Ultrasound imaging for the rheumatologist. I. Ultrasonography of the shoulder

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ABSTRACT
Ultrasonography (US) has proved to be a useful diagnostic tool in patients with shoulder pain and/or limited range of motion. It allows careful assessment of a wide range of changes involving many different anatomic structures of the shoulder girdle, such as the rotator cuff tendons (tendonitis, tendon tears and calcific deposits), the long head of the biceps tendon (tenosynovitis, tendonitis, tears, rupture and displacement), the bursae (bursitis), the soft tissues of the gleno-humeral (synovial proliferation, joint effusion) and acromioclavicular joints (synovial proliferation and joint effusion). In addition, it is also a reliable tool in the evaluation of bony profiles detecting the presence of erosions and osteophytes. The use of high quality equipment and the application of a standard scanning protocol are mandatory for reliable US assessment of shoulder pathology.

Introduction
Shoulder pain is a frequent complaint in daily rheumatological practice (1, 2). Several pathological conditions may account for it and their identification is essential for starting appropriate treatment (3). Physical examination alone is usually unable to highlight both the nature and the exact extent of the soft tissue and/or joint involvement in patients with a painful shoulder (4). Over the last two decades, ultrasonography (US) has proven to be a useful tool for the rheumatologist investigating shoulder pain and functional impairment (3, 5-11). The shoulder does represent one of the most difficult anatomical regions to be assessed by US and in inexperienced hands can lead to misinterpretation and misdiagnosis (12). The aim of this paper is to discuss the role of US in the management of patients with a painful shoulder.

Table I. Pathological conditions detectable by ultrasound (US).

Joints	
	Synovitis
	Bone erosions
	Osteophytes
	Subluxation
Peri-articular soft tissues	
	Tenosynovitis
	LHB tendon subluxation/dislocation
	Tendon tears
	Tendinitis
	Tendinosis
	Calcification
	Bursitis

Indications
US allows careful assessment of a wide range of peri-articular and joint abnormalities in patients with pain and/or limited range of motion of the shoulder (Table I).

Equipment
High quality equipment is essential for reliable and accurate US assessment of the shoulder (Table II). The frequency of the probe commonly ranges from 7.5 to 10 MHz with a lower frequency (5 MHz) required for the evaluation of deeper anatomical structures, e.g. the gleno-humeral joint. Superficial structures should be assessed using a higher

Table II. Equipment requirements.

- High-quality machine
- Linear probes (at least two probes covering a range of frequency from 5 to 16 MHz)
- Range of frequency used in daily practice: 7.5-10 MHz
- Availability of colour and/or power Doppler technique

frequency probe (10 MHz). Colour and power Doppler techniques provide useful additional information concerning the degree of perfusion of the shoulder soft tissues (13, 14).

Scanning technique

At present, several US scanning techniques have been reported for examining the shoulder (6, 16-18). A standard scanning protocol including multiplanar, dynamic and bilateral assessments should be followed in order to avoid missing the assessment of one or more anatomic structures of the shoulder (Table III).

Table III.

Operator position.

- In front of or behind the patient.
- A comfortable position is recommended to obtain stability and avoid hand and arm fatigue.

Patient position

Standard position

- Sitting position
- Upper limb in neutral position with 90° flexed elbow
- Hand in supination and on the thigh

Other positions

- Shoulder in hyperexension, internal rotation & adduction with the arm placed behind the back (scan for the supraspinatus tendon)
- Shoulder in external rotation (scan for the subscapularis tendon)
- Raised arm or shoulder in 90° abduction (axillary scan for the gleno-humeral joint)

Shoulder movements for dynamic study

- External and internal rotation of the humerus over the full range of motion with adducted arm and 90° flexed elbow for assessing LHB subluxation
- Abduction and adduction of the humerus for assessing the supraspinatus tendon.

Bicipital groove

The normal bicipital groove appears as a semicircular depression on the anterior transverse scan and is recommended as the starting point of shoulder US examination. It represents a useful landmark for identifying the peri-articular soft tissues of the joint, such as the long head of biceps (LHB) tendon, the deltoid muscle and the subscapularis tendon.

Long head of the biceps tendon

The tendon of the LHB must be examined in its full course on at least two perpendicular scanning planes. The transverse scan is helpful for detecting the tendon and confirming its relationship with the bicipital groove and its position within the groove should be confirmed during external and internal rotation to detect subluxation.

The transverse scan also allows detection of an increased amount of synovial fluid within the tendon sheath either side of the tendon: a feature sometimes missed on the longitudinal scan.

The longitudinal scan is more useful for assessing tendon morphostructural changes such as thickening and tears. When scanning the tendon on longitudinal view, it is useful to gently compress the distal edge of the probe to better visualize the tendon which runs in a oblique direction from the distal deeper part to the proximal more superficial part.

Subscapularis tendon

Examination of the subscapularis tendon is performed by moving the probe medially and it is completed by internal and external rotation of the shoulder.

Acromio-clavicular joint

This joint is found by identifying the clavicle and then moving the probe laterally until the acromion is identified.

Supraspinatus tendon

This tendon is best visualized with the patient keeping the hand behind the back. The image is further enhanced by passive abduction and adduction of the arm. Moreover, the dynamic evaluation of the tendon is helpful for detecting small tendon lesions by enlarging the gap between the torn edges of a tendon rupture.

Infraspinatus and teres minor tendons

The infraspinatus and teres minor tendons and their attachments are visualized on the posterior scans. Their fibers are deep to the deltoid muscle and superficial to the gleno-humeral joint. Their visualization is enhanced by dynamic examination during internal and external rotation of the shoulder with the arm adducted.

Gleno-humeral joint

The gleno-humeral joint can be assessed on posterior and axillary views (6, 16, 17). The posterior view allows the visualization of a wide area of the humeral head and neck and of the posterior glenoid labrum which appears as a hyper-echoic triangular structure. The axillary scan should be regarded as an additional but not routinely practised view which may be difficult to obtain in patients limited due to pain.

Synovial bursae

Several synovial bursae are found in the shoulder region. Both the subdeltoid-subacromial bursa and subscapularis bursa are virtual spaces lying superficial to the rotator cuff tendons.

US anatomy (Table IV)

Tendons

The long head of biceps tendon is intra-articular but extra-synovial. It is the only tendon with a sheath at shoulder level and this sheath is a recess of the gleno-humeral joint cavity. In healthy subjects this tendon ranges in thickness from 3.3 to 4.7 mm, with a mean value of 4.3 mm (19) and may be surrounded by a thin hypoechoic halo (less than 2 mm in size), which represents the normal physiological amount of synovial fluid within the tendon sheath (6).

Variations in the size of the tendons are dependent both on gender and the degree of muscular activity.

The thickness of the supraspinatus tendon varies from 6 – 6.5 mm when measured 2 cm proximal to its insertion into the humeral greater tuberosity (5, 20, 21).

Synovial bursae

Normal bursae appear as a hyperechoic layer representing the opposing walls

Table IV. US anatomy.

Long head of biceps tendon
- Longitudinal: ribbon-like layer, fibrillar pattern, regular margins, close to humeral bone profile
- Transverse: echogenic oval structure within the grove, surrounded by a small amount of fluid (layer's thickness < 2mm)
- Dynamic: active flexion and extension of the elbow against resistance, with the palm upwards and the arm in adduction

Supraspinatus tendon
- Longitudinal: beaked-shaped structure, fibrillar pattern, regular margins; attachment to the greater tuberosity
- Transverse: arc-shaped layer, medium-level echogenicity
- Dynamic: passive abduction and adduction of the arm

Infraspinatus tendon
- Longitudinal: beaked-shaped structure, fibrillar pattern; attachment to the greater tuberosity
- Transverse: convex-shaped layer, medium-level echogenicity
- Dynamic: passive internal-external rotation, with the arm in adduction

Teres minor
- Longitudinal: thin hyperechoic structure, fibrillar pattern; attachment to the greater tuberosity
- Transverse: thin convex-shaped layer, medium-level echogenicity
- Dynamic: passive internal-external rotation, with the arm in adduction

Subscapularis tendon
- Longitudinal: arc-shaped layer, fibrillar pattern, regular margins; attachment to the lesser tuberosity
- Transverse: echogenic structure, regular margins, medium-level echogenicity
- Dynamic: passive internal-external rotation of the shoulder, with the elbow close to the thorax

Bursae
- Multiplanar

Acromio-clavicular joint
- Triangular hypo- or anechoic area, with the apex direct to articular cavity and the base bounded by the joint capsule. Joint space is delimited by the joint capsule and the bone profiles of acromion & clavicle

Gleno-humeral joint (Axillary scan)
- Thin anechoic area delimited by the bone profile of the humeral head and neck and by the joint capsule. Longest bone-capsule distance < 3.5 mm; differences between sides < 1 mm.

delimiting the bursal virtual space. In some cases the bursal cavity may be depicted as a thin hypoechoic layer in between the bursal walls which appear as two hyperechoic parallel lines. In healthy subjects a small amount of fluid may be demonstrated within the subacromial bursa with a thickness lower than 2 mm (6).

Joints
The acromio-clavicular joint appears as a triangular hypo- or anechoic area with the apex toward the articular cavity. It is delimited by a thin joint capsule and the bone profile of the acromion and the clavicle.

In the gleno-humeral joint, the posterior scan with the humerus in maximal internal rotation, allows exposure to wide areas of articular cartilage of the humeral head. In healthy subjects, the humeral articular cartilage has a mean thickness of 2 mm (5). On axillary scans the greatest distance between the humeral bone profile and the capsule is <3.5 mm and the difference between the right and left shoulder is less than 1 mm. (17).

US pathology (Table V)
In experienced hands, US is an accurate and reliable imaging tool for the detection of a wide range of soft tissue and joint pathology in patients with a painful shoulder. Different patterns of pathological findings may present with the same clinical features. Moreover, physical examination is less sensitive than US particularly in the detection of rotator cuff tear and subacromial-subdeltoid bursitis (6).

Table V. US pathology.

Long head of biceps tendon
- tenosynovitis
- tendinitis
- tear
- rupture
- displacement

Rotator cuff tendons
- partial-thickness tear
- full-thickness tear
- tendinitis
- calcification
- impingement

Bursae
- inflammatory bursitis
- septic bursitis
- periarticular hematoma

Acromio-clavicular and gleno-humeral joints
- synovitis
- osteophytes
- bone erosions

Humeral head
- bone erosions
- irregularities of the greater tuberosity
- bicipital groove abnormalities
- osteophytes

Long head of biceps tendon
The US hallmark of tenosynovitis is tendon sheath widening. Acute tenosynovitis is characterized by anechoic enlargement of the tendon sheath and normal tendon echotexture. In chronic tenosynovitis, tendon sheath widening may be due to a combination of effusion and synovial tissue hypertrophy.

LHB tendinitis presents with diffuse hypoechogenicity and thickening (6). Power Doppler may be helpful for identifying the inflamed soft tissues which may be the synovial tissue and/or the tendon itself. Particular attention should be paid to avoid a frequent pitfall of power Doppler of the LHB which is the misinterpretation of local hyperaemia generated by the normal signal of the antero-lateral branch of the anterior circumflex humeral artery lying on the lateral side of the tendon within the tendon sheath as pathological. In chronic tendinitis, the tendon may appear frayed and fibrous tissue may replace the fibres (19).

Partial thickness tears appear as hypo-echoic areas within the tendon echotexture both in transverse and longitudinal scans (Fig.1A). On longitudinal scans, tendon fibre discontinuity may extend for great distances along the tendon.
Complete tendon rupture is documented by visualizing the two tendon ends floating within a hematoma. The "empty groove" sign is an indirect sign of complete tendon rupture once the pitfall due to anisotropy and tendon dislocation has been accurately excluded.
Dislocation of the LHB tendon (Fig. 1B) usually occurs medially, under the subscapularis tendon. Dynamic evaluation, during external rotation of the shoulder, is particularly useful in the diagnosis (21).

Rotator cuff tendons
US is of value in the detection and evaluation of acute traumatic tears of the rotator cuff (23-25). Considering the surgical findings as the gold standard, US can detect a rotator cuff tear with a sensitivity of 89% and specificity of 93%.
The acute traumatic tear appears as a hypo-echoic defect which may involve only a circumscribed area within the tendon texture (partial thickness tear) or may extend through the entire substance of the tendon (full thickness tear) (Fig. 1C). Other US features of a full thickness tear are focal thinning and loss of visualization of the rotator cuff. During dynamic examination, in both internal and external rotation, the size of the full thickness tear usually increases. Acute traumatic tears may present with a normal superficial tendinous convexity which changes to a flattened or even concave surface under probe pressure.
Full thickness tears have been classified according to size: small (< 1 cm), large (1-3 cm) and massive (> 3 cm).
US sensitivity in the detection of the rotator cuff tears depends on the size of the tear: 78% for partial thickness tears and 92% for full thickness tears and upon the quality of the machine used (26).
Rotator cuff calcification (Fig. 1D) is reliably identified by US and may be detected earlier than conventional radiography (27). Calcific deposits are usually located at the insertional tract of the supraspinatus tendon and appear as hyperechoic areas or lines often with a posterior acoustic shadow.

Bursae
Bursitis is characterized by abnormal bursal enlargement due to an increased amount of synovial fluid and/or tissue (Fig.1A). Inflammatory bursitis in patients with rheumatoid arthritis (RA), polymyalgia rheumatica and crystal-related arthropathies (5, 6, 23) must be distinguished from septic and/or traumatic bursitis. In some cases the US pattern of the fluid collection may be indicative of an abscess but a septic bursitis cannot be definitively excluded with US alone due to considerable overlap between the US findings in soft tissue rheumatism and the septic process.
Bursal aspiration is therefore mandatory to confirm a suspected diagnosis of septic bursitis. In such cases, US guidance is very helpful in obtaining fluid even from small collections. Haematoma in the setting of a rotator cuff rupture may also result in bursal effusion and this underlying diagnosis should be born in mind should a bloody aspirate be discovered.

Acromio-clavicular joint
This joint is frequently involved by degenerative bony changes characterized by bone profile irregularities and osteophytes.

Gleno-humeral joint
Gleno-humeral joint synovitis is best viewed on the posterior transverse scan at the level of the infraspinatus tendon. The posterior recess is the site where synovial fluid tends to collect more frequently due to the thin capsule and the low pressure exerted by the tissues above. Moreover, the gleno-humeral joint cavity is in communication with the LHB tendon sheath, thus an effusion of the joint may lead to an increase of the amount of fluid within the tendon sheath.

Humeral head
US is more sensitive in the detection of bone erosions than conventional radiography in RA (28). Bone erosion may also be detected in healthy subjects (29).
Irregularities of the greater tuberosity appear as focal losses of continuity of the bony cortex (dashed line) and represent reliable indicators of rotator cuff tears (30).
US allows an accurate evaluation of the bicipital groove profile, revealing bone abnormalities such as erosions and osteophytes, and post-traumatic deformities. Moreover, US measurements of the depth and the width of the groove correlate well with radiographic findings and allow the identification of pathological shapes of the groove such as the shallow groove (less than 3 mm of the depth) and the tunnel-shaped groove characterized by osteophytes on the lips of the groove walls.

Limits

Operator experience and expertise may strongly influence the final results of US examination. This is particularly true in patients with chronic shoulder disease. In fact, soft tissue and/or bone pathological changes may be so advanced that the identification of the anatomic US landmarks may become extremely difficult.
In patients with restricted range of motion (e.g., frozen shoulder, humeral fracture, shoulder dislocation, and hemiplegia as a consequence of cerebral infarction), dynamic evaluation may be markedly limited.
In obese patients, supraspinatus tendon visualization is hampered by the difficulty to obtain an adequate degree of adduction and internal rotation of the humerus which is essential to prevent the acromion obscuring the tendon. In addition it may be essential to use a lower frequency probe to assess deeper structures (e.g. gleno-humeral joint)

Table VI. Limits.

- Operator dependence
- Patients with chronic shoulder disease
- Patients with restricted shoulder movement
- Obese patients
- Visualization of the inferior aspect of the acromioclavicular joint

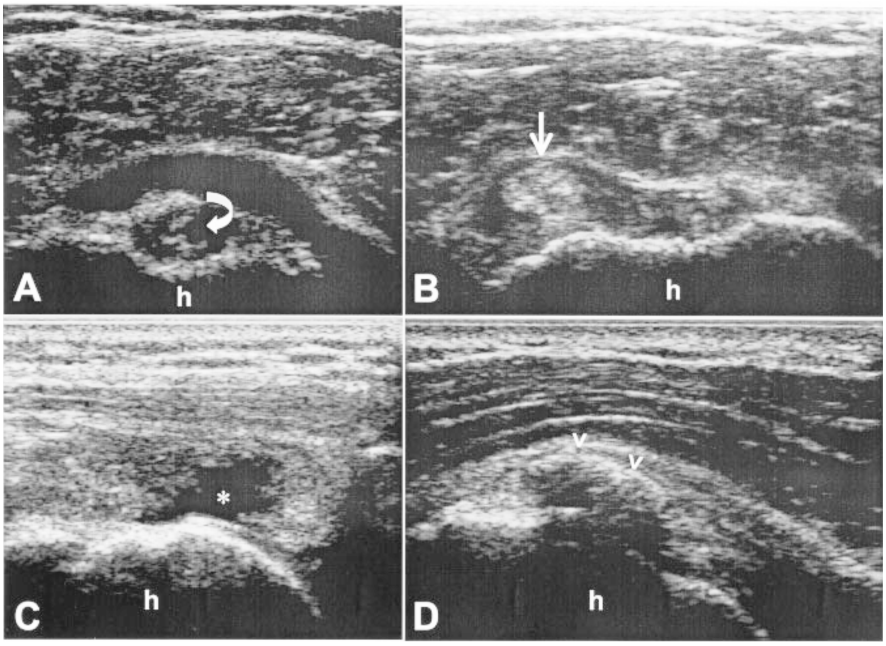

Fig. 1. Representative examples of shoulder US pathological findings. (**A**) Partial tear of the long head of the biceps tendon (**curved arrow**) and subdeltoid bursitis. (**B**) Medial dislocation of the long head of biceps tendon (**arrow**). (**C**) Geographic anechoic defect (full thickness tear) within the supraspinatus tendon (*). (**D**) Calcification of the subscapularis tendon in hydroxyapatite disease (**arrowheads**) (**h**: humeral head).
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thereby reducing image resolution.
Finally, there are limits related to the US imaging modality. Osteophytes protruding from the inferior aspect of the acromio-clavicular joint may lead to a significant reduction of the subacromial space and thus to impingement syndrome, but they cannot be visualized by US. These limits are summarised in Table VI.

Sonographic guided procedures

Steroid injection is a frequent therapy in patients with shoulder pain. Conventional blind injections are often incorrectly placed (31).
US guidance ensures accurate positioning of both the needle and the steroid and improves therapeutic effectiveness of the injection (32). US examination following injection reveals a significant difference in terms of accuracy between blind and US guided injections with a five-fold increase in analgesic effect with the US guided approach. The shoulder also contains several anatomic structures that may be the site of fluid collection Visualization of the fluid collection by US makes aspiration easier and safer.
The use of US guidance to disperse and aspirate calcific depositis within the rotator cuff tendons has been described (33).

Link

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