Original Article

Magnetic resonance imaging and positron emission tomography-computed tomography evaluation of soft tissue sarcoma with surgical and histopathological correlation

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ABSTRACT

Purpose: The aim of this study was to evaluate the role of positron emission tomography-computed tomography (PET-CT) and magnetic resonance imaging (MRI) in characterization and pre-operative staging of soft-tissue sarcoma (STS) and correlating with operative and histopathological findings. **Materials and Methods:** Twenty patients (age range 16-72 years [mean 44.4 years]) with resectable and STS were included in this prospective study. Pre-operative MRI was carried out in all patients with acquisition of T1W, T2W, and short tau inversion recovery (STIR) sequences in appropriate planes. Contrast enhanced MRI was performed in four patients. Whole body PET-CT was performed in 13 patients. Demographic data, clinical features, pre-operative imaging analysis, operative, and histopathological findings were analyzed using SPSS software version 11.5. **Results:** The most common histologic type was malignant fibrous histiocytoma (MFH) (30%). Of 18 STSs 20 were high-grade. Agreement existed between MR and operative size. MRI had 100% negative predictive value (NPV) in predicting neurovascular bundle involvement. However, positive predictive value (PPV) was 33%. MRI had PPV of 20% while PET-CT had 50% PPV in detecting lymph node involvement. Overall staging accuracy of MRI was 75% when correlated with surgical and histopathological findings. Combined PET-CT and MRI staging, in 13 patients, was better (92.31%) when compared with staging with MRI (84.62%). Specific diagnosis on image characteristics was correctly suggested in 35% patients. **Conclusions:** MRI is the robust modality in local staging of STSs and PET-CT adds greater accuracy to overall staging in combination with MRI.

Keywords: Magnetic resonance imaging, positron emission tomography-computed tomography, soft-tissue sarcoma, staging

INTRODUCTION

Although, the soft-tissues constitute a large part of the human body, soft-tissue tumors are rare, accounting for less than 1% of all neoplasms; with benign tumors outnumbering their malignant counterparts by about 100-1.[1] Soft-tissue sarcomas (STS) can arise almost anywhere in the body. Various types of STS include malignant fibrous histiocytoma, liposarcoma, fibrosarcoma, synovial sarcoma, malignant peripheral nerve sheath tumor (MPNST), leiomyosarcoma, rhabdomyosarcoma, clear cell sarcoma, epithelioid sarcoma, alveolar soft part sarcoma, angiosarcoma, spindle cell sarcoma, sarcoma not otherwise classified and undifferentiated sarcoma of soft-tissue. Imaging is required to confirm the clinical diagnosis, to delineate the extent and for staging. The various modalities used for this purpose are computed tomography (CT) and magnetic resonance imaging (MRI); the latter being the modality of choice. CT is primarily reserved to exclude lung metastasis.

MRI provides superior soft-tissue contrast, allows multi-planar image acquisition, obviates iodinated contrast agents and ionizing radiation, and is devoid of streak artifacts commonly encountered with CT.[2] Despite the superiority of MR imaging in delineating soft-tissue tumor, it remains limited in its ability

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to precisely characterize them, with most lesions showing a non-specific appearance with prolonged T1 and T2 relaxation times. Consequently a correct histologic diagnosis is reached solely on the basis of MRI studies in only 25-35% of cases. Local staging is best accomplished using MRI, which can accurately depict the anatomic spaces and structures involved by the tumor.[3]

Positron emission tomography-CT (PET-CT) is widely used for the staging of various malignancies; especially, for nodal and distant metastatic staging. The radionuclide most commonly used for PET is ^{18}F-fluorodeoxyglucose (^{18}F-FDG). PET-CT integrates PET and CT image in a single device. In general, sarcomas tend to be ^{18}F-FDG avid, although, there is significant variability. PET can detect intralesional morphological variation, which is especially, true in STSs, it can predict tumor grade, and is of value in staging, restaging, and prognosis.[4] STS are generally staged according to Memorial Sloan Kettering Cancer Center (MSKCC) staging system.[5,6] Limited studies have described the utility of MRI and PET-CT in evaluation of STS. We did this prospective study to characterize and locally stage STS using MRI and PET-CT findings in STS and correlated this with operative and histopathology findings. Preliminary results of MRI findings from this have been reported earlier in an abstract.[7]

MATERIALS AND METHODS

Over the period of 25 months from May 2006 to May 2008, 20 patients with soft-tissues sarcoma were enrolled in the study. All patients in our study were diagnosed to have STS based on fine needle aspiration cytology or core biopsy findings. The median age was 44 years (range 16-72 years). There were 14 males and 6 females (male:female ratio of 2.3:1). Clinical sites of the STS were upper extremity, lower extremity, and trunk. Patients with age less than 12 years, patients with unresectable disease on MRI and those who refused surgery were excluded from study.

MRI acquisition

MRI was performed in all 20 patients using either of 1.5 Tesla scanners, SONATA or AVANTO (Siemens, Erlangen, Germany). Body and appropriate surface coils were used. Images were acquired in multiple planes. Standard spin echo and/or gradient echo sequences were employed with or without fat suppression. T1W, T2W fat suppressed, and STIR images were routinely acquired in axial and orthogonal planes in all the patients. Post-gadolinium – diethylene triamine pentaacetic acid (DTPA) contrast enhanced (CE) fat suppressed images were obtained in four patients. MR images were analyzed to assess the largest tumor dimension, depth, thickness, local soft-tissue extent, neurovascular invasion, bone involvement, and lymph node metastases.

PET-CT acquisition

Whole body PET-CT was performed in 13 of 20 patients. It was performed 60 min following intravenous injection of 370 MBq (10 mCi) of ^{18}F-FDG on a full-ring dedicated dual slice Leuitium oxy ortho silicate PET-CT 3D scanner, (Biograph 2, Siemens, Erlangen, Germany). CT images were used for attenuation correction. By using iterative order subset expectation maximization reconstruction algorithm PET-CT fusion images were obtained for analysis. After image reconstruction, a region of interest (ROI) was carefully drawn around the site of the abnormal ^{18}F-FDG uptake on the lesion in the consequent 4-6 PET-CT scan slices. The slice with a maximal ^{18}F-FDG uptake in the ROI was chosen for quantitative measurement of metabolic activity that is standardized uptake value (SUV). From these ROIs, the SUV was calculated according to the formula described below:

(SUV = Mean ROI activity [MBq/g]/injected dose (MBq/body weight [g])

Where, "MBq" = Mega-Becquerel and "g" = grams. Maximum SUV value was calculated for each ROI. PET-CT images were analyzed independently by nuclear physician for functional as well as anatomical information and it was used to assess the tumor size, local soft-tissue extent, bone invasion, and lymph node metastases.

Clinical follow-up

Patients underwent surgery after completion of imaging work-up. Average gap between MRI and surgery was 19 days (range 3-28 days). Wide local excision of the primary tumor along with reconstruction was performed. After excision of the primary tumor, separate samples were taken from all the margins of the resected site. The primary tumor, margins, and lymph nodes were submitted for histopathological examination. Imaging, surgical, and histopathological findings were recorded on a pro-forma and evaluated. Results of the imaging findings were correlated with the histopathology and intra-operative findings, which served as a standard of reference. The statistical analysis was carried out using statistical package for social sciences (SPSS) software version 11.5.

RESULTS

Tumor characteristics

Histologic type

The various histologic types of STS are shown in Table 1. The most common histologic types of STS were malignant fibrous histiocytoma (six patients [30%]) followed by synovial sarcoma (four patients [20%]). Due to the small sample size and referral bias this might not reflect the actual incidence and distribution of the disease among the population.

Tumor grade

Eighteen of the 20 patients had high-grade STS based on histopathology findings and categorized on basis of MSKCC staging [Table 2]. Undetermined STSs were grouped in to low- or high-grade depending on histopathological and clinical features. Both undifferentiated sarcomas in our study were of high-grade while fibrosarcoma was of low-grade.

MRI results

Size and location

Size of the tumors on MRI ranged from 5 cm to 23 cm. The tumors were assigned to the different compartments based on anatomical and fascial considerations. Axilla and shoulder was the most common compartment with four (20%) patients having tumors in the same compartment. The compartments involved in our study were shoulder and axilla (20%), forearm posterior (10%), hip and gluteal region (5%), thigh anterior (15%), thigh posterior (5%), thigh medial (15%), knee and popliteal (5%), leg posterior (10%), chest wall (10%), and anterior abdominal wall (5%). Some of these compartments have a distinct fascial covering while the rest are anatomical grouping carried out to facilitate analysis for evaluation of individual muscle involvement. None of the patient had bone involvement; either cortical involvement or bone marrow abnormality on MRI. MRI was correctly able to determine the fascial involvement in 19 out of 20 patients. One patient however, was false negative on MR and found to have fascial involvement on surgery. MR showed a sensitivity of 93% and specificity of 100% in predicting fascial involvement. Skin involvement was overestimated clinically as only 4 of 20 patients (20%) had normal skin clinically. Moreover, it was not possible determine on MRI whether the skin with previous scar was involved or not involved. MR showed skin involvement in 13 patients. It was confirmed at surgery and histopathology and thus, MR was 100% sensitive and 100% specific in predicting skin and subcutaneous tissue involvement. Assessment of individual muscle involvement was performed on MRI and the operative finding was used as gold standard. In 20 patients, muscle involvement (either replaced or contiguously involved with evidence of altered signal intensity, thickening or wide-area of contact) was diagnosed in 59 muscles. On surgery 56 of these were found to be involved but remaining three muscles were free. MRI had sensitivity of 92.3% and specificity of 96.5% in predicting individual muscle involvement. The false positive MR findings in three muscles were reviewed again and we found that all of these muscles had only wide-area of contact with the tumor. There were six muscles that were involved at surgery but had been interpreted as not involved on MRI. All of these patients had high-grade tumors.

Neurovascular involvement

Clinically none of the patient had obvious neurovascular deficit. This may be attributed to selection bias because we excluded advanced cases of STS, which were inoperable. On MR evaluation for involvement of neurovascular bundle (NVB), we found that using less than 180 degree contact as criteria for absence of NVB involvement, 14 patients were considered to have NVB free from tumor. In 9 (45%) of these patients the sarcoma was not in vicinity of the NVB while in another five patients (25%) the tumor was seen abutting the neurovascular structures with angle of contact less than 180°. NVB was free on surgery in these 14 patients. Six other patients were interpreted to have involvement of NVB on MR. on the basis of greater than 180° angle of contact while or complete encasement. At surgery two of these patients were confirmed to have NVB involvement. Rest four patients had no involvement of NV [Figure 1]. On retrospective review of these two patients, one had complete encasement of NVB on MRI while the other had more than 180° tumor contact with NVB and contour deformity of vessels. In the other four patients, with positive MRI the NVB was displaced but not involved at surgery.

Table 1: Histologic types of soft-tissue sarcoma (*n*=20)

Type	Number of patients	Percentage
Undifferentiated	2	10
Angiosarcoma	1	5
Liposarcoma	3	15
MFH	6	30
MPNST	2	10
Synovial sarcoma	4	20
Rhabdomyosarcoma	1	5
Fibro sarcoma	1	5

MPNST: Malignant peripheral nerve sheath tumor, MFH: Malignant fibrous histiocytoma

Table 2: Histologic type correlation with grade of soft-tissue sarcomas (*n*=20)

Low-grade (*n*=1)	High-grade (*n*=16)	Undetermined (*n*=3)
Well differentiated liposarcoma (*n*=1)	Synovial sarcoma (*n*=4)	Fibrosarcoma (*n*=1)
	Rhabdomyosarcoma (*n*=1)	Un differentiated (*n*=2)
	Angiosarcoma (*n*=1)	
	MPNST (*n*=2)	
	Round cell liposarcoma (*n*=2)	
	MFH (*n*=6)	

MPNST: Malignant peripheral nerve sheath tumor, MFH: Malignant fibrous histiocytoma

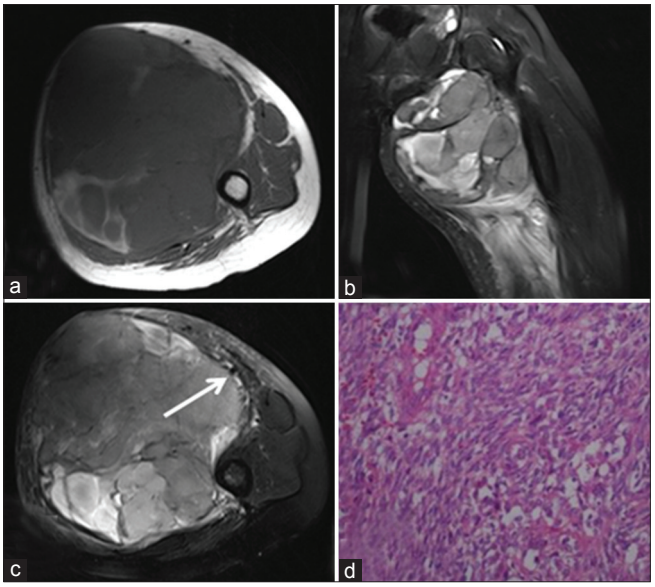

Figure 1: False positive neurovascular involvement; magnetic resonance imaging of 16-year-old female with synovial sarcoma of left thigh shows (a) heterogeneous isointensity on axial T1W and (b) heterogeneous triple intensity on axial T2W and (c) coronal T2W images. The tumor is involving the adductor group muscles and shows > 180° contact with the neurovascular bundle (arrow), however, it was free on surgery. (d) Histopathology microphotograph shows synovial sarcoma

MRI morphology

Most of STS had generally non-specific MR morphology with low-signal intensity on T1W images and high-signal intensity on T2W images [Table 4]. The tumors exhibited variable signal intensities on T1 and T2 weighted images. We also attempted to give specific diagnosis or purpose meaningful differential diagnosis however, this possible in only seven patients (35%). This included synovial sarcoma in three patients, liposarcoma in two patients and MPNST in two patients. We found that there was no statistical difference using Chi-square test in prediction of histologic type between the new and recurrent cases, i.e. recurrent tumors have the same imaging morphology as the original tumor. Liposarcoma has hyper-intensity on T1W images and T2 turbo spin echo (TSE) images with suppression of the bright signal on fat saturated sequences. Synovial sarcoma has characteristic triple signal intensity on T2W images [Figure 1]. Signal intensities exhibited by the tumor on T1W images and T2W images are shown in Tables 3 and 4 respectively. We performed static CE MR in four patients only; which apart from helping in better delineation of the tumor margins on T1W images, did not provide any significant additional information. In two of the four patients there was peripheral enhancement signifying central necrotic component while in the other two the enhancement was heterogeneous.

Staging

Using the MSKCC staging system, we found that one patient (5%) had stage 1, four patients (20%) had stage 2, 10 patients (50%) had stage 3 while five patients (25%) had stage 4 disease. Correlating with surgery and histopathology, MRI correctly staged 15 patients. MR upstaging occurred in four patients and under staging in one patient. All the patients who were upstaged had enlarged lymph nodes which were not involved on histopathology and were reactive only. The one patient who was under staged on MRI had multi compartment disease with fascial invasion on surgery, which was not recognized on MR. MRI was moderately accurate in overall staging. In all 20 patients MR had an accuracy of 75% with a kappa value of 0.578 (fair).

PET-CT results

Location and extent

The site of the tumor was similar to the site as examined clinically, and on MRI and the mean size was 9.76 cm. All 13 patients had a tumor size greater than 5 cm. On a total of 13 patients, 12 had solitary tumor while 1 patient had skip lesions. However, there was no agreement between the size projected on PET-CT and the operative size. The interclass correlation co-efficient was 0.202 while the correlation co-efficient was 0.11 signifying poor agreement. Tumor localization in specific compartment relies on delineating the fascia, which cannot be well-depicted on PET-CT images. Hence, compartment localization was not attempted on PET-CT. Skin and subcutaneous tissue was involved in eight patients on PET-CT. Six patients ($n = 13$) had tumor in vicinity of the expected location of the NVB. Three patients had tumor in close proximity of the neighboring joint. However, actual status of NV bundle or joint was not assessed on PET-CT. Chest CT revealed indeterminate nodules in two patients ($n = 13$). None of the patients showed metastatic dissemination on PET-CT examination.

Standardized uptake value

SUV was calculated reviewing multiple planes through the tumor using a circular ROI: maximum and average SUV was determined. The values were rounded off to the nearest whole number. The maximum and average SUV in the 13 patients are shown in Tables 5 and 6 respectively. The high-grade STS in our study had low-average SUV uptake due to necrosis and showed high maximum SUV. No agreement was found between maximum SUV and average SUV using Spearman rank co-efficient. Figure 2 shows the scatter graph plotted between maximum SUV on Y axis and average SUV on X axis in the 13 patients who had PET-CT examination.

Table 3: Signal intensity of tumor on T1W images (*n*=20)

Signal intensity	No. of patients	Percentage
Isointense homogeneous	5	25
Isointense heterogeneous	7	35
Hypointense homogeneous	1	5
Hypointense heterogeneous	3	15
Hyperintense homogeneous	1	5
Hyperintense heterogeneous	3	15

T1W: T1 weighted

Table 4: Signal intensity of tumor on T2W images (*n*=20)

Signal intensity	No. of patients	Percentage
Hyperintense homogeneous	2	10
Hyperintense heterogeneous	18	90

T2W: T2 weighted

Table 5: Maximum standardized uptake value on positron emission tomography-computed tomography

Patient	SUV_{max}
1	10
2	6
4	21
6	7
11	5
12	6
13	2
14	13
15	2
16	9
17	2
18	7
20	9

SUV: Standardized uptake value

Table 6: Average standardized uptake value on positron emission tomography-computed tomography (*n*=13)

Average SUV	No. of patients	Percentage
1	2	15
2	8	62
3	2	15
5	1	8

SUV: Standardized uptake value

Lymph nodes evaluation

Five patients were found to have enlarged lymph nodes on MR imaging and in two of these patients PET-CT was also carried out. Three patients had enlarged inguinal lymph nodes while two patients had enlarged axillary lymph nodes. Only one patient with enlarged inguinal nodes was found to have malignant lymph node involvement on histopathology while the rest four patients showed reactive changes only. One patient was false positive on PET-CT as shown in Figure 3. In one patient PET-CT helped in ruling out metastatic disease in abnormal nodes seen on MRI and thus, down-staged the disease [Figure 4].

Combined PET-CT and MRI staging

In the 13 patients who also had underwent PET-CT, the MR accuracy was 84.62% with a kappa value of 0.711 (strong). When PET-CT findings were added to the MRI findings in these 13 patients the accuracy of pre-operative staging was seen to increase. Combined PET-CT and MRI in these 13 patients had an accuracy of 92.31% with a kappa value of 0.85 (very strong). MR staging correlation and combined MR and PET-CT correlation is shown in Figures 5 and 6 respectively.

DISCUSSION

STS is a group of heterogeneous primary malignant STS. Although it includes various histologic subtypes, presentation, diagnosis, and management is generally similar. Pre-operative imaging evaluation of STS patients' help in deciding the management options; wide local excision with limb salvage or amputation in unresectable cases. The clinical assessment of the tumor size in our study was not in agreement with the actual histopathological size and was generally an under estimation of the actual size. This may be attributed to the deep seated location of the sarcoma and the ill-defined margin. Edema and hematoma after biopsy may obscure true tumor margins in MR images. Thus, the temporal delay yielded an inaccuracy in the calculation of pre-operative staging parameters such as size, number of compartments involved, etc., Differences in the orientation of MR scan planes and in tumor orientation during imaging and pathologic examination may exaggerate disparities. Shrinkage of the tumor *ex vivo* and rupture of cystic component may also lead to size disparity.[8] In our patients, surgical specimens were tagged with identifying sutures to alert the examining pathologist to the location of the superior, inferior, and deep margins of resection. However, irregular lobulated tumor contours may have been altered when resected specimens were no longer confined within fascial planes, and tumor shrinkage may also occur when desiccation accompanied delays in gross pathologic dissection. Demas *et al.*[8] also observed that there was no exact size correlation between MR, CT, and operative findings. The differences between MR and pathologic measurements for individual tumor varied from 0 to 8.5 cm (mean 2.2 ± 2.3). In the report of the radiology diagnostic oncology group, Panicek *et al.*[9] observed that the CT and MR imaging measurements of the maximum dimension of tumor were significantly different from the measurements obtained at pathologic analysis ($P < 0.001$ and $P = 0.002$ [Wilcoxon signed rank test]), as well as significantly different from each other ($P = 0.02$). The maximum dimension of the tumor tended to be overestimated with both CT and MR imaging compared with pathologic measurement, although, there was a better agreement between the MR size and actual size in our study.

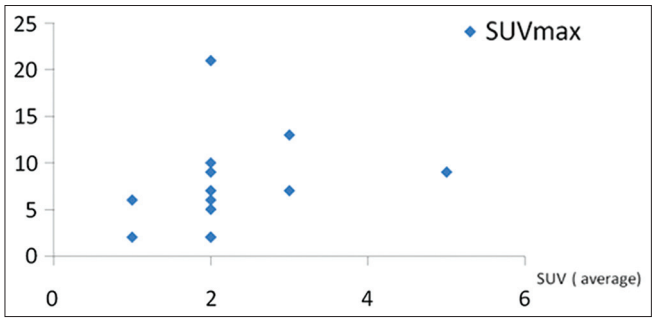

Figure 2: Scatter diagram depicting relationship between standardized uptake value (SUV) maximum and SUV average; SUV maximum values on y-axis and SUV average on x-axis

The local extent of disease is accurately defined with MR imaging. Seven patients (35%) had the tumor confined to a single compartment on MRI evaluation while 13 patients (65%) had extra-compartmental spread of the sarcoma. On surgical and histopathological correlation, 6 of these patients had unicompartmental sarcoma with one patient having multi-compartmental disease was thought to have

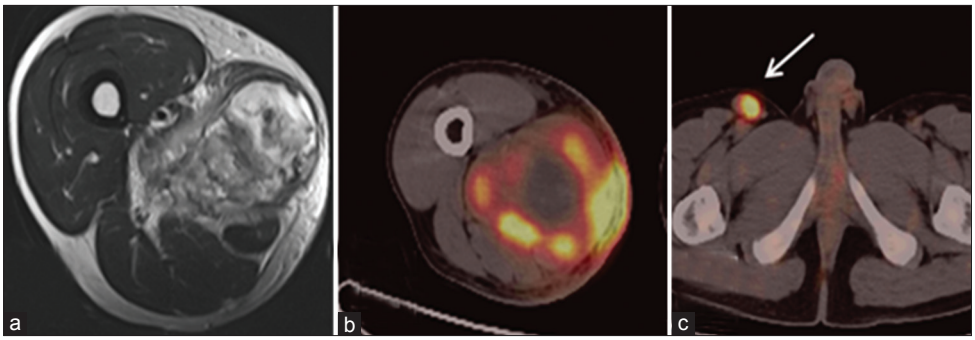

Figure 3: False positive lymph node metastasis on positron emission tomography-computed tomography (PET-CT): Magnetic resonance imaging of 21-year-old male with synovial sarcoma involving of right thigh shows characteristic triple signal intensity on T2W image (a). On PET-CT tumor show high ^{18}F-FDG uptake (b). High uptake was also seen in inguinal lymph node (arrow) on PET-CT (c)

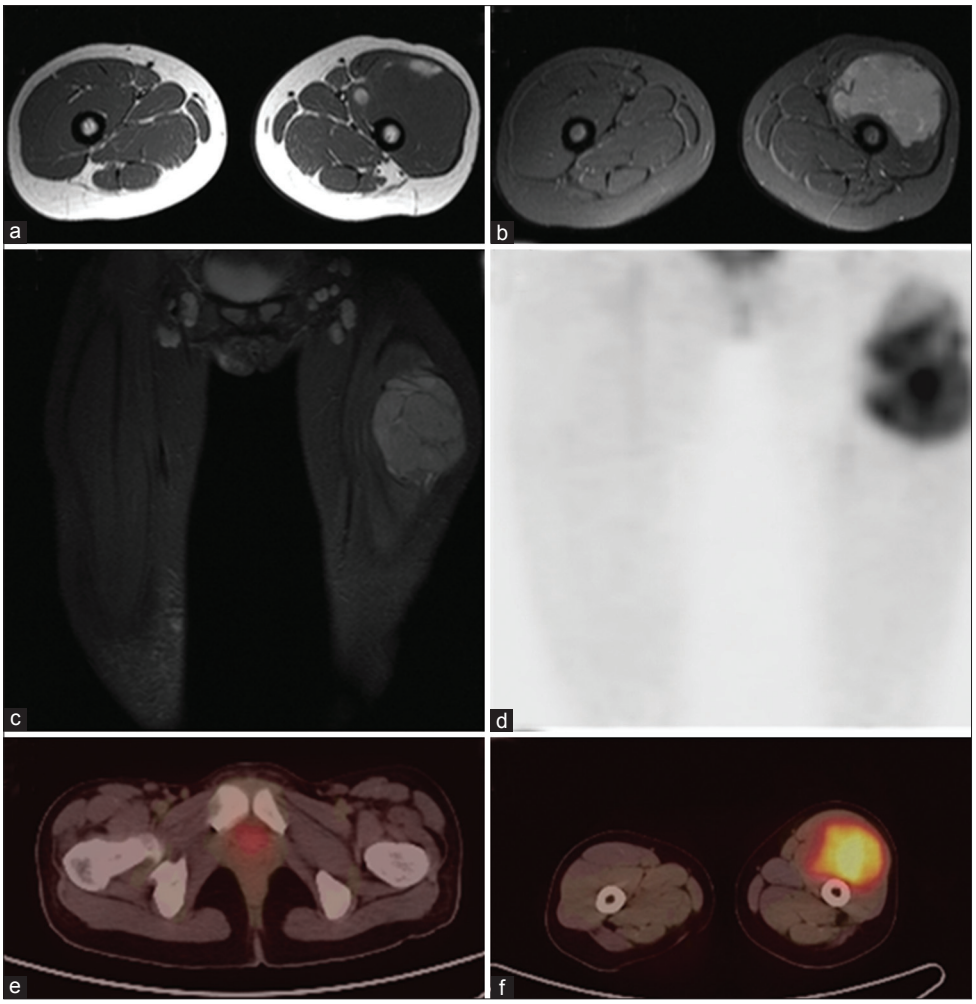

Figure 4: Magnetic resonance false positive and positron emission tomography-computed tomography (PET-CT) true negative lymphadenopathy. 17-year-old female with synovial sarcoma involving left thigh. On magnetic resonance imaging, the sarcoma is (a) heterogeneously isointense on axial T1W images and (b) heterogeneously hyper-intense on axial T2W images. The sarcoma is abutting neurovascular bundle and involving the vastus intermedius (v) and rectus femoris (r) muscles. (c) Enlarged and hyperintense lymph nodes seen in bilateral inguinal region on coronal fat suppressed T2W image. (d) No increased uptake seen in the inguinal region on coronal PET image or (e) axial PET-CT image. On histopathology, the nodes showed reactive changes only. (f) Increased ^{18}F-FDG uptake (asterisk) in the primary tumor is seen on axial PET-CT image

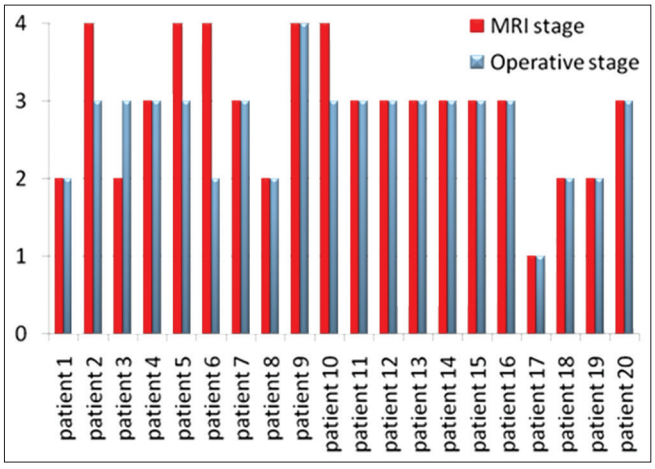

Figure 5: Bar chart showing relationship between magnetic resonance (MR) staging and operative/histopathological staging. The x-axis shows the patients based on serial number and y stage shows the various stages with the red bar showing MR staging and grey bar showing operative and histopathological staging

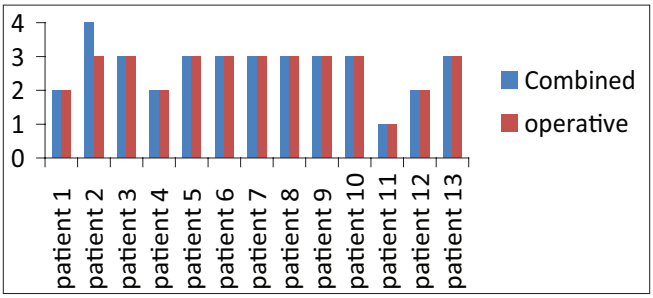

Figure 6: Bar chart showing correlation between on combined magnetic resonance (MR) and positron emission tomography-computed tomography (PET-CT) staging and operative and histopathological staging. The x-axis shows the patients based on serial number and y stage shows the various stages with the blue bar showing MR and PET-CT staging and red bar showing operative and histopathological staging

unicompartmental disease on MRI. All those who had multi-compartmental disease on MRI were shown to have multi-compartmental disease upon surgery. Thus, MRI was 92% sensitive and 100% specific in predicting extra compartmental

disease. Demas *et al.*[8] found that surgical findings confirmed MR assessment of compartmental involvement in all 28 patients, in their study. In three patients, tumor was abutting but not involving the adjoining joint on MRI. This was confirmed on surgery. None of our patients had bone involvement on MRI or surgery. High-accuracy of MRI for bone and joint assessment has been reported earlier.

We found that MRI is also highly accurate in depiction of the individual muscle involvement with a sensitivity of 92% and specificity of 96% similar to the study of Panicek *et al.*[9] who found that MRI had a sensitivity of 96% in evaluating thigh muscles and 100% sensitivity in predicting shoulder and arm muscles. Our experience suggests that MR is accurate in identifying the cases with NVB involvement; however, the involvement may sometimes be over-estimated. In patients with tumor abutting the NVB with angle of contact < 180° the NVB involvement may be reliably excluded. We feel that the most specific MR sign of NVB invasion is complete encasement and even in cases of angle of contact > 180° with NVB or NVB displacement, conservative surgery may be attempted. Chang *et al.* in their study of 20 patients with extremity STS reported that MRI had accuracy of 80% in assessing tumor relationship with major NVB and 80% accuracy in assessing relation to skeletal structures.[10]

We found 75% (15 of 20 patients) accuracy for MR staging while MR upstaging occurred in four patients and under staging in one patient. Similar findings were found in the study by Tateishi *et al.*[11] Although, they used American Joint Committee on Cancer (AJCC) staging protocol for STS, they also found that PE-CT was helpful in correctly under staging the disease in 4% of their patients. They found that interpretations based on combined PET-CT and conventional imaging findings MRI correctly staged tumors in 60 (87%) patients, over staged in 8 (12%) patients and under staged in 1 (1%) patient. Various investigators[2-4] have attempted to categorize the soft-tissue tumor into benign, malignant, low-grade, and high- grade based on the MR imaging characteristics. However, most imaging characteristics in isolation are not accurate enough to be of use in any individual case. However, the studies[2,4] opine that a combination of imaging parameters may best be able to categorize the various soft tissue tumor as benign or malignant. In our study, most of the patients (90%) had high- grade sarcoma and hence, we could not compare the imaging characteristics between the different groups. However, the imaging morphology of the lesions we included in our study was consistent with the imaging characteristics indicative of malignant lesions as purported by De Schepper in his meta-analysis.[12] All the lesions were larger than 3.3 cm and had hyper-intensity on T2 W images. Most of the lesions were heterogeneous on T1 W images and 14 patients had fascial invasion. In the study on 140 patients, van Rijswijk *et al.*[13] had said that combined non-enhanced static and dynamic CE MR imaging parameters were significantly superior to non-enhanced MR imaging parameters alone and to non-enhanced MR imaging parameters combined with static CE MR imaging parameters in prediction of malignancy. Nermin *et al.*[14] have reported that dynamic contrast MRI had an overall accuracy of 95.5% in classifying benign and malignant lesions ($P = 0.004$) and also helped in monitoring the effect of chemotherapy in soft-tissue tumor. However, we performed static CE MR in four patients, which apart from helping in better delineation of the tumor margins on T1W images did not provide any significant additional information.

We attempted to arrive at a specific diagnosis or differential diagnosis of MRI but this was possible in only seven patients (35%). This included synovial sarcoma in three patients, liposarcoma in two patients and MPNST in two patients as these tumors are said to have a characteristic MR appearance [Figure 7]. This observation was in concordance with previous report.[4]

In our study, we found that the high-grade malignant STS had high SUV as has been reported previously. Average SUV values did not correlate with the maximum SUV values in our study. Average SUV values are dependent on the morphology and extent of necrosis in tumor. Average SUV was a poor index of sarcoma grade as a highly necrotic tumor had low average SUV. We had a patient of highly malignant pleomorphic liposarcoma who had maximum SUV of 21 with an average SUV of 2 [Figure 8].

Combined PET-CT and MRI was more accurate and correctly staged the tumor in 12 out of 13 patients (92%) who underwent both MRI and PET-CT. PET-CT correctly down-staged in one patient and wrongly upstaged the disease in one patient due to uptake in reactive lymph nodes. Similar findings were found in the study by Tateishi *et al.*[11] Although, they used AJCC staging protocol for STS, they also found that PET-CT was helpful in correctly under staging the disease in 4% of their patients. They found that interpretations based on combined PET-CT and conventional imaging findings (MRI) correctly staged tumors in 60 (87%) patients, over staged in 8 (12%) patients and under staged in 1 (1%) patient. Overall staging accuracy of combined PET/CT and conventional imaging was significantly higher than that of PET ($P < 0.0001$) in their study.

We had some limitations in our study because of which the generalization of our results to the general population should be carried out with caution. Sample size of 20 patients is too small to make any recommendations regarding standard algorithm for use of MRI in pre-operative staging of STS. The patient population was selected from a tertiary referral center, which introduces reference bias in the sample. Due to the compulsion to obtain surgical and histopathological correlation for the study design, patients who had limb salvage surgery only were included. Thus, we were unable to work out the impact of imaging on determining bone and joint invasion.

CONCLUSION

MRI is the most robust imaging modality in pre-operative evaluation and local staging of STS. However, except for some histological types, MRI is not of much use in predicting the histologic type. We feel that PET-CT would be useful to correctly

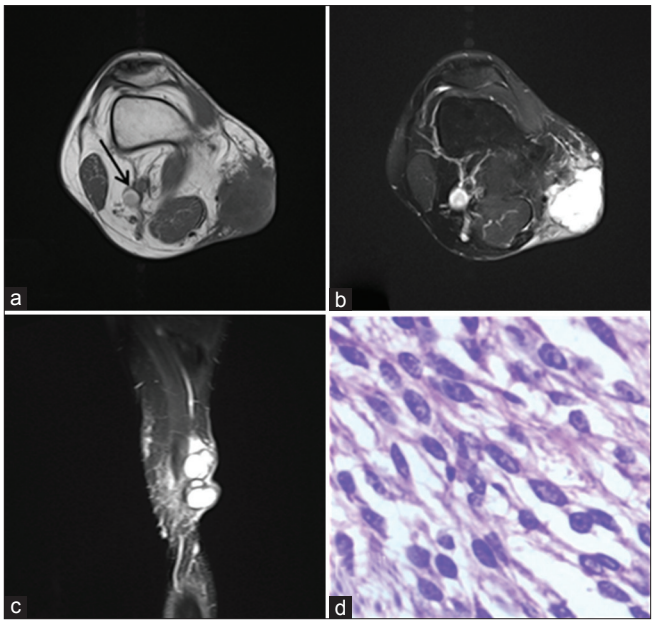

Figure 7: Malignant peripheral nerve sheath tumor (MPNST): A 32-year-old man with MPNST involving the posterior compartment of thigh with skip nodule (arrow). On magnetic resonance imaging, the tumor is (a) homogeneously isointense on axial T1W image and (b) is heterogeneously hyper-intense on axial T2W image. (c) Coronal T2W images show the characteristic fusiform shape of the tumor with course along a peripheral nerve. (d) Photograph of the stained histopathology specimen under × 40 magnifications reveals MPNST

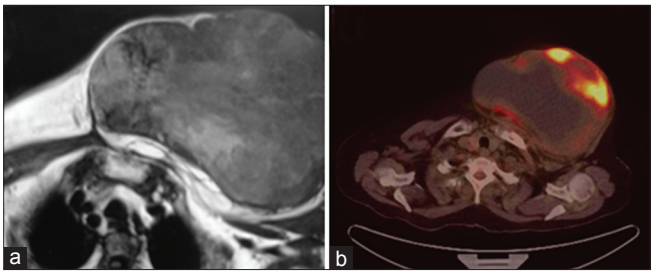

Figure 8: Pleomorphic liposarcoma: A 65-years-old female with chest wall pleomorphic liposarcoma. on magnetic resonance imaging; axial T1W image (a) show heterogeneous tumor; positron emission tomography-computed tomography showing peripheral uptake (b) with large necrotic areas standardized uptake value (SUV) maximum value of 21 and SUV average of 2

stage the disease when there are enlarged (likely involved) lymph nodes on MRI.

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