocartilage disc and the supraspinatus muscle at the bottom of the joint (Fig. 25). In this imaging, we can differentiate between the clavicle and the acromion because the clavicle rises higher than the acromion. The irregularity of the articular surface, joint space narrowing, widening, and vertical offset should be noted carefully. We can also examine the acromion, clavicle, and the articular joint in the transverse plane by rotating the probe 90°.

First, we examine the lateral acromion in the transverse plane. Then the probe resting on the lateral acromion is moved medially toward the clavicle. After moving the probe medially, the joint can be shown in low echogenic area without any bony structure. Sequentially the bony clavicle can be seen in the ongoing transverse plane medially. We can see that the clavicle sits on top of the acromion at the joint, and this configuration makes that the articular surface is slightly tilted from the superiolateral

Fig. 23. (A) Moving the probe medial toward the scapula from Fig. 21B, other structures to be evaluated include the posterior labrum (asterisk), and the posterior glenohumeral joint. Arrow indicates central tendon of infra- spinatus. (B) More medially, the spinoglenoid notch (arrow) should be evaluated for cyst. H: humeral head, G: glenoid.

Fig. 24. (A) Ultrasound image of the ganglion (asterisk) in spinoglenoid notch. (B) Corresponding magnetic resonance finding. (C) Ultrasound-guided aspiration. Arrowheads indicate needle. H: humeral head.

Fig. 25. (A) The probe is positioned in a coronal plane, over the acromioclavicular joint. (B) Image shows acromioclavicular joint with characteristic hyperechoic bone contours of the elevated distal clavicle (left) and depressed acromion (right). Note echogenic fibrocartilage disc (asterisk) covered by superior acromioclavicular ligament and joint capsule (arrowheads). Supraspinatus muscle (arrow) is shown deeply.
to the posteromedial end in most patients. Because of this tilting, a slightly medially tilted probe should give a more accurate sonographic view sometimes (Fig. 26).

To obtain a dynamic view of the subacromial impingement, the probe is moved laterally from the acromioclavicular joint and is positioned over the lateral edge of acromion and parallel to the longitudinal axis of the humerus. Scanning of the supraspinatus tendon, the acromion and the greater tubercle is then performed during dynamic maneuver. The supraspinatus tendon and subdeltoid bursa are evaluated while gliding beneath the subacromial space. The examiner performs this dynamic maneuver with passive arm abduction to control the patient’s active contraction as active abduction causes muscle contraction and disturbs probe positioning. During normal abduction of the shoulder, the greater tubercle turns towards the acromion and then, the supraspinatus tendon and the subacromial-subdeltoid bursa should slide smoothly under the acromion into the subacromial space (Fig. 27). In the case of a subacromial impingement, however, this smooth motion of the supraspinatus tendon and the subacromial-subdeltoid bursa becomes discontinuous.

![Fig. 26](image1.jpg)

Fig. 26. (A) Cross sectional view in transverse plane of acromion level. (B) After moving the probe medially, joint can be shown in low echogenic area. Arrow indicates the echogenic fat stripe over supraspinatus. (C) Cross sectional view in transverse plane of distal clavicular level which is higher than acromion level.

![Fig. 27](image2.jpg)

Fig. 27. (A) Probe placement after abduction of the shoulder for dynamic assessment for subacromial impingement. The probe is moved laterally from the acromioclavicular joint and is positioned over the lateral edge of the acromion. (B) Image of the shoulder in a resting position. Asterisk indicates supraspinatus tendon. (C) Image after abduction of the shoulder. During active arm elevation, the supraspinatus tendon (asterisk) and overlying subacromial-subdeltoid bursa should slide smoothly under the acromion. (D) Pooling of bursal fluid (arrowheads) at the lateral acromion edge indicates subacromial impingement.

Ac: acromion.
and uneven; this event can be dynamically viewed using ultrasound. The disjointed motions may be caused by obliteration of the smooth fit of the supraspinatus tendon. Also, pooling of bursal fluid at the lateral acromion edge or snapping of bursal tissue indicates the subacromial impingement.

Ultrasound-guided Interventions for Shoulder Lesions

The position in which the patient should be placed differs depending on the type of intervention. For biceps tendinitis injections, acromioclavicular injections, and subacromial-subdeltoid bursitis injections guided by ultrasound, the examiner and the patient is facing each other whilst both sitting. For suprascapular nerve block and intra-articular injections, the examiner is standing behind the patient. For axillary nerve block, the patient is in a lateral decubitus position. For brachial plexus block, the patient is lying in a supine position.

Postoperative infection is one of the most serious complications of the intervention. To minimize the chances of infection, we sterilized the skin area of intervention using Betadine. Then we covered the probe with gel and wrapped it with a sterilized vinyl bag, the outer surface of which was sterilized using Betadine again. An injection needle of 6 cm in length and 23 G thickness was usually used (Fig. 28). Below we review the main ultrasound-guided interventions that are currently in use.

Suprascapular Nerve Block

Suprascapular nerve block for shoulder lesions is a promising intervention to alleviate pain. Not only is this nerve responsible for the innervation of around 70% of the shoulder structures including the subacromial bursa, acromioclavicular joint, posterior capsule, coracoclavicular ligament, and coracoacromial ligament; intriguingly, it is known to contain several sympathetic nerve fibers. Blocking the autonomic nervous system which plays a key role in pain relay is one of the key approaches to pain control. As such, suprascapular nerve block has been shown to be extremely effective for the control of many pain-inducing shoulder lesions and postoperative pain.

The suprascapular nerve originates from the 5th and 6th cervical roots. This nerve arises from the upper trunk of the brachial plexus and passes through the suprascapular notch into the supraspinatus fossa, which is the target area for blockage (Fig. 29A). From the posterior side of the sitting patient the probe is used to locate above the scapular spine and placed in parallel to it. We can examine the supraspinatus fossa and the supraspinatus tendon running above it from the resulting ultrasonographic image. On the lateral side of the image we can see the acromion which shows a mountain-top like appearance with a posterior acoustic shadowing (Fig. 29B). Within the supraspinatus fossa, there is an area of depression under the supraspinatus fascia in which the suprascapular artery can be seen (Fig. 30). Adjacent to the artery, which can be confirmed using a Doppler ultrasound, is the small, circular suprascapular nerve with a shape of a honeycomb appearance. With the nerve placed in the center of the image, the in-plane method is used to insert the needle in a lateral direction from the medial side of the probe to perform the blockade (Fig. 31).

Fig. 28. Doctor should take mask and sterile gloves, and then sterilize shoulder area by Bethadine Solution. Probe is enveloped by sterile vinyl after coverage with gel to minimize the risk of infection.

Fig. 29. (A) Schematic drawing for the course of suprascapular nerve (dotted line). Dotted box is the adequate position of probe for suprascapular nerve block. White arrow indicates suprascapular notch. Black arrow indicates spinoglenoid notch. (B) Ultrasound image of supraspinatus fossa. Suprascapitis (SS) is shown below the superficial trapezius muscle. Under the SS inferior fascia (arrowheads), there is the suprascapular nerve on the floor of fossa.

Ac: acromion, C: clavicle.
Axillary Nerve Block

As well as the suprascapular nerve, the axillary nerve innervates the shoulder structures. The axillary nerve can be blocked when pain is not resolved with suprascapular nerve block.\(^ {23,24} \)

The axillary nerve originates from the 5th and the 6th cervical roots and branches from the posterior cord of the brachial plexus. It traverses to the posterior direction through the quadrangular space which is between the teres minor and teres major muscles. When the axillary nerve reaches the surgical neck it move posteriorly together with the posterior humeral circumflex artery; the area where the nerve contacts the surgical neck is the site of blockade. When Rothe et al.\(^ {23} \) performed an axillary nerve block, they inserted a needle from the proximal side of the probe on a sitting patient; in comparison, authors performed axillary nerve blocks with the patient in a lateral decubitus position and the arm in slight internal rotation for the stability during the procedure. We examined the teres minor muscle and the surgical neck of the humerus in the longitudinal plane by placing the probe around 2 cm inferior to the acromial posterior angle and in parallel to the long axis of the humeral shaft. From this scan, we can see the pulsating posterior humeral circumflex artery directly inferior to the teres minor muscle and close to the humerus, and at the proximal side of the artery we can observe the axillary nerve (Fig. 32). Depending on the position of the patient, we chose to insert the needle from either the proximal or the distal side of the probe to make the examiner can hold syringe on his or her right hand.

Fig. 30. Doppler scan shows suprascapular artery. Both suprascapular nerve and artery run underneath the fascia of supraspinatus muscle.

Fig. 31. The in-plane technique from medial to lateral is utilized for needle insertion (arrowheads) due to the position of the acromion on the lateral side.

Fig. 32. (A) The lateral decubitus position for axillary nerve block. Probe should be parallel to the longitudinal axis of the humerus. (B) Needle tip (dotted arrow) should be positioned toward the axillary nerve (opened arrow) just cranial to the posterior humeral circumflex artery (arrowhead), under the deltoid muscle, caudal to the teres minor (Tm) muscle. (C) Location of the posterior humeral circumflex artery can be confirmed by Doppler scan. Opened arrow indicates; axillary nerve.
Acromioclavicular Joint Injection

Degenerative arthritis of the acromioclavicular joint is a common cause of shoulder pain and a key indication for acromioclavicular joint injection.\(^{25}\) Hossain et al.\(^\text{26}\) reported improved pain and function of the shoulders at 5 year follow-up in patients with degenerative arthritis of acromioclavicular joint who received intraarticular steroidal injections. Joint injections guided by palpation has been shown to have an accuracy of 40% to 66% for injecting into the correct compartment, but this is in comparison to the accuracy of 100% that can be achieved using fluoroscopy.\(^{27,28}\) Ultrasound-guided injection shows an accuracy of 95% to 100% also and it is believed as a recommendable tool.\(^{29,30}\)

There are 3 methods of injection into the acromioclavicular joint, (1) when the probe is placed in parallel to the longitudinal axis of the lateral clavicle and its position is adjusted so that we see the joint in the center of the image: an out of plane method is used to insert the needle from the anterior skin to the posterior direction; (2) the image is adjusted so that the joint appears at the lateral side of the scan, then the needle is inserted from the lateral side of the probe so that the needle points towards the lateral edge of the clavicle, passing over the acromion, and penetrates the joint capsule; and (3) the probe is rotated 90° so that the acromion is imaged in the transverse plane and then medially moved until no bony structure can be seen—the joint. The needle is inserted in an in-plane method from the anterior to the posterior.

A successful injection is indicated by the elevation of the joint capsule and widening of the joint space under real-time scanning (Fig. 33).

Injection for Biceps Tendinitis

The main indication for injection around the long head of biceps tendon is biceps tendinopathy, which refers to a spectrum of pathology ranging from inflammatory tendinitis to degenerative tendinosis.\(^\text{31}\) Inflammation of the long head of biceps tendon within the bicipital groove (primary biceps tendinitis) is uncommon. The vast majority of biceps tendinitis is accompanied by rotator cuff tear or a superior labrum anterior to posterior lesion, as the sheath of biceps tendon is an extension of the synovium of the glenohumeral joint until approximately 3 to 4 cm beyond the distal end of the groove and is closely associated with the rotator cuff (secondary biceps tendinitis).\(^\text{32}\) Although there are several methods for injection, authors prefer to inject under the transverse plane image. We usually locate the anterior humeral circumflex artery using Doppler scan before the procedure. The needle is inserted using the in-plane method from the lateral side of the probe to the medial direction until passing the transverse humeral ligament with the avoidance of anterior humeral circumflex artery. A well-directed injection will show the injectant surrounding the long head of biceps tendon at the bicipital groove by observing real-time (Fig. 34).

Glenohumeral Joint Injection

The main indication for glenohumeral joint injections is conditions of shoulder arthrosis such as degenerative arthritis. Adhesive capsulitis is the other indication for glenohumeral injection. A meta-analysis by Shah and Lewis\(^\text{33}\) reviewed the effect of intra-articular steroid injections for adhesive capsulitis and found that they are effective, but the effect of steroid injections on arthrosis has not been proven yet. Injections guided by palpation is a standard practice; however, Sethi et al.\(^\text{14}\) argues that with a 26.8% success rate of intra-articular injections guided by palpation, this guidance alone at least cannot be recommended. Compared to this, studies on fluoroscopic-guided and ultrasound-guided injections report up to 100% in accuracy in guid-
ing the injection to the correct compartment. Altogether these findings reflect the importance of a imaging-guided method for glenohumeral joint injections. Gokalp et al. reported that injections from the posterior side of the patient is more favorable than from the anterior side where important structural elements such as the glenohumeral ligament may get in the way. Agreeing with Gokalp et al’s findings, authors too made the injection from the posterior side of the patient. We used an in-plane method to insert the needle from the lateral side of the probe to the medial direction so that the needle point enters between the free edge of the posterior labrum and the hypoechoic articular cartilage of the humeral head after achieving the image of Fig. 23A. Correct position of the needle tip results in the injectant flowing over the articular cartilage through real-time ultrasonography (Fig. 35).

**Subacromial-subdeltoid Bursal Injection**

Subacromial impingement syndrome accounts for the most common diagnosis for shoulder pain, as reported by Ostör et al. This syndrome is also one of the essential indication for injections of the subacromial-subdeltoid bursa. Although Koester et al. in their analysis of 9 randomized controlled trials found that the effect of bursal injections is insignificant, authors believe it may play a role such as resolution of pain and improvement of functional outcome in the short-term. Yamakado reported that the bursal injection guided by palpation gave an accuracy of only 72%. Similarly, Henkus et al. reported that for the anterior injection this value was 76% and for the posterior injection, 69%; both authors concluded that palpation is not a recommendable method for injection. Conversely, Naredo et al. and Ucuncu et al. reported that ultrasound-guided injection is a better method than palpation for accuracy, and Rutten et al. validated ultrasound-guided injection with magnetic resonance imaging that the accuracy was 100%.

Anatomically, the bursa extends from the subacromion to the subdeltoid space. Ultrasonographically, only the subdeltoid bursa can be viewed and the subacromial bursa that is covered by the acromion cannot. To make the subacromial-subdeltoid bursal injection, first a view of the supraspinatus tendon on the longitudinal plane is obtained with the patient in the Crass position (as in Fig. 15A). From this scan, a hyperechoic peribursal fatty layer in the subdeltoid region can be seen; the isotropic hyperechogenicity in this region makes it distinctive. Underneath the subdeltoid fatty layer we can see another hyperechoic band that depicts a superficial peribursal fatty layer of the supraspinatus or the infraspinatus tendon. The dark area of hypoechogenicity between these two fatty layers is the subacromial-subdeltoid bursa and should be less than 2 mm in thickness in normal situation. Usually it is a very thin layer that is either very thin hypoechoic area or cannot be visualized. Thicker than this

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**Fig. 35. (A) Photograph of the glenohumeral joint injection. The probe is placed just caudal and parallel to the lateral end of the scapular spine. With this position, needle is inserted in-plane from the lateral aspect of the probe. (B) Needle (arrowheads) is directed between the free edge of the labrum and the hypoechoic articular cartilage of the humeral head.**

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**Fig. 36. (A) Photograph of the subacromial-subdeltoid bursal injection. (B) In-plane insertion of needle (dotted arrow) from superior aspect for the injection of the subacromial-subdeltoid bursitis (asterisk). D: deltid, SS: supraspinatus.**
is indicative of a bursitis. And one should consider that too much pressure on the probe may distort the bursa to be disappeared, especially if it is a trivial bursitis. Under ultrasound guidance, the needle is inserted using the in-plane method from the superior side of the probe and directed inferiorly. The bursa is filled with injectant and expanded with elevation of the hyperechoic subdeltoid peribursal fatty layer in a successful case (Fig. 36).

**Brachial Plexus Block**

The authors have already reviewed the interscalene and the supraclavicular ultrasound-guided brachial plexus block at the cervical region. In this article, we review the approaches of blocking the brachial plexus at the shoulder region. In the cervical region, the block might be made to the phrenic nerve that is often associated with risks of respiratory complications but with blocks of the shoulder these risks are low.6,45

1) **Infraclavicular approach**

The blockade can be performed with the patient in supine position. The coracoid process is palpated and the probe placed inferior and slightly medial from it. After that, the probe is approximately parasagittal, just inferior to the coracoid process in longitudinal axis (Fig. 37). From the resulting scan, we can find the beating axillary artery that is located cephalad to the axillary vein and deep to the major and minor pectoralis muscles. The medial cord is situated caudal to the axillary artery, the posterior cord is situated deeper, and the lateral cord is situated cephalad to the axillary artery. We insert the needle from the cephalad side of the probe using an in-plane method to the caudal direction. If the needle goes through too medially or too posteriorly it may lead to a pneumothorax or a damage to the vital organs; thus, it is recommended that the needle is inserted in parallel with respect to the sagittal plane, which is around a 45° posterior angle. Authors inject the lateral and posterior cords first and then the medial cord, but because it is more often that we are unable to check the individual cords it is important to sufficiently surround the axillary artery with injectant. Upon insertion of the needle, slight aspiration should be needed to check for blood before performing the injection. Injection should be performed slowly to monitor the patient’s status.

2) **Axillary approach**

For the axillary approach to blockade, the patient is in supine position but the shoulder is in 90° of abduction and external rotation, the ipsilateral elbow in 90° of flexion, and the hand coming closer to head. The beating of the axillary artery is felt by palpation in the axillary region and the probe is placed over the artery in parallel to and distal to the axillary crease. The position of the probe is adjusted so that the axillary artery is in the center of the screen. From the resulting scan, we can locate a flat, proximal distal P major

![Fig. 37.](image)

(A) Probe position is approximately parasagittal, just inferior to coracoid process. (B) Ultrasound image of the brachial plexus in the infraclavicular fossa. Arrowheads indicate lateral cord. Closed arrow indicates posterior cord. Opened arrow indicates medial cord. The brachial plexus and the axillary artery are located below the fascia of the pectoralis minor muscle (P minor). P major: pectoralis major, A: axillary artery.

![Fig. 38.](image)

(A) Abduction of the arm 90° is an appropriate position that allows for probe placement and needle advancement because the axillary brachial plexus block requires access to the axilla. (B) Median (closed arrow), ulnar (opened arrow), and radial (dotted arrow) nerves are seen scattered around the axillary artery. The musculocutaneous nerve (white arrowheads) is seen between the biceps and coracobrachialis away from the rest of the brachial plexus. Black arrowheads indicate latissimus dorsi tendon. T major: teres major muscle, A: axillary artery.
honeycomb-shaped musculocutaneous nerve within the coracobrachialis muscle that is situated at an 8 o’clock direction from the axillary artery with respect to the patient’s right shoulder. The axillary artery is seen lying on the latissimus dorsi tendon and a median nerve is found between the 10 and 12 o’clock direction of the axillary artery. Near the median nerve, the ulnar nerve at the 2 o’clock direction is identifiable and far from these nerves, the radial nerve is in the 6 o’clock direction. The needle is inserted next to the probe from the anterior side of the patient and pushed in posteriorly by in-plane technique. Authors make the injection in the order of musculocutaneous nerve, radial nerve, median nerve, and ulnar nerve respectively (Fig. 38).

**Conclusion**

Although ultrasonography has limitations such as requirement of a high degree of skill and missing blanks in information regarding intra-articular regions, with shoulder ultrasonography we can take live, dynamic views of the anatomical structures of the shoulder and discriminate these structures to the same level of accuracy as that of MRI but without the hazard of radiation exposure. Not only can we use shoulder ultrasound to diagnose impingement syndromes, we can use it to guide safely and effectively various interventions in a real-time manner. Unlike existing methods of clinical diagnosis and radiological examination that generally require independent assessments in different settings and doctors, ultrasonography gives a doctor the chance to provide direct correlation between the images and the clinical findings of a patient simultaneously, and helps with guided interventional procedures immediately.

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