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Diagnostic accuracy of Contrast enhanced Magnetic Resonance Imaging in bone tumors and its association with surgical findings assuming histopathological findings as gold standard

Radiology

KEYWORDS: Bone tumors, MRI

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ABSTRACT

To determine diagnostic accuracy of contrast enhanced MRI in characterization of different primary bone tumors and to find agreement of association between MRI and surgical findings in primary bone tumors, assuming histopathological findings as gold standard. MRI was performed on 3 Tesla Philips system on 120 patients suspected of bone tumors on conventional radiography. Sequences and planes used were T1w and T2w in axial, sagittal, coronal planes, STIR in coronal plane and post contrast Fat saturated T1w images. Biopsy was done and treatment was planned. Post operative resected specimen was sent for histopathological examination. MRI detected marrow involvement with sensitivity, specificity, PPV, NPV, diagnostic efficacy of 98.8%, 62.5%, 94.44%, 83.33%, 93.33% respectively. MRI detected neurovascular bundle involvement with sensitivity, specificity, PPV, NPV, diagnostic efficacy of 92.31%, 96.81%, 88.89%, 97.85%, 95.83% respectively. MRI detected joint involvement with sensitivity, specificity, PPV, NPV, diagnostic efficacy of 87.5%, 91.67%, 72.41%, 96.70%, 90.83% respectively. MRI detected cortical break with sensitivity, specificity, PPV, NPV, diagnostic efficacy of 88.71%, 77.59%, 80.88%, 86.54%, 83.33% respectively. MRI detected soft tissue involvement with sensitivity, specificity, PPV, NPV, diagnostic efficacy of 92.11%, 88.64%, 93.33%, 86.67%, 90.83% respectively. Although MRI could demonstrate different components of tumor, there was no significant difference in signal intensity patterns of different histological types of tumors. Diagnostic accuracy of MRI for benign and malignant bone tumors against final diagnosis after histopathological examination was 86.67%. Conclusion- Multiplanar imaging capability of MRI helps in delineation of tumor, determine neurovascular bundle involvement, joint involvement, local extent and staging. Accurate preoperative local staging allows planning of limited or limb saving surgery. All lesions raising suspicion for malignancy should be evaluated after gadolinium-based contrast medium injection to optimise border characterisation, separate oedema from active tumour and to determine accurate site for biopsy. (PPV= Positive Predictive Value, NPV= Negative Predictive Value)

Introduction:

The superior contrast resolution of MRI has replaced the need for CT scans in many cases of musculoskeletal neoplasia. MRI is the best modality for focal extent and local staging[1]. MR imaging usually defines the extent of soft tissue masses better than CT in areas such as the arm, leg and foot where fat planes are poorly identified by CT. The excellent contrast resolution and multiplanar capabilities of MRI lead to improved evaluation of both intra-compartmental and extra-compartmental extent of bone tumor, particularly with regards to invasion of muscle, neurovascular structures and adjacent fat planes, degree of marrow involvement, intra-articular extension and the presence of intra-tumoral necrosis and haemorrhage[2]. Contrast-enhanced MRI can reveal the most vascularised parts of the tumour and MRI guidance makes it possible to avoid biopsing necrotic areas.[3] Moreover, newer 3 Tesla MRI are faster with improved SNR, resulting in better resolution and contrast[4]. The role of MRI in predicting malignancy has been inadequately studied in literature.

Materials and methods:

The data for this hospital based comparative descriptive type of observational study was collected from 120 patients having clinical features raising suspicion of or diagnosed as having bone tumor for evaluation with MRI, attending the Radio-Diagnosis department and Department of Orthopedics between March 2015 to November 2016. MRI was performed using a Philips Ingenia 3 Tesla scanner with Apple Osirix workstation. Patients underwent the MRI scan after contraindications were excluded and consent was taken. MRI Protocol consisted of the following:

Position of patient : Depending on the size, anatomic region to be imaged and expected examination time.

Coil used : The particular radiofrequency surface or body coil was selected depending on the size and shape of the body part of interest. Sequences- T1W TSE and STIR sequence of the area of interest in coronal plane,T1 and T2 weighted TSE sequences in axial, sagittal and coronal planes and post contrast fat saturated T1 weighted images after giving 100ml of IV Gadolinium.

Observations and Results:

Age of the patients included in the study ranged from 11- 83 years with mean age 48.40 ±17.556 years. Maximum number of patients in the study were in the age group 40-49 years (27 patients, 22.50%). Minimum number of patients were in the below 19 years age group (4 patients). 81% of the patients were males and 19% were females. Most common presenting clinical feature is pain with swelling. In cases of multiple myeloma, most common presenting complaint is low back pain.

Out of total 120 cases, 36 (30%) cases showed evidence of benign lesion on MRI. 84 (70%) cases showed evidence of malignant bone tumor on MRI. 20 (16.66%) cases showed evidence of benign lesion on final diagnosis. 100 (83.33%) were malignant on final diagnosis. The diagnostic efficacy of MRI in detecting malignant lesion in our study is 86.67%.

Diagnostic accuracy of the radiological diagnosis (MRI) for malignant lesion against final histopathological diagnosis

Radiological Diagnosis	Final Diagnosis		Total
	Malignant	Benign	
Malignant	84	0	84
Benign	16	20	36
Total	**100**	**20**	**120**

Diagnostic Accuracy of the MRI for Bone Marrow Involvement

MRI Findings Bone marrow involvement	Total	Surgical Findings	
		Involved	Not Involved
Involved	108	102	6
Not Involved	12	2	10
Total	120	104	16

Out of total 120 cases, 108 (90%) cases showed evidence of bone marrow involvement on MRI. The bone marrow was uninvolved in 12 (10%) cases. Out of 108, 102 cases showed marrow involvement on surgery. Out of 12 cases reported negative for marrow involvement, showed that marrow was involved in 2 cases on surgery. The sensitivity, specificity, PPV, NPV value and diagnostic efficacy of MRI in detecting bone marrow involvement in our study are 98.08%, 62.5%, 94.44% and 83.33% 93.33% respectively.

Diagnostic Accuracy of the MRI for soft tissue involvement

Soft Tissue involvement	Total	Surgical Findings	
		Involved	Not Involved
Involved	75	70	5
Not Involved	45	6	39
Total	120	76	44

Out of total 120 cases, 75 (62.5%) cases showed evidence of soft tissue involvement on MRI. The soft tissue was uninvolved in 45 (37.5%) cases. Out of 75 cases, 70 cases showed soft tissue involvement on surgery. Out of 45 cases showing absence of soft tissue involvement on MRI, 6 cases showed presence of soft tissue involvement on surgery. The sensitivity, specificity, PPV, NPV value and diagnostic efficacy of MRI in detecting soft tissue involvement in our study are 92.11%, 88.64%, 93.33%, 86.67% and 90.83% respectively.

Diagnostic Accuracy of the MRI for Joint involvement

Joint involvement	Total	Surgical findings	
		Involved	Not Involved
Involved	29	21	8
Not Involved	91	3	88
Total	120	24	96

Out of total 120 cases, 29 (24.16 %) cases showed evidence of joint involvement on MRI. The joint was uninvolved in 91 (75.84 %) cases. Out of 29 cases, 21 cases showed joint involvement on surgery. Out of 91 cases showing uninvolved joint on MRI, 3 cases showed presence of joint involvement on surgery. The sensitivity, specificity, PPV, NPV value and diagnostic efficacy of MRI in detecting joint involvement in our study are 87.50%, 91.67%, 72.41%, 96.70% and 90.83% respectively.

Diagnostic Accuracy of the MRI for Neurovascular bundle involvement

MRI Neurovascular bundle involvement	Total	Surgical findings	
		Involved	Not Involved
Involved	27	24	3
Not Involved	93	2	91
Total	120	26	94

Out of total 120 cases, 27 (22.5%) cases showed evidence of neurovascular bundle involvement on MRI. The neurovascular bundle was uninvolved in 93 (77.5 %) cases. Out of 27 cases, 24 cases showed neurovascular bundle involvement on surgery. Out of 93 cases showing uninvolved neurovascular bundle on MRI, 2 cases showed presence of neurovascular bundle involvement on surgery. The sensitivity, specificity, PPV, NPV value and diagnostic efficacy of MRI in detecting joint involvement in our study are 92.31%, 96.81%, 88.89%, 97.85% and 95.83% respectively.

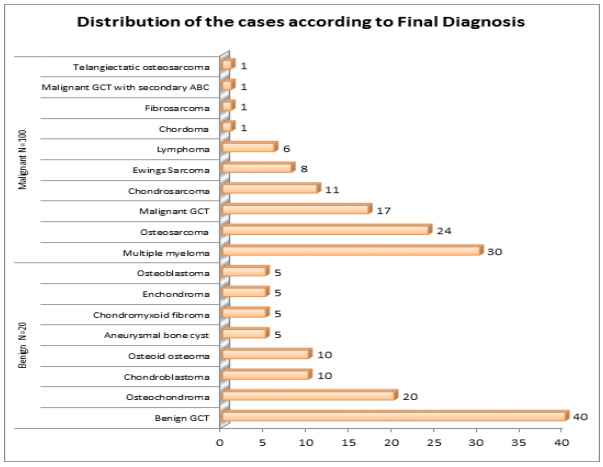
Diagnostic Accuracy of the MRI for Cortex break

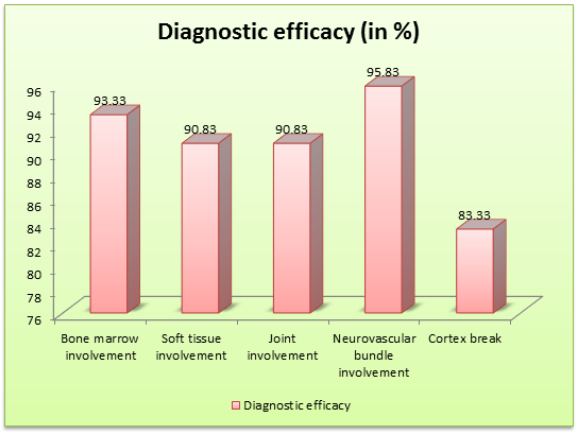
MRI Cortex break	Total	Surgical findings	
		Involved	Not Involved
Involved	68	55	13
Not Involved	52	7	45
Total	120	62	58

Out of total 120 cases, 68 (56.66 %) cases showed evidence of cortical break on MRI. The cortex was uninvolved in 52 (43.34%) cases on MRI. Out of 68 cases, 55 cases showed cortical break on surgery. Out of 52 cases showing uninvolved cortex on MRI, 7 cases showed presence of cortical break on surgery. The sensitivity, specificity, PPV, NPV value and diagnostic efficacy of MRI in detecting cortical break in our study are 88.71%, 77.59%, 80.88%, 86.54% and 83.33% respectively.

Diagnostic Accuracy of the Various Tissue Involvement

	Bone marrow involvement	Soft tissue involvement	Joint involvement	Neurovascular bundle involvement	Cortex break
Sensitivity	98.08	92.11	87.50	92.31	88.71
Specificity	62.50	88.64	91.67	96.81	77.59
PPV	94.44	93.33	72.41	88.89	80.88
NPV Value	83.33	86.67	96.70	97.85	86.54
Diagnostic efficacy	93.33	90.83	90.83	95.83	83.33





Discussion:

The need for accurate preoperative local staging techniques to allow planning of limited or limb saving surgery in patients with primary bone tumors has fostered an interest in radiological staging techniques.

MRI Findings

Marrow involvement

T1 weighted TSE and STIR sequence in a longitudinal plane was used for intramedullary staging.The low signal intensity of tumor on T1 weighted images was shown in sharp contrast with high signal

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intensity of fatty bone marrow. The tumor appears hyperintense on STIR images. In our study Marrow Involvement was seen in 108 out of 120 cases. It was confirmed by surgical findings in 102 cases. One case of malignant GCT and one case of Ewings Sarcoma did not show marrow involvement on MRI but was present on surgery. Two cases of ABC and 4 cases of Benign GCT showed marrow involvement on MRI which was absent on surgery. Ella Onikul, David Parham et al5 in 1996 studied the accuracy of MR imaging for estimating imtraosseous extent of osteosarcoma and they compared how well T1W images and STIR images revealed the extent of longitudinal intraosseous involvement in osteosrcoma. R Golfieri et al6 in 1990 studied the role of STIR sequence in MRI examination of bone tumors and found that the STIR sequence suppressed the high signal from fatty bone marrow giving a clear depiction of tumor extent in its intramedullary component.

Soft tissue involvement

Soft tissue involvement was seen in 75 out of 120 cases. One case of chondromyxoid fibroma, 26 cases of multiple myeloma, 2 cases of osteoid osteoma, 3 cases of aneurismal bone cyst, 4 cases of lymphoma and 3 cases of osteochondroma did not show any obvious soft tissue involvement.

3 cases of multiple myeloma and 3 cases of benign GCT did not show any soft tissue involvement on MRI but was present on surgery. 1 case of multiple myeloma, 1 case of ABC, and osteoblastoma and 2 cases of osteochondroma showed soft tissue involvement on MRI but was absent on surgery. Extra osseous involvement was best shown by T2W axial images. Orest B Boyko and David A cory7 in 1986 evaluated 25 patients with osteogenic sarcoma and Ewings sarcoma with MRI and found that tumor involvement of the soft tissue is best shown by T2 weighted sequence.

Cortical break

Cortical break was detected on MRI in 68 cases .It was absent in 52 cases. One case of ABC, 2 cases of chondrosarcoma, one case of osteosarcoma, one case of Ewing's sarcoma and 2 cases of malignant GCT did not show cortical break on MRI but was detected on surgery. 12 cases of multiple myeloma and one case of chordoma showed cortical break on MRI but was not seen on surgery. It is best demonstrated on T1 longitudinal and T1 axial images.

Joint Involvement:

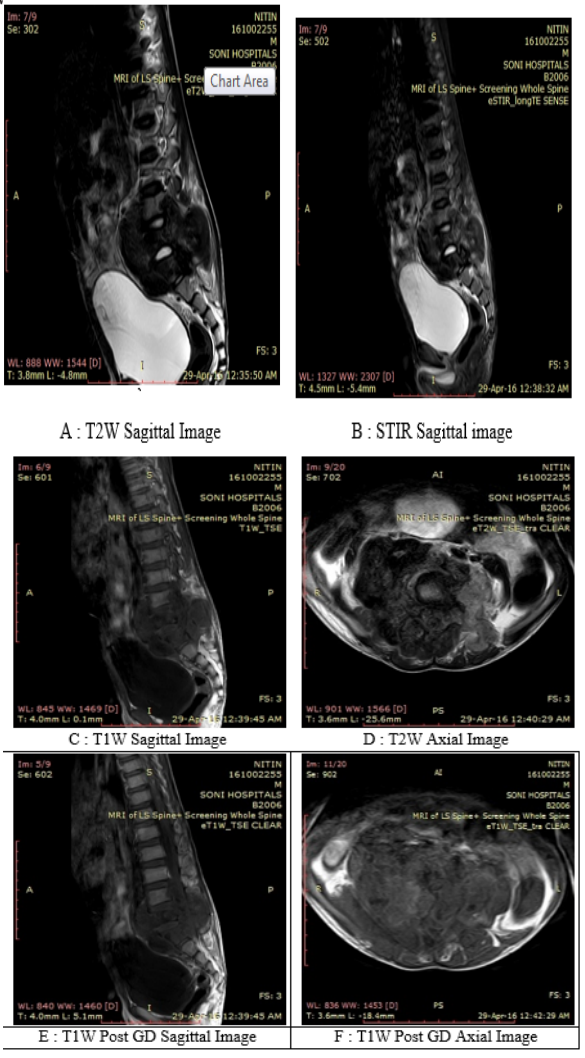
In our study, MRI showed joint involvement in 29 cases .It was uninvolved in 91 cases. On operative findings it was found that 24 cases had involvement of joint and in 96 cases the joint was uninvolved. In 8 cases MRI gave false positive results. One case of chondroblastoma, 4 cases of chondrosarcoma, one case of Ewing's sarcoma and 2 cases of malignant GCT showed joint involvement on MRI which was absent on surgery. Involvement of the joint space was presumed where T1W images showed that a contrast enhancing mass extended into the joint space either by disruption of joint capsule or by intraarticular destruction of cortical bone and/or the articular cartilage. The presence of a joint effusion did not allow differentiation with regard to tumor extension into the joint. Only the absence of a joint effusion had a high predictive value for absence of joint involvement by tumor. Compared with unenhanced T1 weighted images, contrast enhanced T1 weighted images are more useful for assessing joint involvement. When MR imaging is used, the presence of peritumorous inflammatory changes may lead to false positive diagnosis of joint involvement, which may be followed by unnecessarily radical en bloc resection of joint. (Schima 19948).

Neurovascular Bundle Involvement :

In our study MRI showed neurovascular bundle involvement in 27 cases (all of which were malignant). It was uninvolved in 93 cases. Three cases were detected false positive on MRI. Two cases of chondrosarcoma and one case of malignant GCT showed neurovascular bundle involvement on MRI which was not seen on surgery. In 2 cases of osteosarcoma, neurovascular bundle was involved on surgery, but was not detected on MRI. Radiologic depiction of soft tissue mass with respect to neurovascular bundle is important in planning surgical approaches for local tumor control. Tumor with deviation of neurovascular bundle may be considered for amputation instead of a limb salvage procedure because the ability to obtain adequate surgical margins around the tumor may be compromised. On MRI involvement of neurovascular bundle was present when tumor is surrounding these structures or encasing atleast one half the circumference and obliterating the associated fat plane. Suzanne, William Kaufman9 in 1997 found that it is easier to evaluate neurovascular bundle proximity to tumor with Fat sat T1 W post contrast images than with T2W for 64% of cases.

Signal Intensity Pattern:

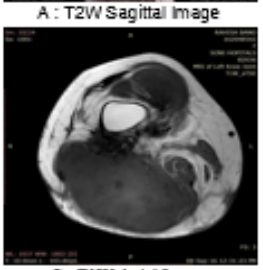
In our study, 12 cases of cartilaginous tumors were correctly characterized with MRI (6 cases of chondrosarcoma, 4 cases of osteochondroma, one case of chondroblastoma and one case of enchondroma). They were profoundly hyperintense on T2W images because of high water content of cartilaginous elements. We demonstrated cartilage cap and determined its thickness in 6 cases of osteochondroma and found its thickness was less than 3 cm in all the cases. 2 cases were finally diagnosed as malignant and 4 cases as benign. Rest of the tumors had a non specific appearance on MRI. Cohen et al10 observed a distinctive MR appearance in chondroid lesions containing a matrix of hyaline cartilage. The unique pattern consisted of homogenous high signal in a discernible lobular configuration on T2 weighted spin echo images. MR imaging also allows precise measurement of thickness of cartilage cap of an osteochondroma. It is agreed that the risk of malignant transformation is directly related to thickness of cartilage cap especially when later exceeds 2 cm.



Marrow infiltrative T2W hypointense lesion seen involving L5 and S1 vertebra and anterior and posterior surfaces of L4 vertebra associated with cortical erosions, large osseous soft tissue component in prevertebral, bilateral paravertebral region and epidural space causing narrowing of canal. Mass is showing intense

A : T2W Sagittal Image

B : STIR Sagittal image



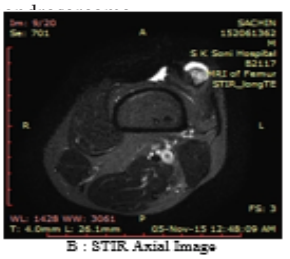
C : T1W Axial Image

D : T1W Post GD Sagittal Image

E : T1W Post GD Axial Image

Heterogenous SI mass in lower one-third of femur with soft tissue component, ill denfined outline and diffuse soft tissue edema. Areas of calcification seen within it. Mass is showing heterogenous

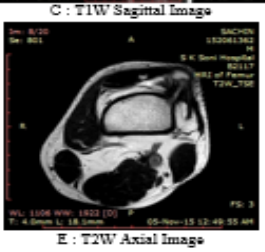
A : STIR Sagittal Image



B : STIR Axial Image

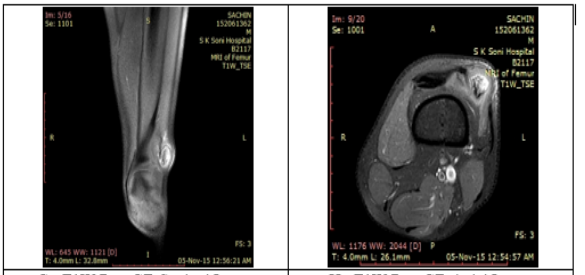
C : T1W Sagittal Image

D : T2W Sagittal Image



E : T2W Axial Image

F : T2W Axial Image



G : T1W Post GD Sagittal Image

H : T1W Post GD Axial Image

Exostosis seen arising from lower metaphysis of femur from its lateral surface showing medullary cavity and bright cartilaginous cap. No breach noted in the osseous portion and cartilageneous portion. Surrounding muscles and subcutaneous tissue normal. Subtle contrast enhancement noted in cartilaginous cap and medullary cavity and surrounding subcutaneous tissue

Limb salvage surgery performed after being diagnosed as osteochondroma without any features of malignancy on MRI.

Conclusion:

MRI is the preferred modality to image musculoskeletal tumours. It helps in delineation of tumour extent in bone and soft tissues with high contrast resolution. T1 weighted images give information regarding intra medullary extent and T2 weighted images, the soft tissue extent. Both T1 and T2 weighted images are equally sensitive in detecting the cortical break. Axial T2 weighted images are the best for the evaluation of Joint and Neurovascular involvement. Accurate preoperative local staging allows planning of limited or limb saving surgery. All lesions raising suspicion for malignancy should be evaluated after gadolinium-based contrast medium injection to optimise border characterisation, separate oedema from active tumour and to determine accurate site for biopsy.

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