Musculoskeletal imaging

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*After several years working in musculoskeletal imaging of all types and developing MRI and ultrasound in Hamilton, Kevin now owns **msk**imaging, which has the newest private MRI scanner in the Waikato.*

New Zealand's outdoors offers a wide variety of work and sporting activities, all of which increase the chance of causing injury to the musculoskeletal system. Congenital and later degenerative disorders involving our skeletal system complicate the range of presentations in clinical practice. Although these are usually minor, any additional joint damage increases the road to recovery. Joint destruction creates debilitating restrictions, which can lead to major occupation and lifestyle changes. Infection must be considered early in the assessment to avoid devastating effects. Numerous inflammatory disorders further complicate the diagnosis of musculoskeletal injury.

Radiology now offers a broad range of techniques to differentiate a new injury or illness from ongoing conditions in your patient. However, it remains a static morphologic picture, which is dependent on clinical assessment and knowledge of the patient, to indicate relevance. Whilst radiology can offer superb imaging and wonderful diagnoses, it cannot indicate if any finding is significant for your patient.

Imaging can assist, complicate, or even delay treatment. As we can image any area, with any tool, I hope the following description and appropriateness criteria will help you to use these imaging pathways more effectively.

X-ray has been used for more than one hundred years, providing an instantaneous, 200 msec image, which has extremely high resolution, down to the size of electrons. An x-ray provides a regional review of a 3D structure as a relatively simple 2D photo, with a grey scale so broad a special light box is required to demonstrate it. The plain x-ray is highly sensitive and specific, providing accurate diagnoses. A fracture, once identified on x-ray, is diagnostic, leading to treatment options based on one hundred years of worldwide experience.

So, take an x-ray; in an instant you can define the diagnosis, treatment and prognosis. It is available and cheap, and therefore should be the first step in any musculoskeletal workup.

The difficulty arises when there is no fracture. What then is the diagnosis?

Imaging options available to help investigate your patient

1. ***X-ray*** review in association with clinical findings to identify subtle lesions, or to image the adjacent joints.
2. ***Ultrasound*** is an excellent way to image the soft tissues, which is the second step for most patients.
3. ***CT scan*** is the modern extension of the x-ray.
4. ***Nuclear medicine*** bone scans identify active bone lesions.
5. ***MRI*** is the most comprehensive imaging test for musculoskeletal assessment, unsurpassed in assessment of bones and soft tissues.
6. ***Arthroscopic visualisation*** by a specialist orthopaedic surgeon offers a final assessment and associated treatment.

Ultrasound is widely available and is not expensive. In the 1990s ultrasound resolution improved as its frequency increased to 10MHz that gave the probes resolution useful for musculoskeletal work. This came to fruition at the 2000 Sydney Olympics when it was used as a major assessment tool. Improved sensitivity of blood flow assessment and improved artefact reduction with probes of 12–15MHz allows impressive superficial musculoskeletal imaging. Ultrasound limitations include the expertise of the practitioner and the small imaging window making it primarily a screening tool. Accuracy for several conditions is reported at 60–80%, although in some centres the accuracy of rotator cuff assessment approaches 90%.

Soft tissue assessment by ultrasound[1]

Depth of penetration is inversely related to scan frequency, so we still struggle with big people. The other restriction is a limited window, with only the distal 2cm of the rotator cuff able to be seen. Ultrasound is user-dependent, as dense tendons reflect sound away and images can look white or black according to the probe angle.

The shoulder is an ideal site to use ultrasound as a major imaging tool. It is often double-scanned by both Sonographer and Radiologist to

improve accuracy. Intervention can be considered by the Radiologist and guided treatment offered according to the imaging findings.

Table 1 represents a selection of possible ultrasound findings, in which a variety of interventions would be considered. I have used, as an example, a patient with limited abduction, as this is a common presentation for a scan, occasionally with a request for a subacromial cortisone injection if appropriate.

Table 1. Conditions limiting shoulder abduction

Diagnosis	Ultrasound Findings	Possible Intervention
Muscle or bone injury	Nil	Stabilisation, Physiotherapy
Bursitis	Bursal thickening	Steroid injection into subdeltoid bursa
Tendon dysfunction	Tendon bunching or blocking	Physical retraining Steroid into bursa
Partial tear	Articular surface cleft rarely bursal side	Steroid injection Intra-articular
Full thickness tear	Fluid gap in tendon	Surgical assessment
Capsulitis	Nil or Cuff interval inflammation	Intraarticular steroid +/- hydro distension
Infection	Inflammation effusion	Aspiration of joint fluid
Labral tear	Nil	MRI arthrogram

Shoulder ultrasound terminology

- ***Tendinosis*** – a pathological description of tendon damage and repair, which results in altered structure and appearance of tendons.
- ***Calcific tendinitis*** – does show an acute inflammatory process, although no direct relation to tendinosis or tears. Tendinitis is otherwise a term restricted to an acute clinical presentation.
- ***Tendinopathy*** – an ultrasound term for visible tendinosis, with loss of the normal linear structure, interstitial tears and altered vascularity relating to ongoing, tear and repair processes of tendons.
- ***Partial tear*** - Most cuff tears begin as an articular surface cleft of tendon margin or an interstitial tear that splits the tendon lengthwise. It will usually need to be less than 50% of the tendon depth to maintain the possibility of repair with the intact tendon maintaining length and strength. Deep partial thickness tears involve more than 50% of the tendon depth, when tendon strength is lost and the tear is then likely to progress.
- ***Full thickness tear*** – Articular surface through to superficial margin is seen as a fluid filled defect. The tear dimensions help consideration of intervention. The intact fibres maintain length and muscle function. I recommend surgical consideration of repair.
- ***Complete tear*** – Full thickness tear through the full width of the tendon, which allows tendon retraction and relatively rapid muscle atrophy. Adjacent tendon integrity is important for function, and reparability.
- ***Massive cuff tear*** – involves two or more tendons; this severe arthropathy may still be considered for steroid injection intervention to reduce pain.

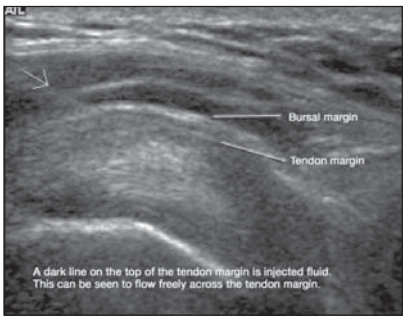
Guided steroid injections have been shown to be more effective than unguided,[2] interstitial injections, as symptomatic treatment in most sites, from plantar fascia to finger pulleys. Efficacy is improved in all depot sites where the injection can be contained, especially by a joint capsule or sheath. They have a similar effect to hyaluronic acid for hip osteoarthritis and shock wave therapy for tennis elbow.

Occasionally bursitis tenderness identifies a site for injection, however, more commonly, inflamed tissues reduce the space for injection or even become adherent. This explains clinically restricted motion and renders accurate unguided injection near impossible.

Intervention for calcific tendinitis involves attempted aspiration of the milk of calcium. A small portion of calcium is aspirated which activates a local inflammatory response and more rapid patient recovery.

Treatment of tendinitis by sclerosing (chemical or the patient's blood[3]) the neovascularity associated with symptomatic tendinosis is aimed at reducing blood flow, reducing the hyperaemic softening and thickening of tendons, to allow healing.

Figure 1. Shoulder ultrasound



Nuclear medicine – Bone scans identify increased osteoblastic activity, making them a sensitive tool for stress fractures. Whole body screening studies offer a guide to symptomatic diseases and their high sensitivity helps in excluding infection, tumour and severe osteoarthritis.

Computed tomography uses an x-ray tube turning as a helix to obtain a volume of radiographic data. The new 64 slice CT scanners obtain 0.75mm isotropic data that can be restored into an image of equal quality in axial, coronal or sagittal planes. This is very helpful in pre-surgical assessment of fractures involving joints, which is a major limit of standard x-rays. The high radiation dose

of these scanners restricts their use in young, especially female, patients.

Magnetic Resonance Imaging (MRI) offers the ultimate assessment of musculoskeletal injury by providing high resolution images of bone and soft tissues. A lack of interference from cortical bone enables a very sensitive assessment of all soft tissues, including bone marrow, for bruises and fractures. It is a sensitive screening tool for stress and insufficiency fractures in the osteoporotic patient, in whom x-rays are insensitive.

A comprehensive joint assessment is available even in deep sites such as the hip, where an arthrogram can highlight small labral tears. The high water content of articular cartilage allows joint surface damage to be assessed. Muscle and tendon injuries are detailed with accuracies reported of 95–100%.

Below are a number of comments related to major musculoskeletal sites commonly imaged.

Shoulder joint evaluation

- ***X-rays*** should include an outlet view, in this hypermobile non-weight bearing joint, for rotator cuff disease but not for arthritis. The Public Hospital series, which looks for clavicle, glenoid and humeral fractures is not required for most shoulder assessments.
- ***Ultrasound*** is useful in middle aged and elderly patients as the commonly torn distal supraspinatus tendon can be seen very well.
- ***MRI*** for patients under 35 years. in whom intra-articular damage is more likely than cuff disease and as a pre-surgical workup of shoulder disease identified on clinical examination, ultrasound or xray screening.

To rationalise radiology investigations, the American College of Radiologists ACR[4] created appropriateness criteria for several clinical situations. This is available on their website. Two examples are given in Tables 2 and 3.

Wrist evaluation

- ***X-ray*** for fractures as these are the most common injury.
- ***Repeat x-ray*** or obtain CT scan for complex joint injury, or a scaphoid fracture.
- ***MRI*** is shown to be cost effective in scaphoid imaging,[5] with the additional benefit of limiting time off work. With a normal x-ray, MR imaging can assess occult fractures, scapholunate and extrinsic wrist ligaments, triangular fibrocartilage TFC and articular surfaces. Clinical diagnosis of scaphoid fractures remains unreliable.

Table 2. Variant 4: Subacute shoulder pain, suspect rotator cuff tear/impingement; over age 35. Normal plain radiographs[4]

Radiologic Exam Procedure	Appropriateness Rating	Comments
MRI, shoulder, routine	9	
US, shoulder	7	With appropriate expertise.
Arthrogram, shoulder, with or without CT	5	Alternative if patient cannot have MR or if US expertise not available.
CT, shoulder	1	
MRI arthrogram, shoulder	1	
Appropriateness Criteria Scale *1 2 3 4 5 6 7 8 9* *1 = Least appropriate; 9 = Most appropriate*		

Table 3. Variant 5: Subacute shoulder pain, under age 35[4]

Radiologic Exam Procedure	Appropriateness Rating	Comments
MRI arthrogram, shoulder	9	Either MR arthrogram or MR routine is appropriate. Depends on availability, expertise, and local conditions.
MRI, shoulder, routine	9	Either MR arthrogram or MR routine is appropriate. Depends on availability, expertise, and local conditions.
CT arthrogram, shoulder	4	This is the procedure of choice if MR is contra-indicated or not available.
US, shoulder	1	US utility is limited in patients with a low likelihood of cuff disease.
Arthrogram, shoulder	1	
Appropriateness Criteria Scale *1 2 3 4 5 6 7 8 9* *1 = Least appropriate; 9 = Most appropriate*		

Figure 2. Hip MRI anthrogram

- ***Ultrasound*** has a limited role in tendon assessment, synovitis and guided intervention.

Hip evaluation

- ***X-ray*** offers a guide to osteoarthritis and its precursors and for excluding tumours and fractures as a cause for symptoms.
- ***MRI*** offers a comprehensive joint review. An arthrogram is the standard technique for identifying small labral tears and improving cartilage details for younger patients. Direct MR imaging is useful for evaluating osteoarthritis, fracture or avascular necrosis.
- ***Ultrasound*** has a limited role for bursitis of the psoas tendon or gluteal attachments, with groin assessment limited to hernia.

Knee injury

- ***X-ray*** for fractures according to Ottawa Knee rules.[6] The rule states that a conventional x-ray is required for acute knee injury in the presence of any of the following findings:
  - Age 55 years or older
  - Isolated tenderness of patella
  - Tenderness at head of fibula
  - Inability to flex to 90°
  - Inability to bear weight both immediately post-injury and in the emergency department.
- ***Ultrasound*** is of little or no benefit.[7]
- ***MRI*** is accurate, consistently reporting near 95% for suspected internal derangements, although it requires specialist orthopaedic assessment. Detailed articular cartilage status including T2 maps to indicate abnormal softening and healing of chondral lesions may also be useful.

ACC – Diagnosis and management of soft tissues about the knee (New Zealand Guidelines Group)[8]

Note 7: Indications for MR imaging

- MRI should generally be used ahead of diagnostic arthroscopy.
- MRI is useful when the clinical diagnosis of meniscal tear or ACL tear is difficult or in doubt.
- MRI is useful for showing the true extent of a multiligament injury complex.
- Atypical pain or unusual circumstances.

Ankle injury

- ***X-ray*** – Ottawa rules are recommended,[9] malleollar point tenderness and limited weight-bearing offers a guide to x-ray.
- ***Ultrasound*** can be useful, as tendons are all superficial. However accuracy for ligament injury is limited and osteochondral injury is not assessed.
- ***MRI*** for ligament sprain, tendon tears and synovitis is accurate, talar dome osteochondral detail is improved and intra-articular detail is where MRI excels.

Summary of patient imaging pathway

1. ***X-ray*** - to look for fractures, not to exclude them! An x-ray provides rapid diagnosis, treatment and prognosis.
2. ***Ultrasound*** if no fracture is present is a screening tool for superficial soft tissue assessment, realising that there are limits to both sensitivity and specificity.
3. Symptomatic treatment, allows most soft tissue sprains to heal, further imaging may be of limited value, unless yellow flags are raised.
4. ***Ultrasound*** re-evaluation by a musculoskeletal radiologist allows guided intervention based on persistent findings.
5. Specialist review if not settling, especially for intra-articular damage. Red flags of infection, joint damage and tumours, need early referral.
6. ***MRI*** provides comprehensive musculoskeletal imaging rapidly. It is likely to become more widely used as an early assessment tool. Currently it is only used in this way by professional sporting bodies but it is proven for detecting scaphoid injuries. Without any of the radiation risks, it provides tremendous detail of fractures, cartilage and soft tissue injury.

   MRI can provide comprehensive diagnoses, thereby indicating treatment pathways and prognosis, to enable a rapid and efficient return to daily activities.

Figure 3. Knee MRI saggital

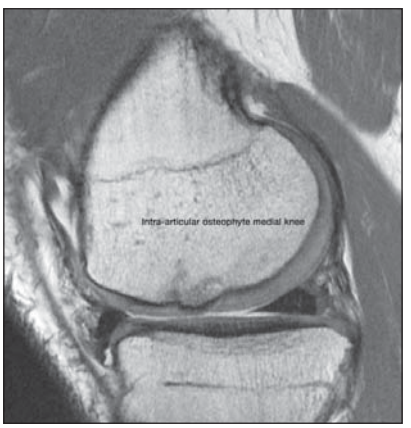
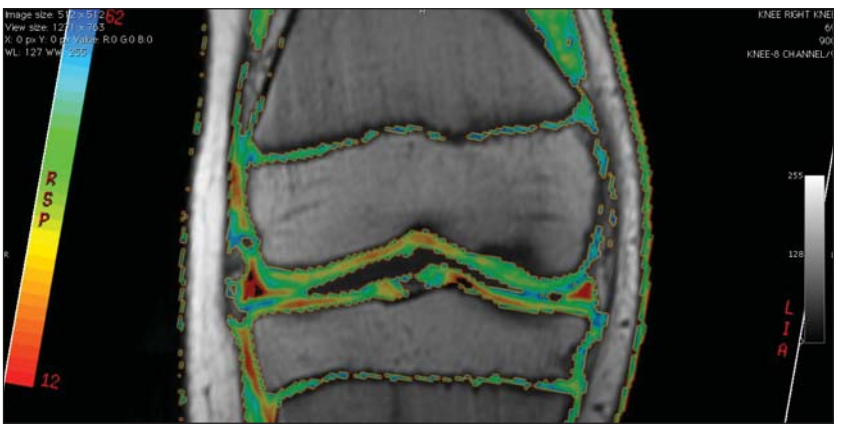


Figure 4. Knee MRI T2 map



Competing interests

Kevin Gilbert is the owner of Hamilton based mskimaging.

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