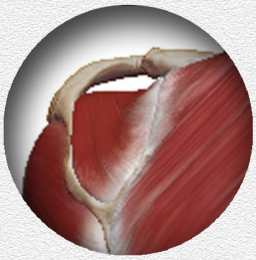
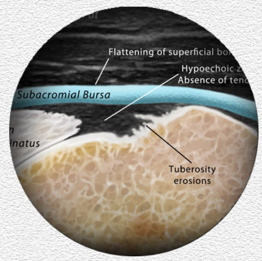
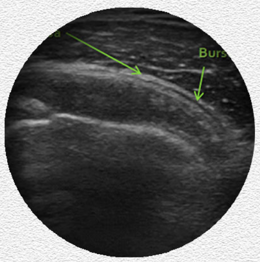
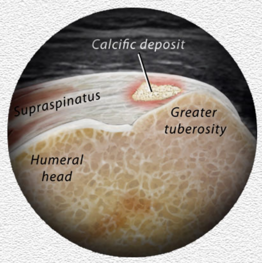




Shoulder Ultrasound





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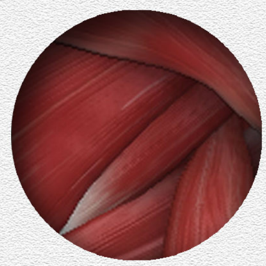

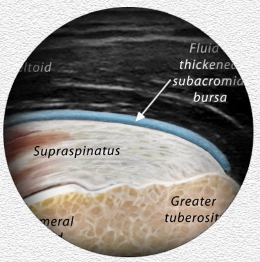

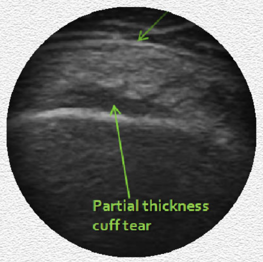

ShoulderScan

SHOULDER ULTRASOUND BOOK

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ShoulderScan

The Shoulderscan book by Lennard Funk (Shoulder and Upper Limb Surgeon), John Leddy (Physiotherapist and Sonographer), Jonathan Harris (Muscoskeletal Radiologist), Tim Bunker (Shoulder Surgeon) and James Brown (Sports Physician), is a high quality, full colour book providing information and images of Ultrasound techniques for the shoulder.

This booklet provides information on Ultrasound Physics, Machine information, Anatomy & Technique, Recognising Pathology and The History of Ultrasound Imaging

First Edition, 2008

Published in the UK by

Shoulderdoc Ltd, 120 Princess Road, Manchester, M15 5AT

Table of Contents

Chapter 1: Ultrasound Physics

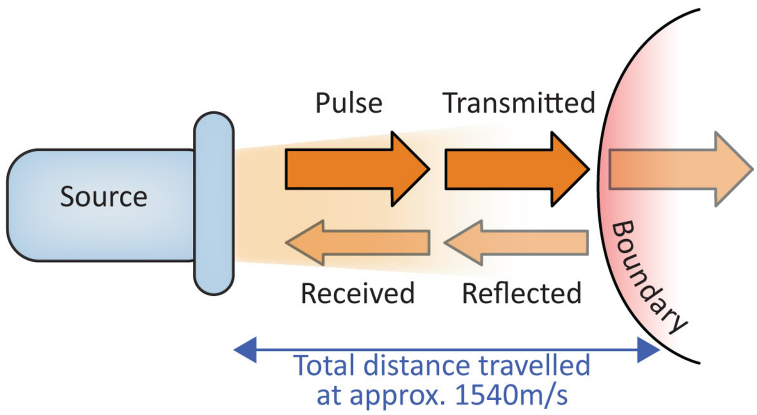
How it Works

The ultrasound image is created by first transmitting sound waves into the body and then interpreting the intensity of the reflected echoes. This is achieved using a hand held probe, which contacts the body via a water based gel. The data collected is then processed within the body of the scanner and displayed as a black and white image generally referred to as grey scale.

The probe contains a large number of transmitters set in a line along its length. Typically around five of these firing simultaneously generate a short pulse of ultrasound that travels in a narrow column away from the probe. The transmitters then act as receivers and record the intensity of the reflected sound.

The process is repeated sequentially along the length of the probe. The time taken for an echo to return is used determine the distance from the probe and is calculated assuming that sound has a constant speed (1540m/s). The strength of the echoes returning from any point is represented by the brightness of that point on the screen.

The path that a single pulse passes along is described as the beam. The width of the beam determines the lateral resolution. The length of the pulse determines the axial resolution. Shorter pulses can be achieved using higher frequency, so the highest frequency practicable is generally used.



Different Types of Reflection

Two distinct patterns of reflection give rise to the echoes that make up an ultrasound image - specular reflection and scattering.

Specular reflection

Specular reflection is responsible for the bright appearance fibrous structures such as tendons and of boundaries between different tissues. It occurs when the sound wave meets a distinct surface (significantly larger than the wavelength of the ultrasound).

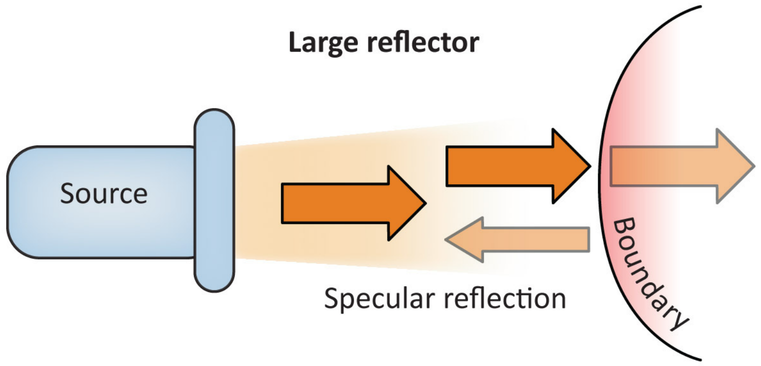
The process that occurs is similar to when light passes from air to water on the surface of a lake. Some of the light travels in to the water, while some is reflected back.

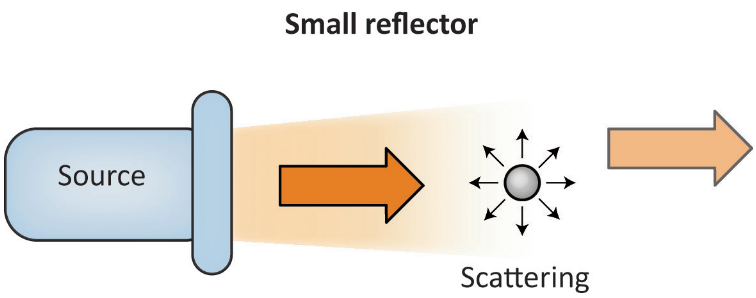
The amount of sound that is reflected at the boundary between two different tissues, such as fat and muscle, depends on how marked the difference is in their acoustic properties. Acoustic impedance, which is the measure of this, varies with the density and compressibility of the tissue.

Scattering

Scattering gives rise to the characteristic texture (echo texture) of the image seen within soft tissue.

This occurs at the small (relative to the wave length of the ultrasound) subtle boundaries that exist within tissue. At these, small amounts of energy are absorbed and retransmitted in all directions as if from a point source, in a manner that loosely resembles a pebble dropped into a pond.





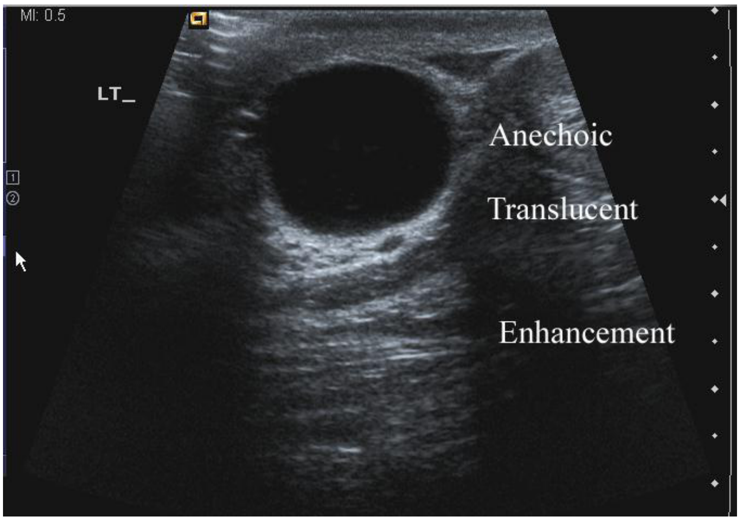
Features of an Ultrasound Image

Recognising structures on ultrasound takes practice and a good knowledge of the anatomy is a big help. What follows is a brief description of some of the features that make up the image.

Presentation

In almost all applications the top of the screen represents the probe and as you look further down the screen you are seeing progressively deeper tissues.

Depth



The depth to which you can see is normally shown on a scale running along side the image. This can be adjusted using the Depth adjustor, which will be a prominent control on any scanner. The maximum depth is dependent on the frequency, with lower frequencies penetrating much further, but at the cost of reduced resolution. Shoulder scanning is usually performed with high frequency probes using frequencies of around 10 MHz, which see reasonably well to a depth of 4cm or more.

Typical Appearance of Normal tissue

Skin appears smooth and bright (echogenic, **hyperechoic**, highly reflective).

Fat can be bright or dark (**hypoechoic**), but subcutaneous fat is typically dark.

Muscle is also dark, when viewed in cross section. In long section sound is reflected back by the muscle fibres and the internal structure of the muscle can be easily seen.

Fluid, be it blood, effusion or cyst is generally black (**anechoic**), though thicker fluids such as puss can be bright or dark.

Tendons are typically bright, but this varies with their orientation relative to the probe.

Nerves are not normally seen when scanning the shoulder, but their appearance is similar to that of tendons.

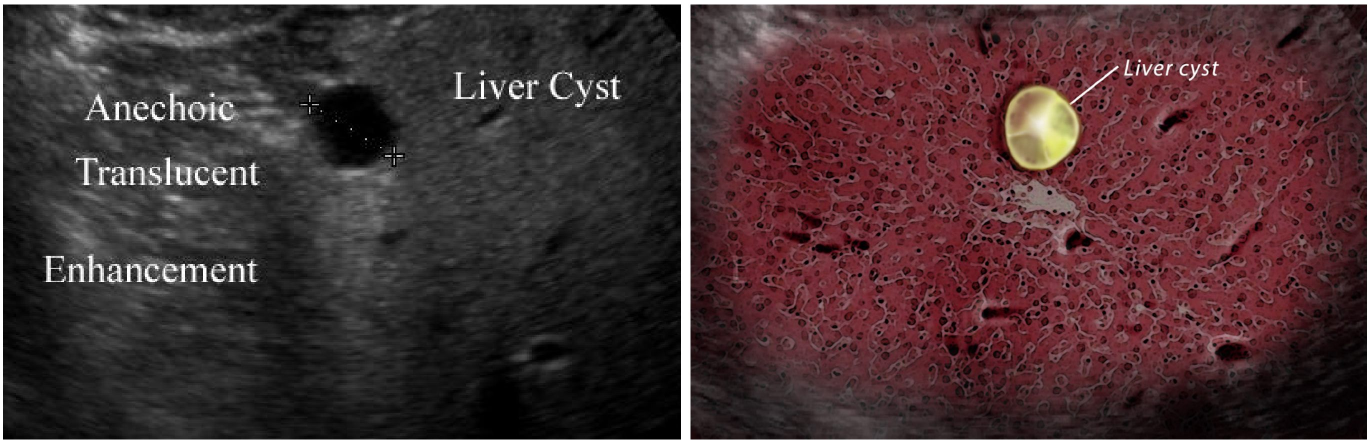
Periosteum appears as a particularly bright line due to the dramatic difference in acoustic impedance between bone and soft tissue. High frequency ultrasound does not penetrate bone effectively and therefore the screen is generally black deep to the periosteum.

Enhancement and Attenuation

One drawback of ultrasound is that each layer of tissue that is passed through reflects and absorbs the pulse to some extent, reducing the strength of the signal that reaches deeper tissue.

As less sound returns from deeper tissues than more superficial ones, the image is processed to compensate for this by applying a standard correction in proportion to the depth.

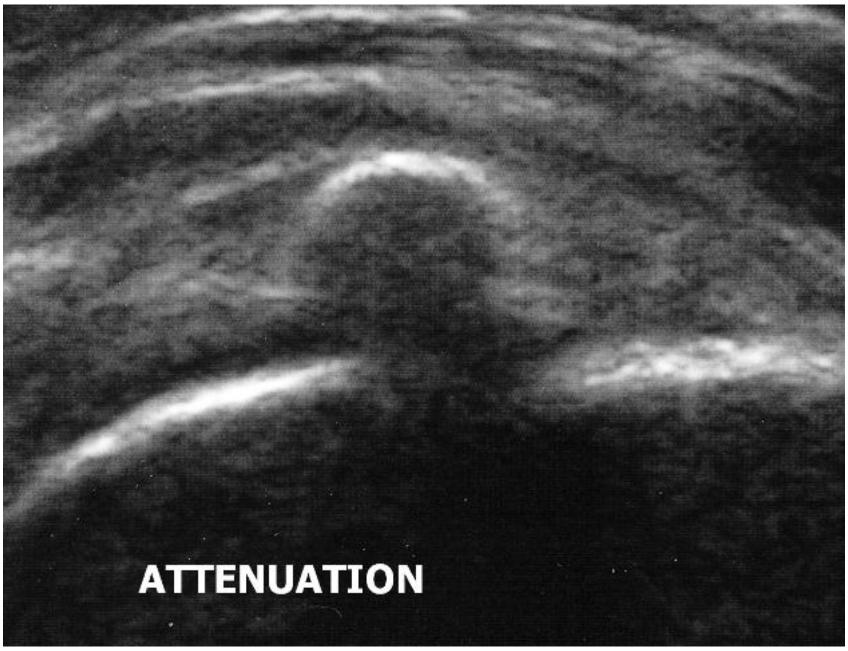
Some structures however allow sound to pass through them more easily than others. The most dramatic example is watery fluid, such as in an effusion, or in a cyst. These are described as being translucent. Because only a minimal amount of energy is absorbed by the fluid, the region that lies behind will receive more sound than the processor expects for that depth. This area will therefore appear uniformly brighter. This effect is called **Enhancement**.



Enhancement demonstrated on a liver cyst

Attenuation or Shadowing is the reverse effect, where some tissues absorb relatively more of the sound. The area of the image deep to this will appear darker. In the extreme almost no sound is transmitted, leaving a dark shadow behind the structure.

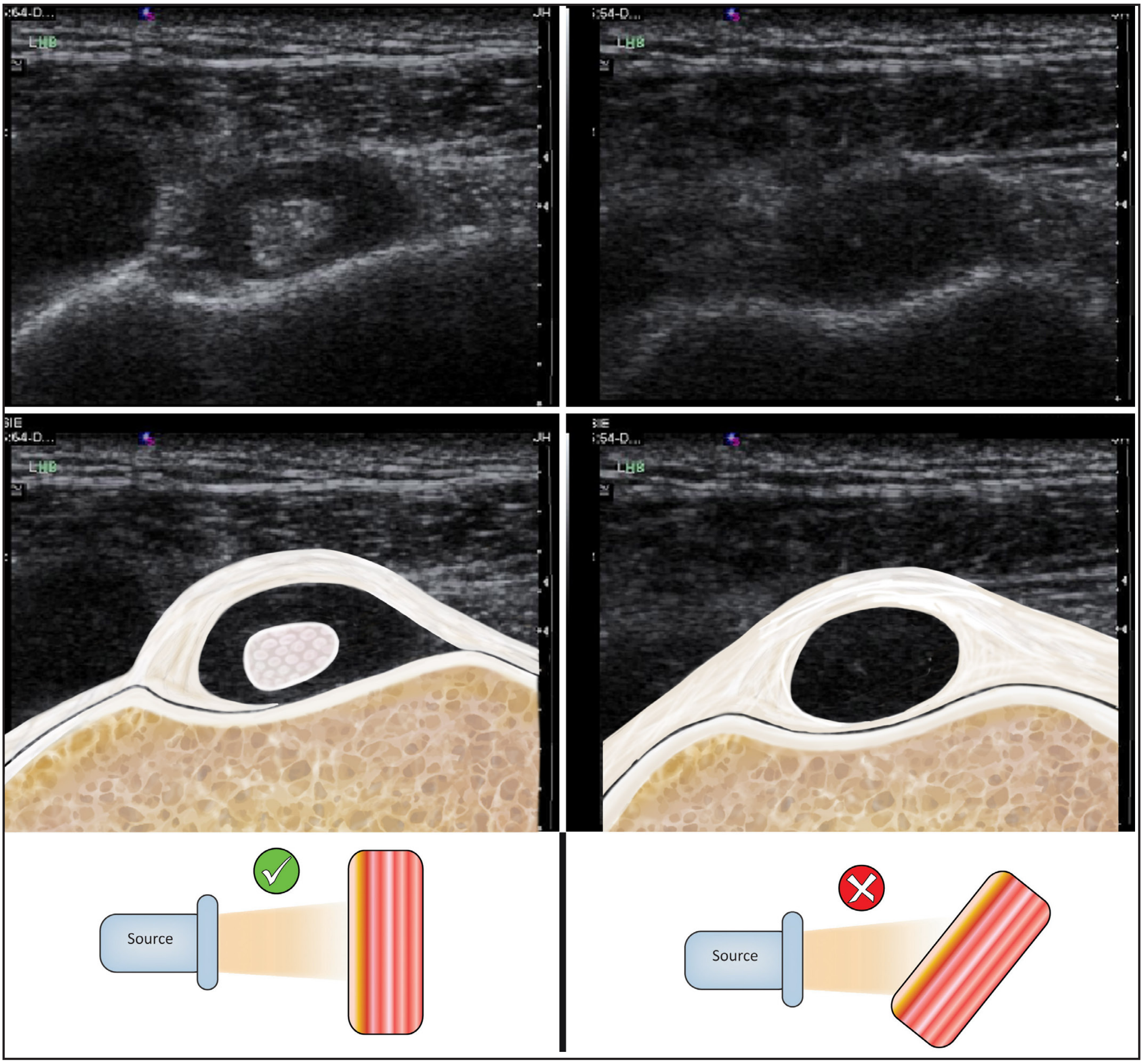
This effect is used as a diagnostic tool in identifying calculi, which if they are larger than the beam width cast a strong acoustic shadow.



Anisotropy

This is the effect that makes a tendon appear bright when it runs at 90 Degrees to the ultrasound beam, but dark when the angle is changed.

The reason for this is that at particularly smooth boundaries, the angle of reflection and incidence are the same, just as they are with a conventional mirror. Thus the probe will only receive the reflected sound if the beam strikes the surface at a right angle.



Anisotrophy demonstrated on the long head of biceps

Frame Rate

This is how quickly the image is updated, and depends on how long the image takes to acquire. If it is too slow, the image becomes jerky and uncomfortable to view, and image quality can be lost due to movement. Too high a frame rate is not normally a problem in scanning the shoulder. The most straight forward factors which slow down the frame rate are the number of focus levels used and the depth of the image.

Artefacts

The ultrasound image is produced assuming that the returning echoes faithfully represent the underlying tissue. Certain conditions can cause significant differences to occur. These are called artefacts.

Attenuation, enhancement and anisotropy described above fall into this category, and can be helpful in scanning the shoulder. Conversely anisotropy can make part of a tendon appear bright while an adjacent section that is not at right angles to the beam appears dark. This can give the impression that there is a tear present. Changing the angle of the probe dispels this illusion and you will quickly become accustomed to this effect.

Some others are listed below. These do not generally have a significant impact on scanning the shoulder, but are worth being aware of as they may occasionally cause some confusion.

Reverberation - this causes evenly spaced lines at increasing depths and is caused by sound reflecting back and forth between the surface of the probe and a strong reflector close to the surface.

Comet tail - this is the same process as reverberation, but occurs within a very small structure, with smooth highly reflective borders, such as a metal fragment. Tiny bright reverberations are seen deep to the structure slowly diminishing is size as if it had a tail.

Mirror images - This is where a strong reflector at an angle to the probe causes structures that lie in front and to the side of it to appear as if they lie behind it, just as something viewed through a mirror appears to lie behind it. This effect is normally only achieved by the diaphragm.

Refraction - Sound is refracted in the same way that light is as it passes from one medium to another. Thus the direction in which it travels changes when it passes through a boundary at an angle less than 90 degrees. This can lead to subtle miss placement of structures and some degradation of image quality when the angle of incidence is particularly acute.

Ghost images - This is a dramatic example of refraction, where a structure is represented twice or more side by side. This classically occurs deep to Rectus Abdominis which due to its shape acts as a lens and can lead to the apparent duplication of the aorta or early foetal sack.

Range distortion - Ultrasound travels at slightly different speeds through different tissues. A rough average of 1540m/s is used, but the velocity through fat (~1460m/s) and water (~1480m/s) is somewhat slower. Structures deep to a large fluid collection can therefore appear a little further away than they actually are.

Side Lobe Artefacts - the probe cannot produce a pulse that travels purely in one direction. Pulses also travel off at specific angles. These side lobes are relatively weak and so normally do little to degrade the image. Their effect is only normally seen faintly superimposed in fluid filled areas which are anechoic and so do not obscure the weak side lobe reflections. The exception is when a side lobe strikes a particularly strong reflector at 90 degrees. In this case the reflector can appear within the image.

Partial volume - the slice that makes up the ultrasound image is 3 dimensional, just as with MR. This typically means that fluid filled areas, where they are very small or adjacent to soft tissue will not appear anechoic (Black) as would be expected, but often contain low level echoes which can be mistaken for debris or even soft tissue.

Safety

Diagnostic ultrasound has not, to date, been shown to have any adverse biological effects when applied to adults or children. It is however prudent to avoid maintaining the probe in a static position for long periods of time, as this has the potential to produce a small localised heating effect. This should in any case be unnecessary, particularly as the image can be easily frozen and the cine loop reviewed.

I recommend that you refuse even the most innocent requests to look at, or take pictures of unborn babies. This is an area where there is at least a theoretical biological risk, as well as a myriad of emotional, medico-legal and clinical issues - Don't Do It!

For a more in depth discussion of Safety visit the British Medical Ultrasound Society web site and in particular:

British Medical Ultrasound Society. Guidelines for the safe use of diagnostic ultrasound equipment. BMUS Bulletin, August 2000. (www.bmus.org)

Chapter 2: Knowing the Machine

Adjusting the Controls

How much you adjust the machine controls and settings as you scan is very much a matter of taste. Some familiarity and understanding of the controls is essential especially if you are not the only one who uses your scanner.

Freeze Button

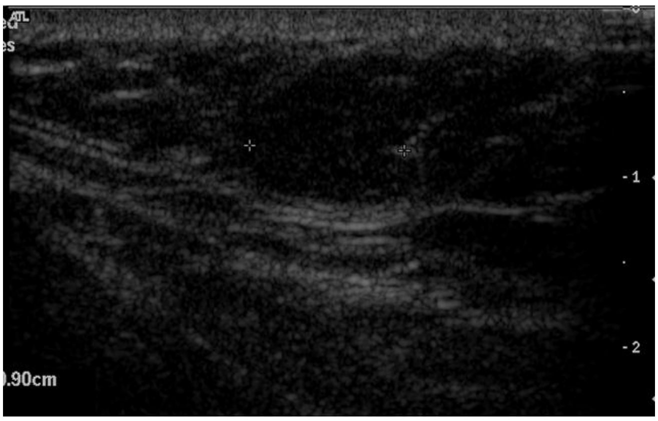
When you press the freeze button the image displayed at that moment is captured on the screen so that measurements can be taken and a print can be made if required. Most modern machines will also have a Cine Loop function that allows you to scroll back through the preceding several seconds of the scan, frame by frame.

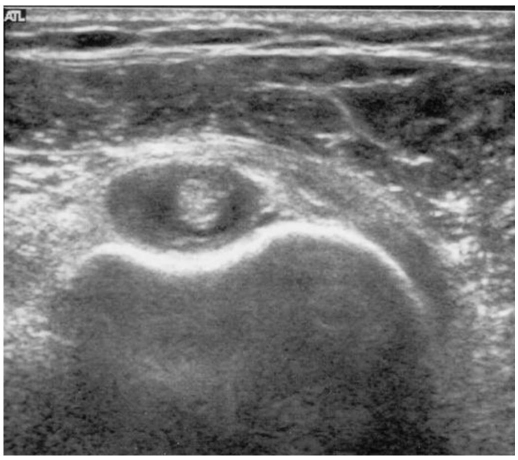
Depth

Increasing the depth allows deeper structures to be viewed, but reduces the scale and also slows down the frame rate, as each line of the image takes slightly longer to acquire.

Gain

The overall brightness of the image can be adjusted. Either too bright or too dark and it is difficult to see subtle differences in texture. This is the most important adjustment to become accustomed to making.





Demonstrating low gain on the left and high gain on the right

TGC (Time Gain Compensation)

Gain can also be adjusted selectively at different depths. This can be a simply near or far field adjustment on some portables, up to 10 separate depth adjustments on platform based machines. This is used to compensate for strong attenuation or enhancement by superficial tissue. It is more useful when examining an area. When examining relatively small specific structures, as is the case in the shoulder, adjustment of the overall gain is usually sufficient.

Focus

The pulse of ultrasound can be manipulated to be at its narrowest at a particular depth. This means that image quality including lateral resolution is maximised at that level. This can be manually adjusted so that a particular area can be examined in more detail. More than one focus level can be selected, though this can significantly slow down the frame rate. As scanners have got better, adjusting the focus has become less important when scanning shoulders.

Zoom

This takes a portion of the screen and magnifies it. This can be done while scanning or once the image has been frozen. For superficial structures it is normally easier to magnify by just to reducing the depth of the image. For deep structures it is necessary to use the zoom; however orientation is more difficult if zoom is used while scanning.

Measuring

Cursers are available on all modern machines and are calibrated so that reasonably accurate measurements can be made.

Taking Pictures and Labelling

It is foolhardy to form an opinion based solely on a still ultrasound image and so any conclusions should be drawn while actually scanning the patient. Images are of value as aid memoirs and for demonstration and discussion. To this end it can be useful to label them, if only with left or right.

Doppler

Doppler allows flow, generally of blood, to be analysed and/or superimposed onto the grey scale image. In the shoulder it can be used to demonstrate active inflammation, but with poor sensitivity. Its principles and properties lies beyond today's discussion.

Others

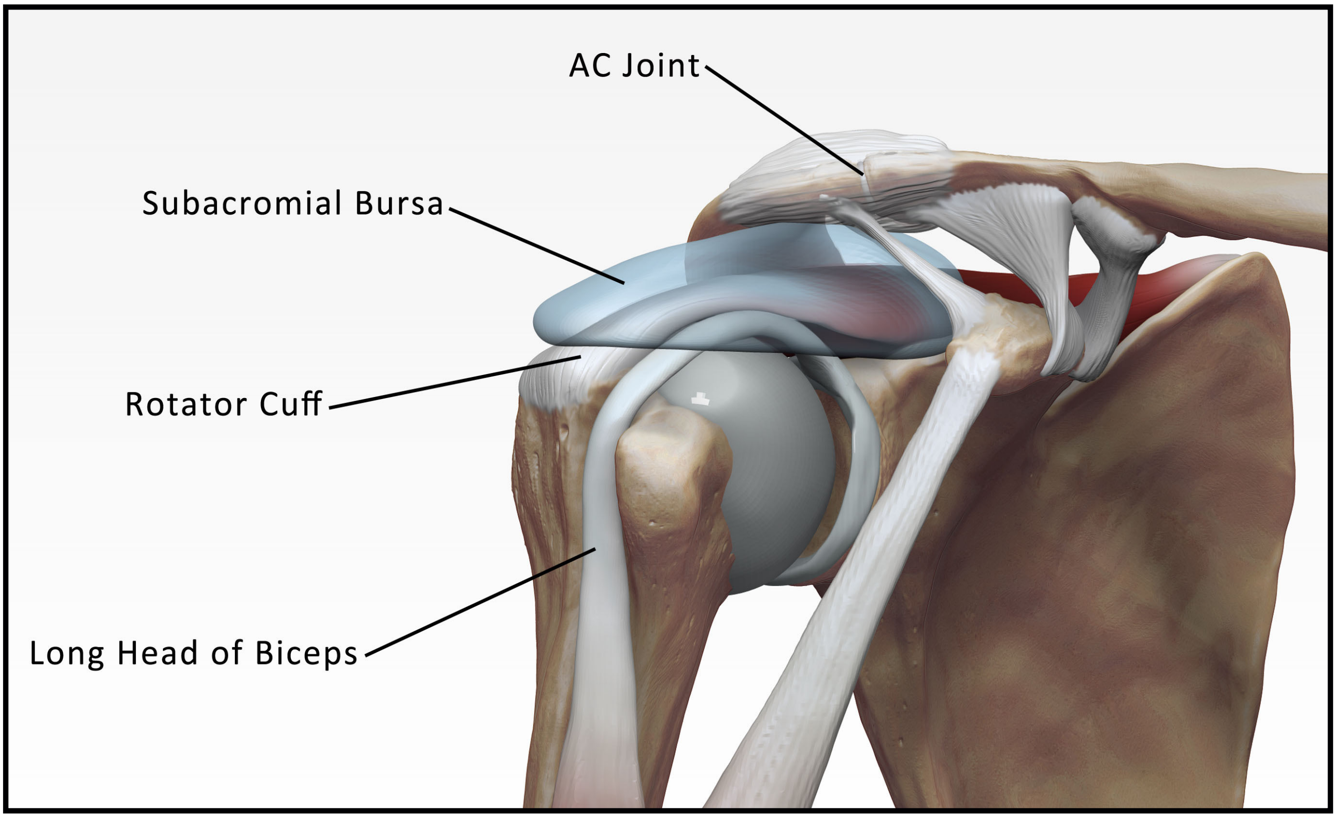
There are many other functions and parameters that are that can be applied or adjusted on modern ultrasound machines, but those above represent the basics to carry out an ultrasound examination.

Chapter 3: Ultrasound Anatomy & Technique

Ultrasound is a very practical and personal skill with very few absolutes in terms of technique. Most people learn a standard technique and then modify it to suit their own preferences, circumstances, patients and facilities.

The shoulder is a complex of five joints, thirty muscles and six ligaments. Many of these structures are deep and not detectable with ultrasound. However, many key and commonly affected structures are detectable on ultrasound. These include the following:

1. Joints:
    a. Acromioclavicular joint – superior part only
    b. Glenohumeral joint – superficial section anteriorly and posteriorly only
2. Tendons:
    a. Rotator cuff – all components
    b. Long head of biceps
3. Subacromial Bursa



Orientating the Probe

Probably the most important skill that must be learnt is orientation between hand and eye. This is made simpler if the probe and screen are in sync, i.e. if you move the probe to your left, the anatomy displayed on the screen appears to pass from left to right.

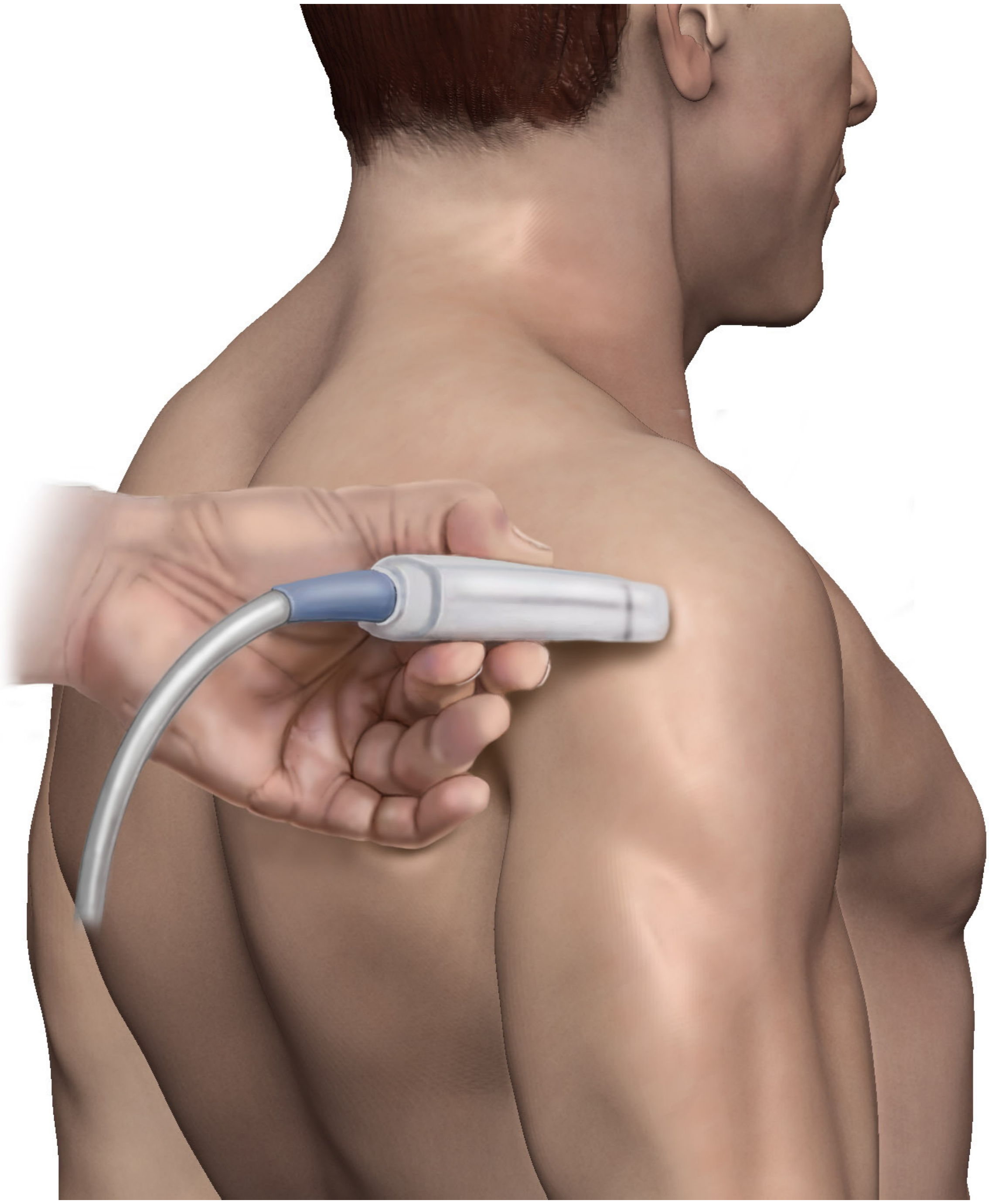
The most common examinations (abdominal and gynaecological) patients in a radiology department are typically scanned on their backs, facing the sonographer. Therefore the convention is that the left side of the screen is right for the patient.

When scanning shoulders however this orientation will not always apply and it is important to disregard the convention if it means that the image does not move in sync with your hand movements.

It is also convention that when scanning in the sagittal or coronal planes, the left of the screen is superior and the right is inferior. The shape of the shoulder means that this orientation may change from time to time as you scan and does not normally cause the sonographer any problem. It is worth considering using this convention when taking still pictures as it does make the images easier to understand at a later date.

Holding the Probe

The technique for holding the ultrasound probe is like a tripod or large pen. The probe is held between the thumb, index and middle fingers with the little finger extended to rest on the patient. This creates a triangular (tripod) configuration, making it more stable to hold the probe on the patient and move around without any loss of positioning.



Applying Pressure

With a steady hand and plenty of gel the shoulder can usually be scanned with a light touch. This is important, because probe pressure can displace fluid away from the region being scanned and therefore be missed. This fluid often fills defects in tendons thereby highlighting them - pressure will therefore reduce sensitivity in picking up small tears.

Positioning the Patient

There is no one best position for the sonographer or the patient, but if either you or your subject is uncomfortable, you will struggle. Below is one technique:

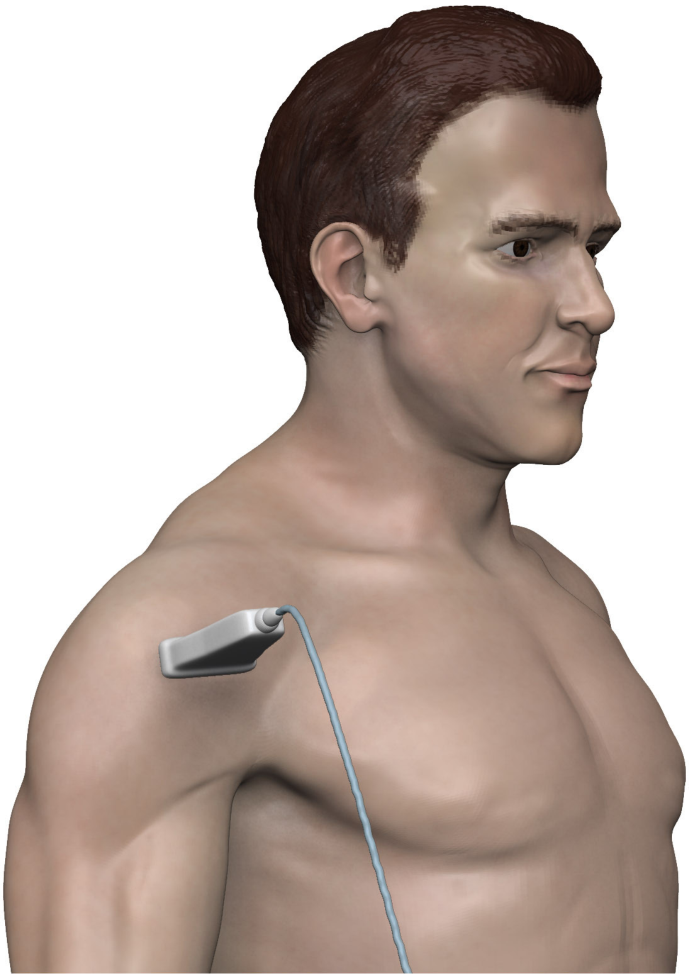
- The patient is seated with the shoulder and arm fully exposed from neck to elbow with free mobility of the arm.
- A chair should be used without armrests and narrow back support.

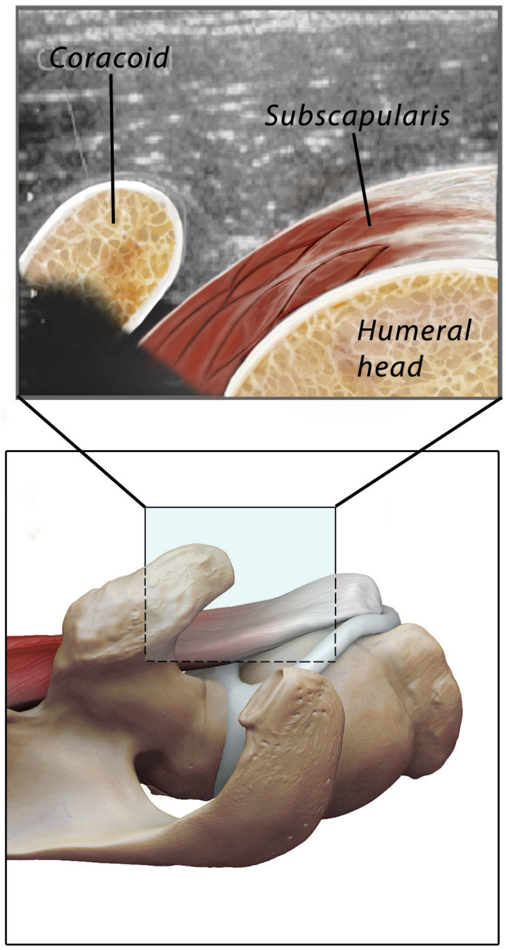
- The patient faces the screen with the examiner standing or seated on the side of the shoulder to be scanned. The patient is then included in the examination and the examiner is able to discuss the findings and scan with the patient keeping them involved during the procedure.
- Ideally the examiner holds the probe in their left hand for a right shoulder with the right arm free to control the buttons on the machine and likewise holding the probe in their right hand for scanning a left shoulder with the examiner's left arm free to control the buttons on the machine.
- Adequate gel and tissue wipes should be easily accessible and available.

Sequential Examination

1. Longhead of Biceps - Transverse.

The coracoid is the lighthouse to the shoulder and the landmark to start at. The probe is placed on the coracoid in the horizontal direction perpendicular to the longhead of biceps.

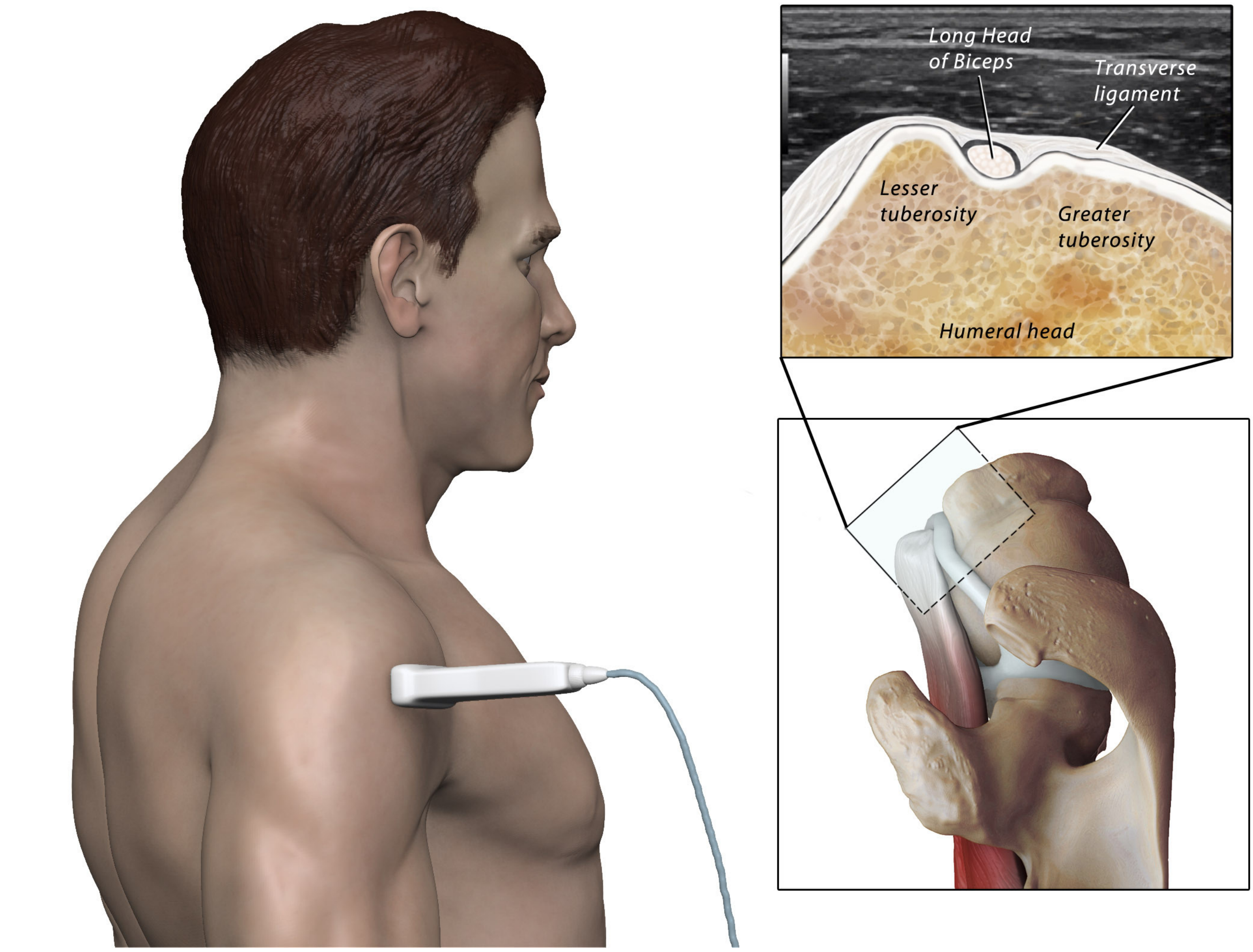




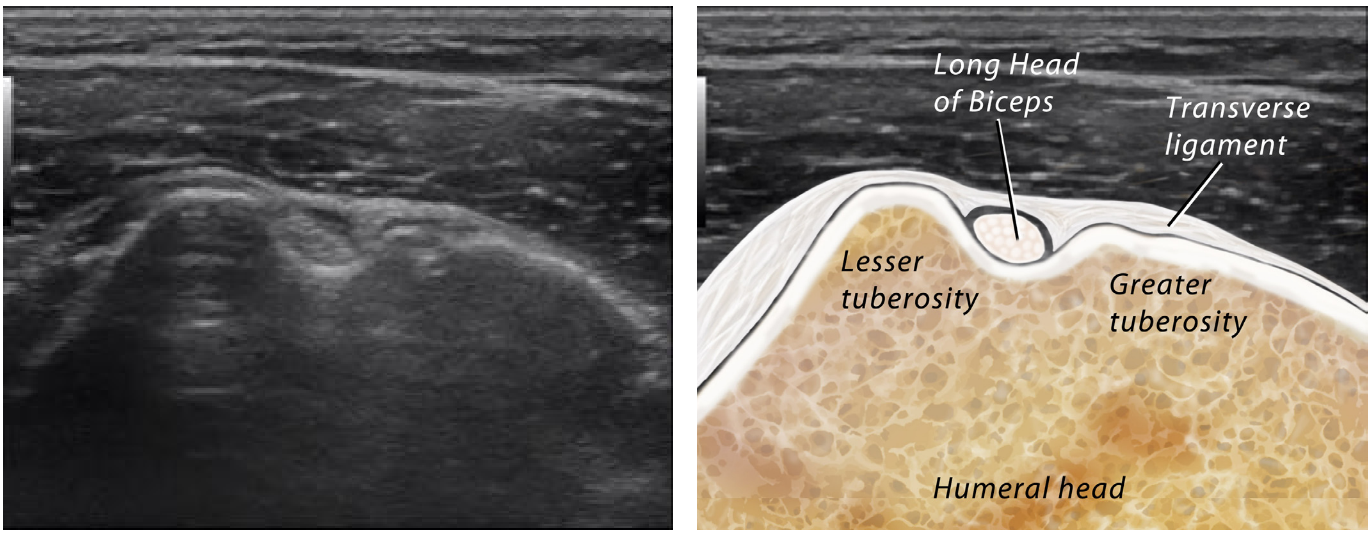
Position of the scan to view the coracoid

Once the coracoid is clearly seen the probe is moved laterally to find the longhead of biceps in the biceps groove lying in the valley between the lesser tuberosity and greater tuberosity.

As the humeral head in this area is quite convex the probe does need to be rocked in the sagittal plane to eliminate anisotropy. The longhead of biceps can then be followed superiorly and inferiorly.



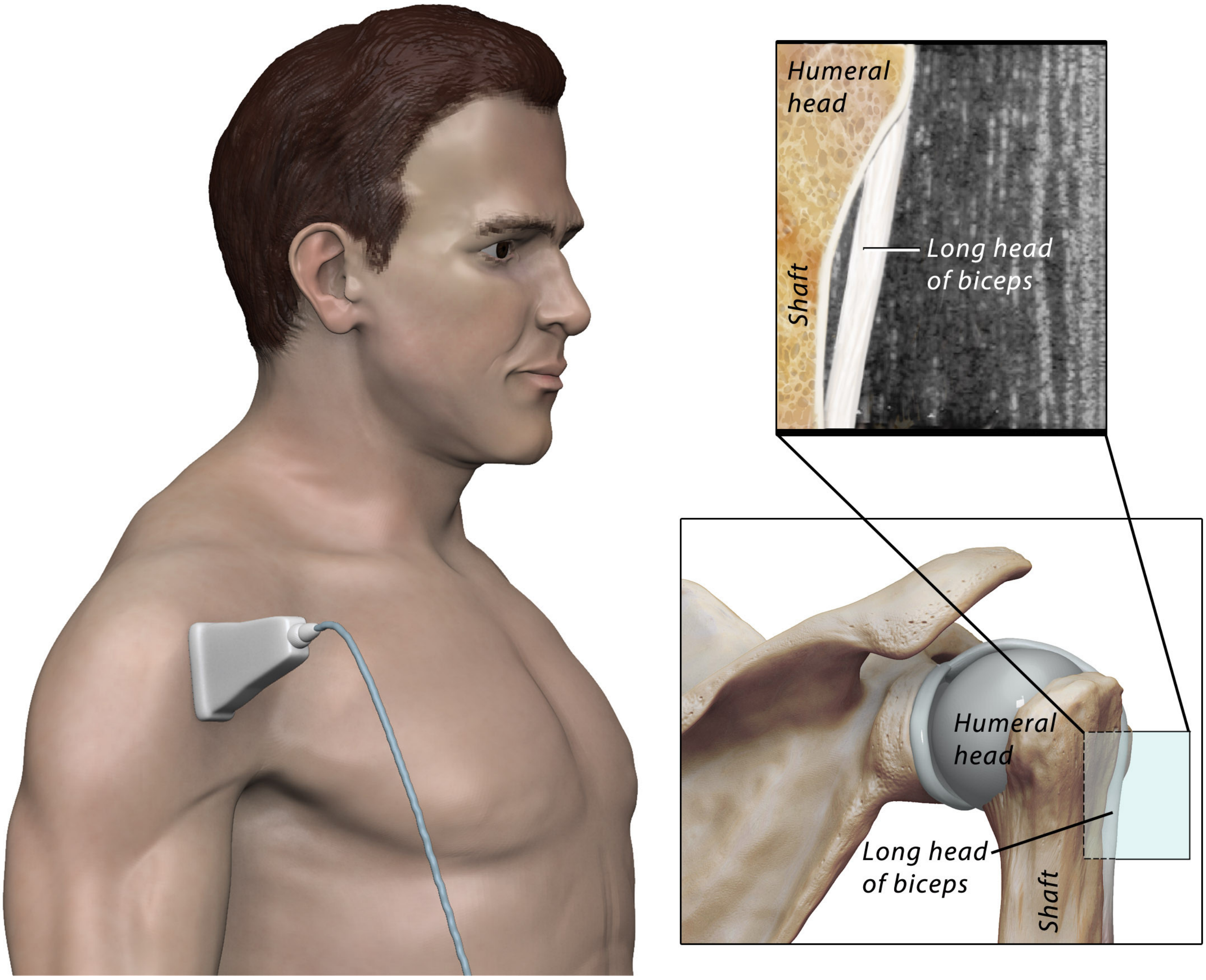
Position of the scan to view the biceps tendon



Horizontal view of the biceps tendon

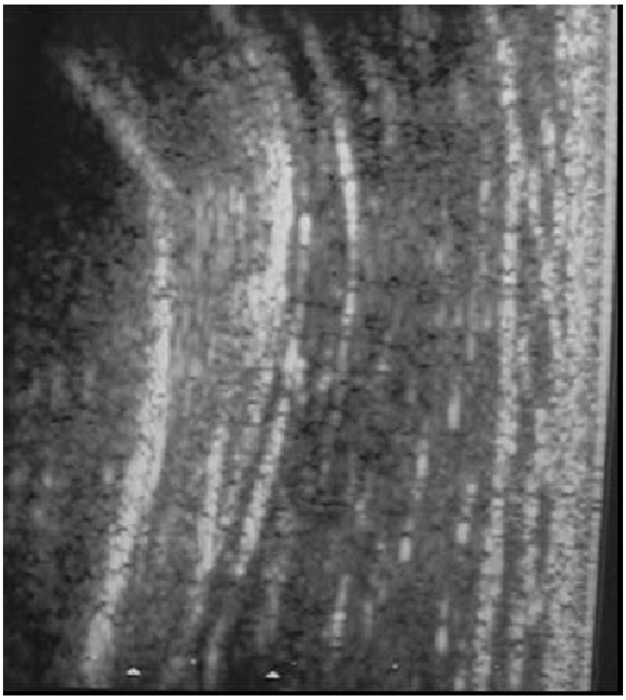
2. Long Head of Biceps - Longitudinal.

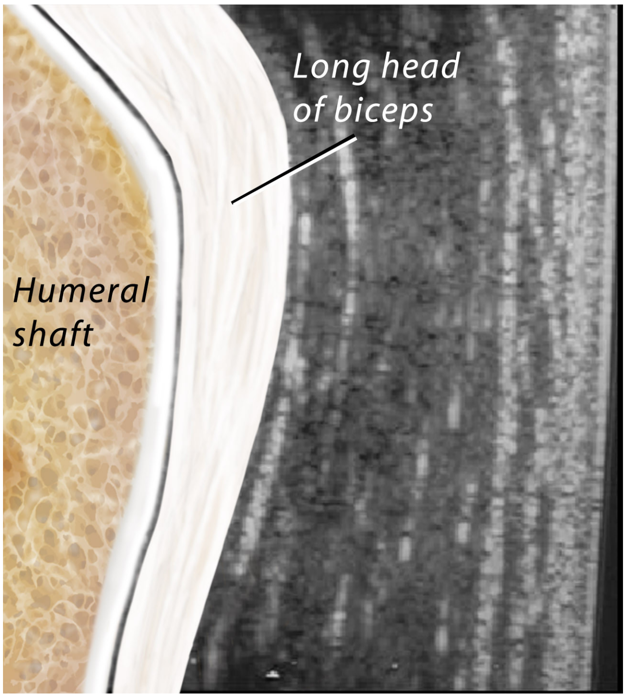
The probe is then rotated 90° for a longitudinal view of the biceps tendon. The probe can be moved medially and laterally to find the valley between the lesser and greater tuberosities where the biceps lies and again anisotropy is eliminated to get a good view of the biceps with the collagen fibres clearly seen within the biceps tendon. The biceps can again be followed superiorly and inferiorly.



Position of the scan for a longitudinal view of the biceps tendon

The long head of biceps follows the curve of the proximal Humerus, therefore to eliminate anisotropy the probe may need to be angled upwards for a good view of the tendon.

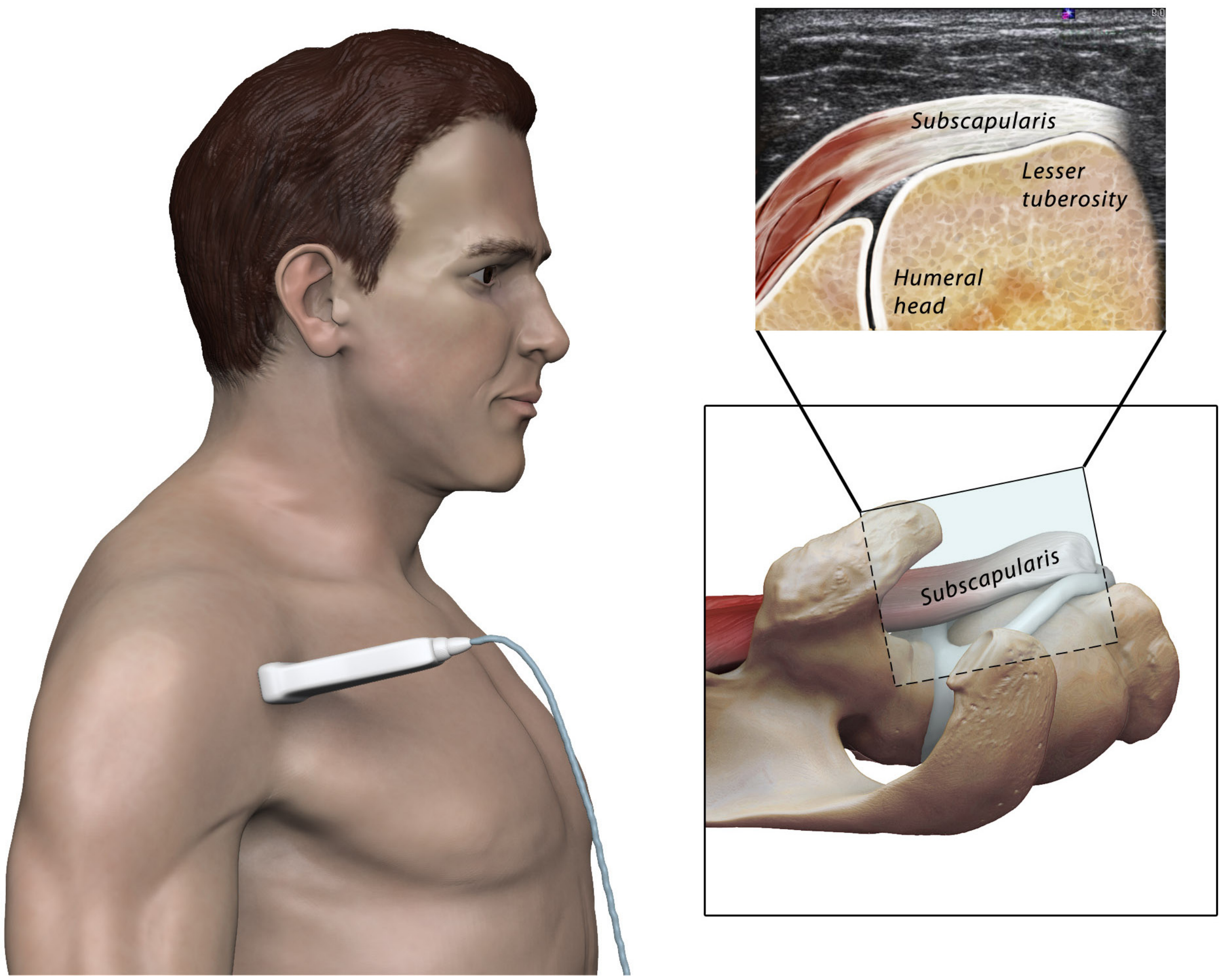




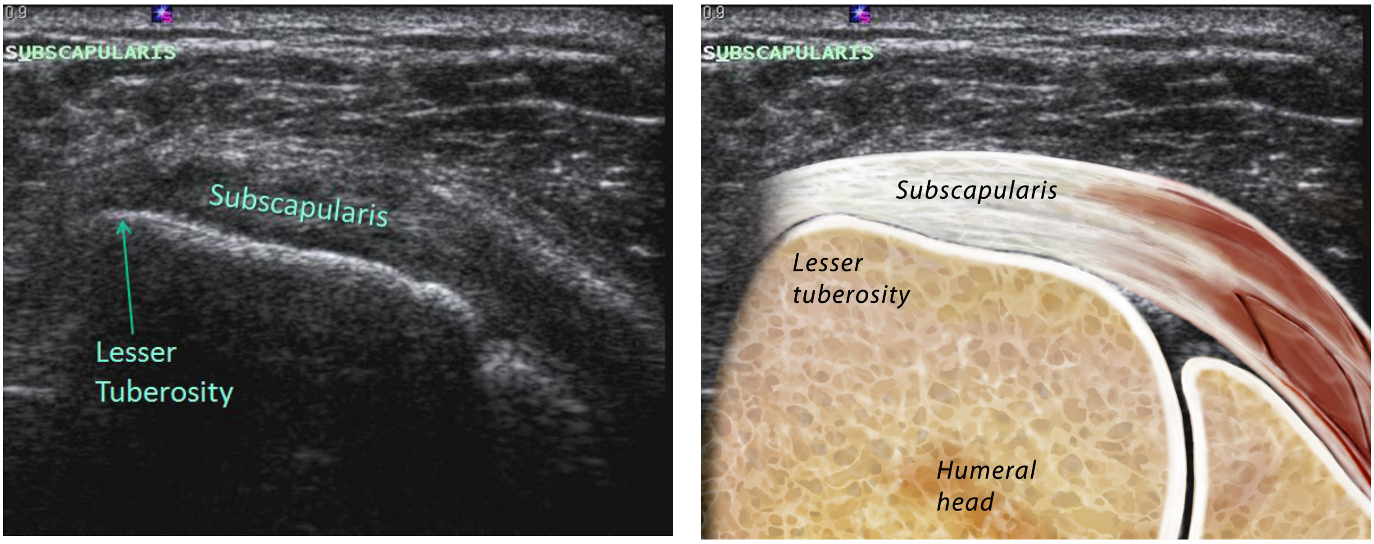
Longitudinal view of the biceps tendon

3. Subscapularis Tendon and Muscle Transverse.

The probe is then changed to the horizontal position again, thus giving a longitudinal view of the subscapularis muscle and tendon as it inserts at the lesser tuberosity of the humerus. The upper third of the subscapularis is more tendinous with the lower two thirds attachments being muscular. Subscapularis tears generally start superiorly, working their way inferiorly, therefore the tendinous portion should be identified first and easily. The arm can be rotated internally and externally to improve visualisation of the subscapularis tendon and muscle.

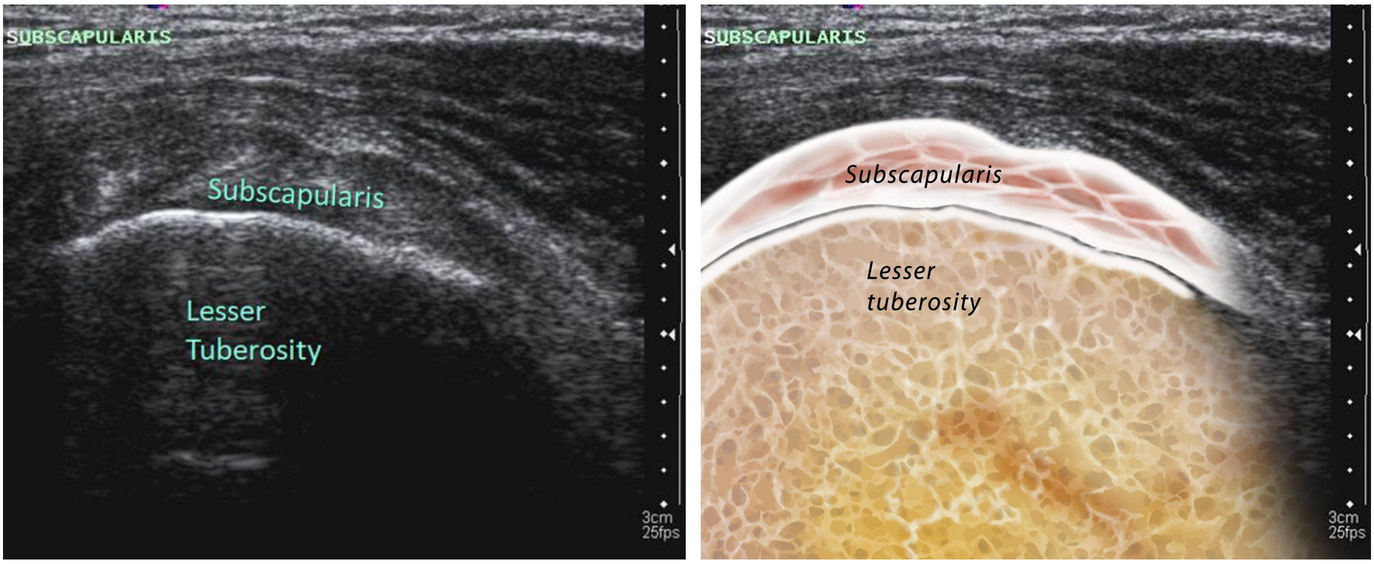


Position of the scan for a longitudinal view of the subscapularis muscle



Longitudinal view of the subscapularis tendon as it inserts into the lesser tuberosity

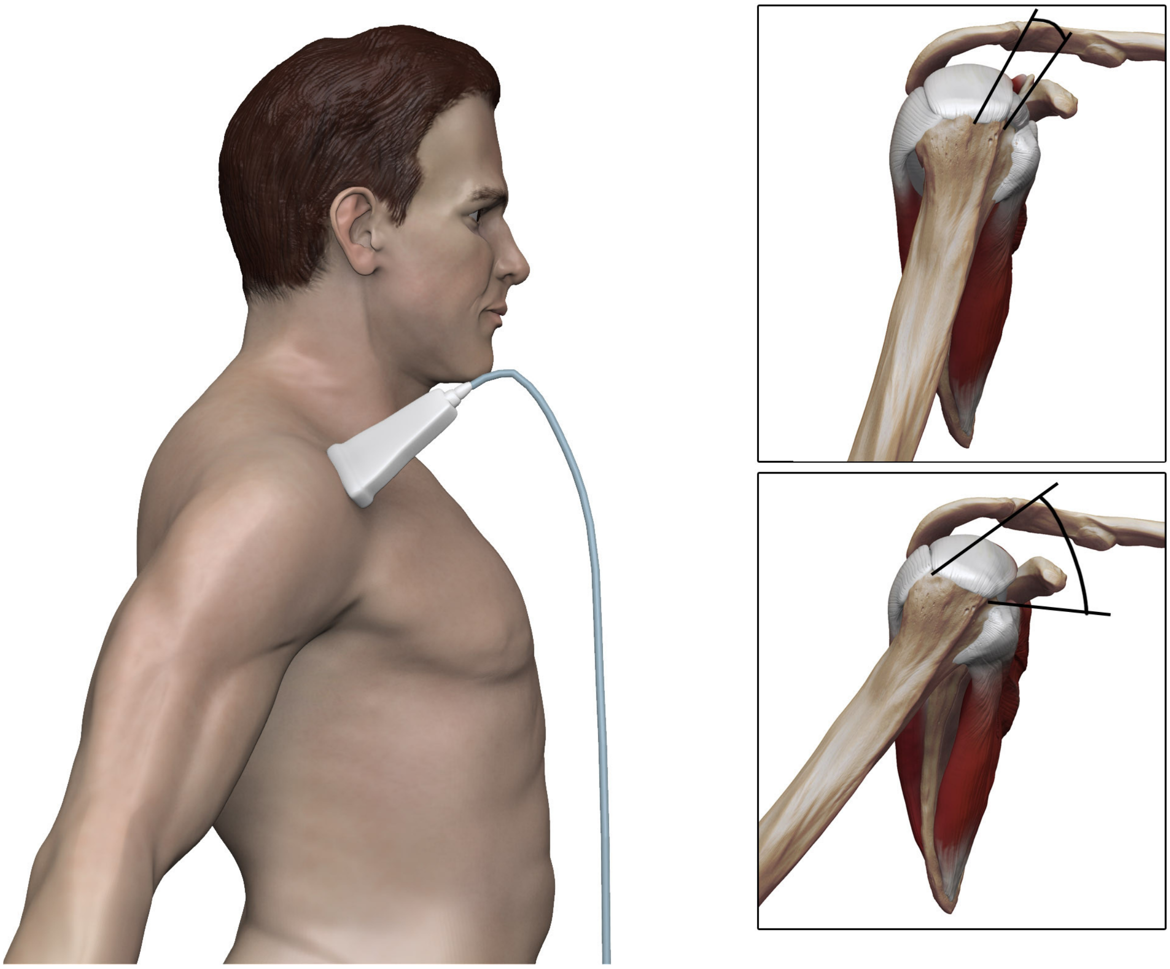
The probe is then rotated 90° for a transverse view of the subscapularis and the probe moved medially and laterally to get an impression of the muscular tendinous unit.



Transverse view of the subscapularis tendon

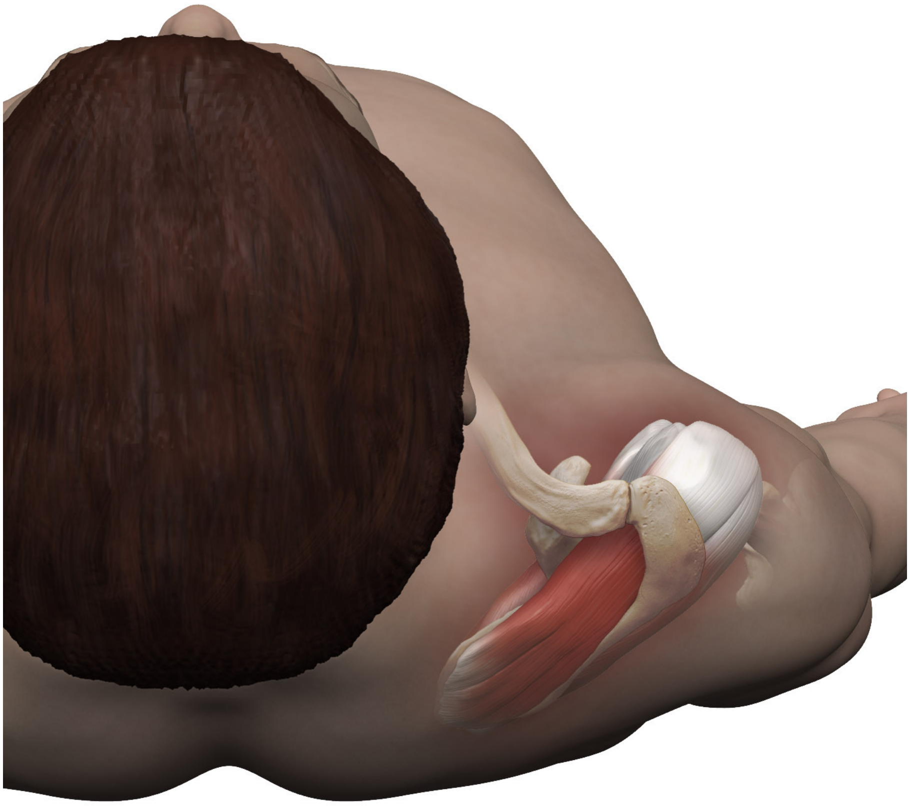
4. Supraspinatus.

The patient is then asked to place their hand on their hip with the shoulder adducted and internally rotated as much as is comfortable for the patient (similar to putting your hand in your back pocket position). This 'uncovers' the antero-superior rotator cuff (Supraspinatus and Infraspinatus), so that they are brought forward and out from under the acromion, as shown below.

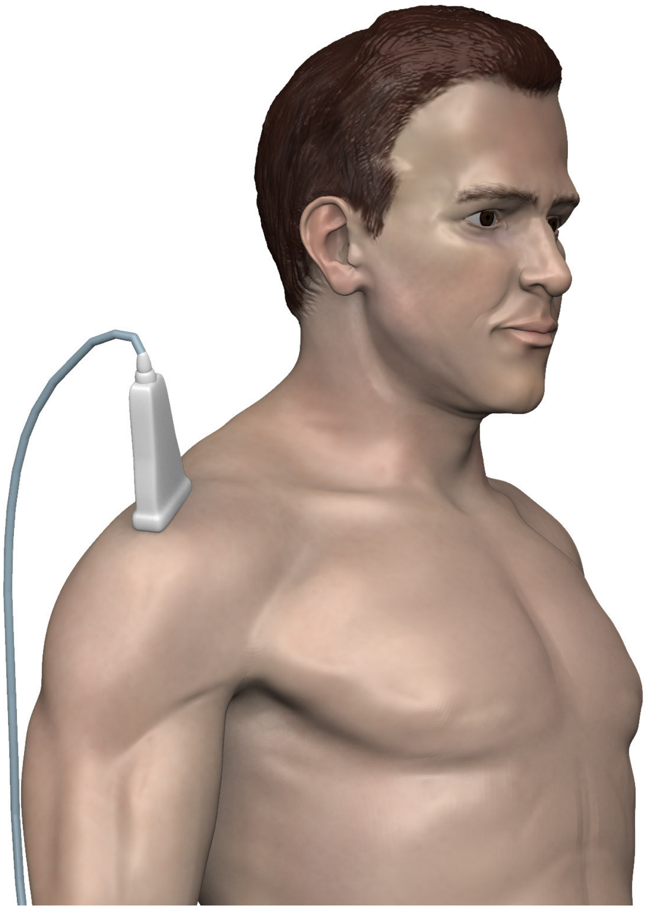


Position of the scan for a view of the antero-superior rotator cuff

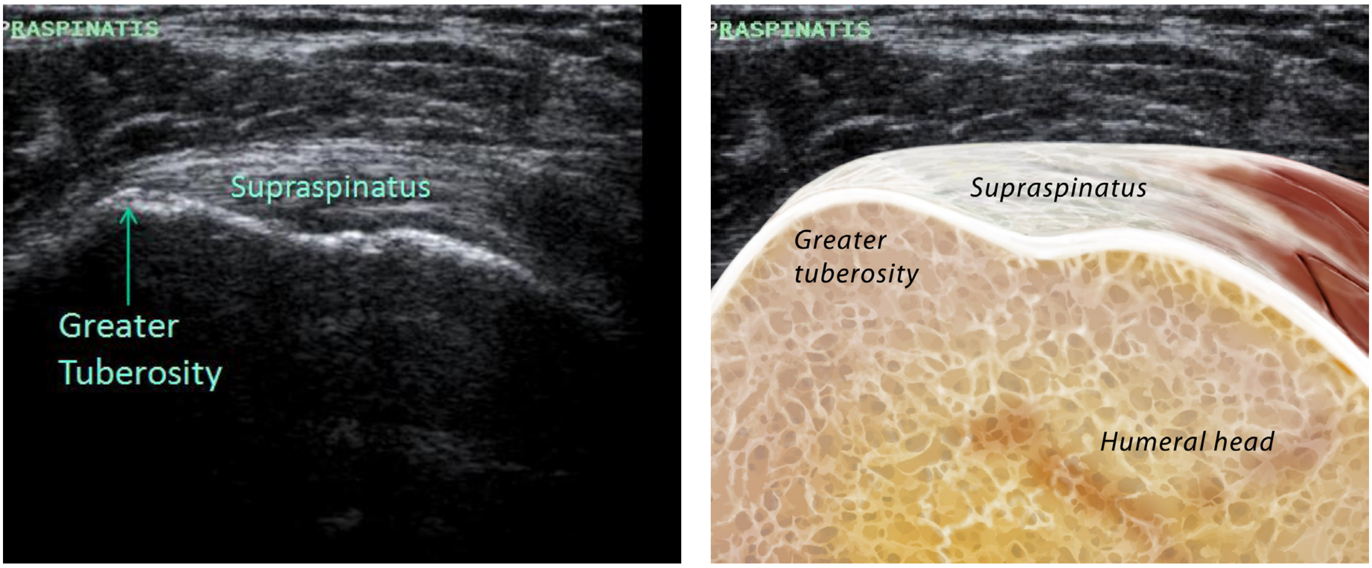
Bearing in mind that the supraspinatus runs in a plane at 30° to the coronal plane of the body the probe should be placed for a longitudinal view of the supraspinatus between 30° and 60° to the coronal axis of the plane of the body. This should give a good view of the greater tuberosity footprint area and superior articular surface of the humeral head. The probe can then be moved from antero-medial to postero-lateral, i.e. from the anterior leading edge of supraspinatus towards the infraspinatus tendon. The commonest area for supraspinatus tears is in this region.



Supraspinatus runs at a 30º angle to the coronal plane of the body

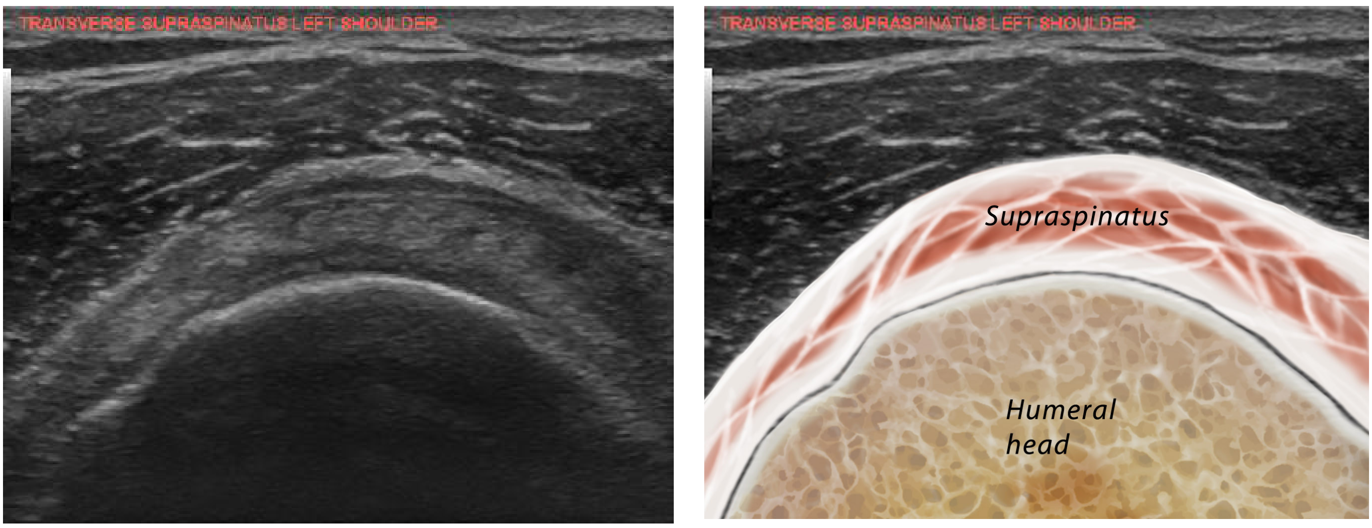


Position of the scan for a longitudinal view of the supraspinatus tendon



Longitudinal view of the supraspinatus tendon

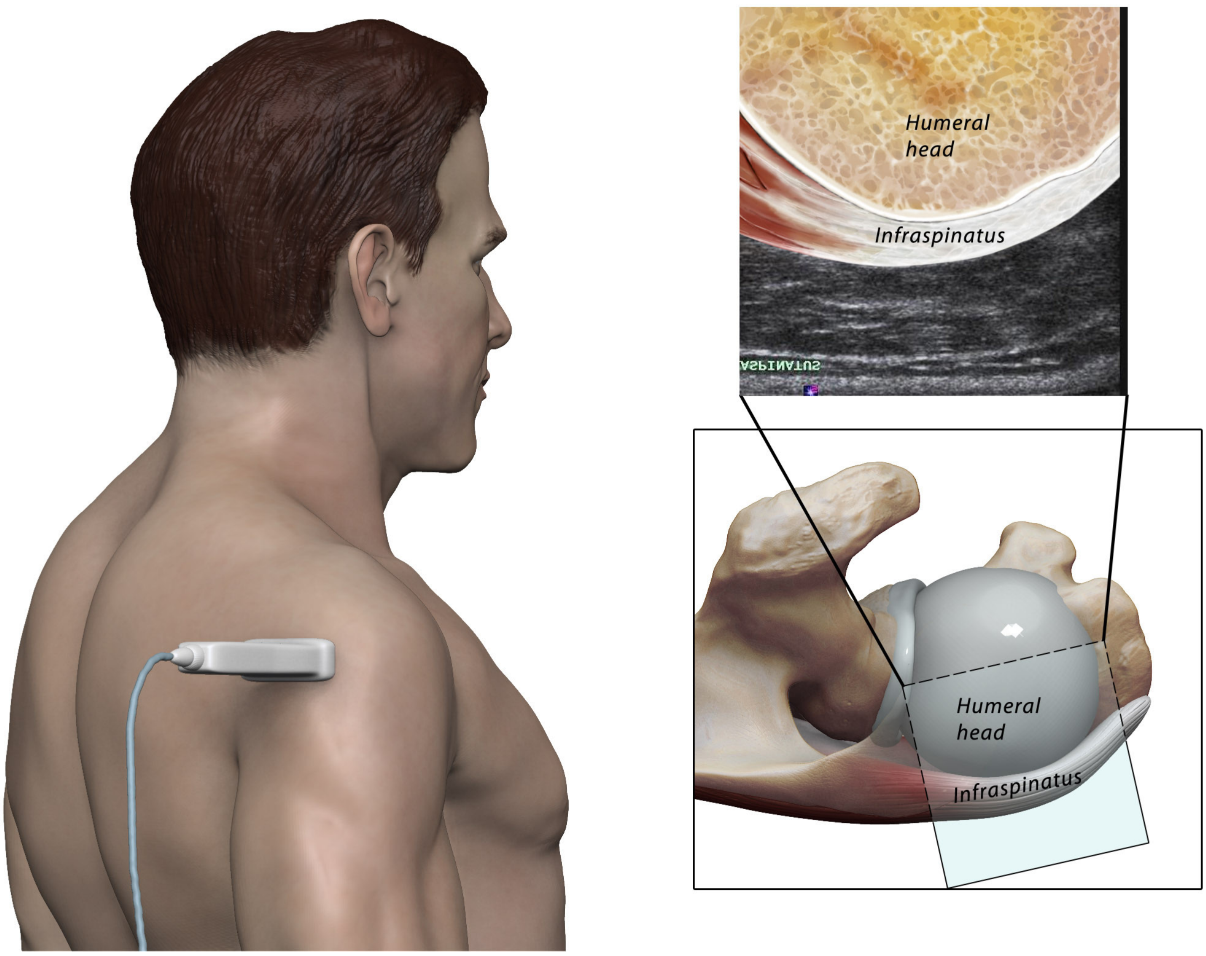
The probe is then rotated 90° for a transverse view of the supraspinatus and anterior portion of the infraspinatus tendons (superior cuff). The probe can then be moved medially and laterally as well as antero-medial and postero-lateral for a good impression of this area. Further medial movement is limited by the acromion.



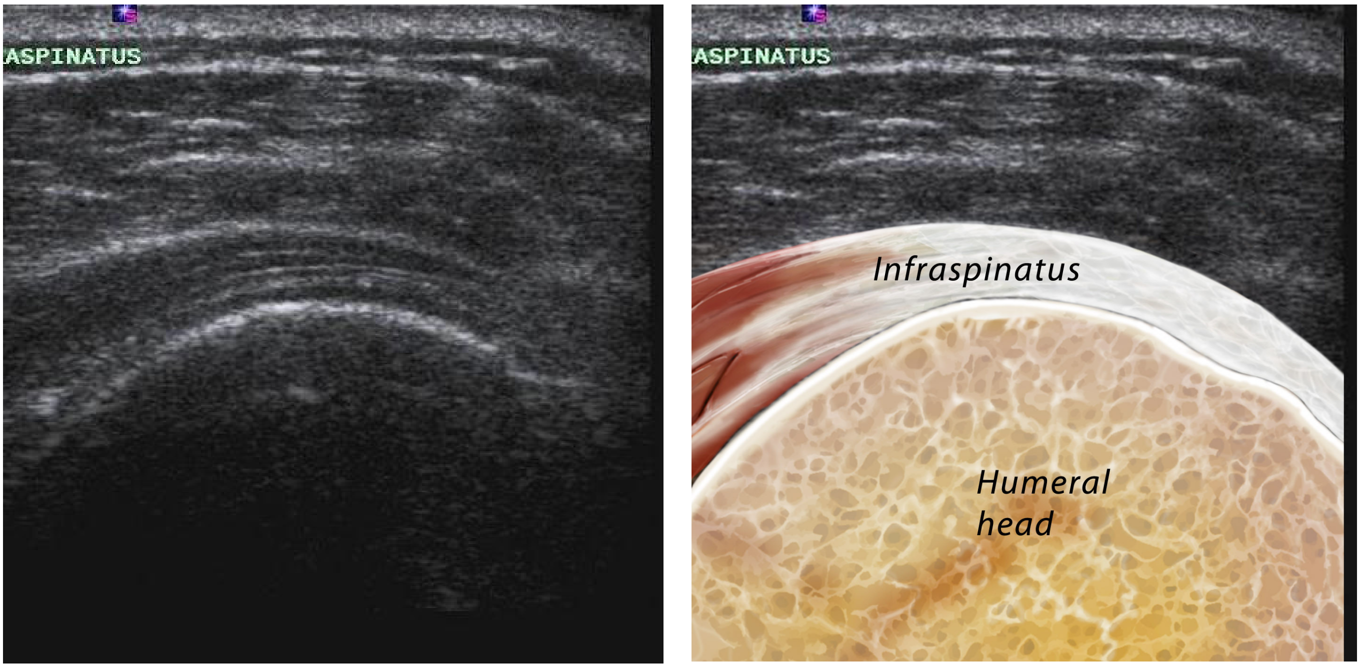
Transverse view of the supraspinatus tendon

5. Posterior Cuff

The patient's arm is brought back by their side with their forearm on their lap. The posterior/inferior cuff (infraspinatus and Teres Minor) lies below the spine of the scapular posteriorly. The scapular spine can be palpated and the probe placed in a longitudinal direction just below the spine of the scapular. The probe is moved laterally to view the posterior gleno-humeral articular surface and insertion of infraspinatus and Teres Minor to the humerus. The arm can be rotated to improve visualisation of this area. The Teres Minor attaches to a prominent tubercle at the posterior humerus which can be seen on the transverse view helping to delineate the infraspinatus from Teres Minor.



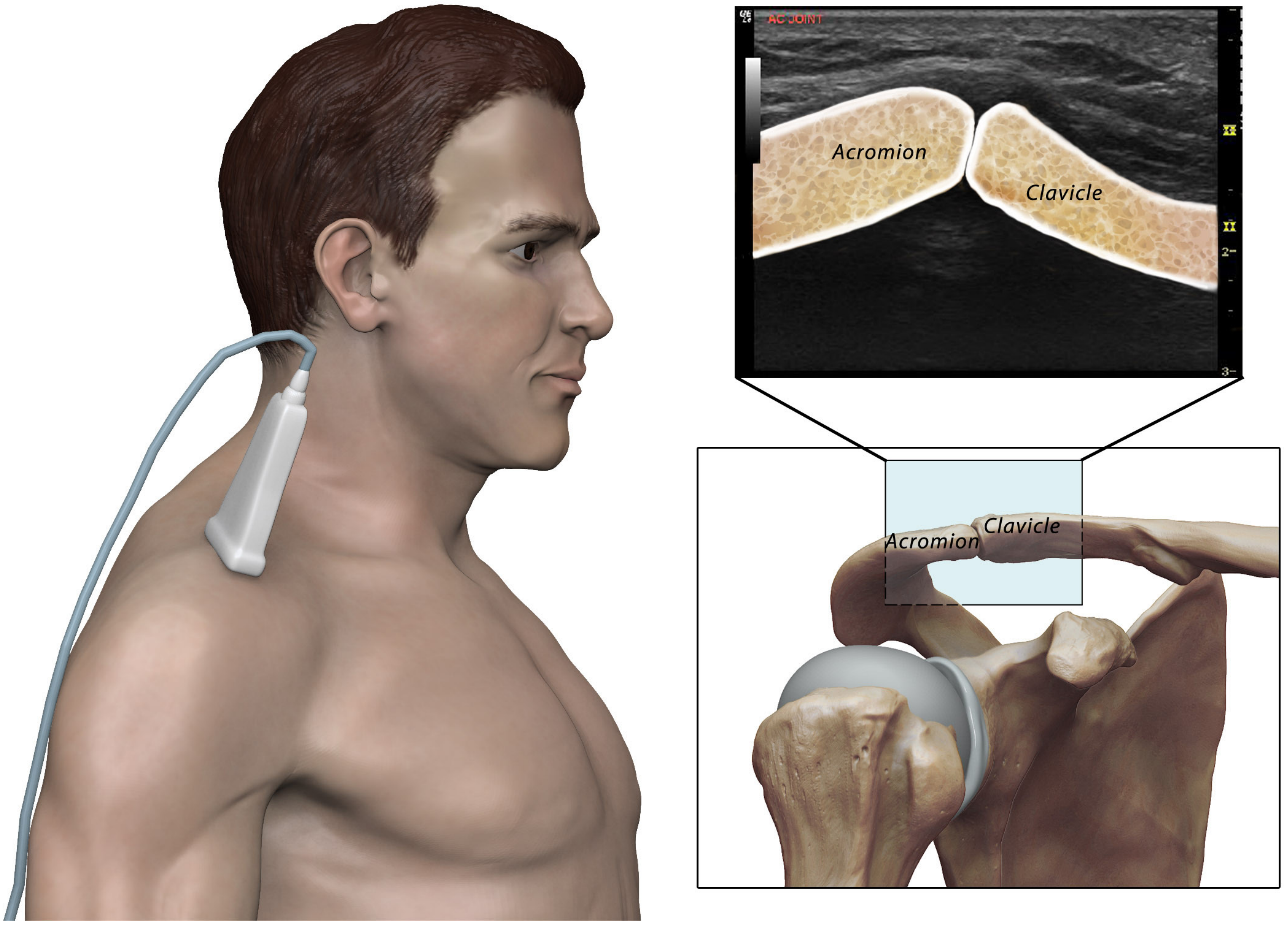
Position of the scan for a longitudinal view of the infraspinatus muscle



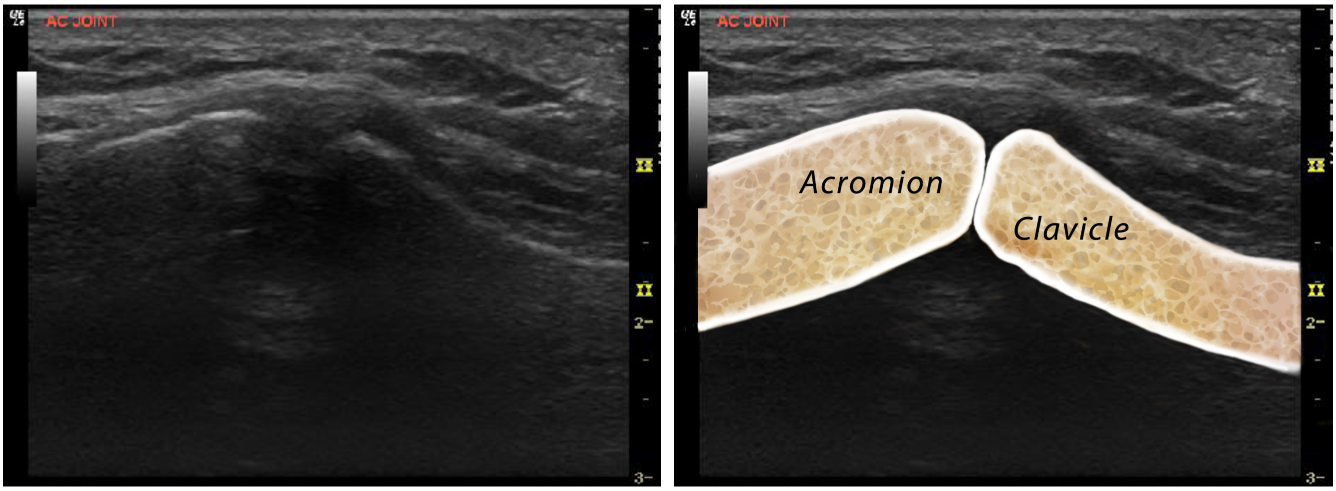
Longitudinal view of the infraspinatus tendon

6. Acromioclavicular Joint.

The acromioclavicular joint can easily be palpated at the top of the shoulder. A large amount of gel is placed over the joint and the probe placed in the long axis of the clavicle over the AC joint for a good view of the AC joint. The probe can be moved anterior and posterior for an overall impression of the joint.



Position of the scan for a view of the acromioclavicular joint



View of the acromioclavicular joint

Chapter 4: Recognising Pathology

The previous chapter demonstrated the technique for getting standardised images of the key areas of common pathology. When one is comfortable with the technique, recognition of pathology and normal variants is essential.

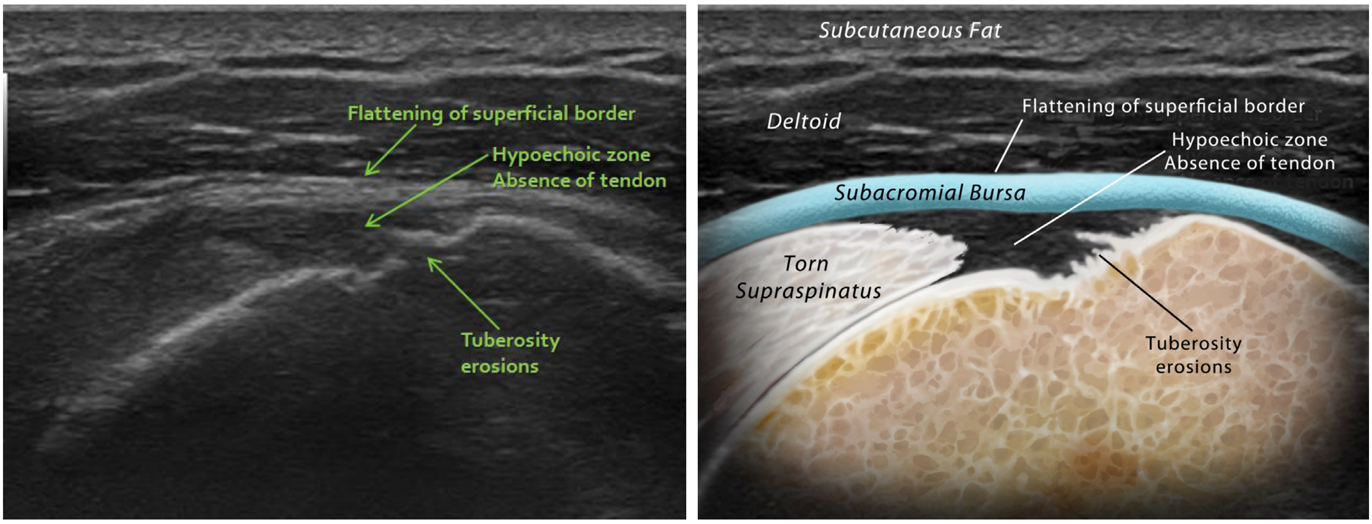
Rotator Cuff Pathology

Complete Rotator Cuff Tear

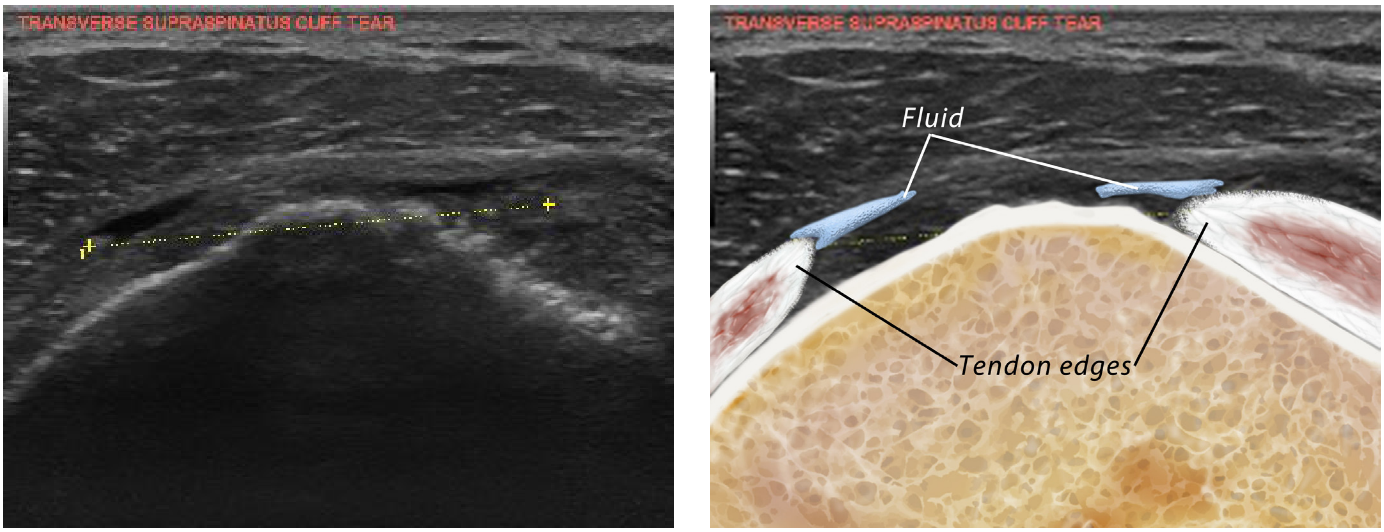
Complete rotator cuff tears are easily seen on ultrasound.

- **Direct signs:**
    1. flattening of the superficial border of the tendon - the normal tendon is convex.
    2. hypoechoic zone separating the tendon edges.
    3. absence of the normal tendon, replaced by a thin hypoechoic line representing the hypertrophic bursa surrounding the greater tuberosity.
    4. compression test - compression of the tendon causes flattening as the tendon edges are further pushed apart. The intact cuff cannot be compressed.
- **Indirect signs:**
    - effusion around the long head of the biceps tendon.
    - double effusion sign : this sign includes a joint effusion seen around the biceps tendon and subacromial subdeltoid bursitis; it is more specific for a rotator cuff tear; some authors quote a positive predictive value as high as 95%.
    - greater tuberosity erosions : this is a sign of enthesopathy, but this condition is often related to a rotator cuff tear.
    - cartilage interface sign.

- muscle atrophy : fatty infiltration of the supraspinatus or infraspinatus muscles are seen in their respective fossae; comparison with the other side can help to make this diagnosis; the involved muscles are abnormally hyperechoic; the subscapularis muscle cannot be seen when it goes between the scapula and the chest wall.



Longitudinal Supraspinatus view of 2cm full thickness rotator cuff tear

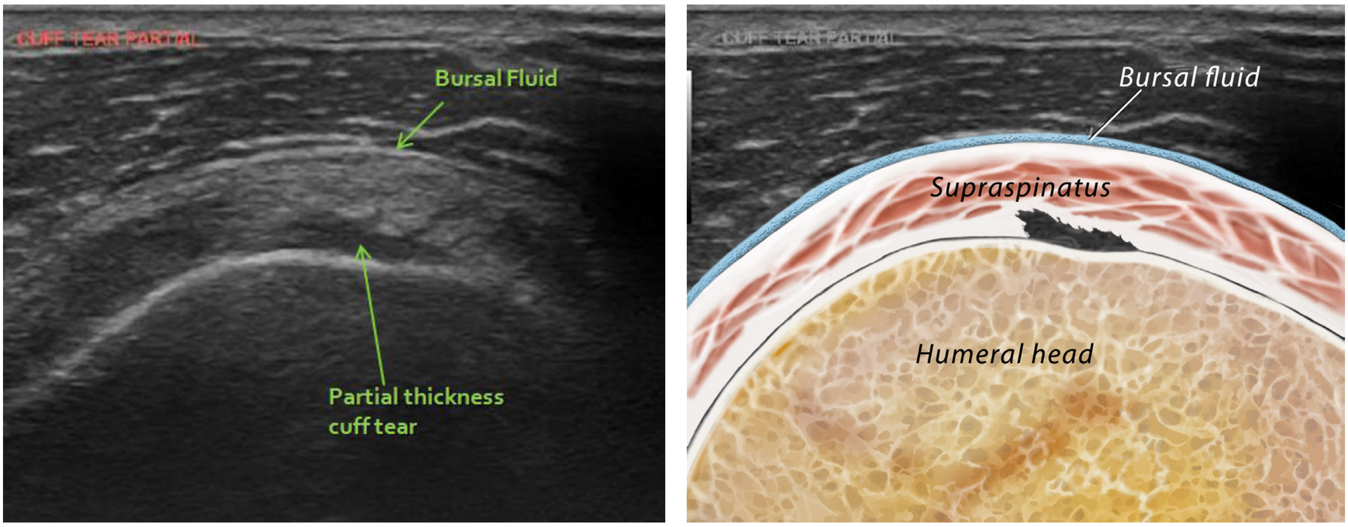


Transverse views of the same 2cm cuff tear. Note the bursal fluid and tendon edges.

Partial Thickness Cuff Tear

Partial thickness rotator cuff tears are more difficult to diagnose than full thickness (complete) tears. They typically occur on the articular side of the cuff in the Supraspinatus tendon. A good quality machine with high frequency probe is essential to detect a partial tear.

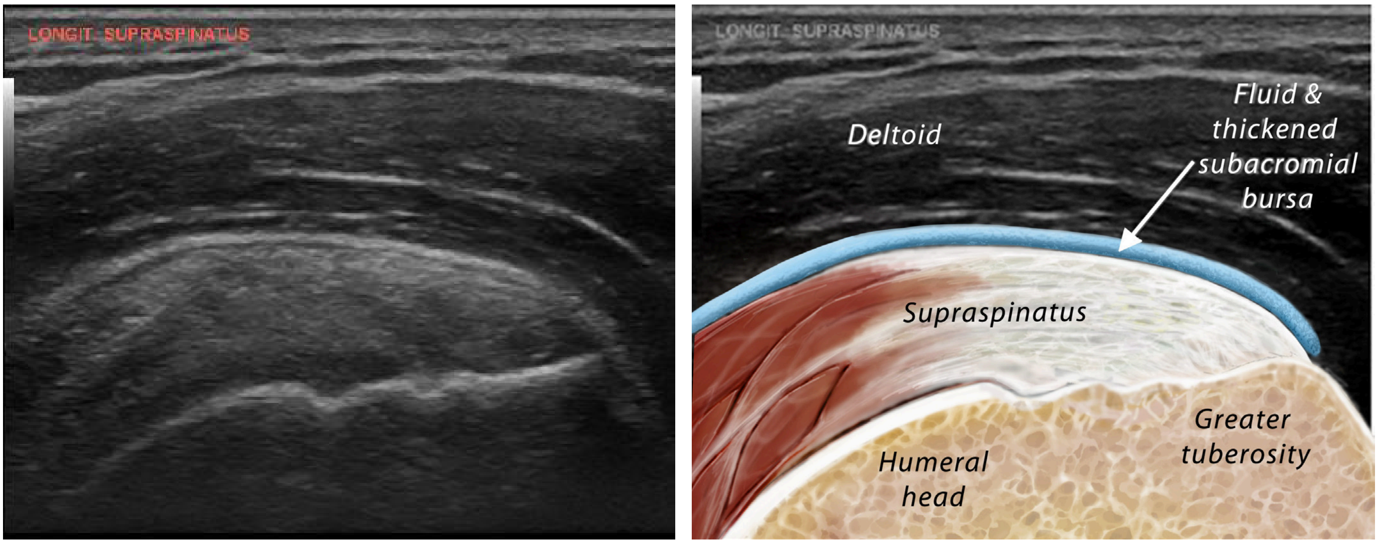
It can be depicted by seeing a hypoechoic extending from the articular side of the Supraspinatus tendon and extending into the tendon. The essential diagnostic criterion is the presence of the hypoechoic area despite anisotropy – i.e. the hypoechoic area does not disappear with rotating the probe in all directions.



Partial thickness tear

Bursitis / Subacromial Impingement

Diagnosed when the bursa is thickened (more than 2 mm thick or clearly asymmetric with the asymptomatic shoulder) and there is excess fluid in the bursa. Cortical irregularity may also be present.



Images showing bursal thickening and fluid. Note cortical irregularity on the second image.

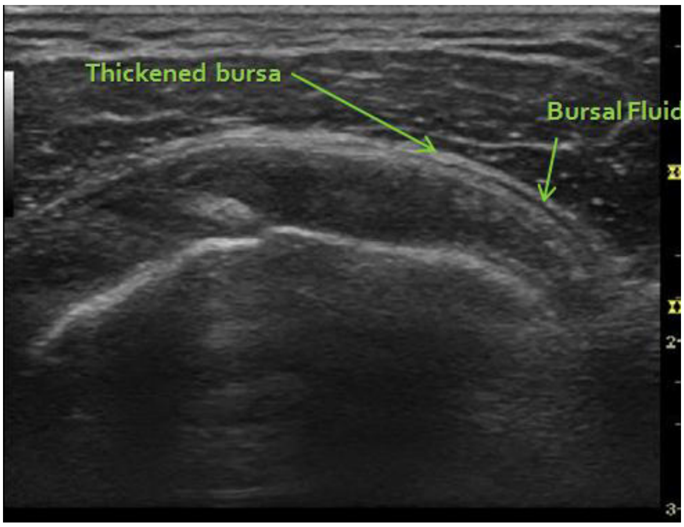
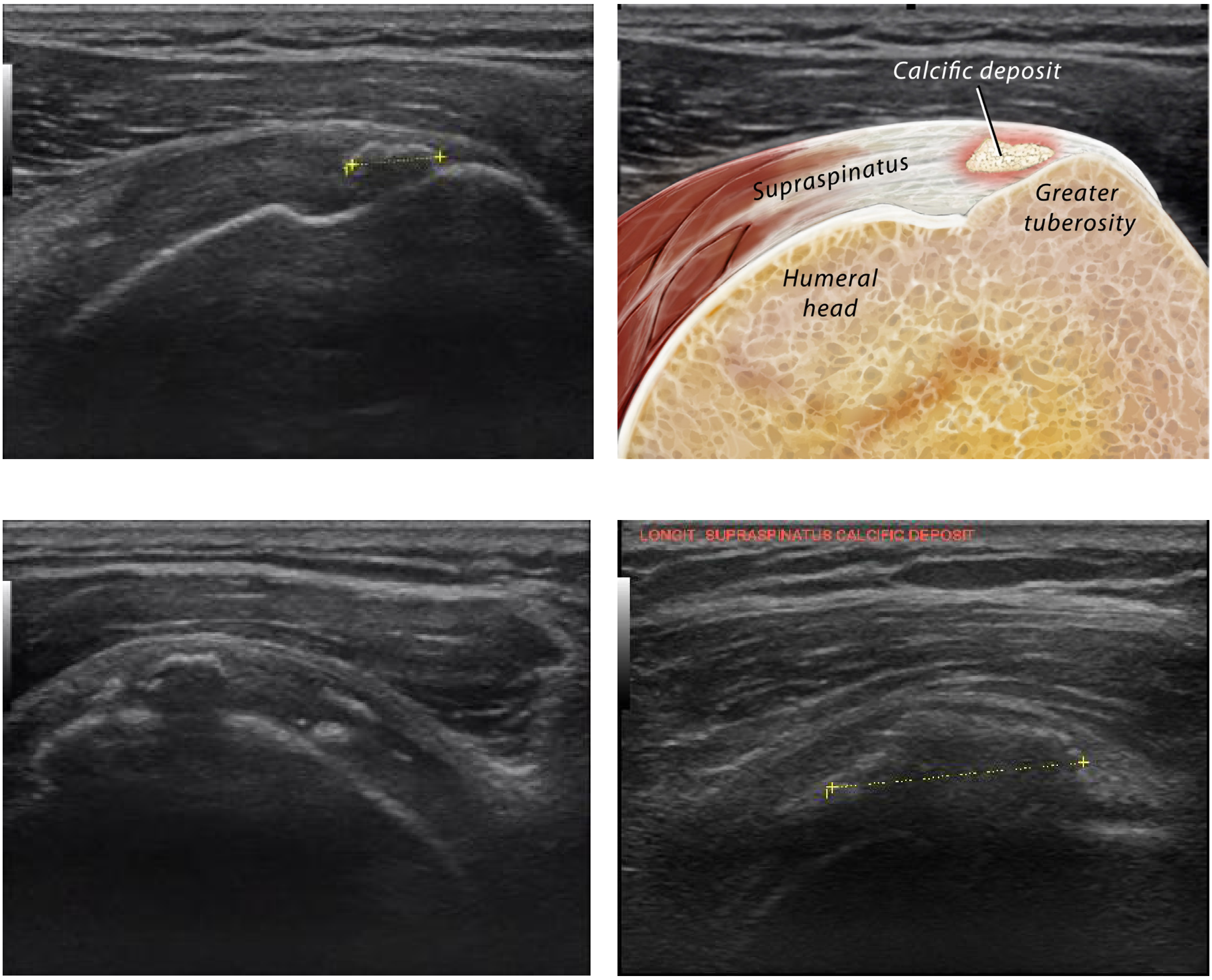


Image showing bursal thickening and fluid with cortical irregularity.

Calcific Tendonitis

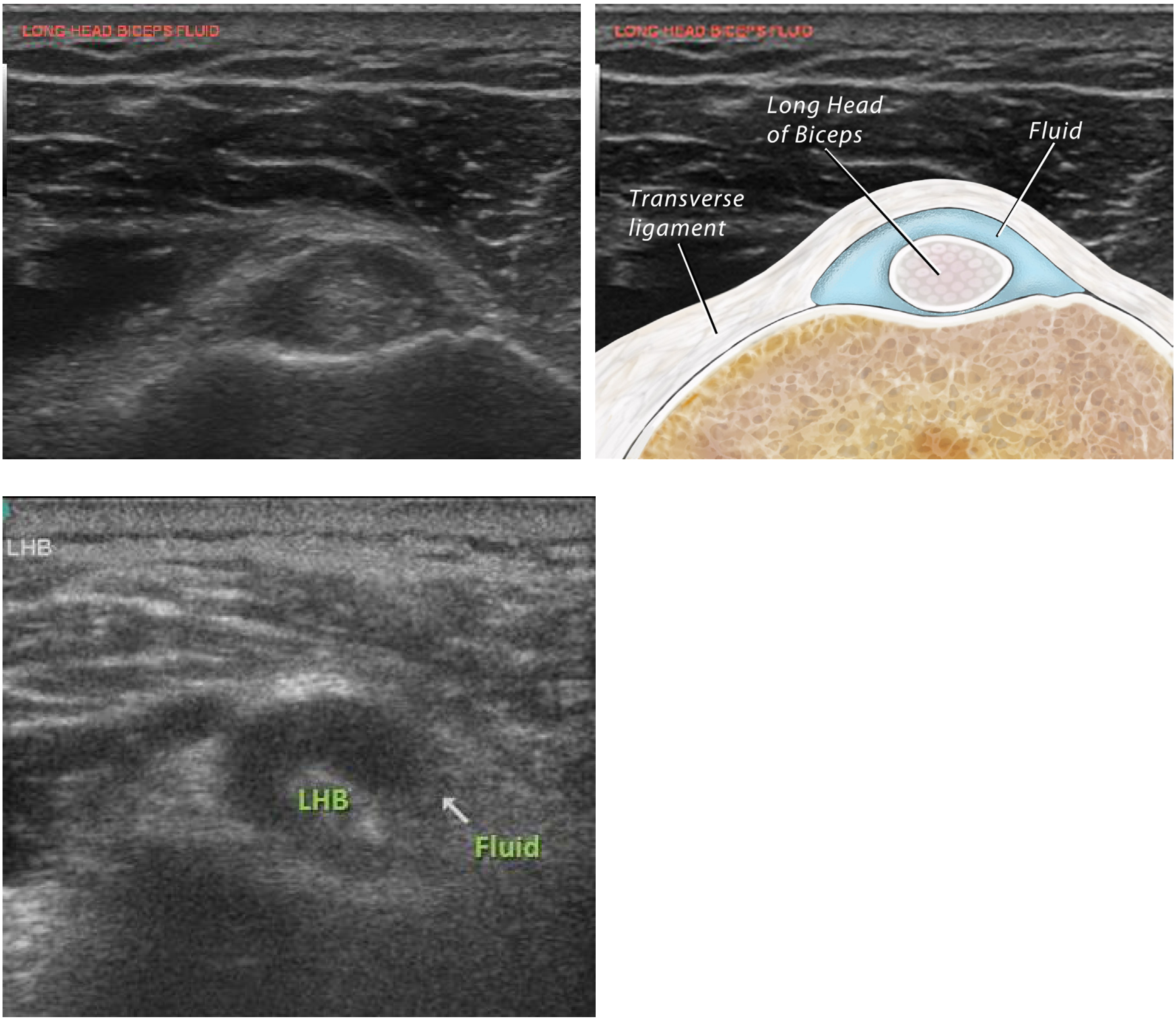
These calcifications are of course almost always seen on the plain films. However, in some cases, they are missed because of their location (subscapularis calcifications) or direction of the x-ray beam. The appearance of the calcifications on ultrasound can predict their action on the symptomatology. Thin, long calcifications are often asymptomatic whereas thick, rounded or irregular calcifications give rise to symptoms. The amount of posterior attenuation can also predict the hardness of the calcifications, eventually helping when arthroscopic removal of the calcium deposits is considered for treatment.



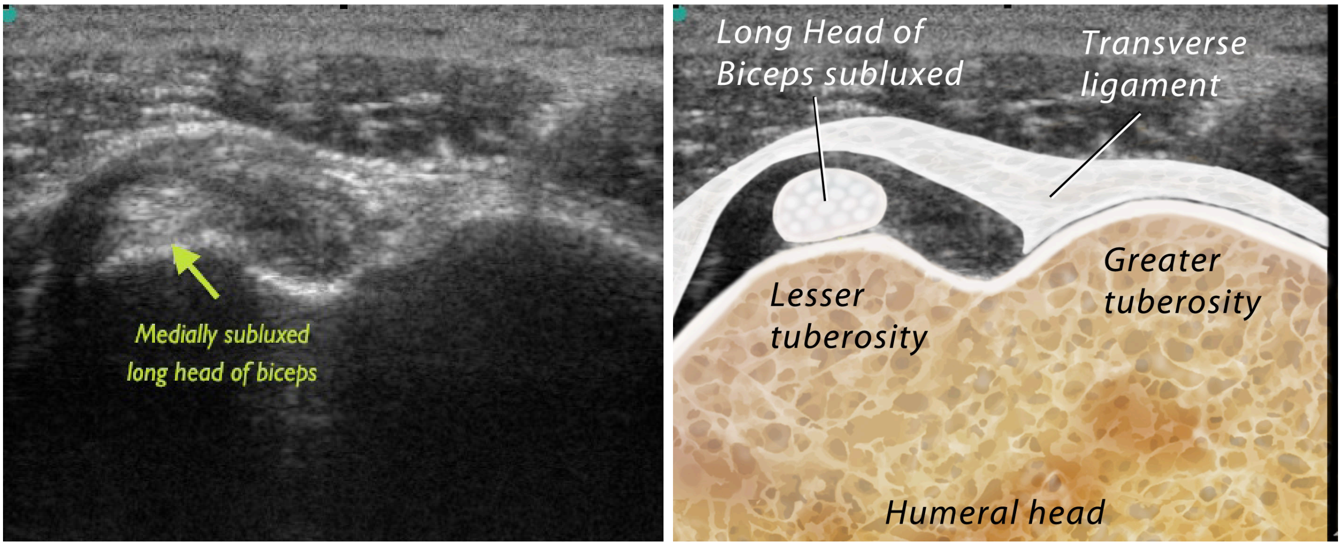
Examples of calcific deposits.

Biceps Pathology

Extra-articular biceps pathology can be seen, such as fluid and inflammation of the sheath. Osteophytes in the biceps groove can be most easily seen on ultrasound, as can a subluxing or dislocated biceps tendon.



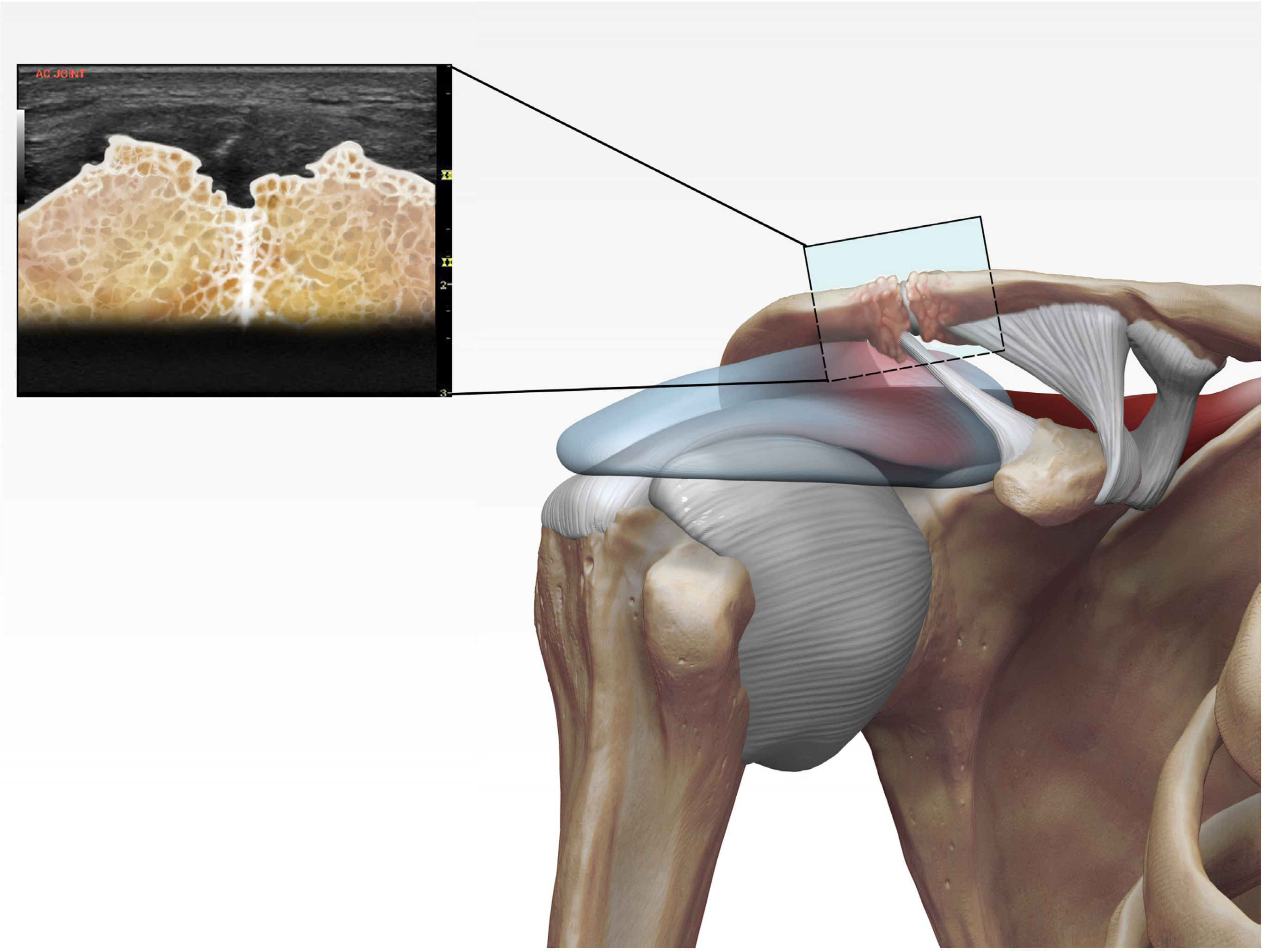
Images showing fluid around the long head of biceps tendon (LHB)



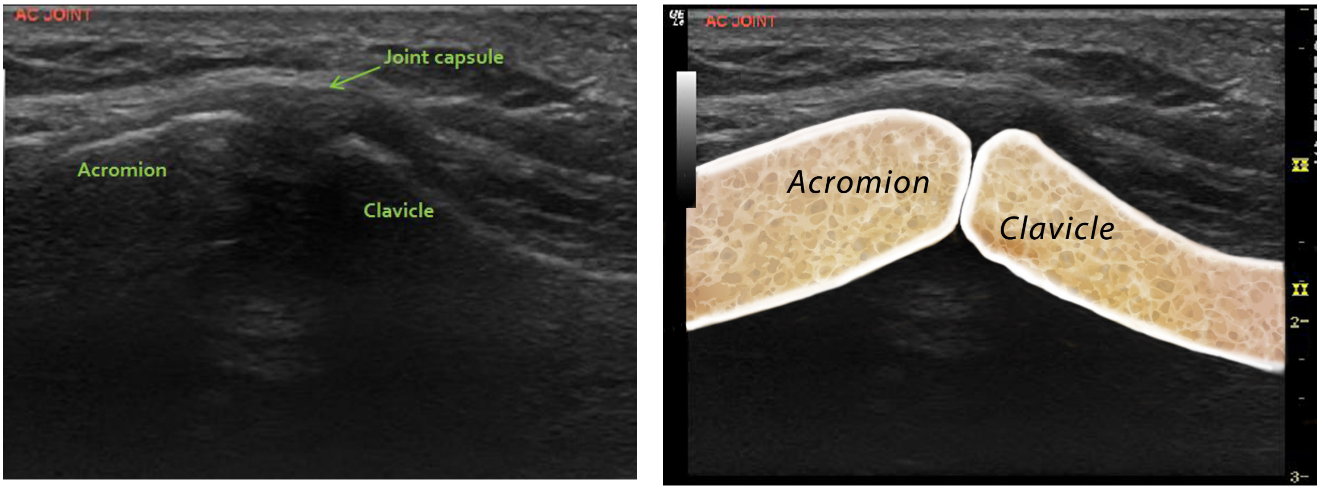
Dislocated LHB (arrow) medial to the biceps groove.

Acromioclavicular Joint

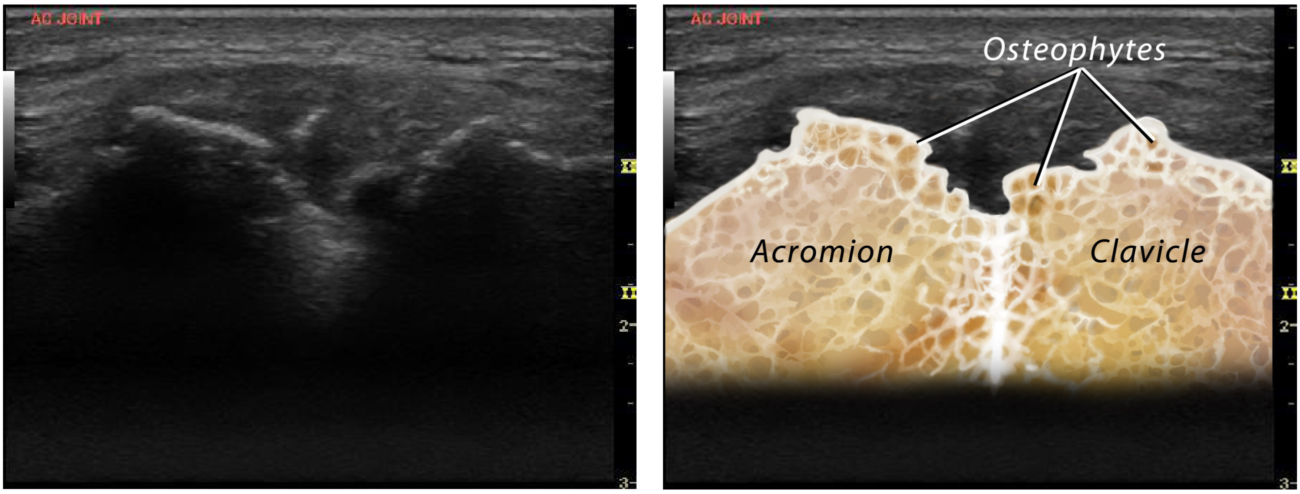
The acromioclavicular (AC) joint can be easily scanned, as it is superficial and easy to identify clinically. Osteophytes of arthritis can be easily seen on the superior surface. Swelling of the joint and capsular thickening can be identified, both signs of inflammation. Osteolysis of the lateral clavicle can be diagnosed as a widened joint.



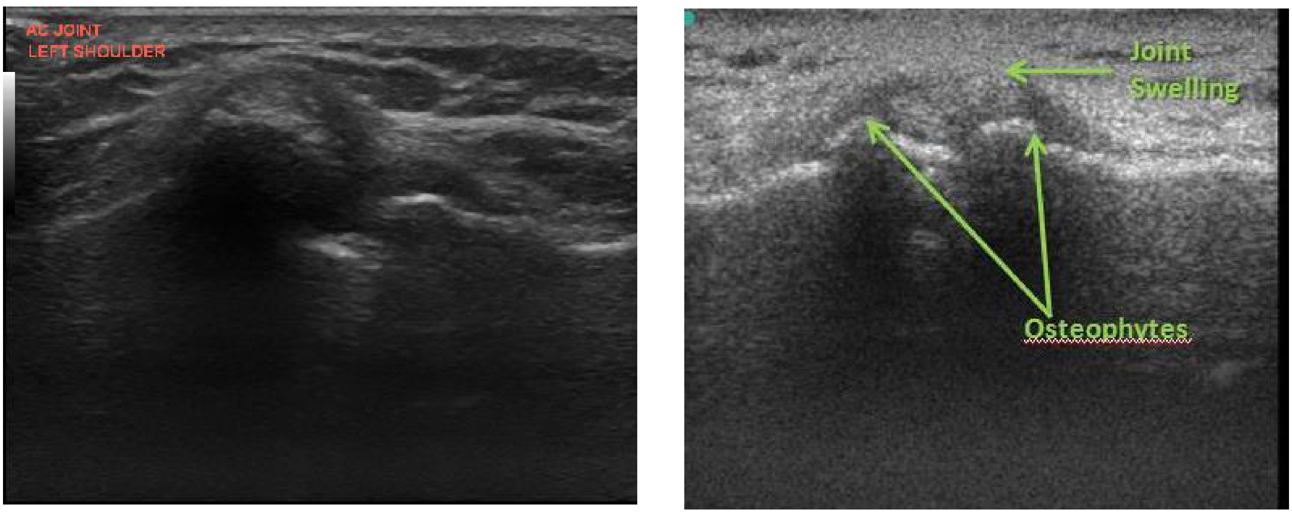
Acromioclavicular joint showing osteophytes of arthritis



Normal AC Joint



Arthritic joint



Two advanced arthritic AC Joints

Other Pathologies

In addition to the pathologies above, many other lesions can be identified with ultrasound. These are less frequently sought with ultrasound as other imaging techniques are preferred.

1. Hill-Sachs Lesion – easily seen and measured at the posterior humeral head.
2. Muscle wasting (atrophy) – the Supraspinatus and Infraspinatus can be statically and dynamically assessed for atrophy in rotator cuff disease or suprascapular nerve entrapments.
3. Bankarts lesion – may be seen scanning via an axillary approach.

Chapter 5: History of Ultrasound Imaging of the Shoulder

Excerpts from Ultrasound Imaging of the Shoulder. Tim Bunker. Seminars in Orthopaedics, Vol2, No 4 (December). 1987: pp 267-276

In 1880, the Curie brothers noted that a potential difference was generated across certain crystals if Pressure was applied to them. They called this the pressure electric effect, or piezo-electric effect. They used this physical phenomenon to both generate and detect high frequency mechanical pressure waves.

In 1916, two pupils of the Curies, Chilowsky and Langevin developed an apparatus using the piezoelectric effect to generate high energy ultrasound waves that could detect underwater obstacles. This was immediately applied by the Navy to the task of detecting submarines. Although the new ultrasound machine could recognize that a submarine was in the vicinity, it could not tell in which direction it lay, a somewhat unnerving experience, no doubt, for the operator! Direction finding had to wait for the technology of World War 2 when both RADAR (Radio Direction And Ranging) and SONAR (Sound Navigation And Ranging) were two of the most closely guarded secrets of the War.

Langevin had also demonstrated that high energy ultrasound passing through this water bath rapidly killed small fish and caused severe pain to the human hand, which made ultrasound even more interesting to the military.

After the war, two US Naval groups, one officially and the other unofficially, started working on the medical implications of ultrasound (Ludwig and Struthers, who detected gall stones in 1949 and Wild's group who investigated the detection of breast and brain tumours with ultrasound).

It was the work of the Denver group that was most important. In 1949, Howry and Bliss developed an apparatus that could detect echoes sent back from tissue interfaces. With remarkable ingenuity, they developed the compound water- bath scanner (Fig 1) using the gun turret of a B29 bomber, filled with water in which the volunteer sat!

This scanner produced excellent pictures of the neck and extremities. However, submerging patients in water baths remained impractical.

Back across the Atlantic, but this time in Glasgow, Scottish Professor Donald was pioneering the use of direct contact scanning. He realised that the full bladder could be used as the water bath, through which the uterus and ovaries could be scanned (Fig 2).

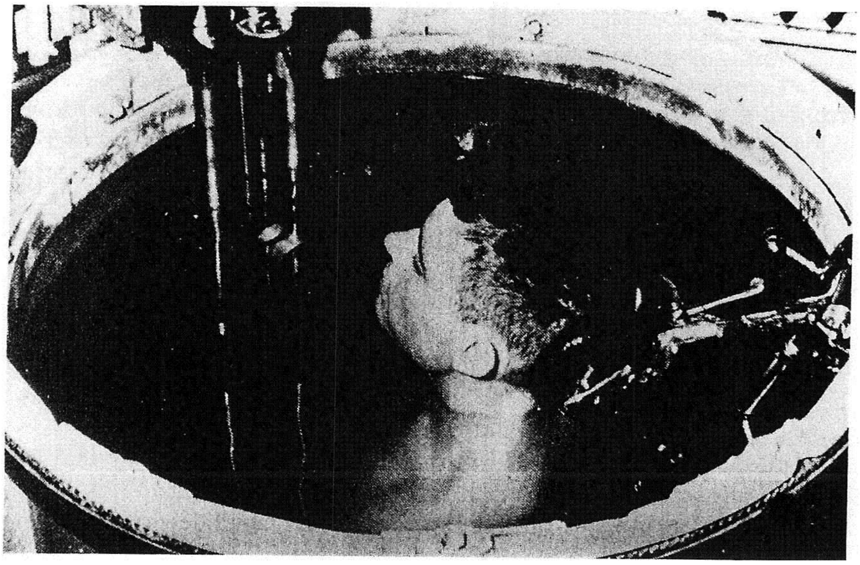


Fig 1 . Howry and Bliss' compound water bath scanner made from a B29 bomber gun turret.

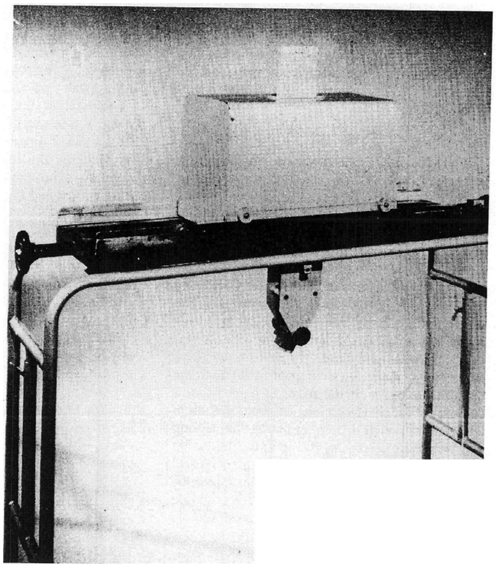


Fig 2. Professor Douglas' original direct contact ultrasound scanner. (Reprinted with permission.)

In 1979 at the Harvard Medical School, Seltzer's team produced grey scale ultrasound images of the shoulders of six rhesus monkeys demonstrating the bony landmarks and muscle structures, and suggesting it is a promising new method of detecting shoulder effusions. Based on this paper, we produced an ultrasound image of the human rotator cuff (mine!) in early October 1984; however, nothing is new in orthopaedics; and in the US, two groups had been working on the same problem for over a year (the Minnesota group, who published their findings on nine rotator cuffs the same month and the St Louis group, who published their findings in 39 patients in 1985. This review was based on our observations on 100 shoulders scanned in 50 patients and volunteers.

Is rotator cuff ultrasound the answer to the surgeon's prayer? Thoughts on this are highly polarised, the continental European school stating that shoulder sonography is a waste of time, whereas the US view is that if sonography detects a rotator cuff tear, then no other form of imaging is necessary. Reality lies between the poles.

What are the advantages and disadvantages of shoulder sonography compared with other methods of imaging, in particular arthrography?

Firstly, ultrasound is non invasive, whereas arthrography is invasive, albeit minimally. Allergic reactions to contrast material, and the possibility of septic arthritis secondary to arthrography are theoretical rather than practical problems. However, exacerbation of shoulder pain may Occur in up to 88% of people after arthrography, the pain being severe in 47% of patients. These problems are not associated with ultrasound, despite Langevin and Chilowsky killing small fish in their water bath, although I have personally experienced a "buzzing" in my shoulder after sessions in excess of half an hour on one shoulder. Because ultrasound is a non-ionising form of radiation, it has been found to be safe, even for repeatedly scanning the human fetus. Shoulder ultrasound scanning can be performed very rapidly. Each shoulder has to be scanned in three directions, and even taking four to five passes with the probe, this only takes five minutes per shoulder. Usually the asymptomatic shoulder is rapidly found to be normal and takes less time to scan, so the whole process can be over in ten minutes, which is far quicker than arthrography, despite being bilateral.

Chapter 6: Shoulder Ultrasound Training for Non-Radiologists

Adapted from the Royal College of Radiologists publication: Ultrasound Training Recommendations for Medical and Surgical Specialties. 2005.

The Royal College of Radiologists have recognised that:

- There are increasing demands for ultrasound services including direct access to facilitate immediate clinical decisions in areas such as 'one-stop' clinics.
- Medical specialists other than radiologists are increasingly wishing to under take ultrasound examinations on patients referred to them for their clinical opinion as a direct extension of their clinical examination.

Ultrasound remains highly operator dependent in spite of advances in technology. All who provide an ultrasound service are ethically and legally vulnerable if they have not been adequately trained. NHS Trusts in the United Kingdom, which provide professional indemnity to practitioners, are unlikely to be able to mount any defence to an action brought against an untrained practitioner. Therefore appropriate ultrasound training is essential before undertaking clinical ultrasound scanning. An appropriate level of training in ultrasound is one that allows for the provision of a safe and effective ultrasound service.

The training of medical non-radiologists should foster relationships between radiological and non radiological sonologists so that mutual support continues beyond the initial training period. Ideally a radiologist would continue to act as a mentor for a medical non-radiologist undertaking ultrasound after their training is completed. In addition regular clinico-radiological meetings should continue in order to ensure an integrated approach to any further imaging that may be required.

A system for recording the results of any ultrasound examination in the patients' record is mandatory. The permanent recording of images, where appropriate, is desirable for the purposes of correlative imaging, future comparison and audit.

Training should be given in departments which have a multidisciplinary (medical, surgical, radiological etc) philosophy, an adequate throughput of work, a radiologist or sonographic practitioner with experience and an interest in training in the module required, appropriate equipment and an active audit process.

Regular appraisal should take place during the training period.

Following training, regular and relevant CME/CPD should be undertaken and documented.

Theoretical Training

Preliminary theoretical training should cover the physics of ultrasound, levels and sophistication of equipment, image recording, reporting, artefacts and the relevance of other imaging modalities to ultrasound. This element of training may be best delivered by linking with some of the excellent courses run by university departments accredited by the Consortium for the Accreditation of Sonographic Education (CASE).

Theory syllabus

This basic theoretical training is a prerequisite to any practical training in ultrasound. This must encompass:

1. Physics and Instrumentation – see Chapter 1
2. Ultrasound Techniques – Chapter 2
3. Knowledge Base
    a. Anatomy in relation to shoulder ultrasound
    b. Pathology in relation to shoulder ultrasound

Practical Training

- For shoulder ultrasound examination by non-radiologists the training should be of a level 1 practitioner, as defined by the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) (see Appendix 1).
- Different trainees will acquire the necessary skills at different rates and the end-point of the training programme should be judged by an assessment of practical competence.
- Examinations should encompass the full range of pathological conditions listed in the modules.
- A logbook listing the number and type of examinations undertaken by the trainee themselves should be kept.
- An illustrated logbook of specific normal and abnormal findings may be appropriate for some modules.
- Training should be supervised by a level 2 practitioner (see Appendix 1). In certain circumstances it may be appropriate to delegate some or most of this supervision to a level 1 practitioner with at least two years experience of level 1 practice.

Practical Training

- Practical training should involve at least one ultrasound list per week for 3-6 months with approximately 10 examinations performed by the trainee under supervision per session.
- A minimum of 250 examinations should be undertaken.
- The end point of the training programme should be judged by an assessment of competencies.
- A log book listing the types and numbers of examinations undertaken should be kept.

- Training should be supervised by an experienced musculo-skeletal sonologist.
- Trainees should attend an appropriate theoretical course and should read appropriate textbooks and literature.

Competencies to be acquired

To be able to:

- Perform a thorough ultrasound examination of the shoulder in different planes.
- Recognise normal ultrasonic anatomy and common normal variants.
- Recognise and be aware of difficulties in distinguishing accurately between tendinosis/ partial-thickness/ complete-thickness tears of the rotator cuff.
- Recognise rotator cuff calcification.
- Recognise tendinosis, rupture and subluxation of the long head of biceps tendon.
- Recognise effusions of the shoulder joint and subdeltoid bursa.
- Recognise abnormalities which need referral to a more experienced ultrasonologist and/or for further investigation.
- Be aware of alternative diagnostic methods including clinical examination and imaging techniques.
- Recognise when to proceed to other imaging examinations following US examination.
- Recognise comparative accuracy of alternative techniques.

Maintenance of skills

Having been assessed as competent to practice there will be a need for CPD and maintenance of practical skills.

Such further ultrasound practice may be intermittent but no more than 3 months should elapse without the practitioner using his/her ultrasound skills and at least 100 examinations should be performed per year.

Practitioners should:

- Include ultrasound in their ongoing CME
- Audit their practice
- Participate in multidisciplinary meetings
- Keep up to date with relevant literature

Shoulder Ultrasound Assessment Sheet

SHOULDER ULTRASOUND SKILLS ASSESSMENT					
Trainer: **Trainee:**					
Date: **Assess No.**					
Case Number					
SHOULDER ULTRASOUND					
Skills	**Assessment**				
	1	**2**	**3**	**4**	**5**
Basic Skills					
Basics					
Physics of ultrasound					
Understanding					
frequencies					
Biological effects					
of ultrasound					
Anisotropy					
Ultrasound safety					
Common artefacts					
Image reporting					
Setting up					
Patient positioning					
Machine settings					
Gain					
Probe selection					
Calliper					
Annotation					
Doppler					

KEY	
Very limited understanding, no previous experience	1
Requires assistance most of the time, limited previous experience	2
Requires assistance some of the time, some previous experience	3
Requires a little assistance, moderate previous experience	4
Requires no assistance, extensive previous experience	5

Demonstrating Pathology							
Skills	**Diagnosis**						**Score (1-5)**
	Intact	**T/osis**	**PTT**	**FTT**	**Ca+**	**Fluid**	
Long head biceps							
short axis							
long axis							
Subscapularis							
short axis							
long axis							
Infraspinatus							
short axis							
long axis							
Supraspinatus							
short axis							
long axis							
Coracoacromial ligament							
Dynamic assesment of impingement							
AC joint							
Comments:							

KEY	
Very limited understanding, no previous experience	1
Requires assistance most of the time, limited previous experience	2
Requires assistance some of the time, some previous experience	3
Requires a little assistance, moderate previous experience	4
Requires no assistance, extensive previous experience	5

Appendix 1

EFSUMB Guidelines

The European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) has proposed minimal training requirements for the practice of medical ultrasound in Europe. These are supported by the Royal College of Radiologists and the British Medical Ultrasound Society. Three levels of minimum training requirements are proposed:

Level 1

Practice at this level would usually require the following abilities:

- to perform common examinations safely and accurately
- to recognise and differentiate normal anatomy and pathology
- to diagnose common abnormalities within certain organ systems
- to recognise when a referral for a second opinion is indicated
- to understand the relationship between ultrasound imaging and other diagnostic imaging techniques

Level 2

Practice at this level would usually require most or all of the following abilities:

- to accept and manage referrals from level I practitioners
- to recognise and correctly diagnose almost all conditions within the relevant organ system
- to perform common non-complex ultrasound guided invasive procedures
- to teach ultrasound to trainees and level I practitioners
- to conduct some research in ultrasound

Level 3

This is an advanced level of practice, which includes some or all of the following abilities:

- to accept tertiary referrals from level 1 and level 2 practitioners
- to perform specialised ultrasound examinations
- to perform advanced ultrasound-guided invasive procedures
- to conduct substantial research in ultrasound
- to teach ultrasound at all levels
- to be aware of and to pursue developments in ultrasound

In the UK this would equate to a consultant radiologist with a subspecialty practice which includes a significant commitment to ultrasound.

ShoulderScan

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SHOULDER ULTRASOUND

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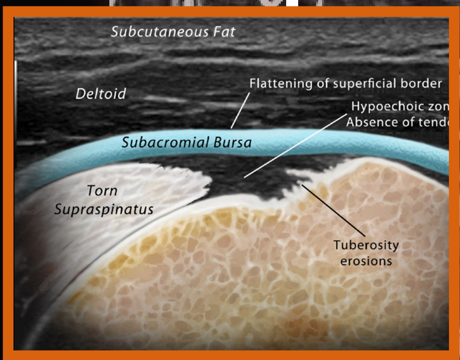

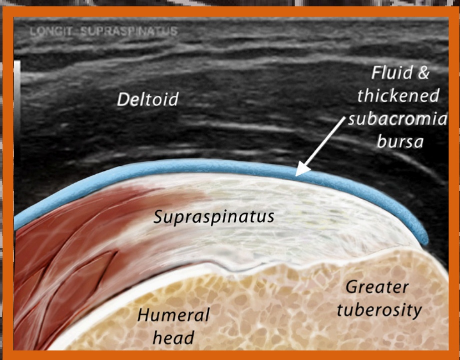

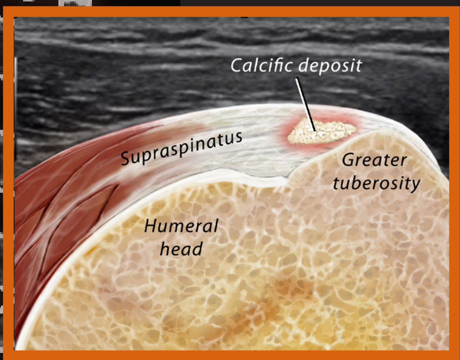

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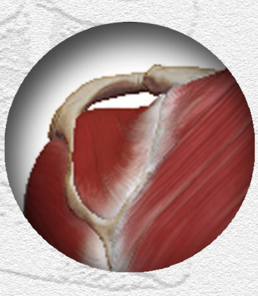

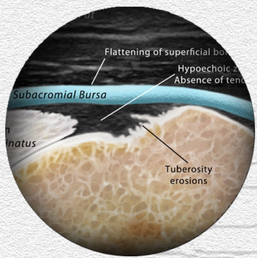

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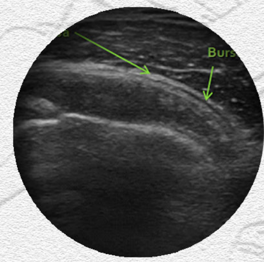

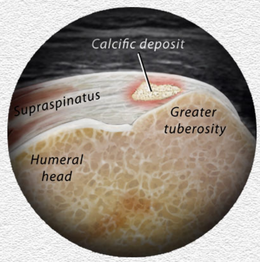

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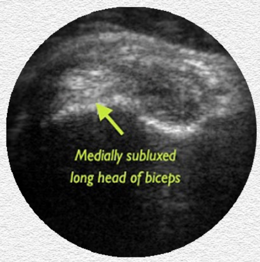

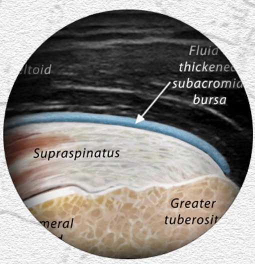

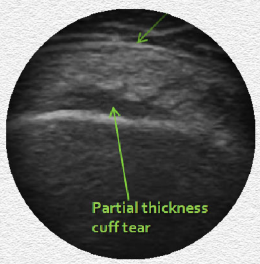

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