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"Role of magnetic resonance imaging in characterization of musculoskeletal soft tissue tumors"

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Abstract:
Background : *Soft tissue tumours (STTs) have various presentations depending on their tumor site and size; they may be accompanied by swelling, pain, tenderness, or motion impairment and are classified by their origin as muscular, fatty, fibrous, neural, vascular, or synovial. STTs frequently occur in the limbs, and the thigh is the most commonly affected site.*
However the characterization of musculoskeletal soft tissue lesions is challenging as most malignant, benign and non-neoplastic soft tissue lesions following trauma or inflammation have similar presentations. Magnetic resonance imaging (MRI) can be used to accurately detect the anatomical extent of musculoskeletal Soft tissue tumours . The technique is important in STT staging because it has higher resolution and tissue contrast, and better multiplanar capabilities, than other imaging modalities(ultrasound, X-ray and CT).
Material and method: *A prospective study which included 55 patients was conducted. All the patients underwent the routine protocols which included physical examination, history taking, plain X-rays and USG.Conventional MRI , DWI-MRI followed by contrast-enhanced MRI was done in all the patients. Diagnosis were confirmed in all cases by biopsy and histopathological examination.*
Results: *In our study 35 patients (63.6% of total patients) were found to be having benign lesions and 20 patients with malignant lesions (36.3 % of total patients). Overall sensitivity, specificity, PPV, NPV, and accuracy of MRI for diagnosing malignant mass lesions were found to be 90%, 71%, 66%, 92%, and 78% respectively.*
Conclusion: *We conclude that Magnetic Resonance Imaging (MRI) is an excellent imaging tool for the detection and local staging of soft-tissue tumours. MR imaging exhibited different advantages like determining the origin of these lesion, in defining their extent and relation to adjacent structures, assessing operability by identifying osseous, neurovascular bundles and joint space involvement by soft tissue tumors. In addition computed tomography or radiograph can be correlatively performed wherever required to further narrow down the diagnosis.*

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I. Introduction:

Soft tissue tumors (STTs) are a heterogeneous group of lesions arising from different nonepithelial, extraskeletal elements which include adipose tissue,smooth and skeletal muscle, tendon , cartilage, fibrous tissue,blood vessels, lymphatic structures.

They have various presentations depending on their tumor site and size; they may be accompanied by swelling, pain, tenderness, or motion impairment and are classified by their origin as muscular, fatty, fibrous, neural, vascular, or synovial [1,2].

STTs frequently occur in the limbs, and the thigh is the most commonly affected site [2]. However the characterization of musculoskeletal soft tissue lesions is challenging as most malignant, benign and non-neoplastic soft tissue lesions following trauma or inflammation have similar presentations [3]. A histopathological work-up is considered the gold standard for the reliable characterization of STTs [4]. It involves invasive sampling methods such as fine-needle aspiration and tissue biopsy which are associated with complications including bleeding, infection, and sampling errors. Therefore, non-invasive STT evaluation techniques are needed to evaluate soft tissue tumors to overcome these problems.

Magnetic resonance imaging (MRI) can be used to accurately detect the anatomical extent of musculoskeletal STTs as it has higher resolution and excellent soft-tissue contrast capabilities as compared to other imaging modalities like Xrays , USG and CT scan.

DW-MRI can be used for quantitative and qualitative assessment of cell membrane integrity and tissue cellularity. Diffusion-weighted imaging (DWI) allows quantitative assessment of water diffusion in the tissue, expressed as the apparent diffusion coefficient (ADC) value [5].

By systematically using clinical history, lesion location, mineralization on radiographs, and signal intensity characteristics on magnetic resonance images, one can (a) determine the diagnosis for the subset of determinate lesions that have characteristic clinical and imaging features and (b) narrow the differential diagnosis for lesions that demonstrate indeterminate characteristics. Correct diagnosis is essential for accurate determination of prognosis and to guide appropriate treatment strategy.

II. Aims And Objectives:

1.To assess the utility of magnetic resonance imaging (MRI) in the detection and characterization of musculoskeletal soft tissue tumours (STTs).

2. To assess the utility of magnetic resonance imaging (MRI) in the determination of whether these tumours are benign or malignant.

III. Material And Methods :

PATIENTS:

A prospective study was conducted between January 2020 to December 2020 in Dept. of Radiodiagnosis, GCS Medical College, Ahmedabad.

- Inclusion criteria:

- Any patient referred to the radio diagnosis department for evaluation of musculoskeletal tumors.
- Any patient with a soft-tissue mass that was either palpable upon clinical examination or visible via another imaging modality.

- Exclusion criteria:

- Patients whose data is incomplete.
- Patient who have allergic reaction to contrast medium.
- Implanted electric and electronic devices are a relative contraindication to the magnetic resonance imaging, and in particular: heart pacemakers (especially older types), insulin pumps,implanted hearing aids , neurostimulators, intracranial metal clips, metallic bodies in the eye.
- Metal hip replacements(old type), sutures or foreign bodies in other sites are relative contraindications to the MRI because they obscure the visualization of normal anatomy due to artefact effect.

IV. Method:

All the patients underwent the routine protocols which included physical examination, history taking, plain X-rays and USG.

Conventional MRI , DWI-MRI followed by contrast-enhanced MRI was done in all the patients. Diagnosis were confirmed in all cases by biopsy and histopathological examination.

Patients were examined with 1.5 Tesla, GE SIGNA EXPLORER magnetic resonance imaging equipment using the best surface coil to accommodate each lesion.

A predetermined examination protocol was applied to all patients and included the following:

I – Non contrast sequences:

- T1-WI (fse) in the axial, coronal, and/or sagittal planes.
- T2- (fse) in the axial, coronal, and/or sagittal planes.
- T2W STIR AND FAT SUPRESSION (FS) in the axial, coronal and/or sagittal planes.
- DW MRI was performed before contrast administration, and images were acquired in the axial plane by a single shot, spin-echo EPI sequence. Images were obtained using b values of 0, 400, and 800 s/mm2. The ADCs are expressed numerically and were calculated by manually placing a region of interest (ROI) over the

solid portion of the tumor and exclude cystic areas. The ROI was applied more than one occasion by a single observer in every case.

II – Post-intravenous contrast sequences:

– Post contrast sequences (in the axial, sagittal, and coronal planes) using intravenous gadolinium DTPA approximately 0.1 mmol/kg body weight, at least one fat-saturated sequence or short tau inversion recovery (STIR) sequence was obtained.

V. Results:

The study included 55 patients.

The age groups of patients in the study area as follows:

0-20 years (n = 10), 21-40 years (n =10), 41-60 years (n = 20), and more than 60 years (n = 15).

The various characteristics evaluated for every lesions were origin , size, margins of the lesion , signal intensity, surrounding oedema , haemorrhage, bone and vascular involvement and post contrast characteristics.

TABLE 1: lists the individual imaging features and the frequency with which they occurred with benign and malignant lesions.

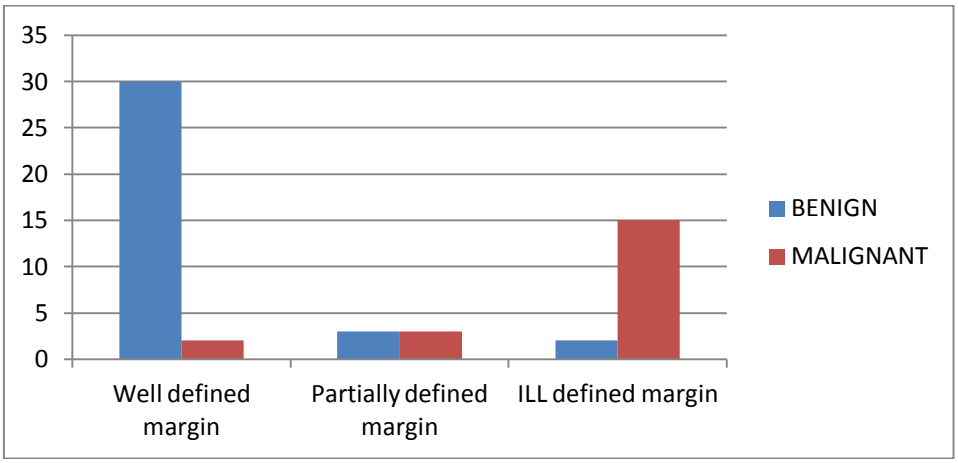
TABLE 2		
CRITERION	**BENIGN**	**MALIGNANT**
SIZE:		
<5 cm	25	2
5-10 cm	6	8
>10 cm	4	10
ORIGIN:		
Subcutaneous	4	2
Intermuscular Fascial planes	10	-
Intramuscular	18	16
Mixed	3	2
Joint	-	-
MARGINATION:		
Well defined	30	2
Partially defined	3	3
ILL defined	2	15
EDEMA:		
Absent	30	3
Present	5	17
HEMORRHAGE:		
Absent	30	2
Present	5	18
BONE:		
Not Involved	35	2
Involved	-	18
NEOVASCULAR:		
Not involved	20	7
Involved	15	13
CONTRAST ENHANCEMENT		
Homogeneous	20	2
Heterogeneous	15	18
TOTAL	35	20

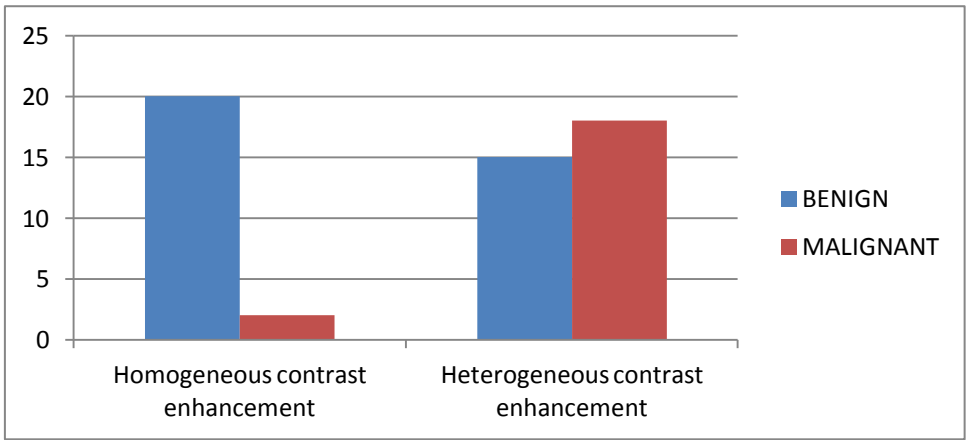
	BENIGN			**MALIGNANT**		
SIGNAL INTENSITY (w.r.t adjacent muscles)	**T1W**	**T2W**	**STIR/FS T2W**	**T1W**	**T2W**	**STIR/FS T2W**
Hypointense	18	5	6	5	-	-
Isointense	5	-	-	10	-	-
Hyperintense	9	28	26	5	20	20
Mixed	3	2	3	-	-	-

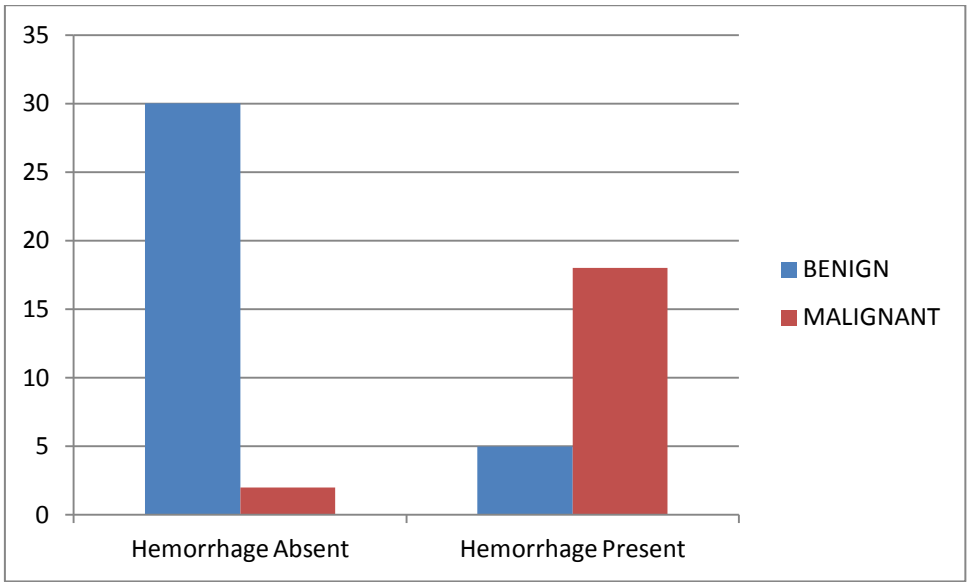
	BENIGN		MALIGNANT	
Homogeneity	**T1W**	**T2W**	**T1W**	**T2W**
Homogeneous	28	13	13	8
Heterogeneous	7	22	7	18

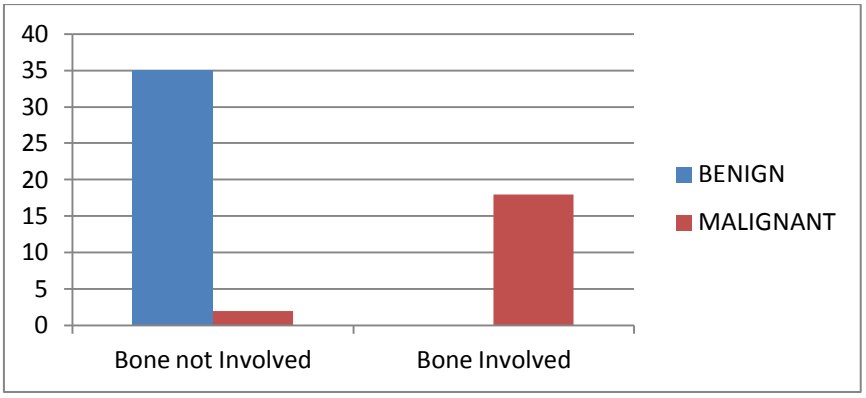
In our study 35 patients (63.6% of total patients) were found to be having benign lesions and 20 patients with malignant lesions (36.3 % of total patients).

Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of size of more than 5 cm size in predicting the malignant potential of a soft tissue mass lesion were 90%, 71%, 64%,92%, and 78%, respectively.
Irregularity of margins had a sensitivity, specificity, PPV, NPV, and accuracy of 90%, 85%, 78%, 93%, 87% respectively, for predicting malignancy.
Heterogenous contrast enhancement had a sensitivity, specificity, PPV, NPV, and accuracy of 90%, 57%, 54%, 90%, 69%, respectively, for predicting malignancy.
Overall sensitivity, specificity, PPV, NPV, and accuracy of MRI for diagnosing malignant mass lesions were found to be 90%, 71%, 66%, 92%, and 78% respectively.
For all STTs, malignant STTs showed significantly larger size, lower ADC, higher frequency of infiltration, lobulation, necrosis, and tail sign; size, ADC, and tail sign retained independent significance on multivariable analysis.

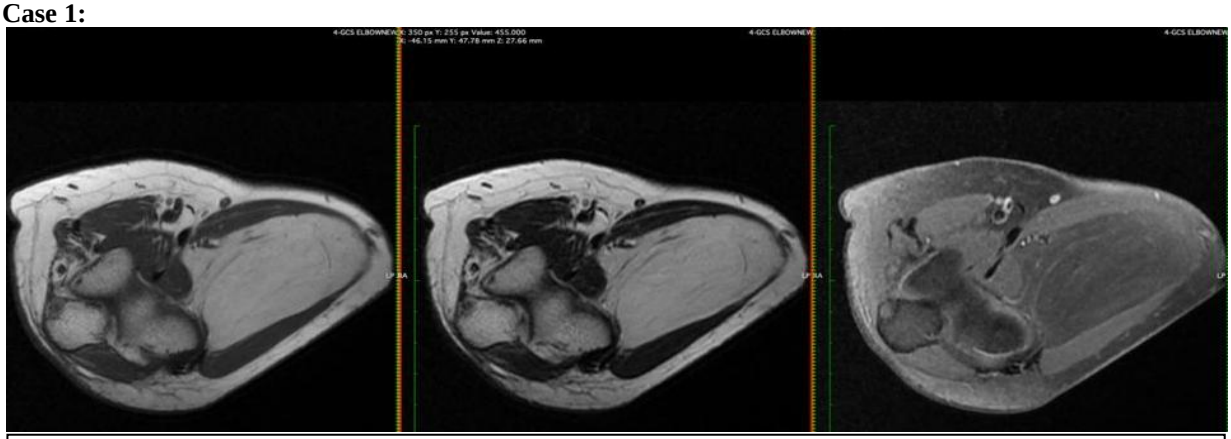








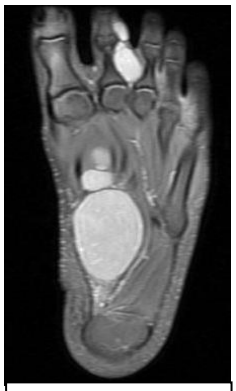
Case 1:



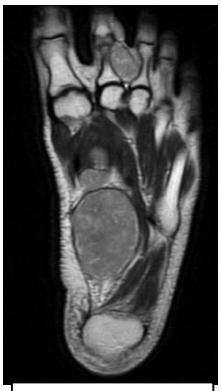
axial T1W (a)	axial T2W (b)	axial PD fatsat (c)

Case of intramuscular lipoma: Presence of large well defined intramuscular fat intensity lesion noted involving long radial extensor muscle and brachoradialis muscle.
It appears isointense to subcutaneous fat on T1W (a) and T2W (b)images and shows loss of signal on PD fatsat images(c).

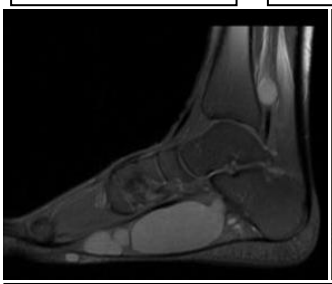
Case 2:

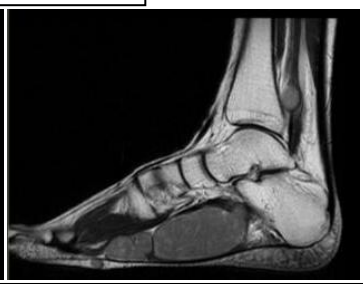


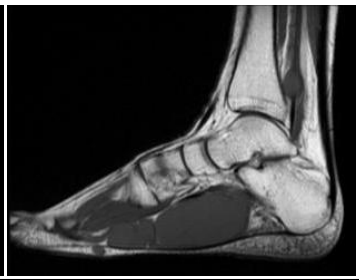
axial PD fatsat



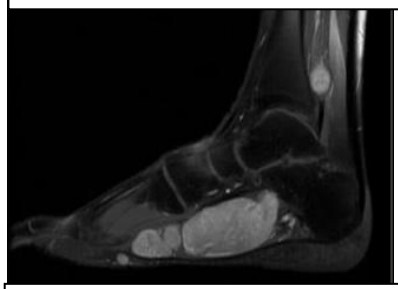
axial T2W

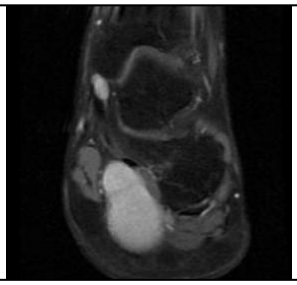


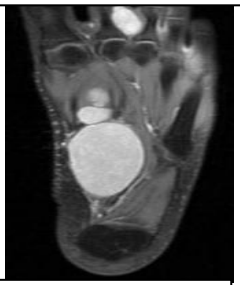




Sagittal PD fatsat (c) Sagittal T2W (d) Sagittal T1W (e)



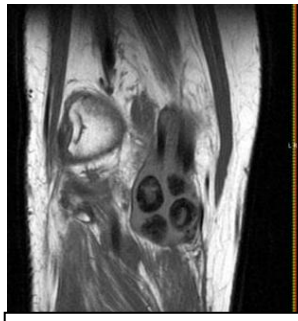


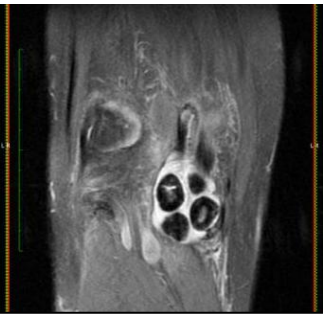


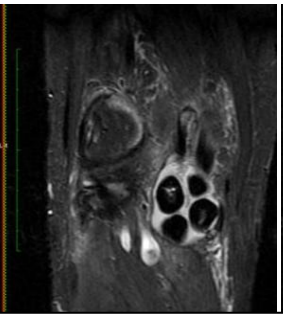
Sagittal fs T1 FS + C (f) Coronal fs T1 FS + C (g) axial fs T1 FS + C(h)

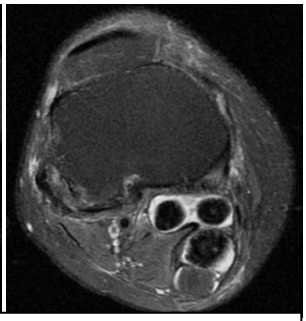
Case of neurofibromatosis: Presence of well defined altered signal intensity lesions noted in plantar aspect of left foot which indents the plantar fascia without any defienitve tear or involvement. The lesions appears hypointense on T1W images (e) and hyperintense on T2W(b)(d) and PD fatsat (a)(c) images. On post contrast study the lesions show homogeneous contrast enhancement (f-h) images. No e/o any bony erosion or tendon tear is noted. All the joint spaces appears normal.

Case 3:

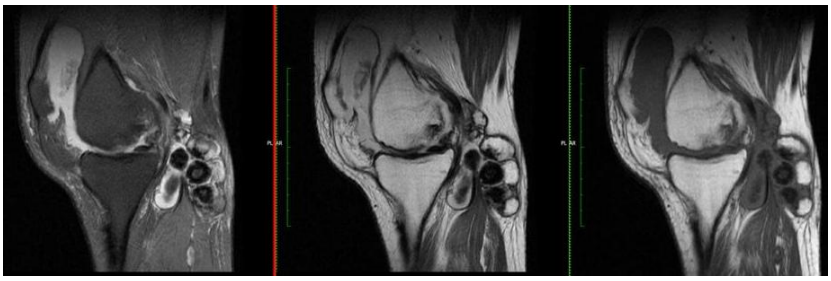




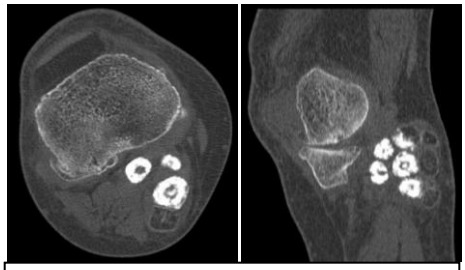




Coronal T1W Coronal PD fatsat Coronal T2W axial PD fatsat



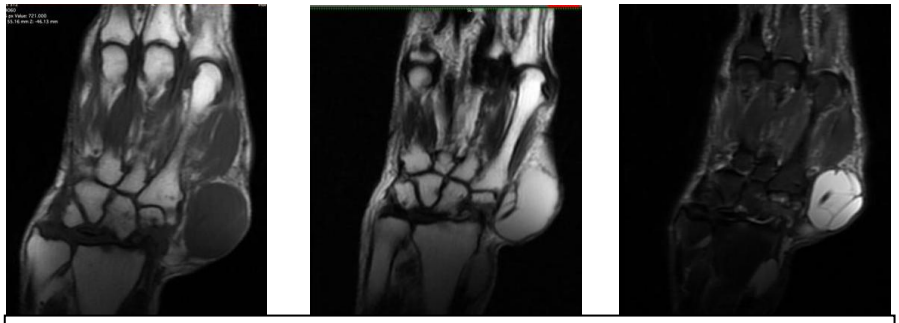
Sagittal PD fatsat Sagittal T2W Sagittal T1W



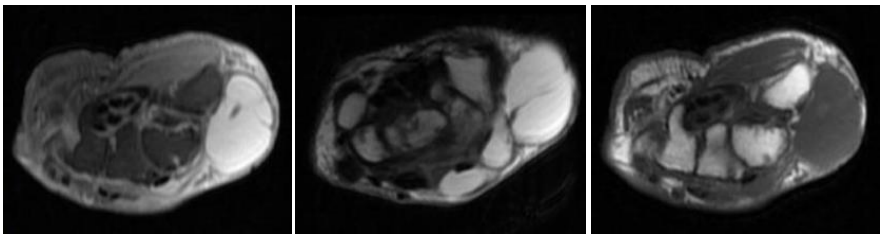
CT axial and Sagittal images

Case of synovial chondromatosis in knee joint : Multiple intramuscular abnormal signal intensity calcified lesions noted in popliteal fossa and in baker's cyst, s/o synovial chondromatosis.
CT images of the same are given.

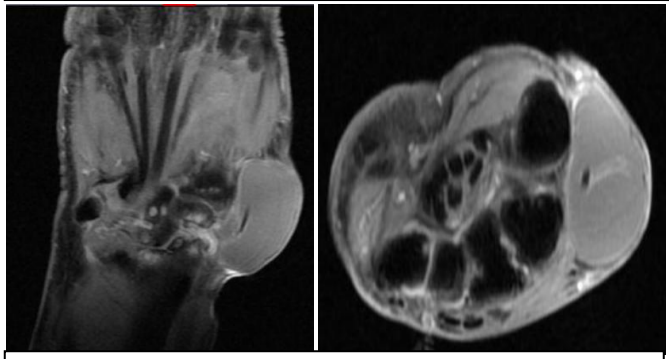
Case 4:



Coronal T1W fse (a) coronal T2W (b) coronal STIR (c)



axial PD fatsat (d) axial T2W (e) axial T1W fse (f)

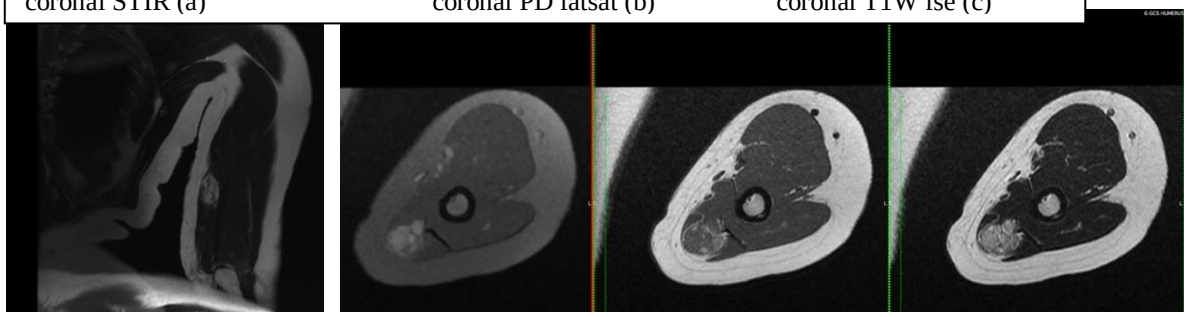


Coronal T1 fatsat + C (g) axial T1 fse + C (h)

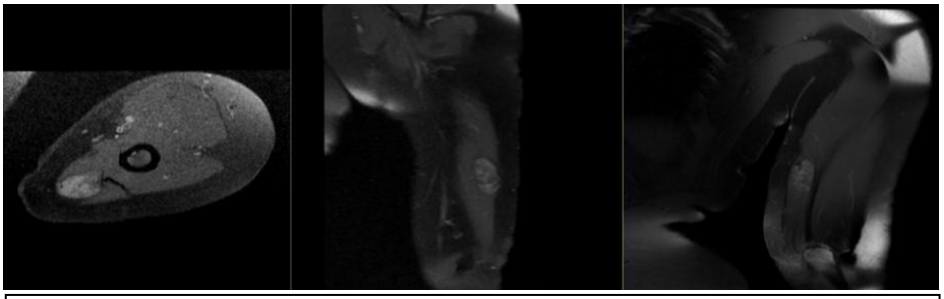
Case of ganglionic cyst : Presence of altered signal intensity lesion noted involving lateral aspect of wrist joint which is extending upto the dorsum of wrist involving peritendinous region of extensor muscle. The lesion appears isointense to muscle on T1W images (a)(f) and hyperintense on T2W(b)(e) and STIR images (c). The lesion on PD fatsat images(d) appears hyperintense. The lesion shows internal septation. Contrast-enhanced fat-suppressed T1-weighted MR image shows the mass with a thin rim and septal enhancement (arrowhead), but no central enhancement or solid components. No e/o any bone erosion is noted.

Case 5 :

coronal STIR (a) coronal PD fatsat (b) coronal T1W fse (c)

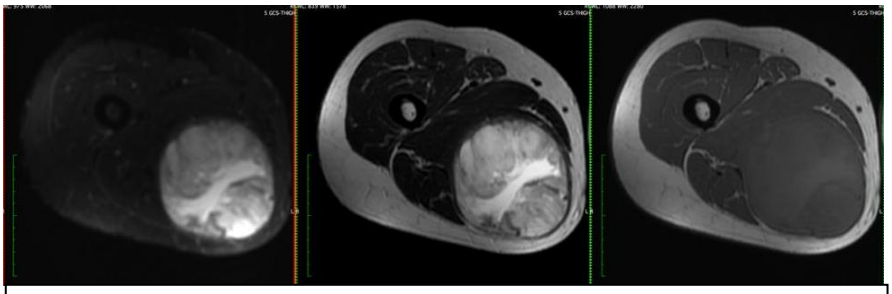


coronal T2W (d) axial PD fatsat (e) axial T1W fse (f) axial T2W (g)

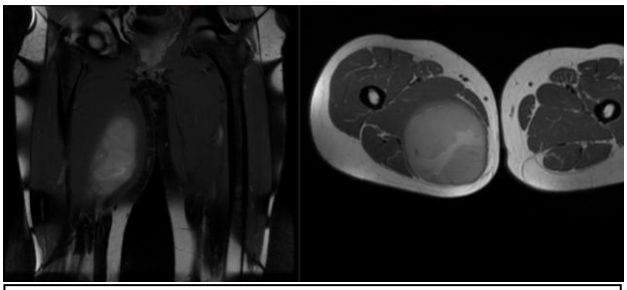


axial fse + C (h) Sagittal fse + C (i) coronal fatsat + C (j)

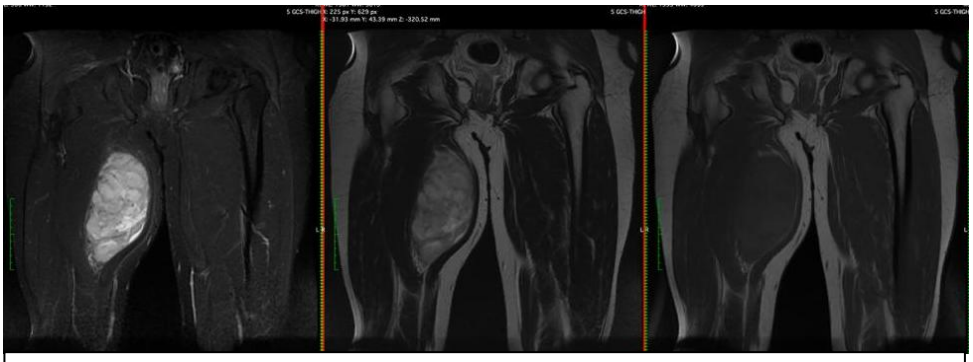
Case of soft tissue arteriovenous malformation: Presence of well defined altered signal intensity lesion noted at posteromedial aspect of left lower arm in muscular plane. The lesion involves triceps muscle. It appears hyperintense on T1W, T2W, STIR and PDFS images. It shows flow void within on T2W images (g). On post contrast study the lesion shows enhancement. Few focal areas of signal drop noted within the lesion, p/o calcification.



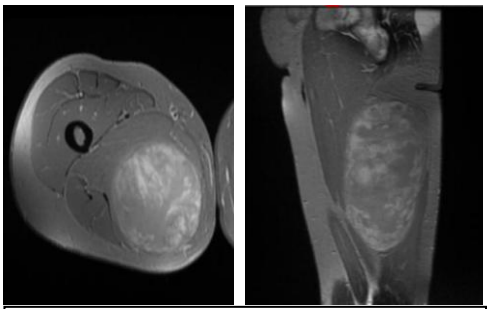
axial STIR fse (a) axial T2 fse (b) axial T1 fse (c)



Coronal PD fatsat (d) axial PD fatsat (e)



Coronal STIR fse (f) coronal T2 fse (g) cornoal T1 fse (h)



axial fse + C (i) Sag fse + C (j)

Case of soft tissue sarcoma: Presence of large well defined altered signal intensity lesion noted involving adductor muscles of right thigh with its extension into intermuscular plane displacing the hemstring group of muscle posteromedially. The lesion shows mixed signal intensity on T1W images and heterogeneously hyperintense on T2W ,STIR and PDFS images. Internal hyperintense signal on T1W images (c) suggests internal bleed. On post contrast study the lesion shows moderate heterogeneous enhancement. No e/o any vascular and bony invasion seen.

VI. Discussion:

MRI is a well-established tool for the detection and local staging of soft-tissue tumours. Characterization consists of both grading and tissue-specific diagnosis ;grading implies a differentiation between benign and malignant tumors and definition of malignancy grades, tissue-specific diagnosis implies pathologic typing.

Although pathological diagnosis is the gold standard in the diagnosis of soft tissue tumors, prediction of a specific radiological diagnosis remains one of the ultimate goals of each new imaging technique. [6] . However ability of MRI to differentiate between benign and malignant soft-tissue lesions has been found to vary widely .[7-13]

In our study 35 patients (63% of total patients) were found to be having benign lesions and 20 patients (37% of total patients) with malignant lesions.

In our study the features that were more common in malignant than in benign lesions includes large size (> 5 cm), deep location, inhomogeneous signal intensity, haemorrhage and necrosis, early and inhomogeneous contrast enhancement, irregular margins, surrounding soft tissue oedema and invasion of adjacent structures, including bone and neurovascular structures.

The above mentioned findings in malignant lesions were found to be consistent with the study done by Hochman. [14]

Datir et al.[15] concluded that significant risk factors for malignancy include increasing patient age and lesion size greater than or equal to 5 cm. In our series also malignant lesions were seen in the older age group. Majority of malignant lesions (90%) were more than 5 cm in size, whereas 72% of benign tumors were less than 5 cm in size.

Moulton et al [6] , in a study of 225 soft tissue masses could detect 59% malignant tumors in intramuscular or mixed (intramuscular + subcutaneous) location, whereas 88% benign tumors were in the subcutaneous tissue.

In the present study, majority of malignant lesions detected on MRI were deep in intramuscular location (80%). Two (10%) malignant tumors were found in the subcutaneous tissue predominantly, whereas 51% benign tumors were centered within the muscle and 10 cases (28%) were in the intermuscular fascial planes.

Benign tumors are well delineated and malignant tumors have rather ill-defined margins, Bongartz et al [16] In our study, majority of benign tumors (85%) had well-defined margins. However 5 benign tumors had ill-defined margins. In our study 90% of the malignant lesions had ill defined margins.

Commonly used individual parameters for predicting malignancy are intensity and homogeneity of the MR signal with different pulse sequences. High signal intensity on T2-weighted images is a sensitive parameter but has low specificity.[17]

In our study, 51% benign tumors were hypointense and 25% were hyperintense on T1-weighted images. On T2-weighted images, 80% benign tumors were hyperintense. The malignant masses were hyperintense in 25% cases on T1-weighted and in 100% cases on T2-weighted images. Absence of heterogeneity is a reliable negative predictive indicator for the presence of malignancy.[18] Hermann et al.[19] reported that changing homogeneity (from homogenous on T1-weighted images to heterogenous on T2-weighted images) and the presence of lobular morphology with intervening low signal intratumoral septations had a sensitivity of 72% and 80%, respectively, and a specificity of 87% and 91%, respectively, in predicting malignancy.

In the present study, the sensitivity and specificity were 67% and 50%, respectively.

Ma et al.[20] suggested that the rim-to-centre differential enhancement ratio has potential as an additional parameter for the MRI differentiation of indeterminate musculoskeletal masses. Similar results were obtained in our series with most of the malignant tumors (90%) showing heterogeneous contrast enhancement.

Intratumoral haemorrhage is a rare finding, which can be observed in both benign and malignant lesions, and is difficult to differentiate from nontumoral soft tissue hematoma.

Our study detected intratumoral haemorrhage in 05 benign (14% of the benign lesions) and 18 malignant tumors (90% of the malignant tumors) among at total of 55 cases.

In our study benign lesions included were lipomas, superficial and deep (skeletal muscle) hemangiomas and arteriovenous malformations, benign neural tumors, peniarticular cysts, hematomas, giant-cell tumor of tendon sheath, and abscesses.

Pathologic confirmation was available in 33 patients (94%), and in all these cases the MR and pathologic diagnoses concurred.

In 2 cases (6%), "proof" was obtained on the basis of other imaging tests and/or clinical follow-up. On the basis of such follow-up, all of these lesions were confidently determined to be benign. Thus, there were no

errors in terms of classifying a tumor as benign or malignant when we thought we could render a specific benign diagnosis.

In our study, all 18/20 were correctly diagnosed as malignant lesions. These were hyperintense and heterogenous on T2-weighted images. Margins were partially or completely irregular in all except 02 cases. The size was >5 cm in all except 02 cases. Neurovascular bundle was involved in 13 patients with malignant lesions, bone involvement was seen in 02, and intratumoral hemorrhage was seen in 18. Heterogenous contrast enhancement was seen in 18 out of 20 patients.

VII. Conclusion:

Soft-tissue tumors and tumorlike lesions are encountered often in daily radiologic practice. The vast array of benign and malignant entities can make lesion diagnosis overwhelming for the radiologist. By systematically using clinical history, lesion location, mineralization on radiographs, and SI characteristics on MR images, the radiologist can develop a short and appropriate differential diagnosis.

It can be concluded from our study results that MRI is an excellent modality for evaluating the size, extent, intensity of characteristics, and involvement of surrounding structures. In our study the overall sensitivity, specificity, PPV, NPV, and accuracy of MRI for diagnosing malignant mass lesions were found to be 86%, 71%, 70%, 89%, and 78% respectively.

We conclude that Magnetic Resonance Imaging (MRI) is an excellent imaging tool for the detection and local staging of soft-tissue tumours. MR imaging exhibited different advantages like determining the origin of these lesion, in defining their extent and relation to adjacent structures, assessing operability by identifying osseous, neurovascular bundles and joint space involvement by soft tissue tumors. In addition computed tomography or radiograph can be correlatively performed wherever required to further narrow down the diagnosis.

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