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Ultrasound of the shoulder

Tzvetanka Petranova[1], VioletaVlad[2], Francesco Porta[3], Goran Radunovic[4], Mihaela C. Micu[5], Rodina Nestorova[6], Annamaria Iagnocco[7]

[1] Centre of Rheumatology "St. Irina", Sofia, Bulgaria
[2] Sf. Maria Clinical Hospital, Bucharest, Romania
[3] University of Florence, Department of Internal Medicine, Section of Rheumatology
[4] Institute of Rheumatology, Medical School, University of Belgrade, Belgrade, Serbia
[5] Rheumatology Division, Department of Rehabilitation II, Rehabilitation Clinical Hospital Cluj- Napoca, Romania
[6] Clinic of Rheumatology, Medical University, Sofia, Bulgaria
[7] Dipartimento Medicina Interna e Specialità Mediche: Reumatologia, Sapienza Università di Roma, Rome, Italy

Abstract

Ultrasonography (US) is a helpful imaging tool in the evaluation of the musculoskeletal system. It has some advantages over the other imaging techniques, such as plain radiography, computed tomography and magnetic resonance imaging, represented by the non-invasiveness and multiplanar imaging capability, repeatability, lack of radiation burden, good patient acceptance, and relatively limited costs. US offers an excellent resolution and a possibility for real-time dynamic examination of the joints and surrounding soft tissues, as well as enables monitoring of therapeutic response. The most common clinical indications for US examination of the shoulder are rotator cuff and biceps tendon pathology (tenosynovitis, tendinosis, complete and partial tears, and impingement) and disorders of other soft-tissue structures (joint recesses, bursae, muscles, suprascapular and axillary nerves) as well as bony cortex abnormalities. US is very useful for US-guided procedures (biopsy, joint and bursae aspirations and injections, aspiration and dissolution of calcific tendinosis). The aim of this article is to analyze the current literature about US of the shoulder and to describe both normal and pathological findings.

Keywords: ultrasonography, shoulder, anatomy, pathology

Introduction

Shoulder pain and limited range of motion are very common complaints in the clinical practice and the shoulder is a joint site that particularly lends itself to ultrasound (US) assessment. Indeed, the composite location of the different local structures and the complex anatomy makes the use of US appropriate for the evaluation of both normal and pathological findings at joint and peri-articular level.

Performance of an accurate shoulder US examination requires a skilled and experienced operator with very good knowledge of shoulder anatomy, US scanning technique and normal imaging findings [1-5].

The most common shoulder disorders, assessed by US, are represented by abnormalities of rotator cuff and long head of biceps tendon, lesions of glenohumeral and acromioclavicular joints, and pathological conditions of other soft-tissue structures of the shoulder girdle. The implementation of US-guided interventional procedures and monitoring of therapeutic response are of significant importance and usefulness [1,6-10].

In this article, the shoulder US scanning technique, normal shoulder US anatomy and most common pathological findings are discussed.

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Corresponding author: Annamaria Iagnocco,
Dipartimento Medicina Interna e Specialità Mediche: Reumatologia,
Sapienza Università di Roma,
V.le del Policlinico 155, Rome – 00161, Italy.
Tel: +39 06 49974634
Fax: +39 06 49974642
Email: annamaria.iagnocco@uniroma1.it

Equipment and patient positioning

The use of high quality equipment and a standard scanning protocol (table I) are the pre-requisites for a reliable US assessment of the shoulder.

Multifrequency linear probes (9-12MHz) are appropriate for US shoulder evaluation. They allow the examination of both superficial and deep structures. Doppler techniques, such as power and color Doppler, permit the identification of active inflammation [7,8,11].

Patient positioning should be comfortable for both the patient and operator. The use of a revolving stool enables a better approach to the anterior and posterior aspects of the shoulder. The examination of different structures should include both longitudinal and transverse scanning planes, followed by dynamic and bilateral evaluations. The basic bone landmarks, used to assist transducer positioning, are the bicipital groove, the lateral end of clavicle, the acromion and coracoid process [4,10,12,13].

Table 1. Standard US scans for Shoulder evaluation according to EULAR Guidelines for Musculoskeletal Ultrasound in Rheumatology [1]

Anterior transverse scan in neutral position.
Anterior transverse scan in maximal internal rotation.
Anterior longitudinal scan.
Anterior longitudinal scan in maximal internal rotation.
Lateral longitudinal scan in neutral position.
Lateral longitudinal scan in maximal internal rotation.
Posterior transverse scan.
Axillary longitudinal scan with raised arm.
Acromioclavicular joint scan.

US scanning technique and normal US anatomy

Biceps Tendon and Rotator Cuff

Usually, the examination of shoulder starts with the long head of the biceps tendon (LHBT), followed by assessment of the tendons of the four rotator cuff muscles: *subscapularis* (SubS) muscle, situated on the anterior aspect of the shoulder, *supraspinatus* (SupraS) muscle, which lies on the superior aspect of the shoulder, and *infraspinatus* (InfraS) muscle and *teres minor* (TM) muscle, located on the posterior aspect of the shoulder. Each tendon should be individually assessed in short and long-axis views, from its myotendinous junction to the bony insertion [1,10] (table II).

Long Head Biceps Tendon

The LHBT is included within a recess of the glenohumeral joint cavity and is the only tendon with a sheath at the shoulder level. The US assessment is performed with the arm in neutral position. The patient is sitting, facing the examiner, with the elbow joint flexed at 90°. The arm should be positioned in supination on the patient´s

Table 2. US assessment of rotator cuff tendons and long head of biceps tendon. Patient position, US scans and US anatomy.

Tendon	Position examined	Dynamic assessment	Long-axis view	Short-axis view
Long Head Biceps	90◦ flexion of the elbow, hand positioned in supination on top of patient's thigh /neutral position/	Active flexion and extension of the elbow against resistance, with the palm upwards and the arm in adduction	Ribbon-like layer with fibrillar pattern, regular margins, close to humeral bone profile	Oval echogenic structure within the groove, surrounded by a small amount of fluid
Subscapularis	Neutral position, after that arm externally rotated	Passive internal-external rotation of the shoulder, with the elbow close to the thorax	Arc-shaped layer with fibrillar pattern and regular margins, attachment to the lesser tuberosity	Echogenic structure with hypoechoic clefts due to the multipennate structure
Supraspinatus	Crass position Middleton position	Passive abduction and adduction of the arm	Convex beak-shaped structure, fibrillar pattern, regular margins, attachment to the greater tuberosity	Convex-shaped layer, homogeneous texture of medium level echoes
Infraspinatus	The palm of the ipsilateral hand placed on the contralateral shoulder	Passive internal-external rotation, with the arm in adduction	Beak-shaped structure with fibrillar pattern, attachment to the greater tuberosity	Convex-shaped layer with medium level echogenicity
Teres minor	The palm of the ipsilateral hand placed on the contralateral shoulder	Passive internal-external rotation, with the arm in adduction	Thin hyperechoic structure with fibrillar pattern, attachment to the greater tuberosity	Thin convex-shaped layer, with medium level echogenicity

thigh. The probe is placed axially, at the anterior aspect of the shoulder and should be searching for the intertubercular sulcus (the bicipital groove), recommended as a starting point of shoulder US examination. The groove comprises the LHBT and its synovial sheath, the ascending branch of the anterior circumflex artery and fatty tissue. In transverse view, the LHBT appears as an ovalar hyperechoic structure within the groove, surrounded by a small amount of fluid in the sheath (halo thickness less than 2 mm). The mean value of normal tendon thickness is 4.3 mm, but it may vary, depending on different factors, such as gender, habitus and muscular activity [13]. Both transverse and longitudinal views should be obtained, starting from the proximal aspect of the bicipital groove and extending distally to the musculotendinous junction. The fibrillar pattern of the biceps tendon may appear hypoechoic in the longitudinal view, because in its proximal portion, the bicipital groove is deep and narrow, while in its distal portion, it is wide and shallow. By gently pressing on the inferior aspect of the transducer, the fibrillar pattern will, in normal tendons, become homogeneous. This is known as the heel–toe maneuver. Dynamic assessment during active flexion and extension of the elbow against resistance should be performed [1,11,15]. Another dynamic assessment with internal and external rotation is recommended for evaluating the integrity of the transverse humeral ligament, appearing as a very thin hyperechoic band over the sulcus, and in cases of biceps tendon subluxation and dislocation. The proximal intra-articular part of the LHBT can be evaluated with the arm in external rotation, shifting the probe superiorly in the longitudinal plane within the groove [1,11].

Subscapularis tendon

The SubS tendon originates from the anterior aspect of the body of the scapula and inserts onto the lesser tuberosity with a broad tendon, formed by two or three intramuscular tendons. Some of the superficial fibers overlay the bicipital groove, reach the greater tuberosity, merging with the transverse humeral and coracohumeral ligament [1].

After the examination of LHBT, the patient is requested to rotate the arm externally for evaluating the SubS tendon. In order to perform a long-axis scan, the probe is placed axially, approximately at the level of the coracoid process. The tendon lies deep in the deltoid muscle and is superficial to the humeral head. In long-axis view, the SubS tendon has a convex shape and well-defined fibrillar echostructure. It is broad and, therefore, the probe must be swept up and down until its full width visualization is achieved. The mean value of the SubS tendon sagittal diameter, measured at 2 cm medially from the LHBT, is 4.2 mm [16]. For evaluating the muscular and tendon integrity, dynamic assessments during passive internal and external rotations, with the arm adducted, should be performed.

In short-axis view, the multipennate structure of the normal SubS tendon creates a series of hypoechoic clefts. The lesser tuberosity has a flat appearance with a smooth downsloping contour, extending distally to the tendon insertion [4,10,11,17].

Supraspinatus tendon

The SupraS tendon takes its origin from the supraspinous fossa of the scapula, passes under the acromion and above the glenohumeral joint, and inserts on the upper facet of the greater tuberosity. It consists of two different portions, ventral and dorsal. The specific position of the SupraS tendon between the acromioclavicular arch and the humeral head, makes it partially obscured by the overlying acromion process. This allows only the examination of its distal part in standard neutral position. A better visualization of the SupraS tendon and identification of subtle pathological findings could be ensured in complete internal rotation and hyperextension of the shoulder, with the elbow flexed, the forearm positioned behind the back and the palm facing out. This position places the tendon under stress and is known as a stress maneuver or the Crass position. The modified Crass or Middleton position is performed with a posteriorly extended arm, flexed elbow, pointing directly posteriorly, and the palm of the hand placed on the ipsilateral iliac wing. With this maneuver, the SupraS rotates and becomes more anteriorly situated structure, the acromion is moved away from the tendon and is visualized in its full extent. The SupraS tendon is examined in long-axis and short-axis views. The greater tuberosity and the humeral head are very important bone landmarks during the SupraS tendon examination. In long-axis view, the SupraS tendon is visualized as convex beak-shaped hyperechoic structure over the smooth hypoechoic band of the articular cartilage and the hyperechoic humeral cortex, ending into the great tuberosity. It lies under the layers of the subacromial subdeltoid bursa with hypoechoic fluid within it and the hypoechoic deltoid muscle. The thickness of the SupraS tendon varies from 6-6.5 mm, measured at 2 cm proximally to its insertion on the greater tuberosity. In short-axis view, the SupraS tendon has a convex shape, composed of homogeneous texture of medium-level echoes. Dynamic assessment is performed by passive abduction and adduction of the arm [1,11].

Infraspinatus and Teres Minor Tendons

The InfraS tendon originates from the infraspinatus fossa, with a wide tendon that inserts onto the greater tuberosity, posteriorly and inferiorly to the SupraS tendon. The TM tendon arises from the lateral border of the scapula and inserts posteriorly and inferiorly to the InfraS tendon on the greater tuberosity.

The InfraS and TM tendons are evaluated using a posterior approach, with transducer positioning on the glenohumeral joint, when the forearm is placed across the chest and the palm is placed on the opposite shoulder. The InfraS tendon is larger and longer than the TM. This makes the differentiation between the two tendons easier at their site of insertion onto the greater tuberosity. There are two separate facets in the posterior aspect of the greater tuberosity for the insertion of the two tendons. In long axis view, both of them have a fibrillar pattern. The InfraS tendon has a beak-shaped morphology, while the TM tendon appears as a thin triangular-shaped structure. In short axis view, they are visualized as convex-shaped layers with medium-level echogenicity. Dynamic assessment is performed by passive internal-external rotation, with the arm in adduction [1,11].

Rotator Cuff Interval

The "Rotator Cuff Interval" is the free space between the SubS and SupraS tendons, which contains the LHBT, the coracohumeral and superior glenohumeral ligaments. It can be examined by using the anterior scan in maximal internal rotation [1,11].

Bursae

Multiple bursae are seen in the shoulder area – subacromial subdeltoid bursa, subcoracoid, *subscapularis*, *infraspinatus*, *teres minor*, supraacromial, *coracobrachialis*, anterior and posterior *latissimus dorsi* bursae.

The subacromial-subdeltoid (SASD) bursa has the greatest clinical significance. It is the largest bursa in the body. In normal states, it does not communicate with the glenohumeral joint. It is located deep to the deltoid muscle and the acromion process and extends laterally beyond the attachment of the rotator cuff, medially to the acromioclavicular joint, anteriorly, to overlie the bicipital groove, and posteriorly over the rotator cuff. On normal US, it appears as a 2 mm-thick complex, including two opposing hyperechoic layers of fibro-adipose tissue and a hypoechoic inner layer of the viscous fluid within the bursa. In normal states, the synovial membrane of the bursa cannot be seen by using US [1,11].

Glenohumeral Joint

The glenohumeral Joint (GHJ) is a "ball-and-socket" joint with a wide range of motion. It's capsule is lax and extends from the margins of the labrum and glenoid rim to the anatomic neck of the humerus. In normal states, there is a small amount of synovial fluid contained in the joint space, that usually cannot be recognized with US. The main synovial recesses, appreciated with US, with high sensitivity for detecting pathological fluid inside them, are the axillary poach, the anterior and posterior recesses and the sheath of the LHBT. There are two approaches for evaluation of the axillary pouch, a caudal approach through the axilla and posterior transverse scanning, that are usually preferred. After localization of TM tendon, the probe is shifted caudally to investigate the space, where the axillary pouch lies. The posterior recess is located between the humeral head and the posterior aspect of the glenoid under the InfraS. Best evaluation is performed on transverse scans, placing the transducer over the InfraS tendon. The examination of the anterior recess is more difficult, because it is deeply located and often requires lower frequencies of transducer.

The glenoid labrum forms a rim around the glenoid. It is composed of fibrous tissue, hyaline cartilage and fibrocartilage. Anteriorly, the labrum is deeply located. It is best scanned with a curved-array transducer and low frequencies, using a transverse approach. It has a triangular hyperechoic and homogeneous appearance, with the base attaching to the glenoid rim. The US evaluation of the posterior labrum is easier, because it is more superficially located. The assessment is usually performed by using transverse planes, while the patient's hand is placed on the opposite shoulder. It appears as a triangular structure with the base directed medially and the apex pointing laterally [1,10,11,18].

The posterior scan allows the assessment of the articular cartilage of the humeral head, as its mean thickness is 2 mm. On an axillary scan, the greatest distance between the humeral bone profile and the capsule should be less than 3.5 mm, with a difference between the left and right images of less than 1mm [10].

Acromioclavicular Joint

The acromioclavicular Joint (ACJ) is a diarthrodial joint between the acromion and clavicle, with a lax capsule. Anteriorly the joint space is wider. An articular fibrocartilage disk is usually present. For the US assessment, the patient's arm is in neutral position. The clavicle is usually located slightly higher than the acromion in the coronal position of the probe. The joint space is delimited by the joint capsule and the bone profiles of acromion and clavicle. The capsule has a convex form and lies above the hyperechoic cortical line of the adjacent clavicle. The ACJ is visualized as a triangular hypo- or anechoic area, with the apex directed to the articular cavity and the base orientated to the joint capsule. The transducer should be moved from anteriorly to posteriorly and dynamic assessment can be performed by abducting and adducting the arm. The joint width should be compared with the contralateral side [1,11].

US pathology

US is a useful imaging tool for determination of different soft-tissue and joint pathological changes in patients with shoulder pain and dysfunction (table III). Physical examination and plain radiographs are less sensitive in the differentiation of the wide range of pathological findings, leading to similar clinical features.

Rotator Cuff Pathology

The main US pathological findings of the rotator cuff tendons are represented by partial- and full-thickness tears, tendinitis, calcification and impingement.

The SupraS tendon is most commonly involved in rotator cuff tears. The classification of the latter includes the terms complete and incomplete tears. Incomplete tears involve only a part of the tendon width on the short-axis plans. Tears are divided into partial-thickness and full-thickness types. The partial-thickness tears affect most frequently the anterior third of the SST. On US, they appear as small localized hypoechoic areas, affecting only a part of the tendon thickness. The size of the tear should be measured both on short-and long-axis views. The partial-thickness tears may involve the bursal side, articular side or the midsubstance of the tendon. The full-thickness tears extend from the bursal to the articular surface of the tendon. They have been classified as small (less than 1 cm), large (1-3 cm) and massive tears (more than 3 cm) [3]. In acute lesions, the tendon is less retracted and more easily detected by US. In chronic ruptures, the end of the tendon disappears beneath the acromion. In this case, the tendon and deltoid herniation are absent from the US findings. Usually, a broad area of the humeral head remains uncovered by the SupraS, the so called "naked head" sign. The presence of abnormal fluid collection in the SASD, GHJ, ACJ (Geyser sign) could be a sign for a full-thickness tear. After determination of a complete rupture of the SST, a careful evaluation of the InfraS and SubS tendons should be performed, searching a massive tear of the rotator cuff. Detachment of the InfraS tendon from its insertion on the humeral head could be easily detected using dynamic scanning during internal and external rotation of the arm. InfraS atrophy is another sign for a possible tear. While InfraS tendon tears are associated with SupraS rupture, the SubS tendon tears could occur independently. US signs of complete tears include absent tendon and naked surface of the humeral head. SubS tendon tears usually lead to secondary instability of the biceps tendon [1,11].

Rotator cuff calcifications are frequent findings of the shoulder US examination. They are usually located at the insertional site of the SST. The calcific deposits can appear as intratendinous hyperechoic areas with well-defined posterior acoustic shadow (type I calcifications) (fig 1) or as hyperechoic foci with a faint (type II) or absent (type III) shadow – "slurry" calcifications [1,19].

Table 3 Anatomic structures of the shoulder and corresponding US pathology

Rotator cuff tendons	Partial- thickness tear Full-thickness tear Complete and massive tears Tendinitis Calcification Impingement
Long head of biceps tendon	Tenosynovitis Tendinitis Tear Dislocation
Gleno-humeral joint	Synovitis Bone erosions Osteophytes
Acromio-clavicular joint	Effusions Erosions Osteophytes Cysts Dislocation
Bursae	Bursitis

Fig 1. Calcification of the supraspinatus tendon with posterior acoustic shadow.

Impingement

Three main types of shoulder impingement have been described: anterosuperior or subacromial (the most common), anteromedial and posterosuperior.

Possible subacromial impingement can be observed by dynamic assessment. The probe should be placed over the lateral acromion in coronal oblique position. The examination starts with the shoulder in internal rotation and adduction, followed by shoulder abduction. In normal conditions, the SST and the SASD bursa move smoothly under the acromion, without limitation of motion or pain.

Two impingement maneuvers, Neer's and Hawkin's tests, may be performed to assess shoulder pain, related to rotator cuff disease or biceps tendinitis. The first is performed with a maximal passive glenohumeral forward-flexion, with the shoulder in neutral position, to obtain impingement of the supraspinatus and the biceps against the anterolateral margin of the acromion. The second is performed with a 90° forward-flexion, slight horizontal adduction and internal rotation, to compress the insertion of the supraspinatus and the subacromial bursa under the coracoacromial ligament [1,4].

Long head biceps tendon pathology

The most frequent pathological findings of the LHBT are tenosynovitis, tendinosis, biceps tendon dislocation, tear and rupture.

A characteristic US sign of tenosynovitis is the tendon sheath distension caused by the presence of hypoechoic or anechoic thickened tissue, with or without local effusion and possible local Doppler signal; the abnormalities should always be seen in 2 perpendicular planes. In acute tenosynovitis, anechoic tendon sheath widening and normal tendon echotexture are present. Typical for chronic tenosynovitis is the concomitant involvement of the tendon fibers with local inhomogeneity and loss of the fibrillar echotexture. The US signs of LHB tendinitis are represented by hypoechogenicity and thickening of the tendon. In cases of biceps tendon dislocation, the US findings include an empty groove and commonly medially displaced tendon. Partial thickness tears are visualized as hypoechoic areas within the tendon texture, assessed in both transverse and longitudinal plans. The complete tendon rupture of LHBT is not a difficult clinical diagnosis - the retracted muscle can be palpated as a soft-tissue lump over the anterior aspect of the middle third of the arm, the so-called Popeye sign. Usually, US assessment detects the two tendon ends, floating within a hematoma, in recent ruptures [1,11,15].

Fig 2. Transverse view on anterior shoulder: subdeltoid bursitis (between calipers); BT biceps tendon, Ss subscapularis tendon, DM deltoid muscle.

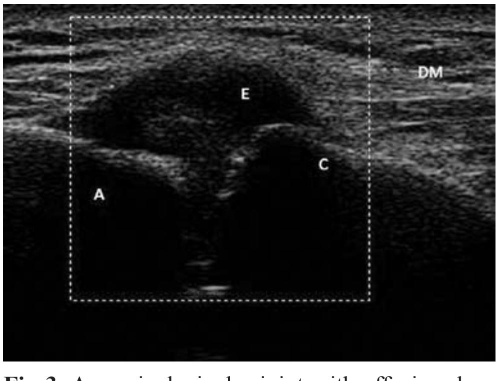

Fig 3. Acromioclavicular joint with effusion, longitudinal view. A acromion, C clavicle, E effusion, DM deltoid muscle

Subacromial-subdeltoid bursa

Inflammatory SASD bursitis can be observed in different shoulder disorders. It is characterized by bursal widening, due to an increased amount of synovial fluid with or without synovial hypertrophy (fig 2). Because intrabursal fluid can migrate, depending on gravity and arm position, the various portions of the bursa should be systematically examined. No pressure should be applied with the probe over the bursa, because it could lead to overlooking of small effusions. When the patient is standing or in sitting position, fluid tends to accumulate in the most dependent portions of the bursa, more commonly, along the lateral edge of the greater tuberosity, producing a typical "tear-drop" sign [1,11].

Glenohumeral joint

US is very useful for detecting even a minimal amount of pathologic fluid and synovial hypertrophy in the synovial recesses of the GHJ (the axillary pouch, the posterior and anterior recesses and the sheath of the LHBT). The most common site for joint effusion and synovitis is the posterior recess, due to the local thin capsule and the low pressure from the surrounding structures. The detection of effusion and synovitis is facilitated by the external rotation of the arm, which leads to an easier capsule distension. Effusion appears as an abnormal hypoechoic or anechoic intra-articular material that is displaceable and compressible but does not exhibit Doppler signal. Synovial hypertrophy is imaged as an abnormal hypoechoic, intra-articular tissue that is non displaceable and poorly compressible and which may exhibit Doppler signal. In larger effusions or severe synovitis, the InfraS tendon could be displaced posteriorly. Fluid collections in the anterior recess can be seen as hypoechoic halos surrounding the anterior labrum.

US depicted shoulder fluid and synovial hypertrophy in Rheumatoid Arthritis are very useful for localising and quantifying rheumatoid activity in one of the joints most difficultly to evaluate clinically. Rheumatoid effusion is most offen depicted in the posterior recess. Recently, an US score for large joints- SOLAR- was developed [20], quantifying semiquantitatively on a 0-3 scale Gray Scale (GS) US and Power Doppler (PD) US findings in large joints, including shoulder, before and after treatment. GSUS values for shoulder effusion evaluation showed a statistically signifficant decrease. PDUS score did not have the same responsiveness after treatment, due to the fact that profound joints are characterized by poor depiction of synovial vascularity.

US is very sensitive in the detection of bone erosions of the humeral head that are imaged as intra-articular discontinuities of the bone surface which are visible in 2 perpendicular planes. Irregularities of the greater tuberosity direct to possible rotator cuff tears; they appear as focal loss of continuity of the bony surface [1,10].

Acromioclavicular joint

The most common pathological findings of the ACJ, detected with US, are irregular bone surfaces, osteophytes, effusions (fig 3), erosions, acromioclavicular cysts and dislocation [1,10,11]. The presence of those abnormalities has similar US appearances as for the description of the GHJ reported above.

US guided procedures

Most of the US-guided procedures used in clinical practice at shoulder level consist of aspiration of fluid collections for both diagnostic and therapeutic aims and injection of drugs (mainly represented by corticosteroids) in the GHJ or ACJ, bursae, LHBT sheath or other periarticular soft tissues. Compared with the blind technique, the US-guided procedures ensure easier and safer aspiration of fluid collection and improve the performances of the procedures. US enables the real time visualization of the needle while procedure is performed. In addition, US-guidance represents an efficient tool for percutaneous treatment of calcifying tendinitis, represented by the rupture and aspiration of the calcification [1,6,10,14,21].

Conclusions

US represents a useful imaging modality for the assessment of a wide range of abnormalities involving the anatomic structures of the shoulder. It is able to detect and identify most joint and periarticular soft tissues changes as well as to guide local interventional procedures such as aspirations of fluid collections, injections and biopsies. US is a safe, rapid and limited-cost tool that can be used as a bedside modality during clinical evaluation of patients with painful shoulder.

Conflict of interest: none

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