The evaluation of bone and soft tissue sarcomas involves initial detection of a clinically suspected mass, diagnosis of the mass, staging of a suspected or known malignant neoplasm prior to treatment and monitoring treatment response. Prior to the advent of magnetic resonance imaging (MRI) and more recently positron emission tomography (PET) scanning, plain films, nuclear scintigraphy (Technetium$^{99m}$ bone scans) and computerised tomography (CT) scans were the major means by which bone and soft tissue lesions were evaluated. Our unit sees approximately 100 new bone and soft tissue sarcomas each year. Plain radiographs and MRI scans are the mainstay of diagnosis, while MRI and PET CT scans are performed for staging and restaging following treatment. Other modalities such as CT, bone scans and less commonly ultrasound and angiography are used only in specific cases.

**Plain x-rays**

Both bone and soft tissue sarcomas can present as a palpable mass, although bone tumours frequently present with pain and change in function. The most useful initial radiological investigation is plain radiography and this should be performed first. Information that can be gleaned from the plain film includes the site of the lesion, whether it arises from bone or soft tissue or involves both, some indication of size of the lesion, presence of bony destruction or periosteal reaction which gives some information regarding rapidity of growth, and characteristics such as calcification or ossification (figure 1). Plain radiography is more useful than MRI for characterising the aggressiveness of most bone lesions.
Figure 1a: Plain radiograph of the tibia in this 26 year-old female shows a calcified lesion involving soft tissue and tibia. The pattern of calcification suggests a cartilaginous lesion. Involvement of the tibial cortex by this mesenchymal chondrosarcoma is evident.

By identifying the bone involved, the site of the lesion in the bone and the age of the patient, the potential diagnoses can be narrowed. The diagnosis of some malignant lesions may be evident on the x-ray, for example some osteosarcomas and Ewing sarcomas have a typical appearance which is diagnostic, however further imaging is always required for staging.

Although plain x-rays are less useful in the assessment of soft tissue sarcomas, they should be performed as part of the work up of all soft tissue masses. Calcification on an x-ray associated with a soft tissue mass is always worrying. Only myositis ossificans and haemangiomas with phleboliths are common benign lesions that calcify. More often it is an indication of malignancy.¹

Figure 1b: Coronal T1 MRI demonstrates the soft tissue mass with extension into the tibia.

MRI - Detection and diagnosis

MRI is the most useful investigation following plain x-rays in the detection and further evaluation of both bone and soft tissue sarcomas. The multiplanar capability, combined with the excellent soft tissue contrast and anatomical detail, mean that even small soft tissue or bony lesions can be detected with accuracy (figure 2).

The MRI appearance of some tissues is characteristic, so that the diagnosis may be apparent or the differential diagnoses narrowed following the MRI scan. Tissues that have a characteristic appearance on MRI include fat and hyaline cartilage. Some vascular lesions are also typical, such as arteriovenous malformations that exhibit flow voids due to rapid blood flow and venous malformations with bright slow flowing or stagnant blood. Other tissues may have an appearance that, while not diagnostic, may be suggestive of a few tissue types, for example fibrous tissue, haemorrhagic tissue or calcification.

Although initially there was debate in the literature regarding the value of MRI in assessing cortical involvement in...
comparison with CT, other studies have shown MRI to be comparable to CT in assessment of cortical involvement.\textsuperscript{3, 4, 5}

**Staging**

When either a bone or soft tissue lesion is suspected of being malignant, staging is necessary. Cross sectional imaging for local staging should be performed prior to biopsy, as it can assist in planning the biopsy to ensure that other compartments are not contaminated and image interpretation is not compromised by post-biopsy oedema or haemorrhage. As the biopsy track should be excised with the tumour, there should be consultation with the surgeon prior to biopsy. The biopsy must not contaminate other compartments, neurovascular structures or areas that might be used for reconstruction.\textsuperscript{2} Biopsies that are poorly planned or executed can influence the subsequent treatment options available to the patient.

MRI is the examination of choice for local staging of both bone and soft tissue tumours.\textsuperscript{2, 6, 7} As McDonald states, an MRI of the entire bone gives the most accurate representation of intra and extraosseous extent of lesion.\textsuperscript{8}

Various scanning protocols for performing MRI for staging purposes have been proposed. These involve a combination of T1, T2, fat suppressed T2 or short tau inversion recovery STIR and post-gadolinium sequences performed in multiple planes. The particular sequences employed are largely influenced by machine capability radiologist and referring clinician preference. While not commonly used in the published literature for tumour imaging, we have found the same fast spin echo proton density (FSEPD) sequences that are used in other musculoskeletal imaging to be useful as part of the MR protocol for local staging. These sequences permit high resolution imaging without a long acquisition time. The tissue contrast achieved allows identification of the neurovascular bundle, fascial planes and the tumour mass. While the TNM system for staging bone tumours reflects the size and grade of the tumour, the Enneking system reflects whether a tumour is intra or extra-compartmental.\textsuperscript{9, 10} This is important for surgery. Owing to the clear delineation of adjacent anatomic structures, the radiologists and referring orthopaedic oncologists at our centre favour this FSEPD sequence over T1, T2 or post-gadolinium T1 scans in determining anatomical relationships and for operative planning (figure 3).

**Figure 3a:** Axial T1 scans show an aggressive intramedullary lesion with soft tissue extension.

**Figure 3b:** Axial FSEPD scan shows greater contrast details. The cortex is better defined and areas of cortical destruction are more clearly seen than on the T1 image. Tissue contrast is greater on this sequence, so a focus of hypointensity that represents tumour ossification, allowing prediction of the pathology, becomes apparent. The margins of the soft tissue mass are clearly seen. Biopsy revealed an osteoblastic osteosarcoma.

**Figure 3c:** Axial fat saturated T2 scan highlights the mass and the peritumoural oedema, but the sciatic nerve is no longer as conspicuous with fat suppression.

**Figure 3d:** Axial post gadolinium T1 fat suppressed scan shows that the tumour enhances less than the surrounding reactive zone. The neurovascular structures critical for surgical planning are less clearly delineated due to the fat suppression technique reducing tissue contrast.
Although gadolinium is now generally used in the evaluation of soft tissue masses, its use remains controversial. Contrast frequently increases signal intensity of tumours on T1 images and may enhance demarcation between tumour and surrounding soft tissue, however the distinction between tumour and adjacent muscle is usually well demarcated on non-contrast scans. Not only does the administration of contrast increase the time and cost of the examination, significant but rare adverse reactions can occur including bronchospasm, anaphylaxis and death. More recently the development of nephrogenic systemic fibrosis has been reported in patients with renal impairment following gadolinium administration.

As a result of these reports the renal function in patients with, or considered at risk of, renal impairment must be assessed prior to administration. The advantage of gadolinium is that tumours become more conspicuous on T1 imaging and tumour margins are more distinct. It is generally considered of little value in the assessment of primary bone tumours because of sufficient contrast between the tumour and normal marrow. Although it can assist in distinguishing tumour margins from reactive oedema, this is of little value for the zone of oedema is resected en bloc with the tumour in a limb salvage procedure.

Dynamic gadolinium enhanced MRI refers to the process by which MR images are obtained at time intervals during and immediately following injection of gadolinium, as opposed to conventional or static gadolinium scans where scanning is performed after injection. Graphs charting rates of tissue enhancement (concentration) versus time can be generated. This technique has been widely studied as a means of identifying benign from malignant masses. In general, malignant lesions show more marked enhancement and a greater rate of enhancement than benign lesions, but there is such a broad overlap that the distinction has not been found to be of practical value.

While we perform gadolinium enhanced fat suppressed sequences on all patients with a soft tissue mass or bone lesion with a soft tissue component, we do not use dynamic sequences. Similar limitations with this method have been found in assessing treatment response with dynamic enhanced images. Overlap complicates the distinction between responders and non-responders. However, Dyke et al suggest that there may be a role for dynamic contrast enhanced gadolinium imaging in patients with osteogenic or Ewing sarcomas who are undergoing chemotherapy prior to surgery.

The administration of gadolinium with static MRI has been found to be particularly useful in the assessment of tumour recurrence. In the post treatment monitoring of patients with both bone and soft tissue sarcomas, like others we have found the scans with gadolinium and fat suppression to be of the greatest value in the detection of recurrent tumour.

**PET CT**

Identifying systemic disease in initial staging of sarcomas has previously been done by chest radiographs and/or chest CT scans and bone scintigraphy. Subsequently, Positron emission tomography added to conventional imaging was shown to improve pre-operative staging. More recently PET CT scans have been demonstrated as having higher sensitivity, specificity and accuracy than PET or CT alone.

Follow-up imaging to detect recurrent tumour for three to five years after treatment had until recently been assessed by MRI of the primary site, with 99mTc MDP bone scanning and chest CT for systemic disease. However, PET, and more recently PET CT have been found to be useful in both initial staging and detecting recurrence in the evaluation of sarcomas and are being increasingly used.

There are exceptions where PET may be less useful in detecting recurrence, particularly with less metabolically active tumours where sensitivity is reduced, such as low grade liposarcomas.

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**Figure 4a:** Sagittal T1 scan through the forefoot in this 27 year-old man demonstrates a rhabdomyosarcoma arising from the plantar soft tissues.

**Figure 4b:** After treatment a pelvic recurrence is detected by a follow-up PET scan.

**Figure 4c:** A T1 coronal MRI scan shows this recurrence to be two lymph node metastases along the external iliac and common femoral vessels.
Bone scintigraphy

According to the American College of Radiology Appropriateness Criteria for Bone Tumours, nuclear medicine bone scanning is a good option if there are persistent symptoms and a bone lesion is suspected, but the patient cannot have an MRI. It is deemed slightly more appropriate than CT in this circumstance.

CT

Where MRI is unavailable, CT can be useful to detect and diagnose a lesion not evident on plain x-rays, although as mentioned above it is rated as slightly less useful in the detection of a suspected lesion, with a negative radiograph by the American College of Radiology Appropriateness criteria.

CT is of use in assessing cortical breakthrough and pathological fracture. A lesion arising in or from a bone may be identified. Some soft tissue lesions can be diagnosed, as some tissue types such as fat, are characteristic.

CT is more sensitive to calcification than MRI, so small foci of calcification can be detected that would not be seen on MRI. If calcification is faintly evident on the initial plain film, CT may be more useful than MR as characterisation of calcification is possible. For example, punctate dystrophic calcification seen in some synovial sarcomas can be distinguished from ossification seen in myositis ossificans, or chondroid calcification that occurs in cartilage forming lesions.

Although CT scanning is not generally used in local staging, Panicek et al found that it was comparable to MRI. While it may be used for local staging in circumstances where the patient is unable to have an MRI, its current use in staging is confined to chest CT scanning to exclude pulmonary metastatic disease.

Ultrasound

Ultrasound is readily accessible and frequently performed to evaluate a palpable soft tissue mass. It is useful to confirm presence of a mass and assess size and depth. Ultrasound can be particularly useful if the mass is cystic and close to a joint. It has no role in assessment of bone sarcomas. Ultrasound is also widely used in image guidance for biopsy, particularly for superficial masses. However, if a malignancy is suspected cross-sectional imaging by MRI, or CT if MRI is unavailable, should be performed prior to biopsy so local assessment and staging can be performed using images not already altered by intervention. Soft tissue compartments are more readily assessed on cross-sectional imaging, permitting biopsy planning so other compartments are not unintentionally breached.

Although suspicion of a sarcoma is raised if a lesion is large and deep, numerous sarcomas are small and superficial in location.

Angiography

Angiography is now generally reserved for those bone and soft tissue lesions that appear to be vascular on MRI or CT scan. Pre-operative angiography and possibly embolisation is performed for clarification and potential control of feeding vessels.

Conclusion

Soft tissue sarcomas are two to three times more common than malignant bone tumours. Imaging plays a role in the assessment of bone and soft tissue sarcomas in the initial detection and diagnosis, staging of both local and systemic disease, monitoring response to treatment and detection of recurrence. The most important modalities currently are plain radiographs, MRI and PET/CT. Nuclear medicine (Te 99m), bone scanning and CT scanning are generally reserved for situations where MRI is unavailable or contraindicated, or where further specific information is sought.

References