Musculoskeletal ultrasound: its current use and its place in the ADF

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Although ultrasound has been used in musculoskeletal medicine for the last 15 years, it has only been in the last five years that dramatic advances in transducer technology have allowed resolution of soft tissue detail to an extent where accurate assessment can be made of the underlying pathology. Current high frequency (10–14 MHz) transducers can resolve to about 0.3 mm. High quality ultrasound assessment requires a detailed knowledge of the anatomy and pathology of the area being examined. The best results are obtained when the clinical setting and other diagnostic and imaging results are available for comparison. This provides a far more clinically relevant report than simply an assessment of the sonographic findings in isolation.

Equipment

Ultrasound is most useful for musculoskeletal diagnosis of structures within 0.5 cm to 3.0 cm of the skin surface. Modern high frequency transducers (in the range of 7.5 MHz to 12 MHz) give optimal spatial and contrast resolution, but are limited by a fairly short depth of view (usually less than 5 cm). The best results can be obtained from broadband devices that produce ultrasound at a range of frequencies, allowing the selection of the optimal frequency for best internal resolution. The transducer should be focused to the level of the structure being studied.

Because tendons and muscles are often superficial and lie in a course parallel to the skin surface, linear array transducers, which produce beams perpendicular to the superfi-

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Synopsis

♦ Recent advances have made ultrasound useful in the diagnosis of soft tissue injury.

♦ In musculoskeletal diagnosis, ultrasound is most useful for structures within 0.5 cm to 3.0 cm of the skin surface.

♦ Successful musculoskeletal ultrasound demands a consistent and meticulous examination technique in the hands of a specially trained operator.

♦ Ultrasound is a real-time examination technique, allowing dynamics of joint and tendon movement to be studied.

♦ Ultrasound is a very cost and time effective alternative to magnetic resonance imaging for the diagnosis of certain conditions.

♦ The small size of ultrasound machines allows some mobility in military operations.

♦ In military medicine, ultrasound is also useful in the diagnosis of abdominal trauma and vascular injury, obstetrics and gynaecology and testicular investigations.

cial structures, are preferred to sector scanners, which generate divergent beams of sound waves that can produce unsharpness in the near field and excessively oblique lateral ultrasound images. These features tend to accentuate anisotropy, one of the main artefacts that can lead to incorrect diagnosis of tears or mucoid degeneration in tendons, where there is loss of the internal echopattern of the tendon simply because of the angle of the ultrasound beam, not because of a true defect in the tendon.

Also vital in the resolution of ultrasonic detail is the number of channels. This is the number of active and electrically independent transmitting and receiving elements within the transducer. Good quality modern transducers will have at least 128 channels.

There are also now modern specialised transducers with a very small footprint (2–3 cm) with an ultra-near field beam thickness, which can offer very good resolution of superfi-

cial structures such as the nerves in the wrist and ligaments around the intercarpal joints of the fingers. The small footprints are also useful for maintaining skin contact around small surfaces without the need of an acoustic stand-off.

The presentation of musculoskeletal ultrasound requires a good imaging chain as well as a good ultrasound machine. The objective is to display a wide variety of ultrasonic signals ranging from the very highly echogenic structures, such as bone, down to very low echogenic structures, such as fluid and synovium. The grey scale setting should be set at a level which displays both at the same time. The dynamic range is also important in the production of the image and this should be set as wide as possible without the introduction of excessive noise.

Examination technique

Successful musculoskeletal ultrasound demands a consistent and meticulous examination technique. Static images are required in both a transverse and longitudinal plane to the structure being imaged. Optimal visualisation of tendons and muscles is usually obtained when the tendon is put slightly on the stretch, so specific positioning is required for each muscle and tendon which is to be examined. All structures must be examined with the ultrasound beam vertically oriented to the structure. Any alteration in the internal echo pattern of a tendon must be carefully viewed to make sure that it does in fact represent pathology and is not simply ultrasound artefact.

A great advantage of ultrasound is the ability to examine

1 Structure of striated muscle
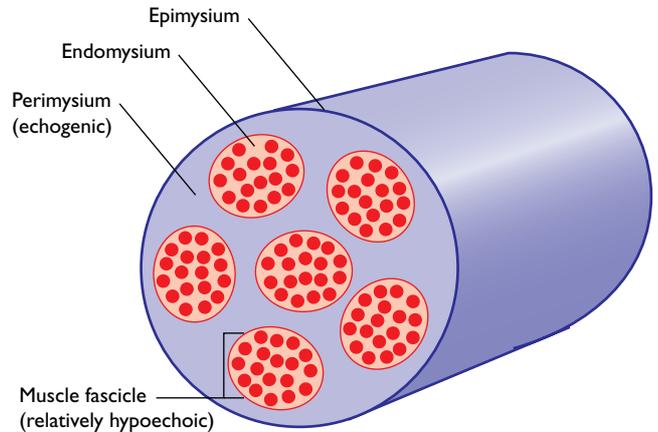
In striated muscle, individual muscle fibres are surrounded by connective tissue, called the endomysium, which provides the pathway for blood and nerves to the muscle fibres. Muscle fibres are arranged in bundles called fascicles. Each fascicle is surrounded by a stronger connective tissue layer, termed the perimysium, which also contains nerves and blood vessels. Each muscle consists of multiple fasciculi.

2 Structure of tendon
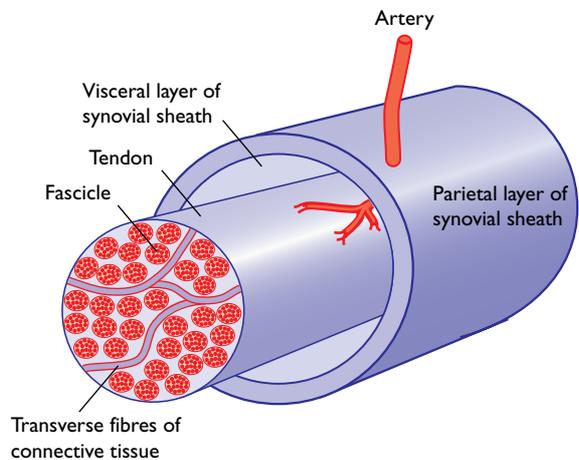
Collagen fibres are grouped together in fascicles, bound together between transverse fibres of connective tissue. The fasciculi are surrounded by loose connective tissue containing blood vessels and nerves. The tendons may be surrounded by a synovial sheath to minimise friction between surrounding tissues, especially adjacent tendons and bones. The synovial sheath consists of an internal (visceral) layer attached to the tendon and an outer (parietal) layer attached to the periostium or other surrounding connective tissue. These two layers are separated by a thin film of synovial fluid.

muscles and tendons in real time, observing their movements and contraction. This adds significantly to the diagnostic accuracy of the test.

Failure to adhere to a meticulous, consistent scan technique is the most common cause for inaccurate or unreliable ultrasonic diagnoses.[1] One of the weaknesses of musculoskeletal ultrasound is its dependence upon a highly skilled and experienced operator to perform the examination.

Structures for ultrasound examination

Muscles

An understanding of the anatomy of the structures being examined is essential to accurate diagnosis. Three types of muscles exist: non-striated muscle (or smooth muscle), cardiac muscle and striated muscle (or skeletal muscle). In ultrasound, almost all muscles being examined are striated muscles (Figure 1). The typical pattern is that of hyperechoic stripes, which represent the perimysium, surrounding hypoechoic stripes, which are the muscle fibres. This produces the characteristic striated appearance when the muscle is examined longitudinally. Contraction of the muscle fibres increases their diameter, thus widening the areas of decreased echogenicity within the muscle and compressing the echogenic perimysium.

Tendons

Tendons are strong cords of fibrous tissue consisting of collagen fibres which are grouped in bundles known as fasciculi (Figure 2).

On ultrasound the parallel series of collagen fibres are hyperechoic, separated by the more hypoechoic surrounding connective tissue, in a pattern similar to that of striated muscle.

Peripheral nerves

The advent of high resolution, small footprint transducers has meant that peripheral nerves can now be reliably assessed where they pass close to the skin surface. Like muscles and tendons, nerve fibres and their supporting fibrous matrix are grouped into fasciculi. These fasciculi can be of a variable size within the individual nerves, and each nerve trunk consists of multiple bundles of fasiculi bound by a thick layer of connective tissue containing fat, lymphatics and blood vessels. On ultrasound, peripheral nerves therefore appear as parallel hyperechoic and hypoechoic lines similar in appearance to, but generally less echogenic than, tendons.[2]

## 3 Normal longitudinal scan of supraspinatus tendon

Note:

- smooth convex upper surface of tendon
- uniform internal echo pattern
- smooth "beak shape" insertion of tendon into the greater tuberosity of the humerus.

This image and the following images were produced using an ATL Ultramark 9 ultrasound machine from ATL in Bothell, USA. The transducer is a 7–10 MHz linear probe.

4 Full thickness tear of supraspinatus tendon
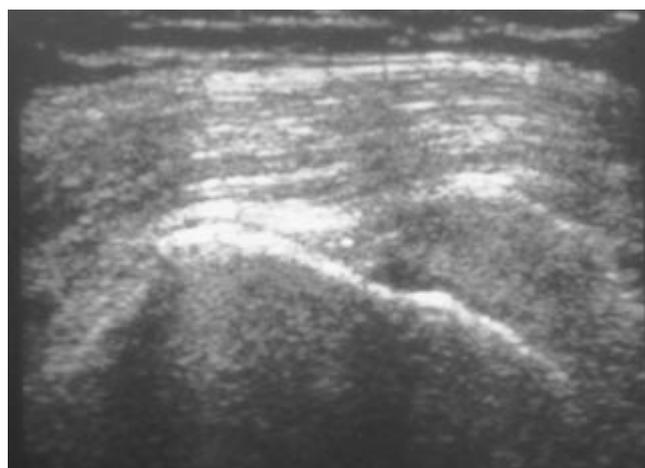
Note;

- sudden change in size of the tendon with loss of "beak" shape
- a few fibres still inserting into the greater tuberosity of the humerus
- fluid in overlying subacromial bursa.

Cartilage

Two main types of cartilage are visualised in the performance of musculoskeletal ultrasound.

Fibrocartilage consists of dense layers of collagen fibres woven in a complex pattern. Fibrocartilage is typically hypoechoic, as demonstrated in the articular discs of the knee, the glenoid and the acetabular labrum.

Hyaline cartilage, which lines the articular surface of bones, has a much lower density of cartilage cells and a homogeneous appearance of decreased echogenicity. It can be well visualised overlying the humeral head in ultrasound of the shoulder. Focal defects in hyaline cartilage can now be quite well visualised with the higher frequency transducers.[3]

Ligaments

Ligaments are composed of dense connective tissue, like tendons, but there is much more variability in the relative amounts of collagen, elastin and even fibrocartilage within them, so they have a much more variable echopattern.

Bone

Detail of the cortical outline of bone can be obtained via ultrasound, and cortical irregularity and pitting are often seen as early signs of degenerative change at tendon insertions (such as supraspinatus into the humeral head). The underlying trabecular structure, however, remains inaccessible because sound waves cannot penetrate dense bone.

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5   Severe partial thickness tear of supraspinatus tendon
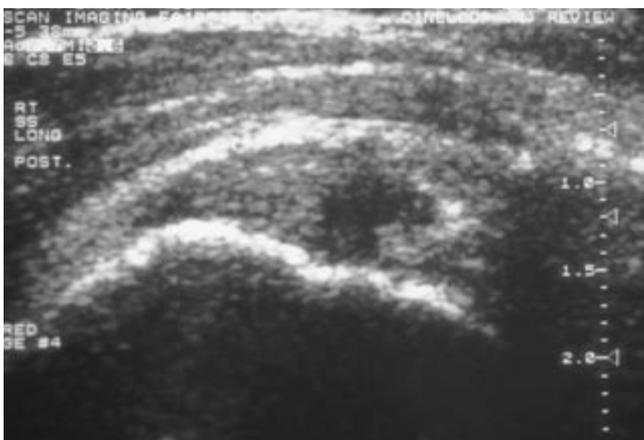
Note:

- superior surface of tendon is still smooth and convex
- focal change to internal echo pattern

Regions suitable for ultrasound examination

Shoulder ultrasound

The shoulder joint is one of the most frequently examined joints in musculoskeletal ultrasound. It lends itself to examination, as, with the exception of the obese or the extremely heavily built patient, it is fairly superficial. Hypermobility is vital to the function of the shoulder, and the ability of ultrasound to examine the shoulder in real time aids significantly in the diagnosis of conditions such as impingement on the joint.

The four main tendons studied in the shoulder are the long head of biceps, supraspinatus (Figure 3), subscapularis and infraspinatus. Assessment is also made of the subdeltoid bursa, the bicipital groove, the articular surface of the humeral head and the base of the greater tuberosity of the humerus as well as the acromioclavicular joint.

Full thickness tears of the supraspinatus tendon are seen on ultrasound as a focal concavity in the superior surface of the tendon (Figure 4). Minor degrees of concavity in the superior surface are a very sensitive indicator of underlying tendon pathology and highlight the need for careful ultrasonic technique. More extensive full thickness tears with retraction of the tendon fibres are seen as hypoechoic clefts within the muscle tendon. The degree of separation can be quite accurately measured on ultrasound. Assessment can also be made of any atrophic change within the muscle belly, which is an important determinant of the likely success of any reparative surgery.[4,5]

Partial thickness tears of the supraspinatus tendon appear as areas of decreased echogenicity within the tendon. They typically commence from the inferior surface of the tendon and extend into the substance of the tendon. In some cases partial thickness tears can appear as hyperechoic areas extending from the inferior surface of the tendon (Figure 5). Careful examination in multiple planes should be performed to make sure that the hypoechoic areas are in fact tears and not simply artefact. The separation of a partial tear from focal tendinitis is often quite difficult on ultrasonic grounds alone, but this is probably not of great clinical significance as the treatment of these two conditions is usually the same.[6]

Ultrasound is very sensitive at demonstrating both tendinous and bursal impingement on the joint. However, the ultrasonic demonstration of impingement does not always correspond with the clinical production of pain, hence the separation of impingement from impingement syndrome.

Generalised tendinitis of the supraspinatus tendon is usually manifested as a thickened tendon with decreased echogenicity, but more severe tendinitis can also be manifested by areas of increased and decreased echogenicity irregularly distributed throughout the tendon.

The long head of biceps can be examined both for tears

and tendinitis. The transverse humeral ligament which binds the tendon within the bicipital groove can be clearly seen on ultrasound and an assessment of subluxation of the tendon can be easily made by dynamic scanning.

Tears or tendinitis involving the subscapularis and infraspinatus tendons as isolated muscles is rare, except in unusual stress upon the shoulder. Injuries to these tendons are usually associated with more extensive tears to the supraspinatus tendon.

Ultrasound of the shoulder in patients who have had previous repairs is technically very difficult unless baseline scans taken in the immediate postoperative period are available. It may be difficult to differentiate small recurrent tears from the appearances created from a partial tendon repair, as the surgical change can produce focal areas of hypoechogenicity identical to that of small recurrent tears. I feel that magnetic resonance imaging (MRI) with gadolinium within the shoulder joint is far more sensitive and specific in the diagnosis of this condition.[7]

Ultrasound of the shoulder is not a good means of assessing labral abnormalities. If a patient is thought to have a superior labrum anterior and posterior component tear, MRI remains the imaging modality of choice. Similarly, although ultrasound can detect fractures or cortical bone irregularities associated with degenerative change, if bony pathology is thought to be the primary diagnosis for the shoulder pain then either plain x-ray films or MRI is the examination of choice. I feel that with the use of x-ray, MRI and ultrasound, arthrography as a means of investigating shoulder pathology now has little or no role to play.[8]

Elbow ultrasound

Ultrasound of the elbow is very sensitive at defining pathology involving the common extensor tendon origin from the lateral epicondyle, in particular distinguishing tendinitis from partial tear or mucoid degeneration. Chondrocalcinosis can also be assessed.

On the lateral aspect, the radial nerve and its two branches can be assessed as it extends across the anterior aspect of the common extensor origin and over the radial head. Signs of nerve entrapment are manifested by alterations in the size of the nerve above and below the level of entrapment.

On the anterior aspect of the elbow joint, the biceps insertion and the brachialis muscle can be assessed for signs of tear or tendinitis and the median nerve is visualised as it travels on the medial aspect of the brachial artery. This is a common site of entrapment as the median nerve passes between the heads of pronator teres. By scanning transversely over the maximum point of tenderness and asking the patient to pronate and supronate their arm, one can sometimes see the nerve being dragged down between the heads of the muscle, the so-called pronator teres syndrome.

On the medial aspect of the elbow joint, the common flexor tendon origin can be assessed. More posteriorly, the ulnar nerve can be assessed as it travels down the medial aspect of the upper arm and passes through the bony groove formed by the olecranon process of the ulna and the medial epicondyle. Subluxation of the nerve from the groove can be easily demonstrated by flexing and extending the elbow while scanning in a transverse plane. Focal variations in the size of the nerve correspond well with clinical symptoms. Small bony spurs or fluid surrounding the nerve can also be visualised. At the distal end of the groove, the nerve can be entrapped by the heads of flexor carpi-ulnaris (the cause of the cubidal tunnel syndrome), which can be demonstrated by dynamic scanning.

Assessment of the ulnar nerve after surgery is very difficult and precise details are required as to what surgical procedure has been performed, in particular where the nerve was transposed. This is a highly specialised examination, requiring considerable experience and practice.

Posterior to the elbow joint, the triceps insertion can be assessed as well as the olecranon bursa.

Wrist ultrasound

The wrist has the advantage for ultrasound examination of being relatively small. Most of the structures are close to the skin surface and dynamic scanning makes identification of the structures much easier. Although MRI remains the gold standard for examination of the wrist, offering superior resolution of soft tissues, bony and cartilaginous structures, ultrasound does provide suitable imaging of certain conditions much more quickly and cheaply.

All the tendons around the wrist can be easily assessed and ultrasound is very sensitive at showing both tendinitis and tears, particularly in relation to conditions such as DeQuervan's tendinitis (Figures 6 and 7). Very accurate assessment can be made of synovial thickening and also of bursitis. Ganglia are well demonstrated on ultrasound and their connection to the underlying joint can sometimes be identified.
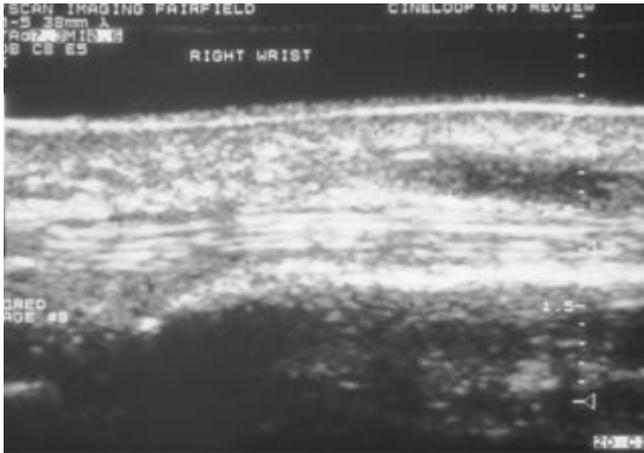
The median nerve is easily identified with modern high frequency transducers as it enters the carpal tunnel superficial to the tendon of the flexor for the index finger (Figure 8). It is seen as a flatter, more hypoechoic structure and can be easily distinguished from the flexor tendon by flexing the index finger.

Carpal tunnel syndrome is usually caused by either increase in the size of the tunnel contents or a decrease in the size of the tunnel itself. The median nerve is forced against the rigid flexor retinaculum, which causes swelling of the nerve. The aims of ultrasound of carpal tunnel syndrome are to quantify the enlargement of the ulnar nerve and to determine the cause of the compression, whether it be tenosynovitis, ganglia, tumours, deformity of the tunnel via trauma or diffuse thickening of all the tissues (as is seen in diabetes or pregnancy).

The advent of small footprint, high resolution transducers with spectacular near field resolution has enabled the examination of the ligaments and tendons of the fingers and carpal bones to be assessed. This is a developing and new role for ultrasound and its role in diagnosis of hand and finger injuries, particularly in comparison with MRI, is still being assessed. Recent studies are producing quite exciting results, but the improved ability of MRI to assess the bony and cartilaginous changes often associated with these injuries will probably see it remain as the imaging method of choice.
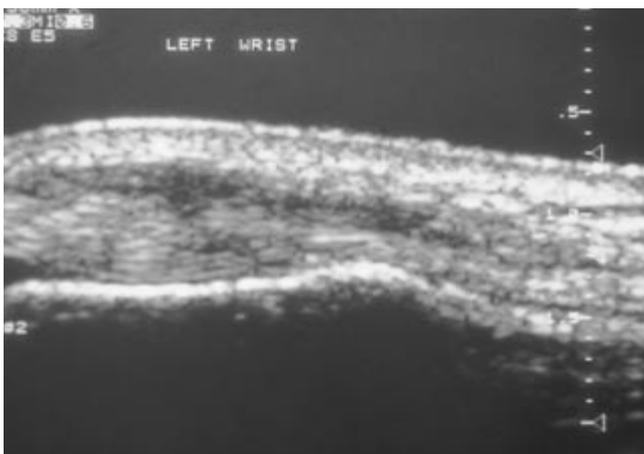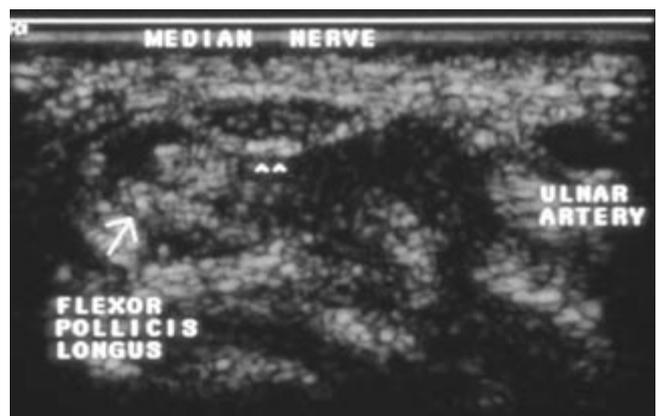
Inguinal region

Musculoskeletal ultrasound has recently been used to accurately assess pathological changes in the region of the inguinal and femoral canals. These areas are well visualised in most patients, with the possible exception of the very obese patient. The vascular anatomy can be clearly identified and the presence or absence of any inguinal lymph nodes or masses can be accurately assessed. The inguinal canal itself is well visualised. Both the internal and external rings can be clearly demonstrated in most patients. By use of the Valsalva manoeuvre, the herniation of either bowel or, more commonly, fat through the inguinal canal can be accurately assessed. The degree of dilatation of the external ring can be measured and an accurate assessment can be made of whether the hernia is direct or indirect. In experienced hands, this method of assessment of hernias has very good surgical correlation.[9]

The presence of femoral hernias can also be accurately assessed, as can the presence of any arterial or venous disease or malformations.

Also seen in the study of the inguinal region are labral cysts arising from a tear to the superior margin of the acetabular labrum. The other cystic structure which can sometimes

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6 Normal abductor pollicis longus tendon

Note:

• uniform thickness of tendon

• normal fibrillar pattern of parallel echogenic lines

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7 DeQuervan's disease with thickened tendons

Note:

• thickened tendon

• fibrils are wider spread, with decreased echoes between them (indicating oedema)

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8 Normal medial nerve

Note:

• median nerve is clearly defined

• nerve fascicles seen as internal echoes

• size can be easily measured for comparison with the other side.

be seen is an iliopsoas bursa. Symphysitis pubis is seen as a thickened, conjoined tendon at adduction origin with irregularity of the underlying cortical bone.

Another use of ultrasound (but not in the Australian Defence Force) is in assessment of congenital dislocation of the hips and dysplastic hips. Ultrasound is the examination of choice, as it is cost-effective, quick and painless, and has been proven over a number of years to have high sensitivity and specificity in the diagnosis of this condition.[10] It is also useful in its ability to grade the severity of the dysplasia and, via real time scanning, to accurately assess the degree of subluxation and laxity. These are important determinants in the choice of appropriate treatment for the child.[10]

The question of groin strain due to muscular injury is more complex. Torn muscles in the inguinal regions have the same appearance as elsewhere in the body. Although complete tears of these muscles can be quite easily visualised, these are unusual, the more common situation being one of chronic strain or partial tear. This is seen as focal areas of increased echogenicity within the muscle bellies, but the depth of the muscle bellies in the inguinal region makes this fairly subtle change more difficult to assess. I feel that MRI still remains the examination of choice if muscle strain is suspected as the cause of the patient's inguinal pain.
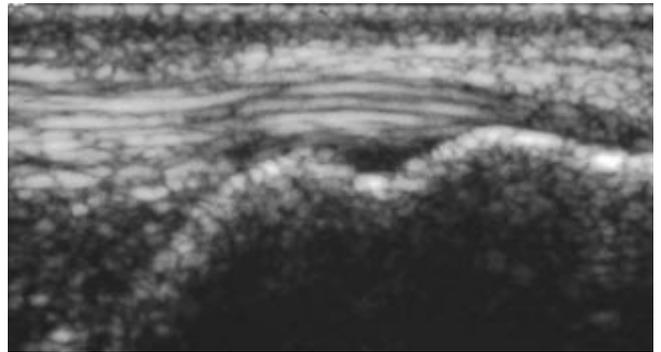
Knee ultrasound

Traditionally ultrasound of the knee has been used for the diagnosis of cystic lesions (such as Baker's cyst between the heads of medial and lateral gastrocnemius) and aneurysms of the popliteal artery. More recently, improved resolution of the transducers has allowed accurate examination of the quadriceps tendon and its musculotendinous junction as well as the insertion of the superior pole of the patella. The patellar tendon itself can be well seen, as can both the medial and lateral collateral ligaments, and the iliotibial tract. Tears, partial tears and tendinitis of these structures have characteristic appearances. The presence of an effusion can also be assessed, as can synovial disease such as rheumatoid and synovial osteochondromatosis.

Although there are many reports describing tears of the cruciate ligaments on ultrasound,[11] my experience is that, with the exception of the very slim patient or those patients with an effusion in their knee joint, it is extremely difficult to see the cruciate ligaments. I feel that ultrasound plays no role in the imaging assessment of the cruciate ligaments. This is best performed by MRI, where there is considerable specificity and sensitivity.[12-14]

Similarly, the assessment of the menisci is best performed by MRI. Although the outer portions of both the medial and lateral menisci can be seen on ultrasound, the deeper portions of the menisci are not reliably visualised. MRI also remains the imaging method of choice for the assessment of

9   Normal Achilles tendon

Note:
- typical features of a normal tendon, with smooth margins and uniform fibrillar pattern internally

bone and cartilaginous disease within the knee. Some portions of the articular surface can be seen quite well on ultrasound, and osteoarthritic change together with osteochondral defects are seen, but the deeper portions of the cartilage remain unreliably visualised. Bone bruises and contusions are usually not visualised on ultrasound, but are seen very clearly with MRI.

Foot and ankle ultrasound

As most of the soft tissues of the foot and ankle are superficial and the tendons are parallel to the skin surface, it is an ideal area to be examined by ultrasound. The exception to this is where the tendons bend around the medial and lateral malleoli: failure to have the transducer at right angles to the tendon in these locations can produce anisotropic effects with false diagnosis of tendinitis and tear, but careful technique in these regions should avoid this pitfall.

The two major lateral tendons, the peroneus longus and brevis, travel together behind the lateral malleolus. The peroneus brevis is the more anterior and superior of the two. The superior and inferior retinaculum stabilise these tendons at the ankle joint and can also be identified. The ability for dynamic scanning allows ultrasound to diagnose not only the tear, but also any subluxation which may occur if there is an associated retinacular disruption.

The medial tendons (tibialis posterior, flexor digitorum longus and flexor hallucis longus) can all be well visualised and show the typical ultrasonic features of tendinitis, partial tear and complete tear. It should be noted that fluid within the tendon sheath of the flexor hallucis longus can be a normal finding due to its communication with the ankle joint in about 15% of people.

The tendons anterior to the ankle joint are also well visu-

alised as they pass beneath the extensor retinaculum. It is usually only gross injury that causes rupture of these tendons. More commonly the presentation is one of overuse tendinitis. Tibialis anterior is the most commonly involved. The extensor digitorum or peroneus tertius tendons are rarely injured.
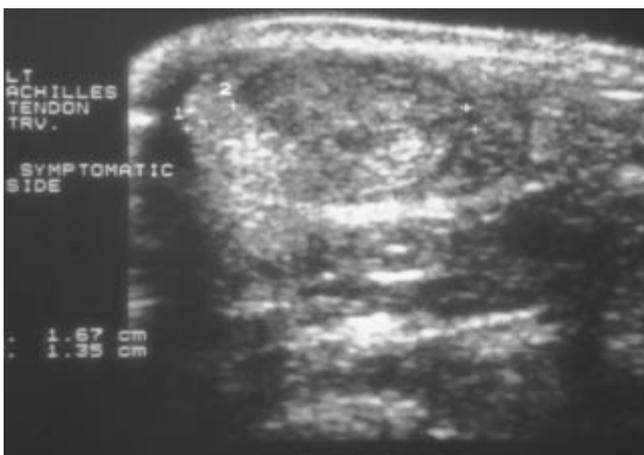
10 Longitudinal scan of partial thickness tear to the Achilles tendon
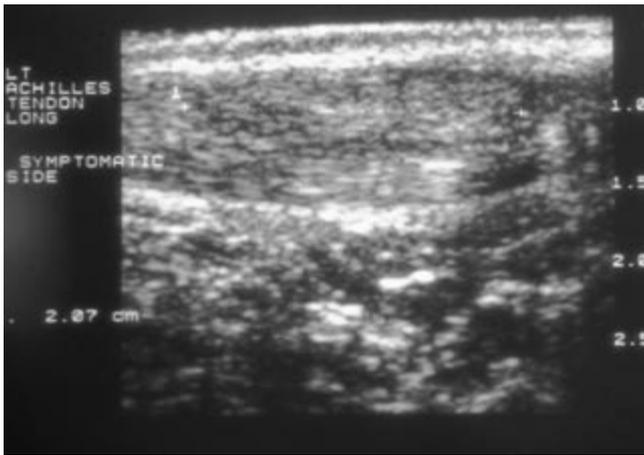
Note:
- focal disturbance to the fibrillar pattern at the site of the tear. The size of the tear can easily be measured.

11 Transverse scan of a partial thickness tear to the Achilles tendon

Note:
- transverse scans show a cross-sectional appreciation of the percentage of tendon involved in the tear and its position within the tendon.

In the forefoot, ultrasound is the imaging method of choice for examination of Morton's neuroma, which appears as hypoechoic mass lesions between the metatarsal heads. Sonographic sensitivity is markedly increased if the web space is evaluated from above while pressure is applied to the sole of the foot between the metatarsal heads. Sometimes the size of the neuroma is overestimated by ultrasound because of coexisting thickening of the intermetatarsophalangeal bursa and the adjacent connective tissue, but sensitivities and specificities of well over 95% can now be reliably obtained by experienced operators using high resolution transducers.

Plantar fasciitis can also be accurately assessed using ultrasound, which can also be used to quantify improvement with treatment.

The region of the sinus tarsi and the deep structures of the foot, together with the bony and cartilaginous structures of the tarsal bones, are still best assessed by MRI.

One of the great success stories of musculoskeletal ultrasound has been the assessment of the Achilles tendon (Figure 9). Ultrasound is now the imaging method of choice for assessment of both acute and chronic tears to the Achilles tendon, where it can with great sensitivity and specificity separate tendinitis from partial tear and quantify the exact portion of the tendon involved in a tear. It is also of use in postoperative assessment (Figures 10 and 11). The real time dynamic nature of ultrasound gives it significant advantages over MRI in the assessment of the Achilles tendon. Assessment can also be made of the bursae typically above and beneath the distal portion of the tendon (Figure 12).

12 Achilles bursitis
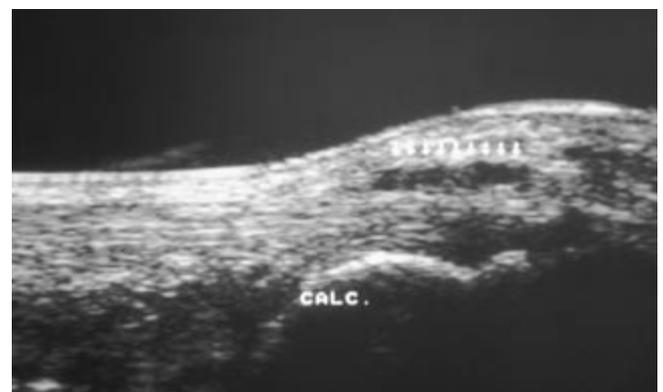
Note:
- the distended bursa is seen as the echo-free elliptical structure above the distal achilles tendon.

The leg

It is not unusual in our practice to have patients referred for assessment of a possible deep venous thrombosis within the leg, suspected on the basis of pain and swelling, and then to find instead a tear of medial or lateral gastrocnemius or the soleus muscle.

Role of musculoskeletal ultrasound in the ADF during peacetime

The recent developments in musculoskeletal ultrasound have added a cost-effective dynamic method of scanning to be brought to the diagnostic procedures of musculoskeletal medicine. It requires highly skilled operators with considerable experience using the correct equipment to get the right results. Only certain conditions are appropriate for musculoskeletal ultrasound, but in those circumstances it provides a sensitivity and specificity that compares favourably with MRI as well as having the significant advantage of a dynamic study.[3]

It is important for all referring practitioners to carefully assess the quality and specialty interest of their radiology practice before they refer patients. I would also strongly suggest a referrer check with the radiologist to make sure that ultrasound, and not another imaging modality, is the appropriate examination of choice. Given the right indications, ultrasound provides a very cost effective and very quick method of examination.

Musculoskeletal ultrasound in a combat environment

The equipment and expertise required for musculoskeletal ultrasound is inappropriate for the front line in an operational environment.

The role, however, in a level 3 or level 4 facility is more complex and difficult to answer. One of the big disadvantages of musculoskeletal ultrasound in this situation is that it requires highly skilled and experienced operators and high quality equipment. Neither of these may be available at a level 3 facility, but are more likely to be present at a level 4 facility.

However, there are other uses of ultrasound in operational environments, such as the assessment of blunt abdominal trauma, particularly to the liver, spleen and kidneys. It is useful in assessing pelvic and gynaecological conditions, and arterial and venous injuries. It also has a role to play in interventional medicine, particularly the drainage of abscesses, fluid collections and the assessment of the presence of foreign bodies. When all these roles are combined with the capability for musculoskeletal ultrasound, then I feel there is a place for an ultrasonologist with appropriate expertise, training and good equipment in a level 3 or level 4 facility.

References

1. Read JW. The basics of musculoskeletal ultrasound. *Bull Aust Soc Ultrason Med* 1998; 1: 5-9.
2. Lisle D. Tissue characterisation musculoskeletal ultrasound. *Bull Aust Soc Ultrason Med* 1998; 1: 11-13.
3. Erickson SJ. High resolution imaging of the musculoskeletal system. *Radiology* 1997; 205: 593-618.
4. Weiner SN, Seitz WH. Sonography of the shoulder in patients with tears of the rotator cuff: accuracy and value for selecting surgical options. *AJR Am J Roentgenol* 1993; 160: 103-110.
5. Hodler J, Fretz CJ, Terrier F, Gerver C. Rotator cuff tears — correlation of sonographic and surgical findings. *Radiology* 1988; 169: 791-794.
6. Van Holsbeeck MT, Kolowich PA, Eyler WR. Ultrasound detection of partial thickness tears of the rotator cuff. *Radiology* 1995; 197: 443-446.
7. Beltran J, Bencardino J, Mellado J. MR arthography of the shoulder: variants and pitfalls. *Radiographics* 1997; 17: 1412-1415.
8. Sonnabend DH, Hughes JS, Giuffre BM, Farrell R. The clinical role of shoulder ultrasound. *Aust N Z J Surg* 1997; 76: 630-633.
9. James P. Femoral and inguinal anatomy. *Bull Aust Soc Ultrason Med* 1998; 1: 24-25.
10. Rosendahl K, Markestad T, Lie RT, et al. Cost effectiveness of alternative screening strategies for developmental dysplasia of the hip. *Arch Paediatr Adolesc Med* 1995; 149: 643-648.
11. Ptasznik R, Feller J, Bartlett J, et al. The value of sonography in the diagnosis of traumatic rupture of the anterior cruciate ligament of the knee. *AJR Am J Roentgenol* 1995; 164: 1461-1463.
12. Sonin AH, Fitzgerald SW, Hoff FL, et al. MR imaging of posterior cruciate ligament: normal, abnormal and associated injury patterns. *Radiographics* 1995; 15: 551-561.
13. Barry KP, Mesgarzadeh M, Triolo J, et al. Accuracy of MRI patterns in evaluating anterior cruciate ligament tears. *Skeletal Radiol* 1996; 25: 365-370.
14. Maurer EJ, Kaplan PA, Dussault RG, et al. Acutely injured knee: effect of MR imaging on diagnostic and therapeutic decisions. *Radiology* 1997; 204: 799-805.

Further reading

◆ Fornage B, editor. Musculoskeletal ultrasound. New York: Churchill Livingstone, 1995: 234-237.
◆ Van Holsbeeck MT, Introcaso JH. Musculoskeletal ultrasound. St Louis: Mosby, 1991: Chapter 4, 57-86.
◆ Steiler M. Ultrasound of shoulder impingement. *Bull Aust Soc Ultrason Med* 1998; 1: 16-17.
◆ Simmons N. Ultrasound of the wrist. *Bull Aust Soc Ultrason Med* 1998; 1: 14-15. ❏