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Imaging update on soft tissue sarcoma

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ABSTRACT

Soft tissue sarcomas (STS) are rare tumours presenting as soft tissue lumps. Ultrasound is often the primary modality for the initial assessment, with MRI the mainstay for lesion characterisation. PET/CT along with other emerging MRI sequences are used in certain situations as an adjunct and problem solving tool in STS staging and assessment of disease recurrence. Recent advances include the promise of whole body MRI, hybrid PET/MRI, diffusion weighted imaging, dynamic contrast enhanced MRI and advances in artificial intelligence. This article discusses current concepts in extremity STS imaging and highlights recent advances.

1. Introduction

Soft tissue sarcomas (STS) are rare malignancies of mesodermal origin. They make up 1% of all malignant tumours and commonly occur in the extremities or trunk. The American Cancer Society estimates that in 2021 the incidence of new STS will be 13,460 and the mortality to be 5350.[1] STS will present as a soft tissue lump, often to Primary Care and the first line of imaging is usually ultrasound. Initial imaging with ultrasound is often performed in the community or local general hospital. If there is a radiological suspicion of a STS, it is important that the case is referred to a specialist regional centre for further advanced imaging and/or biopsy. Approaches to management and prognosis depend on several factors including tumour size, location, histologic subtype, stage, grade, patient comorbidities and age. The mainstay of treatment is limb-sparing surgical resection. Radiotherapy is used as a neo-adjuvant or adjuvant treatment to resection, or for unresectable tumours. The role of chemotherapy is not clear-cut and is still the subject of debate. This article will discuss current imaging modalities and their use in the assessment of extremity STS. We will also highlight recent advancements in imaging techniques for STS. Retroperitoneal sarcomas will not be discussed as they are beyond the scope of this article.

2. Radiographs

Radiographs are limited in their usefulness for STS assessment and are often performed as an adjunct to ultrasound or MRI to

Keywords: STS, soft tissue sarcoma; MSK, musculoskeletal; MRI, magnetic resonance imaging; CT, computed tomography; PET, positron emission tomography; FDG, fluorodeoxyglucose; WBMRI, whole body MRI; DWI, diffusion weighted imaging; DCE-MRI, dynamic contrast enhanced magnetic resonance imaging.

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consolidate a suspected diagnosis. Soft tissue lumps will be seen as a non-specific soft tissue swelling and their density may suggest the nature of the underlying mass, i.e. fat density in lipomas (Fig. 1). Detection of calcification or the ossification pattern can aid the diagnosis of certain tumours such as synovial sarcoma[2] (Fig. 2a and b) or myositis ossificans[3] (Fig. 3a and b). Osseous involvement (Fig. 4a and b) can be assessed and radiographs may demonstrate phleboliths in cases of suspected haemangiomas. However the majority of the time conventional radiographs will not provide any helpful diagnostic information in STS assessment (Fig. 5a and b).[3]

3. Ultrasound

Patients will often present to their primary care physician with a soft tissue lump. It is important that suspected STS cases should be referred for an initial ultrasound scan and if the lesion is indeterminate or aggressive (Fig. 6), cases are referred to specialist STS centres.[4] Ultrasound can diagnose a benign lesion with an accuracy of between 80 and 90% and aggressive lesions can be determined with a sensitivity and specificity of both 84% based on several ultrasound techniques.[1,5–8] Ultrasound is extremely effective in triaging lumps particularly if they are benign and can prevent further unnecessary investigations (see Table 1).[9]

There are limitations with ultrasound such as difficulty in reviewing serial examinations due to operator dependence, and also ultrasound is inadequate when planning surgical re-excision of a recurrent sarcoma.[7,8,10–12] Ultrasound can characterise the location and depth of a lesion; whether it is superficial (Fig. 7a and b) or deep to the deep fascia (Fig. 8a–c) or intramuscular (Fig. 9a and b).

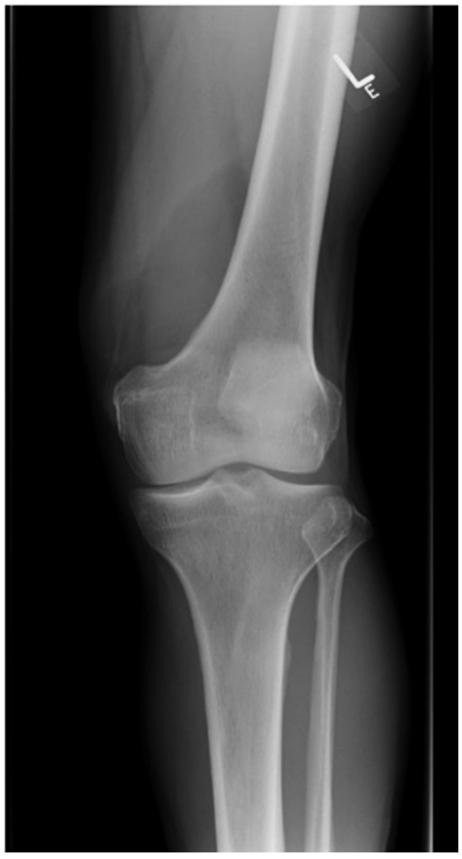

Fig. 1. Lipoma. AP radiograph of the left knee shows a well-defined ovoid lucency overlying the medial aspect of the distal femur that was subsequently shown to be a lipoma.

Ultrasound is very useful in determining if a lesion is cystic or solid in nature. Having an ultrasound prior to MRI is helpful as one can confirm if a lesion is truly cystic, particularly in the absence of contrast enhanced MRI. For example, myxoid lesions may appear 'cystic' on MRI but can be confirmed as solid on ultrasound (Fig. 10a–f). Ultrasound has been shown to have 96% specificity for diagnosing superficial lipomas.[9,10] Ultrasound can be a useful and cost-effective tool in the detection of early local STS recurrence and for guiding biopsies. Ultrasound-guided biopsy allows direct visualisation of the lesion and avoidance of adjacent neurovascular structures (Fig. 10f). Ultrasound can also visualise and avoid biopsy of cystic areas. The diagnostic accuracy of ultrasound in the detection of tumour recurrence has been reported with an overall sensitivity and specificity of 83%–84% and 93%–94% respectively; although no studies have shown superiority in the use of ultrasound over MRI in local recurrence surveillance when the two imaging modalities were compared.[13,14] Ultrasound may be beneficial in the presence of orthopaedic hardware, and if recurrence is clinically suspected. Doppler interrogation may aid in distinguishing recurrent tumour from avascular fibrous tissue at the post-operative resection bed, although hypovascular tumour recurrence could mimic benign appearances.[14]

4. Computed tomography

Computed tomography (CT) has a limited role in STS imaging. MRI is superior to CT for locoregional staging as it provides far superior soft tissue resolution and in addition MRI can produce images in any plane or multiple planes to more optimally match familiar anatomical, surgical or even conventional radiographic orientations.[15] Certain features on CT are considered markers for malignant behaviour, including margin irregularity, infiltration into adjacent organs, calcification, necrosis and hypervascularity. For assessment of osseous involvement which includes calcification, cortical destruction, endosteal and periosteal reaction; MRI is either no better or inferior to CT or even plain film radiography. CT may also be the only possible investigation for further characterisation of a suspected STS if MRI is contraindicated or if the patient cannot tolerate an MRI scan. CT can provide some lesion characterisation by identifying fat and vascularity.[16] CT plays a specific role in the TNM staging of certain types of STS. STS predominantly metastasises to the lung and so Chest CT is of great importance in STS staging and assessment of disease progression (Fig. 11). Regional lymph node spread is uncommon, however is sometimes seen in epithelioid and clear cell sarcomas.[14] In these situations, a CT scan is essential for staging. Other specific indications include an Abdominal CT for limb myxoid liposarcomas where abdominal metastases are present in up to 12.1% of patients; Abdominal CT for myxofibrosarcoma which may metastasise to the adrenal glands and mesentery; and Brain CT for alveolar soft part sarcoma, clear cell sarcoma and angiosarcoma.[17,18] CT is the modality of choice for distant metastasis assessment and surveillance. According to the American College of Radiology Appropriateness Criteria for the assessment of metastatic disease to the lungs from STS, high-risk patients should undergo follow-up non-contrast Chest CT every 3–4 months for the first 2–3 years, then every 6 months for up to 5 years, and then annually.[19] CT Chest should be considered every 6–12 months for low grade STS patients.[20] CT can also be used for percutaneous biopsy guidance in particular cases when the lesion is too deep to access or important structures cannot be confidently visualised by ultrasound. An example of this is in CT-guided biopsy of lesions in the posterior intercondylar notch of the knee (Fig. 12a and b), where popliteal neurovascular structures need to be avoided (Fig. 13).

Positron emission tomography (PET) commonly uses 2-deoxy-D-

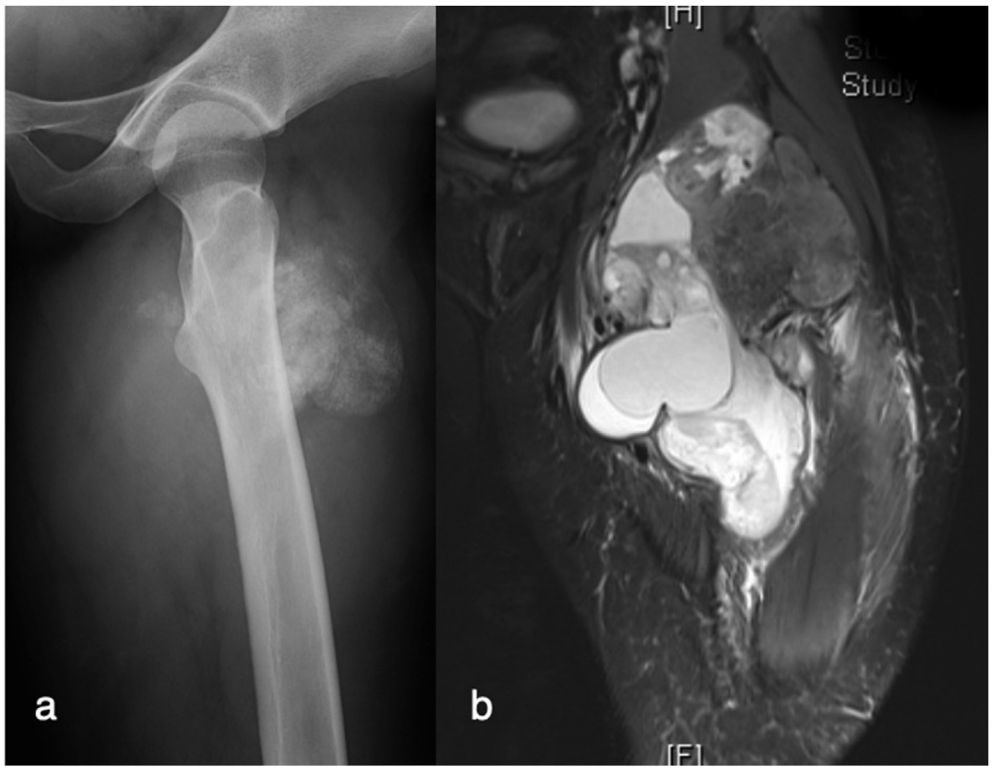

Fig. 2. Synovial sarcoma. AP radiograph of the left proximal femur (a) demonstrates amorphous calcification partially overlying the left proximal femur without any evidence of periosteal reaction. A coronal fluid-sensitive fat-suppressed image (b) reveals a complex heterogenous mass which was subsequently proved to be a synovial sarcoma on biopsy.

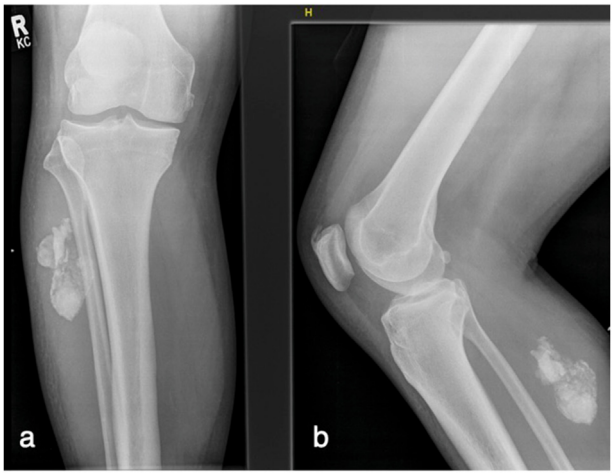

Fig. 3. Myositis ossificans. AP (a) and lateral (b) radiographs of the right knee demonstrate a well-defined irregular lesion within the soft tissues of the proximal posterior lower leg. More mature osteoid is seen peripherally with less mature osteoid centrally. The patient had a history of trauma to the region, concordant with the imaging findings suggestive of myositis ossificans.

glucose labelled with F^{19} (FDG) to measure tumour glucose uptake as a marker of tumour activity, and can thus quantify tumour activity. FDG-PET can be used to predict STS grade at primary diagnosis, and has been shown to be sensitive for high grade lesions.[21–23] Two meta-analyses have shown PET/CT to be superior to MRI or CT for the detection of nodal and soft tissue metastases.[14] Although studies have also shown 98% of adult STS to be FDG-avid, its routine use for the detection of metastatic disease in the initial staging of STS was found to have altered management in less than 5% of cases.[24] PET can play an important role in local surveillance, particularly as a problem-solving modality in instances where MRI is contraindicated, or where findings are equivocal or non-diagnostic for example due to metal artefact. In addition, PET/CT can help identify the target regions for biopsy when CT is equivocal (Fig. 14a and b). FDG-PET/CT is sensitive for the detection of disease recurrence however appearances in the post-operative resection bed are quite often non-specific due to post-surgical or post-radiation inflammatory change which can persist for years following treatment. In these cases the standardised uptake value of STS overlaps with inflammatory changes.[14] There is currently no standardised role for PET/CT in STS diagnosis or staging. Further research assessing the efficacy of FDG-PET/CT in the staging and re-staging of STS would be welcome.

5. Magnetic resonance imaging

Magnetic Resonance Imaging (MRI) is the conventional imaging modality of choice for evaluating soft tissue masses due to its inherent soft tissue contrast resolution. MRI plays an important role in the pre- and post-operative assessment of STS. Novel developments with MRI in STS imaging are emerging. In addition to its superior inherent contrast resolution MRI does not emit ionising radiation, whereas CT does. MRI can produce numerous sequences each which characterise different tissue foci, with conventional protocols including T1-weighted (T1W), T1-fat suppression (T1FS), T2-weighted (T2W) and diffusion-weighted imaging (DWI) and magnetic resonance spectroscopy (MRS). It is important for a skin marker to be placed overlying the region of interest of the suspected STS during imaging to help ensure the correct area is evaluated when reporting. Contrast-enhanced MRI (CEMRI) with intravenous gadolinium-based contrast can be useful for the characterisation of cystic versus solid lesions, assessment of vascularity,

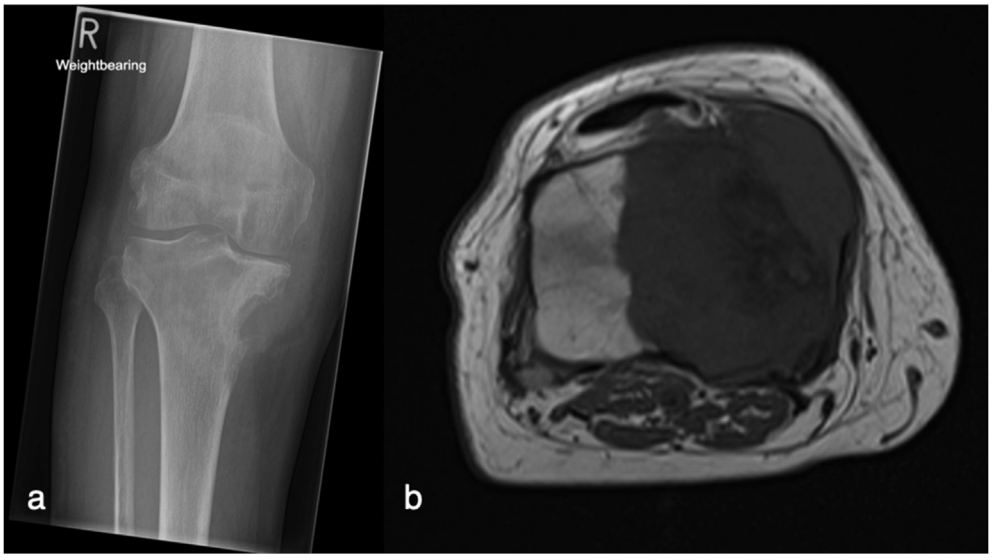

Fig. 4. Leiomyosarcoma. AP radiograph of the right knee (a) shows marked periosteal scalloping of the medial aspect of the proximal tibia by a slow-growing soft tissue lesion. Axial T1W image through the proximal right tibia (b) demonstrates a soft tissue mass with osseous erosion. Biopsy revealed a diagnosis of leiomyosarcoma.

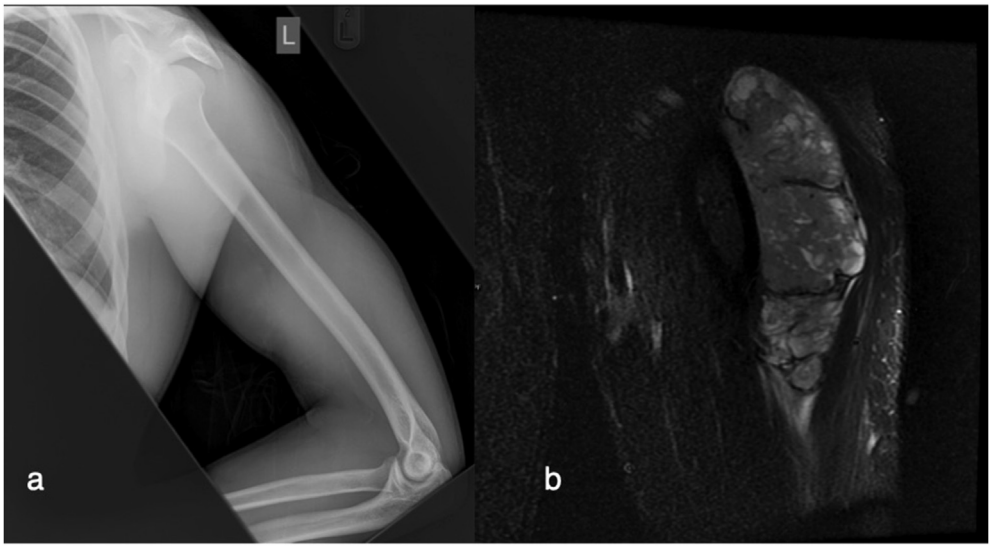

Fig. 5. Ewing sarcoma. A frontal radiograph of the left upper arm (a) shows no soft tissue abnormality. A coronal STIR image (b) demonstrates a heterogenous soft tissue mass arising from the brachialis muscle which was confirmed on biopsy as Ewing sarcoma.

tissue planes and vascular invasion of the lesion. Although there is strong evidence to support both contrast enhancement and heterogenous signal in a contrast-enhanced study in the characterisation of benign versus malignant soft tissue masses, the consensus opinion from a systematic review determined that a non-contrast MRI will provide adequate information to determine the underlying identity of a mass particularly if there are characteristic features of benign entities such as a synovial cyst or lipoma; or if there are features characteristic of a STS in which case referral to a specialty sarcoma centre is undertaken.[3] It was felt that if intravenous contrast was deemed necessary, a limited CEMRI could be performed on an individualised basis. There is mounting evidence regarding the retention and deposition of gadolinium mainly in the bone and brain. The potential long term implications of this are currently unknown. There have been recent changes to policy by the Medicines and Healthcare Products Regulatory Agency, European Medicines Agency and national radiology colleges regarding the use of gadolinium.

When evaluating an MRI for a suspected STS the radiologist should seek to identify the presence or absence of a number of features. Tumour size and location with respect to anatomical compartments as well as neural, bone and nodal involvement can help stratify the TNM stage and these features are well assessed by routine MRI sequences. Additionally other features such as fluid-fluid levels, peritumoral oedema and transition zones should be assessed for. Certain benign lesions such as myxoid tumours, haemangiomas, intramuscular lipomas, peripheral nerve sheath tumours and fibroblastic tumours (Fig. 15a–c) have characteristic MRI features. Certain masses are found in specific locations; for instance an elastofibroma most commonly presents as a subscapular mass deep to the serratus anterior muscle (Fig. 16a–c). A mass arising from a nerve is likely to represent a peripheral nerve sheath tumour

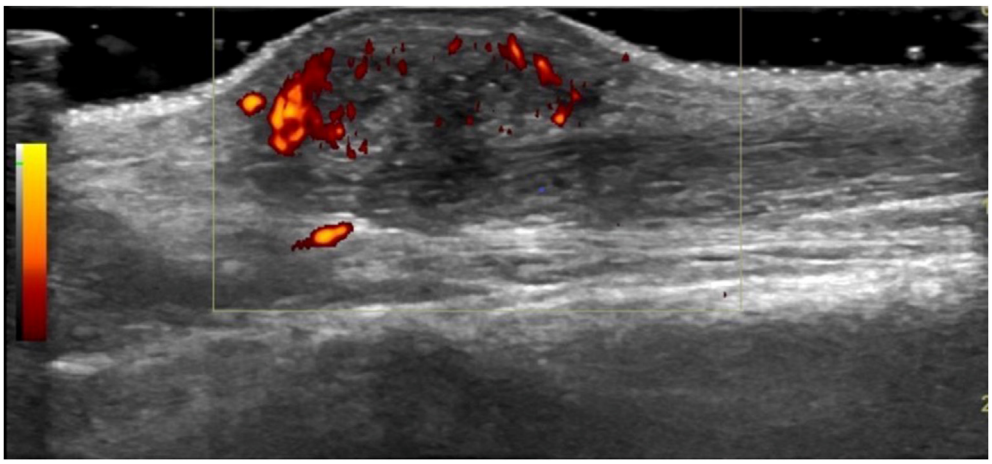

Fig. 6. Soft tissue sarcoma. A longitudinal ultrasound view of the right forearm reveals a subcutaneous well-defined, heterogenous lesion with marked internal vascularity that was proven to be a soft tissue sarcoma following biopsy.

Table 1
Sonographic features of benign versus aggressive soft tissue lesions[9]. It is important to remember that soft tissue sarcomas can also have apparently benign features. It is therefore important cases are discussed in multidisciplinary meetings if there is a concern.

Benign soft tissue ultrasound characteristics	Aggressive or indeterminate soft tissue ultrasound characteristics
Longest diameter less than 46 mm	Longest diameter greater than 46 mm
Usually avascular, except for haemangiomas	Hypervascular lesions with multiple peripheral poles or with internal vessels
Well-defined margins	Heterogenous solid lesion with ill-defined margins
Subcutaneous location	Deep location
Synovial and ganglion cysts are well-defined, anechoic lesions with posterior acoustic enhancement and no internal vascularity.	Recurrent STS typically appear as low reflectivity nodules which are often round, oval or lobulated.
Lipomas are well-defined, encapsulated masses iso- to slightly hyperechoic to adjacent fat with absent or minimal internal vascularity.	

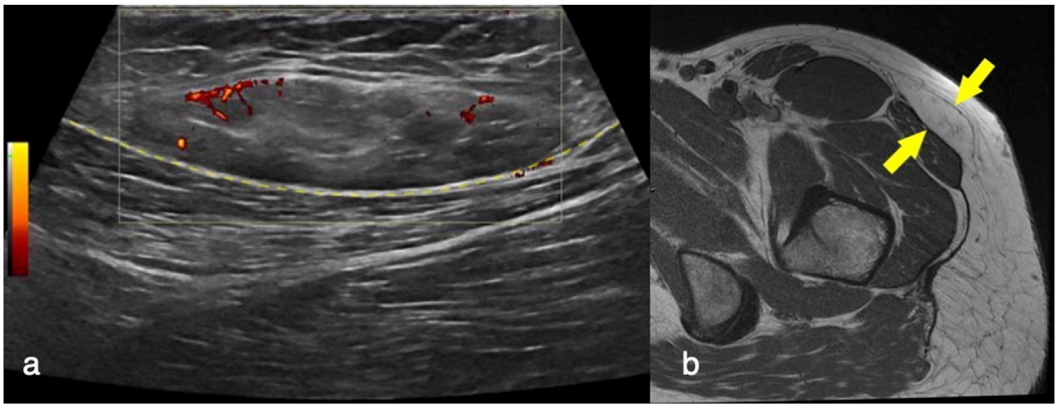

Fig. 7. Superficial lipoma. A longitudinal ultrasound view of the left upper thigh (a) revealed a fat-containing lesion in the subcutaneous tissues, which lies superficial to the deep fascia (broken yellow line). Further characterisation with T1W images (b) confirmed a superficial lipoma.

(Fig. 17a–c). T1W and T1FS sequences are excellent for characterising lipomas as well as raising the index of suspicion for STS. Well-differentiated liposarcomas can look similar to lipomas, with a higher probability if the lesion is larger than 10 cm, has thick septa, is globular or contains non-adipose areas. It has been observed that very few benign soft tissue masses exceed 5 cm in diameter and are rarely found in deep anatomical compartments.[9] Morphological appearances of STS can be falsely reassuring as it is common for them to grow within compartments, form pseudo-capsules and not infiltrate adjacent structures until an advanced stage. Whilst MRI is excellent in evaluating soft tissue lesions, it is rarely possible to get a diagnosis from MRI alone. There is significant overlap in appearance between benign and malignant soft tissue masses and one should have a low threshold for biopsy. It has been observed that the highest sensitivity for detecting malignancy with MRI comes with absence of low-signal intensity on T2W imaging, a mean diameter of greater than 33 mm and inhomogeneous signal on T1W imaging. The highest specificity however was seen with evidence of necrosis, bone or neurovascular involvement, metastasis, and a mean diameter greater than 66 mm.[25] MRI, using both T1W and T2W sequences, is sensitive and specific in identifying bone invasion. MRI has an important role to play in the post-

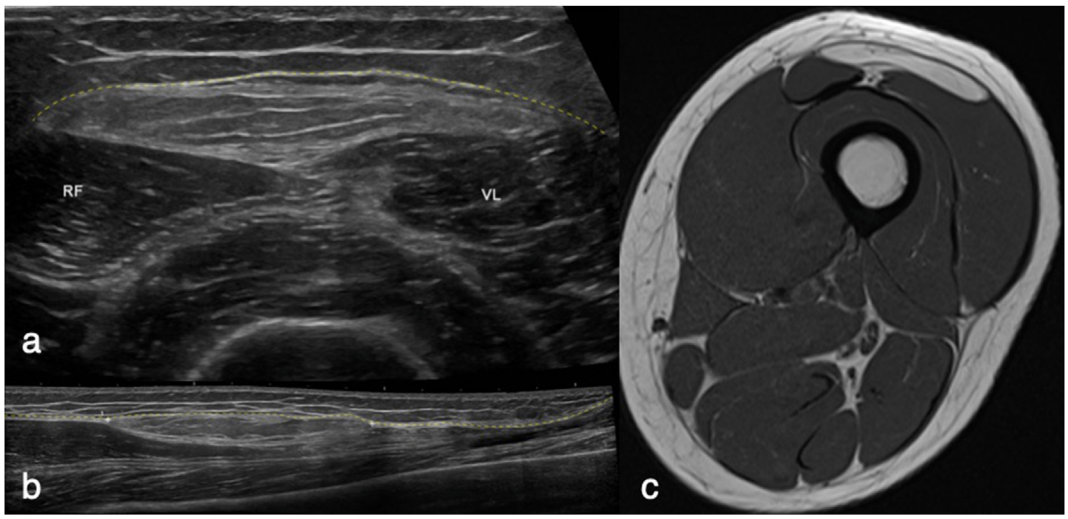

Fig. 8. Deep lipoma. A transverse ultrasound view through the left anterior upper thigh (a) reveals a lipoma deep to the deep fascia (broken yellow line) and superficial to the rectus femoris and vastus lateralis muscles. A longitudinal ultrasound view (b) again demonstrates the lipoma just deep to the deep fascia (broken yellow line). An axial T1W image through the left upper thigh (c) confirms the lipoma.

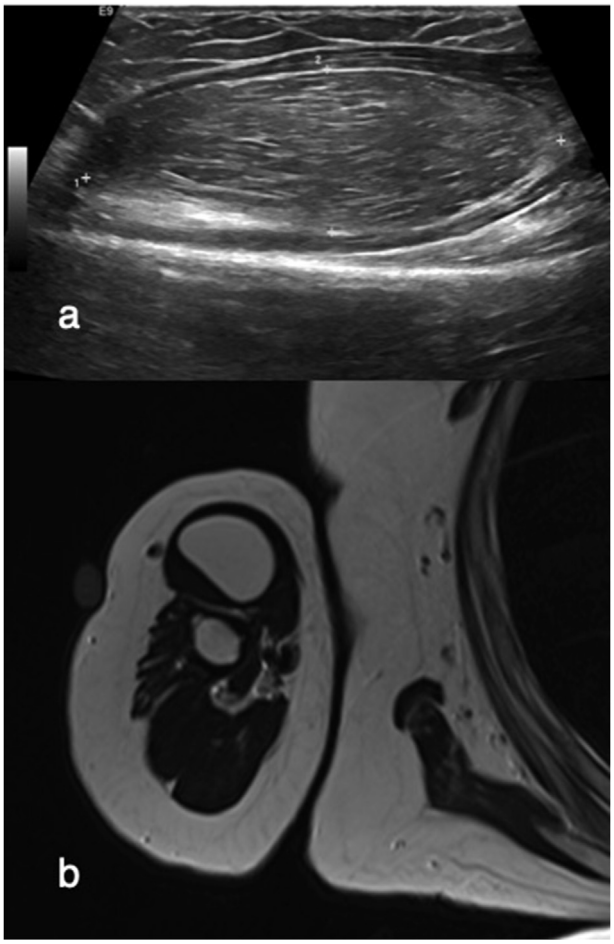

Fig. 9. Intramuscular lipoma. A longitudinal ultrasound view through the right upper arm (a) reveals an encapsulated intramuscular fat-containing lesion within the biceps brachii suggestive of an intramuscular lipoma. An axial T1W image (b) confirms a well-defined fat-containing intramuscular lesion diagnostic of a lipoma.

operative imaging of STS. More than one third of local recurrences can be detected on MRI before they present with signs and symptoms, and thus MRI is an important component of routine surveillance.[26] MRI can help differentiate post-surgical seroma, inflammation, scarring and haematoma from recurrent tumour. Conventional T1W, T2W and static post-contrast sequences often cannot discern post-operative changes from disease recurrence. The complete absence of fluid signal in the surgical bed is a specific however infrequently observed indicator of no disease recurrence. Recurrent tumour can sometimes be characterised by regions of architectural distortion on T1W images, and intravenous contrast can further illuminate disease recurrence by revealing mass-like or a nodular area of enhancement. Some exceptions to this include undifferentiated pleomorphic sarcoma and myxofibrosarcoma which may recur as plaque-like tails of tumour on MRI.[14]

Whole body MRI (WBMRI) using STIR and T1W sequences can prove useful in assessing the extent of suspected metastatic disease in soft tissue and bone, and in locating the site of an unknown STS presenting with lung metastases.[27] Myxoid liposarcomas have a known predilection for extra-pulmonary metastases, and WBMRI has been shown to be useful in their detection and has also been shown to directly alter patient management.[28] One study demonstrated a sensitivity of 80% and 84.6% and a specificity of 97% and 98.9% respectively in the detection of soft tissue and bone metastases from myxoid liposarcoma.[29] Compared with CT alone, WBMRI has been shown to identify more sites of myxoid liposarcoma metastasis. It has been suggested that in this setting WBMRI be used at diagnosis of relapse to confirm whether only a solitary metastasis is present prior to metastectomy, and at the initial diagnosis where the finding of an occult metastasis would alter management (Fig. 18).[28] FDG-PET has proved limited in the detection of metastatic myxoid liposarcoma, which further adds weight to the case for the use of WBMRI in this setting. Additionally with WBMRI the diagnostic accuracy of detecting soft tissue metastases is high as the signal intensity of the metastatic lesion can be easily matched to that of the primary lesion.[29] The use of WBMRI in paediatric STS imaging has emerged as a very useful tool for the assessment of malignant disease spread. It avoids the risks of ionising radiation that a staging CT would otherwise confer, particularly as children have an increased sensitivity to ionising radiation.[30] In addition WBMRI allows assessment of bone marrow, soft tissues and solid viscera with superior soft tissue contrast

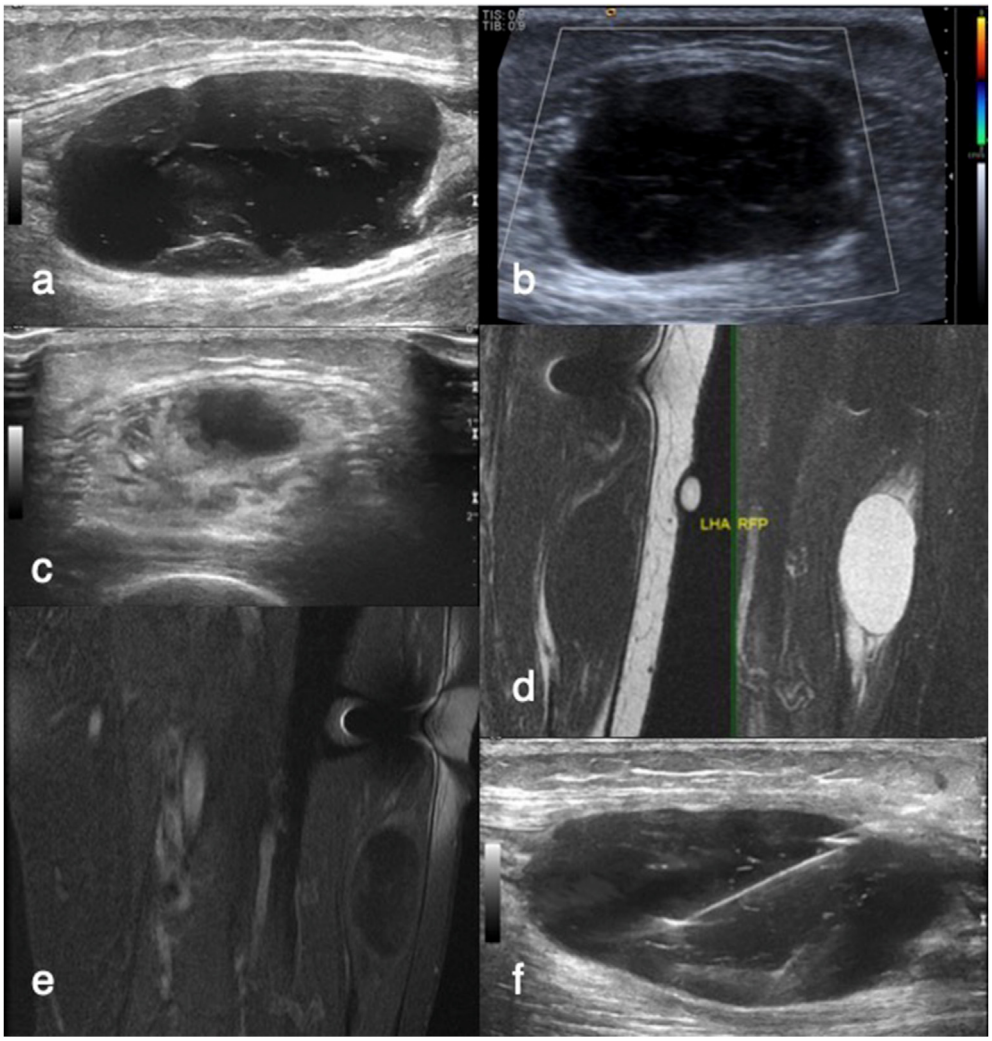

Fig. 10. Myxoid lesion. A longitudinal ultrasound view through the left upper thigh (a) reveals a hypoechoic lesion with a few low-level internal echoes. Doppler ultrasound of the same lesion (b) demonstrates no vascularity. A longitudinal ultrasound view with an increased time gain compensation of the same lesion (c) revealed the solid nature of the previously thought cystic lesion which is now suggestive of a myxoid lesion. Coronal T1W (left) and STIR (right) images (d) demonstrate an intramuscular cystic lesion with surrounding inflammatory change in the adjacent muscles. A coronal T1W fat-saturated and contrast-enhanced image (e) demonstrates faint peripheral contrast enhancement, which was inconclusive. An aggressive process could not be excluded on ultrasound or MRI, and an ultrasound-guided biopsy (f) was performed. Histopathology supported a diagnosis of a benign intramuscular myxoma.

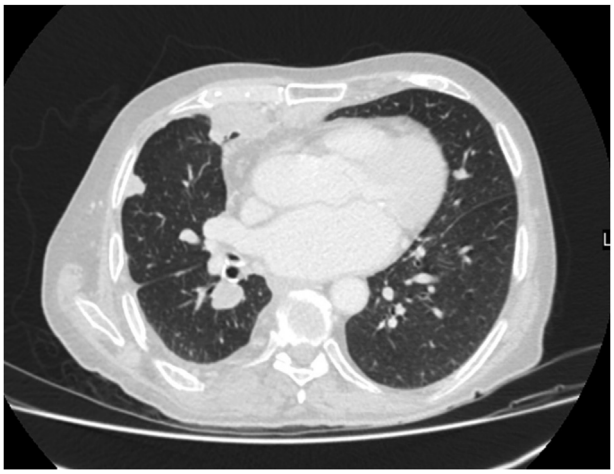

Fig. 11. Lung metastases. Unenhanced CT demonstrates multiple bilateral lung metastases from a primary soft tissue sarcoma.

resolution to other techniques. Performing whole body imaging also allows for a fewer total number of investigations required in the paediatric population.[31] Hybrid PET/MRI combines anatomical, metabolic and molecular imaging and has the potential for being superior to PET/CT in STS imaging. One study demonstrated a higher detection rate of STS recurrence with PET/MRI as well as provided greater diagnostic confidence when compared with MRI alone.[32] Hybrid PET/MRI in the evaluation of STS is still in its infancy and needs further research with respect to improving staging, evaluating treatment response and decreasing ionising radiation dose.[33]

Advanced MRI techniques include functional MRI comprising of dynamic contrast-enhanced MRI (DCE-MRI) and DWI. DCE-MRI is a method of physiologic imaging that evaluates the early enhancement kinetics of water-soluble MRI contrast media. It can provide detailed analysis about the microcirculation of soft tissues. This can provide the ability to assess lesion size, locally stage it and monitor treatment response. DCE-MRI can indicate strong suspicion for high-grade STS through evidence of peritumoral contrast enhancement.[34] Some tissue signal characteristics of peritumoral

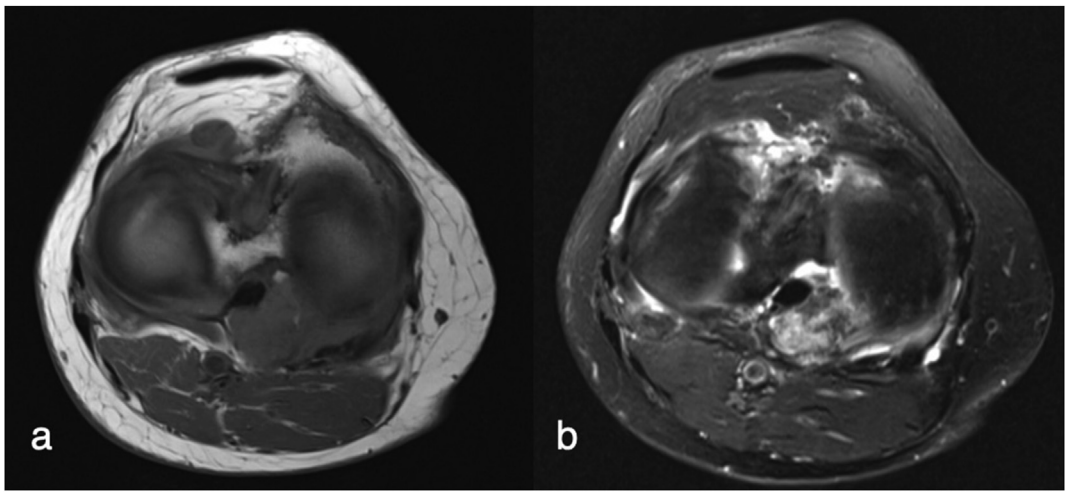

Fig. 12. Tenosynovial giant cell tumour. Axial T1W image (a) revealed a soft tissue lesion in the posterior intercondylar notch of the knee. A corresponding T1W fat-saturated image (b) demonstrated contrast-enhancement within the lesion.

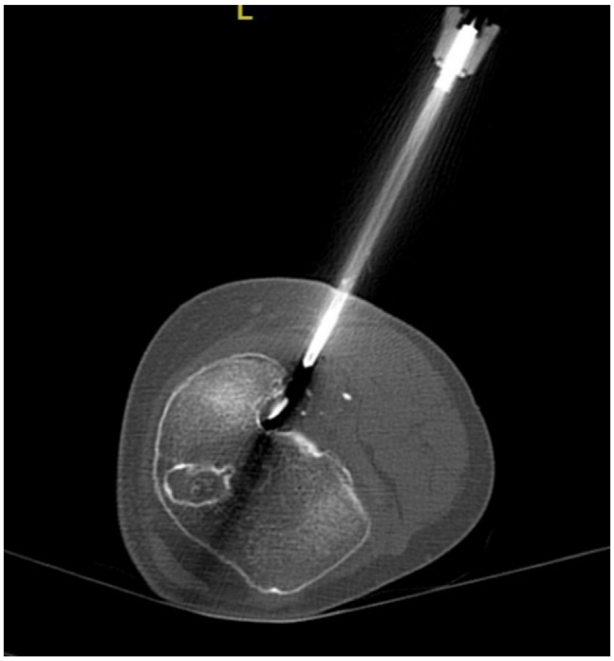

Fig. 13. CT-guided biopsy of tenosynovial giant cell tumour. Due to the indeterminate imaging appearances of the enhancing soft tissue lesion in Fig. 12, a CT-guided biopsy was performed which avoided critical adjacent neurovascular structures such as the popliteal artery. Histopathology revealed a diagnosis of tenosynovial giant cell tumour.

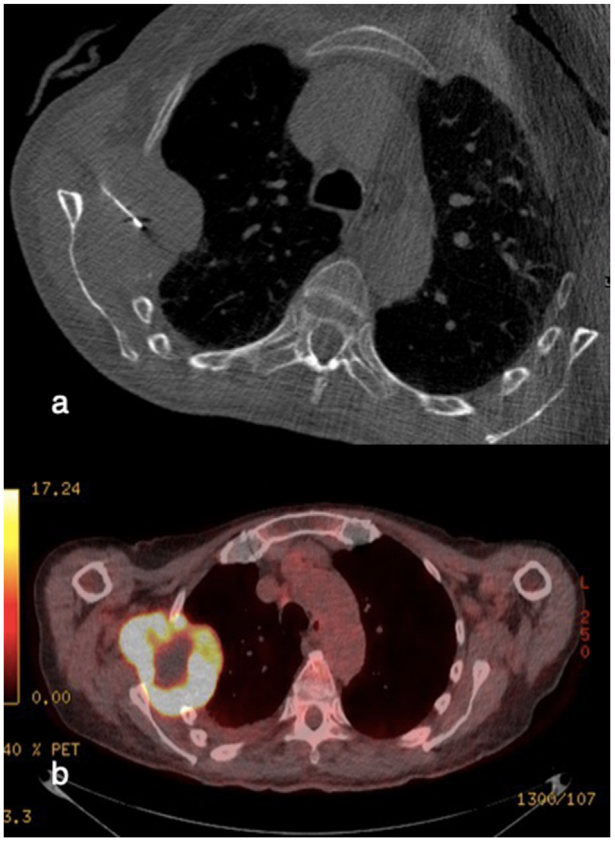

Fig. 14. The value of PET-CT in identifying target regions for biopsy. An axial CT image of the thorax performed for CT-guided biopsy of a suspected right chest wall soft tissue sarcoma (a) was non-diagnostic. Note the trough of the biopsy needle lies within the centre of the lesion. A subsequent PET-CT (b) demonstrated a non-viable central region of tumour where the biopsy sample had been acquired. The FDG-avid regions at the periphery of the lesion (bright areas) reveal the regions of viable tissue likely to yield a diagnostic sample.

oedema can help suggest a specific sarcoma subtype. Whilst there is clear evidence of the effectiveness of DCE-MRI, it is considerably more expensive and time-intensive than conventional T2W imaging. Another drawback is that peritumoral oedema may result in overestimation of tumour size. Adding these functional MRI sequences to a standard protocol that includes fluid sensitive, T1W, and static post-contrast T1W images improves MRI recurrence detection from 27% to 97%. Additionally, a DCE-MRI sequence reduces the false-positive rate from 48% to 3.2%.[35] The potential translational benefit for improving patient care by decreasing the false-positive detection rate in STS postsurgical surveillance is significant. Additionally as postsurgical surveillance for STS commonly includes a CEMRI examination, adding a DCE sequence requires no extra contrast material administration. DWI also offers increased specificity (97%) in differentiating tumour recurrence from postoperative inflammation and fibrosis; however the sensitivity was shown to be only 60%.[35] Viable tumour consists of tissues

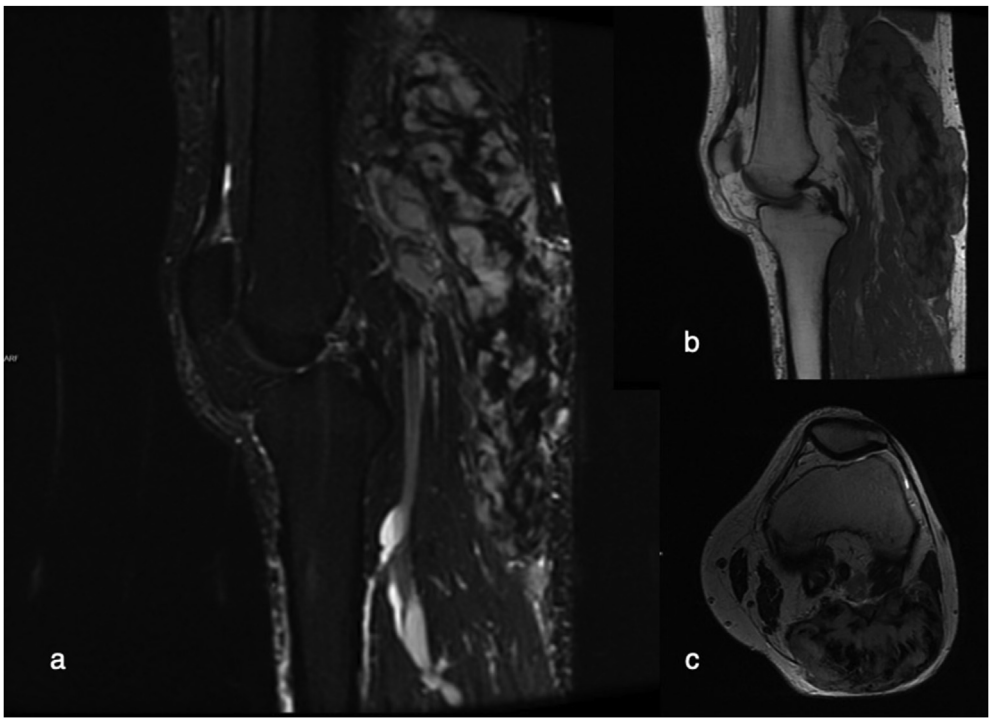

Fig. 15. Desmoid-type fibromatosis. A sagittal STIR image of the knee (a) reveals a multilobulated soft tissue lesion in the popliteal fossa with heterogenous signal and hypointense internal components suggestive of fibromatosis. A corresponding sagittal T1W image (b) demonstrates hypointensity with more hypointense internal components; further adding confidence to a diagnosis of fibromatosis. An axial T2W image (c) again demonstrates hypointensity with more hypointense internal components. Core biopsy confirmed desmoid-type fibromatosis.

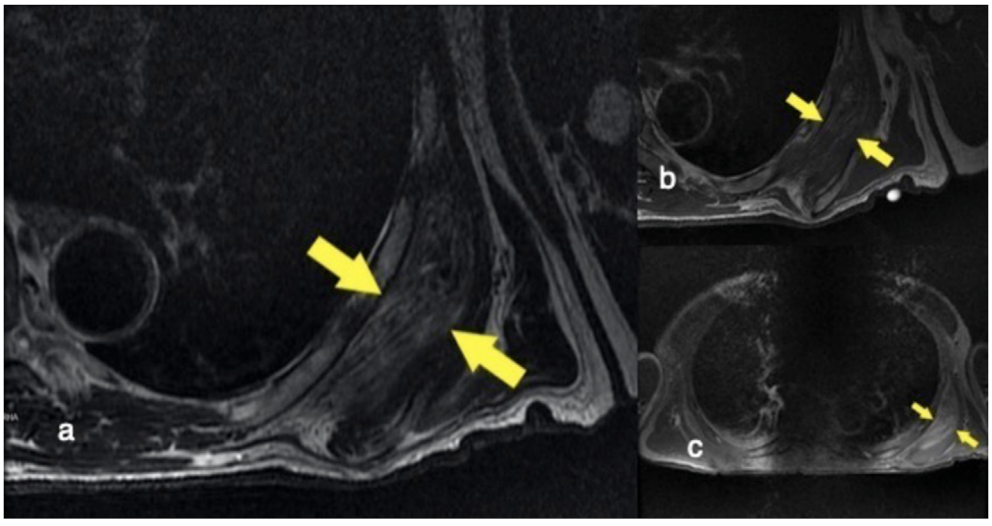

Fig. 16. Elastofibroma. An axial T1W image through the left chest wall (a) reveals an intermediate to low signal intensity subscapular mass deep to the serratus anterior muscle (yellow arrows), abutting the chest wall. An axial T2W image (b) also returns intermediate to low signal intensity (yellow arrows). An axial T1W fat-saturated post contrast image (c) demonstrates enhancement of the mass (yellow arrows), a common feature of elastofibromas.

that have increased vascularity, capillary permeability and perfusion, and demonstrate rapid enhancement approximating to arterial enhancement. Non-viable tumour and postchemotherapeutic or postoperative inflammation enhances more slowly and later because their tissues have less vascularity, higher capillary resistance and lower capillary permeability. Different tissues within a tumour can be differentiated with DCE-MRI as they can demonstrate temporally different enhancement curves. Viable tumour correlative with histologic examination will demonstrate rapid early enhancement, and all tissues including viable, nonviable tumour and inflammation will enhance simultaneously in the late phase, similar to conventional CE-MRI obtained several minutes after contrast injection. Thus DCE-MRI can help define chemotherapeutic response, disease recurrence and biopsy sites and in doing so help in the initial workup, treatment and follow-up of patients with STS.[36] The addition of DWI to conventional MRI imaging may improve specificity for assessing tumour margin infiltration. Peritumoural high signal intensity on conventional MRI

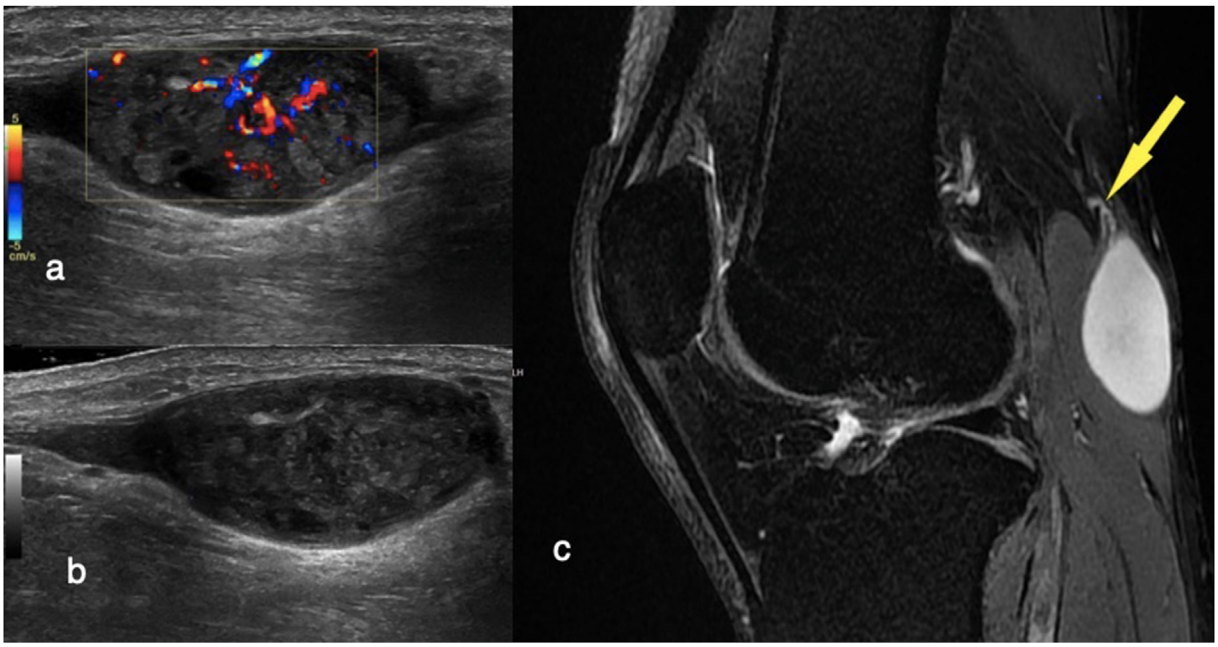

Fig. 17. Peripheral nerve sheath tumour. A longitudinal ultrasound view in the right ankle (a) demonstrates a heterogenous lesion with cranial and caudal 'tails' that exhibits marked central vascularity. The 'tail' represents contiguity with a peripheral nerve, in this case the sural nerve. This lesion was subsequently proven to be a malignant peripheral nerve sheath tumour on biopsy. A longitudinal ultrasound view of the right popliteal fossa in another case (b) again contains a heterogenous lesion with a 'tail' characteristic of a peripheral nerve sheath tumour. No internal vascularity was demonstrated. A sagittal proton density fat-suppressed of the right knee (c) demonstrates a well-defined, fusiform and hyperintense mass with a target sign (central low signal focus) contiguous with the muscular branches of the tibial nerve (yellow arrow) in keeping with a peripheral nerve sheath tumour. Subsequent histopathology revealed a benign morphology.

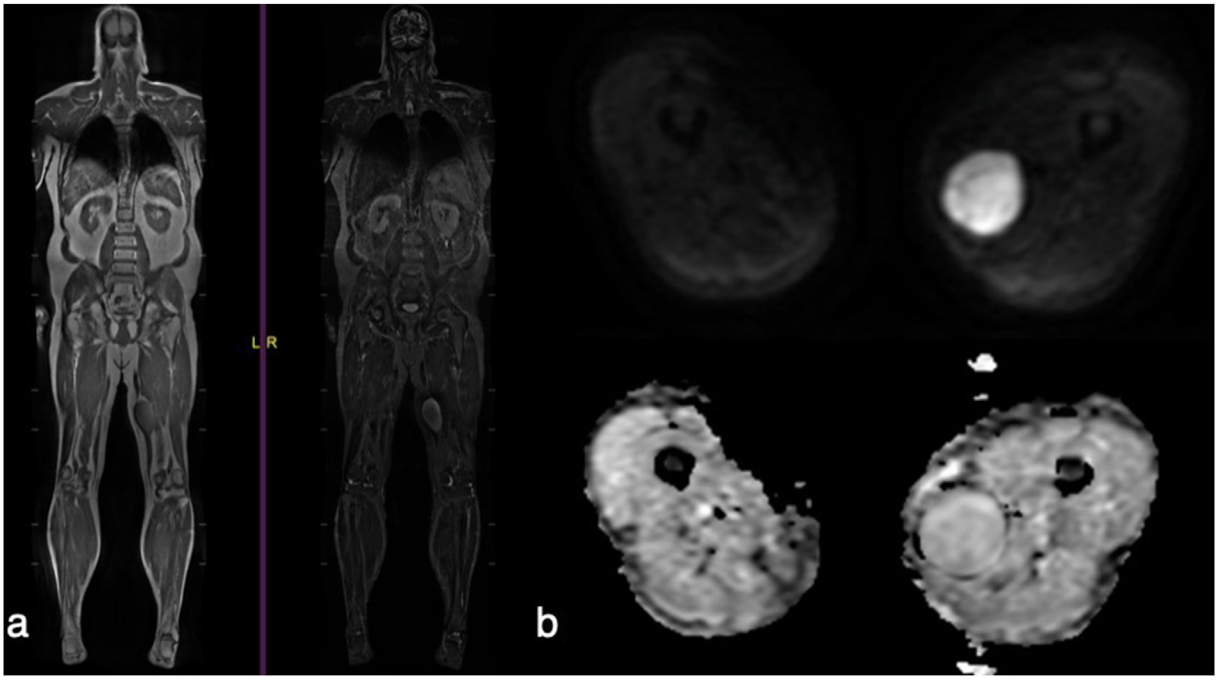

Fig. 18. Myxoid liposarcoma. Coronal whole body MRI (a) with T1W (left) and fat-suppressed fluid sensitive (right) images demonstrate a well-defined myxoid lesion with solid and fluid components in the medial aspect of the left thigh. Axial diffusion weighted (DW) images with their corresponding apparent diffusion coefficient (ADC) maps (b) demonstrate some restricted diffusion of the lesion with a relative increased signal intensity in the DW image (top) and a corresponding lower signal in the ADC map (lower image). Histopathology revealed a diagnosis of myxoid liposarcoma.

sequences can indicate either tumour infiltration or simply reactive change. Hong et-al have found that a poorly defined tumour margin on DWI indicates infiltrative tumour margin rather than reactive change.[37] Hence the addition of DWI may help preserve adjacent essential structures in limb salvage surgery.

Magnetic resonance elastography is a noninvasive MRI technique that can quantify mechanical tissue properties. An early feasibility study to quantify stiffness and perfusion parameters in

STS with the goal of evaluating response to radiation therapy has demonstrated the ability of MRE and DCE-MRI to accurately assess early response.[38] This is promising in its potential to evaluate new and targeted treatments with the ultimate aim to move towards more individualised treatment options for STS patients.

Further advances in artificial intelligence may also contribute towards STS imaging. A limited study has attempted to predict STS response to radiotherapy using longitudinal DWI and a deep neural network with generative adversarial network-based data augmentation. This is based on the premise that DWI can assess early treatment response before anatomical changes are evident. The trained prediction network is quoted to accurately predict tumour pathological treatment response on independent test patients with accuracies of 97.1% and 83.3% for patient-based and slice-based prediction respectively. This preliminary study suggests an opportunity for personalised treatment adaptation based on longitudinal DWI assessment.[39] DWI quantification using multiple models other than the apparent diffusion coefficient including the intravoxel incoherent, the stretched-exponential and the diffusion kurtosis models have been developed in an attempt to characterise tumour microstructural heterogeneity and tissue complexity. This was done to better capture functional and anatomical properties of STS. Manikis et-al have suggested that DWI quantification using multiple models and the design of composite parametric maps after model selection are significant and highly discriminatory in distinguishing low from high grade STS.[40]

6. Conclusion

STS are rare tumours and require a multidisciplinary team approach in specialist centres to ensure appropriate management. Ultrasound is the often the primary modality for the assessment of soft tissue lumps and is often performed by non-specialist practitioners. It is important one recognises when lesions are clearly not benign and suggest further imaging with MRI. Due to the wide variation in available services, this may be performed in general hospitals prior to the patient being referred to specialist centres. All centres should know and liaise with their specialist centre so that MRI can be performed with the appropriate protocols. Recent advances include the promise of WBMRI, DWI, DCE-MRI and artificial intelligence. These are likely to be very useful adjuncts and problem solving tools rather than being integrated into standardised imaging protocols. Additionally they are likely to be performed predominantly in specialist centres due to the advanced training required for image acquisition and interpretation.

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