Ultrasound imaging in musculoskeletal injuries-What the Orthopaedic surgeon needs to know

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ABSTRACT

Patients with musculoskeletal complaints have either been ignored or advised investigations far beyond their means or comfort. Focusing attention only on spine and head restricted the evaluation in cases of trauma and were followed up only if the injuries were life threatening. In the same vein, the extremities often got overlooked or at best were evaluated only by plain radiographs. Soft tissue injuries were therefore often missed and not only raised the morbidity in the patient but also dissatisfaction towards the treating physician. Recent exponential improvement in medical ultrasound technology has revolutionised the field of musculoskeletal imaging. Cutting-edge technology using state-of-the-art machines and high-frequency transducers have placed it in a stronger position as compared to in the past in many aspects of musculoskeletal imaging. Also, with better techniques and understanding of the modality, under given set of circumstances MSK ultrasound has far reaching results allowing for detailed evaluation of soft tissues including nerves, ligaments and tendons.

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1. Introduction

“At Cleveland Clinic, a team of sports and exercise medicine physicians and musculoskeletal radiologists consider ultrasound a shared interest,” notes Dr. Susan Joy, MD, a Cleveland Clinic sports and exercise medicine physician and Director of the Community Sports Health Network. “We have a range of imaging choices relevant to athletic injuries or overuse, and we regard musculoskeletal ultrasound as an important tool in addition to CT, X-ray and MRI.” Dr. Joy adds, “Our goal is to use the most appropriate imaging modality for each injury.”

There could not be a better preamble than the above statement with respect to musculoskeletal complaints or injuries evaluation.

Diagnostic ultrasound (US) of the musculoskeletal system has been a significant component of sports medicine and orthopaedics for decades. With the development of higher resolution probes,

diagnostic musculoskeletal ultrasound (MSK-US) in small joints is becoming more common and a very, welcomed tool in the world of sports medicine, soft tissue injury, rheumatology and rehabilitation. Instability of tendons and ligaments are, too, often recognized with the aid of a dynamic US analysis. Partial or complete muscle or tendon tears (Fig. 1) can be distinctly and accurately identified and differentiated. In general diagnostic ultrasound can offer a quick, non-invasive way to diagnose soft tissue injuries and accessible way to monitor them during treatment and the rehabilitation process. Currently diagnostic US can also confirm that injuries are healed and determine the appropriate time to return to sport. In addition to using musculoskeletal ultrasound for scanning for tendon (Fig. 2), ligament and muscle injuries, common orthopaedic applications include aid in analysing joints and uses as a guide in joint injections, identifying miscellaneous, sports related soft tissue problems, and ultrasound guided injections (Fig. 3), often regenerative medicine (stem cell therapy and platelet rich plasma).

2. Some important facts about MSK-US

- There are no contraindications to Ultrasound: Many patients with pacemakers & metallic implants cannot undergo

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Fig. 1. Extended field of view showing Full thickness Rotator-cuff tear involving tendon of Supraspinatus with retraction from the insertion foot print of Greater tuberosity (GT). Thickened Subacromial sub-deltoid bursa is seen.

Fig. 2. Soft putty like echogenic Calcification noted in the Supraspinatus tendon with minimal distal shadowing. Underlying bony acoustic margin of Greater tuberosity is showing subtle irregularity but no cortical erosion. Maintained overlying Subacromial subdeltoid bursa noted with absence of effusion.

Fig. 3. Ultrasound guided intra-articular injection at sternoclavicular joint with echogenic needle shaft in position showing reverberation artefacts. Tip of the needle is well visualized within the hypoechoic synovial proliferation.

Magnetic Resonance Imaging (MRI) scan. A large number of patients with claustrophobia cannot undergo MRI. No such contraindications exist for US. US of the patients can be easily performed with the patient in a comfortable position without having to undergo prolonged immobilization in the MRI suite. This holds true especially for patients in the paediatric age group, where US of the superficial structures can

be easily performed without having to administer short sedation or anaesthesia.

- The resolution of US exceeds that of MRI: High resolution US can detect many small abnormalities that are seen on standard MRI techniques. The axial resolution (150 μm) of the standard 10 MHz probe is almost three times better than the resolution (469 μm) obtained in a standard MRI scanner. Finer structures like small nerves (Fig. 4), ligaments & foreign bodies are much better depicted on MSK-US than standard MRI.
- POCUS – Point of care ultrasound i.e. bedside, on-site, on sports field or by road-side Ultrasound becomes the modality of choice by virtue of having flexibility, ease of operability and portability, conforming to legal norms.
- US allows dynamic examination of the anatomical structure in question: There are quite a few musculoskeletal abnormalities which are not apparent when the patient is at rest. Pathologies like snapping hip syndrome, shoulder impingement, extensor carpi Ulnaris tendon subluxation, trans-fascial muscle hernias, biceps tendon subluxation, etc. are extremely well demonstrated on US, when static MRI images may be inconclusive.
- The US probe can be placed over the area of maximum pain (point tenderness): Application of the probe directly over the area of maximum pain increases the chances of finding an abnormality & makes sure that the US report will be clinically relevant (Fig. 5). Flexibility of positioning of the part without making patient too uncomfortable adds to the list of advantages of this modality.
- Patients with metallic implants can easily undergo US imaging: US is easily the modality of choice in imaging of soft tissues around a metallic implant. This is especially true in post-arthroplasty imaging (Fig. 6) & assessment of the post-operative rotator-cuff. Nerve impingement caused by metallic implants can be easily evaluated with US.
- Doppler imaging can give important information without having to inject any intravenous contrast: Power Doppler has brought a paradigm shift in the way Rheumatoid Arthritis (RA) & other inflammatory arthropathies are managed by rheumatologists. Presence of vascularity on Power Doppler indicates persistent disease activity of the pannus (Fig. 7).

Fig. 4. Peripheral nerve sheath tumour (PNST) involving the Ulnar nerve. Proximal segment of the nerve fibres with typical cable like appearance are well preserved and are noted within the eccentrically positioned tumour.

Fig. 5. Olecranon bursitis with thick walls and internal relatively iso to hyperechoic synovial proliferation. Overlying Subcutaneous tissues are thickened. Underlying bony acoustic margins of olecranon process are normal. Partially seen superficial fibres of tendon of triceps show normal echoreflectivity at the insertion.

Fig. 6. Knee effusion with distended suprapatellar recess showing echofree contents. No evidence of synovial proliferation noted. Acoustic margins of distal femoral shaft is showing smooth margins with absence of destruction at the level of implant host site in a post-arthroplasty patient (TKR- Total knee replacement).

Fig. 7. Active synovitis (Rheumatoid arthritis) in the proximal inter-phalangeal joint. On colour Doppler imaging, intense vascularity is raised in the synovium. No cortical erosions of underlying phalanges noted. (GSU score 2/PDU score 3) (PP- Proximal phalanx, MP- Middle phalanx).

- US is better for differentiation cystic vs solid lesions: Ganglion cysts, Baker's cysts & para-labral cysts can be easily diagnosed on US.
- Therapeutic interventions can be easily done using US: US aids in aspiration of joints, bursae & cysts by accurately guiding the needle tip in the drainable areas. US guided therapeutic injections of corticosteroids & other medications can be done in joints, bursae & tendon sheaths.

- US allows bilateral comparison: Due to the high prevalence of anatomic variability in the musculoskeletal system, comparison with the asymptomatic side can help in detection of bilateral asymmetry, which can help in deciding whether the abnormality is present or not.
- Multiple review follow-up interval scans: The ease with which follow-up studies can be conducted without excess economic burden, additionally examining the other site injuries or complaints, helps in extending a wholesome management in multi-organ trauma.

3. Indications

Acute indications refer to tendon, muscle and ligamentous injuries, foreign bodies, subtle fractures and other forms of soft tissue trauma. Chronic indications such as infection, impingement, suspected non-union and nerve degeneration should not be overlooked.⁴

3.1. Acute injuries involving

1. Tendons - Ultrasound can be used to confidently diagnose tendon rupture, tendonitis and tenosynovitis. The dynamic nature of the examination helps in establishing the integrity of the tendon and allows the sonographer to assess whether the gap between the torn ends of a tendon can be made to oppose.¹⁰

2. Ligaments - In recent years, ultrasound has firmly established itself in this area and can provide rapid non-invasive assessment of these injuries. The ligaments most amenable to ultrasound assessment include the medial collateral ligament of the knee, lateral ligament complex of the ankle and the thumb-stabilising ligaments.¹¹

3. Muscle - A widely used clinical grading system divides muscle injuries into three degrees according to functional impairment of the affected muscle. In grade 1, muscle function loss amounts to less than 5%; in grade 2, muscle function loss ranges from 5 to 50%; in grade 3, muscle function loss exceeds 50%.⁹

4. Bursal pathologies - Serous bursae consist of a synovial membrane enveloping a film of liquid. They are located at interfaces between moving structures, where friction must be reduced. They are therefore found between tendons and bones or between two tendons (sub-tendinous bursae); between muscles and tendons, bones, or ligaments (submuscular bursae); between aponeuroses and bones (subfascial bursae); and between cutaneous/subcutaneous tissues and bone, muscles, or tendons (subcutaneous bursae). They can also develop in areas where friction occurs (adventitial bursae).^{14–16}

Inflammation of a bursa is often caused by bleeding secondary to acute traumatic injury or repetitive microtrauma. In acute post-traumatic forms, the blood irritates the thin synovial membrane, provoking an abundant sero-hematic effusion. Forms caused by repeated micro-traumatic injury are typically associated with a synovial effusion and uniform thickening of the walls of the bursal sac. Other causes of bursitis include infection (tuberculosis, etc.); seropositive or seronegative arthropathy (rheumatoid arthritis and psoriatic arthritis, respectively); villonodular synovitis; osteochondromatosis; and amyloidosis.¹⁵

5. Fractures - Some fractures are subtle and as such are not seen on early plain radiographs. Ultrasound is extremely useful in finding a cause for the patient's continuing symptoms. Point tenderness and focussed scan of the ROI gives clue to step-off deformity of the underlying bony acoustic margins. Also callus formation at a later stage (2–3 weeks) and comparative assessment with asymptomatic side gives the much-needed clue to underlying

occult fracture (Fig. 8a.).

6. Nerve injuries/entrapment neuropathy -Ultrasound with its superior resolution and ability to rapidly assess the entire course of a nerve can readily assess nerve morphology and continuity. It is used as the first-line modality for assessing nerve entrapment syndromes after trauma.¹³ It is not practical to trace the entire course of the nerve with any other cross-sectional modality and ultrasound with “Escalator technique” of sliding transducer along its course becomes the modality of choice to rule out nerve injuries. Stump neuromas are classical findings in presence of nerve transactions.

7. Fascial defects with herniation of underlying muscle belly specially noted post-tibial fractures and herniation of Tibialis anterior muscle.

8. Foreign bodies which are not radio-opaque cause difficulty in visualisation by routine X ray. These if left unattended can cause infective nidus within the soft tissues. Ultrasound has an excellent soft tissue interface resolution and foreign bodies such as wooden splinters, gravel, glass shrapnel are extremely well localized.¹² (Fig. 8 b.) In addition, there is always an opportunity to extract the offending body under ultrasound guidance if easily accessible in the same sitting.

3.1.1. Shoulder

Grey-scale (GS) ultrasound (US) and Power Doppler (PD) visualisation of RC tendons may be helpful to detect signs of tendinopathy, such as hypoechoic areas, fibrillar disruption (FD),

neovascularisation (NV), calcifications (CAs) embedded in the tendon or oedema, and confirm the ‘a priori’ hypothesis of RC tendinopathy, provided satisfactory properties of the US method.^{5,6}

- US of the rotator-cuff is one of the commonest MSK-US examinations to be performed. US is used to diagnose of cuff tears & differentiate between full-thickness & partial thickness tears.
- US is used to assess subacromial impingement of the rotator cuff during dynamic abduction of the shoulder.
- Calcific tendinosis of the cuff
- US guided injections within the gleno-humeral joint are far more accurate compared with blind injection techniques.

3.1.2. Elbow

- Tennis elbow (Common flexor or extensor tendon inflammation)
- Assessment of joint effusion & intra-articular loose bodies
- Olecranon bursitis -complex (haemorrhage/infective) (Fig. 9)
- Triceps & biceps tendon injuries
- Assessment of the Ulnar & Radial nerve neuropathies (Fig. 10).

3.1.3. Wrist & hand

- Flexor & Extensor tendon injuries of the wrist & hand
- Tendon sheath inflammation
- De Quervain's tenosynovitis
- Carpal tunnel syndrome (Fig. 11a and b)
- Ganglion
- Trigger finger
- US assessment of small joint synovitis in RA & other inflammatory arthropathies

3.1.4. Hip

- Transient Synovitis of the Hip (Fig. 12)
- Greater trochanteric bursitis

(a)

(b)

Fig. 8. a.— Fracture lateral end of clavicle, persistent pain 2 weeks after a fall and Negative radiograph. Step off discontinuity noted at the lateral third shaft clavicle (f). Acromio-clavicular joint is well preserved. (CL- Clavicle, AC- Acromion, ACJ- Acromioclavicular joint)

8 b- Linear echogenic foreign body (F.B) in forearm subcutaneous tissues – wooden splinter. No distal acoustic shadowing or reverberation artefacts of metallic F.B.

Fig. 9. Olecranon complex bursitis grey scale imaging assisted with Colour doppler. Vascularity noted in the surrounding thick wall of the superficial bursa with normal smooth acoustic margins of the olecranon process. Internal contents show fine separations of haemorrhagic fluid (1. Wall thickness of the bursa).

Fig. 10. Entrapment Neuropathy – Cubital tunnel syndrome (Ulnar nerve). Enlarged ulnar nerve with typical honey-comb pattern noted in short axis scan. Thick Osborne's ligament noted forming the roof of cubital tunnel. (OL- Olecranon process, MED- Medial epicondyle, CUBITAL – Tunnel, 1. Ulnar nerve).

(a)

(b)

Fig. 11. a. Normal Median nerve long axis scan at wrist joint with 'Rising lunate sign' as the level of Flexor retinaculum. No evidence of entrapment noted and the median nerve is showing comparable thickness in the entire extent. (RA – radius, LU- Lunate, MN- Median Nerve, FDS – Flexor Digitorum Superficialis, FDP- Flexor digitorum Profundus)

11 b. Median Nerve entrapment with Ultrasound signs of Neuropathy changes – Carpal tunnel syndrome. Enlarged oedematous proximal segment of Median nerve. distal to the flexor retinaculum the nerve shows normal thickness. Convex Bony echogenic margin of lunate noted in deeper planes marking the site of overlying retinaculum.

Fig. 12. Hip effusion in a paediatric patient 2 yrs. Relatively echogenic synovial proliferation noted. Capsule is showing thickening. (FL- Fluid, M- Metaphysis, E -Ossific Epiphysis, C- Capsule, Black E- Unossified cartilaginous epiphysis).

- Greater trochanteric pain syndrome
- Snapping hip
- Sportsman's hernia
- Groin injuries
- Joint aspiration

3.1.5. Knee

- Detection of joint fluid (Fig. 13)
- Inflammation of the pre-patellar bursa
- Assessment of Quadriceps & Patellar tendon injuries
- Baker's cyst (Fig. 14)
- Pain in the post-arthroplasty knee

3.1.6. Ankle & foot

- Achilles tendon injuries (Fig. 15 a, b)
- Retrocalcaneal bursitis

Fig. 13. Knee effusion with synovitis (SY) long axis scan. Grey scale imaging assisted with PDU imaging showing minimal vascularity in synovium. Tendon of quadriceps is showing normal tri-lamellar pattern. Bony margins of superior pole of patella and distal femoral shaft anterior margin are normal. (QT- Quadriceps tendon, EFF- Effusion, P- Patella).

Fig. 14. Baker's cyst with internal echoes of minimal synovial proliferation noted extending in between the tendon of Semimembranosus and Medial Gastrocnemius. Neck is well demonstrated to differentiate it from other cystic swellings. (SY- Synovial proliferation, MGM- Medial Gastrocnemius, SM- Semimembranosus, CY- Cyst).

(a)

(b)

Fig. 15. a.: Achilles tendon with a partial thickness tear. Superficial fibres of the tendon are intact. (CAL- Calcaneum).

15 b.: Achilles tendon with complete tear- Clapper bell sign. Fluid noted in between the torn retracted segments.

- Plantar fasciitis
- Injury to ankle ligaments (Fig. 16)
- Tibialis Posterior dysfunction
- Assessment of joint effusion
- Midfoot arthritis
- Morton's neuroma
- Bursitis

3.1.7. Nerves

- Post traumatic stump Neuroma
- Assessment of post-traumatic nerve injuries
- Carpal tunnel syndrome-entrapment neuropathies
- Neuritis (leprosy or post-traumatic)

a.

b.

Fig. 16. Ultrasound demonstrating normal anterior talofibular ligament (ATFL) (a). (b) Complete tear. The ATFL are injured when a plantar-flexed foot is forcefully inverted. (F- Fibula, Arrows- normal ATFL).

- USG guided Interventions - Peri-neural injections & hydrodissection

3.1.8. Masses

- Ganglion
- Fibromatosis – chronic repetitive trauma
- Vascular lesions
- US guided aspiration/biopsy
- Fascial defects with muscle herniation (Fig. 17 a)

(a)

(b)

Fig. 17. a. The defect in the fascia of Tibialis Anterior with muscle bulging through is pathognomonic of a muscle hernia.

17b. Morel Lavallee Injury- Degloving injury arm showing subcutaneous haemorrhagic collection (H) with underlying triceps belly (TR). HU- humeral shaft.

3.2. Ultrasound application in assessment of sequelae of injuries

1. Morel Lavallée lesions (Fig. 17 b)
2. Fat necrosis
3. Osteoarthritis
4. Muscle atrophy
5. Impingement syndromes
6. Infection
7. Foreign body localization

3.3. Limitations of ultrasound in musculoskeletal system

1. MSK US is not conducive to valuation of bone marrow oedema.
2. Intra-articular structures are not entirely accessible
3. In evaluation of spine/head, ultrasound has significant limitations
4. Steep learning curve of MSKUS
5. Majorly operator dependent
6. Lack of awareness of this modality's application in musculoskeletal complaints— Not only amongst the clinicians, even many radiologists are unaware of the superiority of ultrasound for musculoskeletal imaging and still prefer MRI/CT for this clinical setting.

3.4. Overcoming the challenges

High frequency linear probes- Musculoskeletal ultrasound has benefited from the recent exponential improvement in probe technology to the extent that it is now the imaging modality of choice for many peripheral soft tissue injuries.

Further following software incorporations in ultrasound units and their liberal utilization while scanning helps improve the diagnostic efficacy:

1. Beam steering -Trapezoid US imaging is often used, as this technique provides an image which is enlarged through lateral beam steering
2. Extended field of view (Panoramic view) - Panoramic imaging provides reconstruction of a composite image by simultaneous

recording and acquisition in order to create a single image with a large field of view. This technique has the main advantage of making it easier for the clinician to interpret the US image^{7,8}

3. Tissue harmonics
4. Contrast enhanced ultrasound -CEUS
5. Elastography-shear wave

4. Conclusion

Although MRI remains the imaging reference standard for a wide range of musculoskeletal disorders. MSK-US is an important complementary, and in some cases alternative, technique to MRI. In many instances, sonography should be the modality of choice on the basis of the advantages that we have discussed here.

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