Ultrasound of musculoskeletal trauma

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Introduction
Dynamic ultrasound (US) assessment of musculoskeletal injuries is usually performed in the subacute setting. Ultrasound is used to evaluate the joints and periarticular soft tissues in patients presenting with pain, swelling, instability or functional loss. Referral indications predominantly involve injury to muscles, tendons, ligaments and subcutaneous tissues. Detection of foreign bodies, demonstration of occult fractures and assessment of chronic complications of trauma are also important.¹

Ultrasound is well tolerated across the patient population and is particularly useful in children and in patients with metallic hardware in situ or those with absolute or relative contra-indications to magnetic resonance imaging (MRI).¹ Sonographic assessment is quick, with no radiation burden or need for sedation or general anaesthetic. During the dynamic examination, the operator can discuss the injury mechanism and observe active and passive movement of joints, ligaments and muscle-tendon complexes in order to obtain functional information.

Technological advances and the wide availability of high frequency (9-17 MHz) and small footprint (hockey-stick) linear transducers have brought US to the forefront of musculoskeletal imaging. The spatial resolution of US is superior to MRI allowing exquisite depiction of the internal architecture of tendons, ligaments, muscles and other superficial soft tissues.² US and MRI are complementary – US is often used as the first line investigation with subsequent MRI where lesions are large, deep, diffuse or difficult to fully evaluate with US. While performing the examination it is important to switch US transducer according to the depth of the structure being evaluated. Copious US jelly is required, especially to utilise extended field of view capabilities, to demonstrate entire muscles from proximal origin to distal insertion. Pressure with the probe must be minimised in order to avoid compressing fluid collections or areas of hypervascularity that occur following injury. Structures should be moved for dynamic functional assessment and comparison with the normal side is extremely helpful. This article discusses the sonographic appearance of commonly encountered musculoskeletal injuries.

Subcutaneous tissue injury
Normal skin and subcutaneous tissues
Subcutaneous tissue consists of hypoechoic fat lobules separated by reflective strands of connective tissue septa. Hypoechoic muscle fibres are bound into fascicles by loose connective tissue, forming a featherlike appearance, as hyperechoic fibro-adipose septa converge on the reflective internal aponeuroses. These layers are separated by the superficial and deep muscle fasciae which are closely apposed and appear as a hyperechoic band.

Fat layer trauma
A contusion of fat occurs following a direct blow. Haemorrhagic infiltration appears diffusely echogenic effecting the difference between the dark fat lobules and bright septa. With time, a contusion can progress to fat necrosis. Well-circumscribed areas of hypoechoic infarcted fat are seen, initially surrounded by anechoic oedema, then an ill-defined echogenic rim of fibrosis. Fat fracture occurs with blunt trauma or a shearing force and a fluid filled gap is seen reflecting the plane of force (figure 1).

Haematoma
A haematoma is a subcutaneous collection of blood, the appearance of which varies over time. When acute it contains fresh blood, plasma and fibrin, is of increased echogenicity and may appear pseudo-solid. It becomes anechoic and enlarges after approximately 48 hours as the clot liquefies. By two weeks, multiple thin fibrin strands develop as the clot starts to organise. A haematoma may take several months to resolve, often leaving an echogenic fibrous scar (figure 2).

Muscle-tendon-bone complex
In general skeletal muscles attach to bone via a tendon forming the muscle-tendon-bone complex. The site of injury varies with age, skeletal maturity and type of sporting activity (figure 3).

Figure 3

Traumatic muscle injury
Extrinsic or compressive trauma
Extrinsic muscle injury is common in contact sports and involves a compressive force. The injury occurs at the site of blunt trauma as a result of compression of the muscle against the underlying bone. These injuries are most common in the lower limb. The severity of the injury is proportional to the force and may include contusion, haematoma, muscle tear or complete transection.¹

Intrinsic or distraction injury
Distraction type injuries occur with forced muscle contraction and are common in running sports requiring sudden acceleration, weightlifters and gymnasts.¹ Injury results from sudden eccentric contraction while the muscle is being lengthened during activity. Predisposing factors that increase risk of this type of injury include: muscle origin and insertion across two joints, eg rectus femoris, biceps femoris and medial gastrocnemius muscles; perform eccentric contraction and have a high percentage of fast twitch, type II muscle...
fibres used in rapid acceleration. The injury occurs at the myotendinous junction or along internal aponeuroses. There may be a strain injury, partial tear or complete muscle rupture. Diagnostic accuracy of injury extent is best when the US is performed 48-72 hours after traumatic insult, allowing haemorrhage to become anechoic, increasing conspicuity, and before clot organisation and fibrotic repair starts to occur. Power Doppler may also help by showing hypervascularity around torn muscle fibres.

**Muscle injury classification**

Muscle injuries can be graded by their sonographic appearance. Grade 1 strain or elongation injury has subtle findings on US, muscle enlargement with ill-defined hypo or hyperechoic intramuscular areas or swollen aponeuroses. Grade 2 partial muscle tears involve between 5 to 50% of muscle volume or cross sectional area. Grade 3 is complete muscle tear with retraction and functional loss.

**Apophyseal injuries**

In children and adolescents the weakest link in the muscle-tendon-bone complex is the attachment of the tendon to nonossified cartilage at the apophysis.

**Acute apophyseal injuries**

Sudden acute injury occurs with violent traction tension applied to apophysis from sudden muscle contraction. The apophysis can partially or completely detach, occasionally with complete functional loss. These injuries are most common in the adolescent pelvis and the majority involve the ischial tuberosity, anterior inferior iliac spine (AIIS) or anterior superior iliac spine (ASIS).

**Chronic traction apophysitis**

Chronic overuse injuries result from repetitive traction trauma on the attachment of the tendon to the apophysis, with no time for recovery from the insult before it happens again. This leads to progressive insertional tendinopathy and microtears within the cartilage, progressing to osteochondral fragmentation. The knee is the most common site for traction apophysitis in adolescents, with Osgood-Schlatter’s occurring at the distal patella tendon insertion on the tibial tuberosity apophysis and Sinding-Larsen Johansson syndrome at the proximal origin of the tendon from the patella.

**Tendon injury**

These injuries occur once the apophysis has fused, frequently in older adults and acute tears are common in racquet sports.

**Chronic tendon injury**

Normal tendons have a fibrillar internal appearance with multiple linear, parallel echogenic interfaces, best appreciated when the US probe is perpendicular to the tendon. Anisotropy is signal drop off when the tendon is no longer perpendicular to the linear transducer but has a slightly oblique angle of incidence. This can mimic a tear but is overcome by changing the angle of the probe back to perpendicular. Repetitive abnormal overload of a tendon may result in inflammation of the sheath or paratenon, internal degeneration or both in combination. This is a common injury especially in distance runners; the Achilles is the most commonly affected tendon in the body. Internal myxoid degeneration or tendinosis causes swelling and hypoechogenicity of the tendon and disruption of the normal fibrillar pattern. There may be internal cystic areas, partial thickness tearing and internal neovascularisation within the tendon. Chronic tendinopathy predisposes the tendon to partial or full thickness tears.

**Acute tendon injury**

Acute injury results in partial or full thickness tears that almost exclusively occur in tendons that are abnormal and tendinopathic. Partial thickness tears demonstrate incomplete disruption of tendon fibres and often extend to the tendon surface. Complete, full thickness tears involve the entire cross section of the tendon with retraction and a tendon gap filled with haematoma and debris. An initial scan may show a fluid filled defect, or compression may be required to demonstrate tendon gap and free ends. As with other injuries, scanning in the 48-72 hour post injury time frame is optimal. It is important to move the tendon to see whether the free ends can be made to oppose as these may be treated by conservative measures. If a gap persists, surgical repair is often necessary to restore function.

**Bone and joint trauma**

Plain film radiograph or x-ray is the first choice for fracture diagnosis, but occult fractures are readily identified by US. X-ray is also the first choice investigation for the evaluation of joints following injury and MRI will often be needed to assess internal derangement. However, US can be a useful adjunct to demonstrate effusions, ligament injuries or non-ossified cartilage in children.

**Foreign bodies**

US is excellent for detecting and evaluating foreign bodies (FB). Fragments may migrate, so interrogate a wide area. Location may be harder in acute injury if laceration and subcutaneous air are present. In general, wood splinters show posterior acoustic shadowing and glass and metal fragments have posterior reverberation artefact and are often harder to locate. Long-standing FBs have a hypoechoic halo from oedema and granulation tissue. US may demonstrate complications such as abscess formation, infective tenosynovitis or septic arthritis. The relationship of the splinter to the neurovascular bundle and other structures is important in deep lesions. For surgical removal, place a skin marker and measure the depth from skin surface and distance from any visible entry wound.

**Summary**

US is extremely well tolerated and has a spatial resolution superior to MRI providing excellent depiction of musculoskeletal soft tissues and the internal structure of tendons. It is a real-time targeted examination that allows easy comparison with normal and movement and stress manoeuvres to provide additional functional information. Although operator dependent, US is well placed for use as the primary imaging modality or adjunct to plain film or MRI in the assessment of musculoskeletal trauma.

**References**

Figure 1
Nine-year-old boy who fell across the handlebar of his bicycle sustaining injury to left abdominal wall. Extended field of view transverse sonogram shows normal fat on the right that demonstrates hypoechoic fat lobules separated by reflective septa (arrowheads). Fat fracture (arrow) occurs in the plane of force and appears as a fluid filled gap surrounded by echogenic contusion.

Figure 2
(A) Acute haematoma, a subcutaneous collection of fresh blood that appears echogenic and pseudosolid, on this extended field of view longitudinal image. (B) The clot liquefies after 48 hours to become anechoic, fibrin strands (arrows) develop as the clot begins to organise, about two weeks after the traumatic insult.

Figure 4
(A) Longitudinal sonogram shows normal appearance of the medial head of gastrocnemius (G) and soleus (S) muscles. (B) Grade 2 injury of medial gastrocnemius with some fibre retraction and haematoma interposed between it and soleus. (C) Grade 3 complete rupture of rectus femoris (RF) at the myotendinous junction with a large tendon gap (arrows) filled with anechoic haematoma and debris.

Figure 5
(A) Normal insertion of the distal patella tendon (PT) onto the apophysis for the tibial tuberosity (TT). Note linear, parallel echogenic interfaces in normal tendon (arrowheads) and the thin layer of anechoic cartilage separating the tendon from the apophysis (arrow). (B) Chronic repetitive trauma leads to insertional tendinopathy and osteochondral fragmentation. The tendon becomes thickened and hypoechoic with loss of the fibrillar pattern and contains foci of heterotopic ossification (*). (C) Colour Doppler demonstrates hyperaemia within the thickened distal patella tendon.

Figure 6
(A) Normal Achilles tendon (arrows) with tightly packed parallel echogenic tendon fibrils. (B) Extended field of view sonogram demonstrates a normal myotendinous junction. The mid Achilles shows diffuse fusiform thickening, is hypoechoic with disruption of the fibrillar pattern consistent with tendinopathy. The distal calcaneal insertion appears normal. (C) A complete full thickness tear of the Achilles with a measured tendon gap filled with haematoma and herniation of Kager’s fat pad.
Figure 8
Transverse sonogram of a wooden splinter (measured) within the finger pulp. The splinter appears linear and echogenic and is surrounded by a hypoechoic rim of inflammatory tissue that makes it more conspicuous.

Figure 7
(A) Longitudinal sonogram of a normal metatarsal shaft. (B) Stress fracture of the metatarsal (arrow) shows cortical irregularity and callus formation. Occult fractures can be encountered while performing a scan to look for joint disease, Morton’s neuroma or other causes of foot pain.