Original Research Article

Study to evaluate the role of MRI in cases of primary malignant bone tumors

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Abstract

Background: Radiographs are the primary screening technique used for bone tumours and tumor-like lesions. When a lesion is indeterminate or shows signs of aggressiveness, magnetic resonance imaging (MRI) is indicated for further characterisation. Contrast-enhanced MRI (CEMRI) can reveal the most vascularised parts of the tumour and MRI guidance makes it possible to avoid biopsing necrotic areas.

Objective: The purpose of this study was to evaluate the role of MRI in cases of primary malignant bone tumors and to determine the MRI characteristics of different primary malignant bone tumor and correlate and compare the imaging findings with surgical and gross pathological findings wherever possible.

Materials and methods: We prospectively evaluated forty patients of suspected primary malignant skeletal neoplasms for two year period. Plain radiograph both antero-posterior and lateral projections were taken. Once the tumor was diagnosed on plain radiography, Magnetic Resonance Imaging (MRI) was performed in forty consecutive patients with malignant bone tumors. There were 21 males and 19 females.

Results: Out of the 40 cases, thirteen were Osteosarcomas, eight were Ewing's sarcomas, six were Chondrosarcomas, eight were Giant cell tumours, three were Chordomas, and two were multiple myelomas. Out of the thirty one cases operated, cortical involvement was seen in 27 cases and was absent in 4 cases. Thus sensitivity, specificity, positive predictive value and negative predictive value of MRI in detecting cortical involvement in our study were 96.2%, 100%, 100% and 80% respectively. Marrow involvement was seen in all cases on MRI and was confirmed by surgical and pathological findings in thirty one cases. Extra osseous soft tissue involvement was seen in 34 cases out of 40 cases. Soft tissue involvement was not seen 4 cases of GCT, two cases of Ewing's sarcoma. Out of total forty cases, 12 cases showed joint involvement on MRI 32.5% cases demonstrated

involvement of joint and 67.5% cases did not show joint involvement on MRI. The sensitivity was 100%, specificity 90.4%, positive predictive value 83.3% and negative predictive value 100%. Out of a total of forty cases, MRI showed neurovascular bundle involvement in four, so 10% cases demonstrated involvement of neurovascular bundle. The sensitivity in our study was 100%, specificity 96.2%, positive predictive value 100 % and negative predictive value was 96.2%.
Conclusion: MRI is the modality of choice for determining local extent and tumour staging.

Key words

Bone tumors, Magnetic Resonance Imaging, Tumour staging.

Introduction

Radiographs are the primary screening technique used for bone tumours and tumor-like lesions. When a lesion is indeterminate or shows signs of aggressiveness, magnetic resonance imaging (MRI) is indicated for further characterization [1]. It can extend the diagnostic evaluation by demonstrating components such as cartilage, vascular tissue, fat, liquid and hemosiderin. Even when a specific diagnosis cannot be made, MRI can help by narrowing the differential diagnosis. These are the reasons why MRI has changed from a single study-based diagnosis (solely based on radiographs) to a multimodal imaging approach (which now includes MRI).

Faint lytic/ sclerotic bone lesions can be difficult to visualise using only radiographs. MRI is superior to the other imaging modalities in detecting bone marrow lesions [2].

Aggressive indeterminate cases will require histological confirmation before proceeding to staging and establishing a therapeutic approach. The high percentage of biopsy tract contamination [3] indicates that this track should be included in the surgically removed area. Contrast-enhanced MRI (CEMRI) can reveal the most vascularised parts of the tumour and MRI guidance makes it possible to avoid biopsing necrotic areas [4-6].

MRI is very helpful in local staging and surgical planning because it assesses the degree of intra medullary extension (and dimensions) and invasion of the adjacent physeal plates, joints, muscle compartments and neurovascular bundles.

MRI provides superior contrast, allows multi-planar image acquisition, obviates iodinated contrast agents and ionizing radiation, and is devoid of streak artifacts commonly encountered with CT [7]. Despite the superiority of MR imaging in delineating bone tumor, it remains limited in its ability 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 [8].

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 intra lesional morphological variation, which is especially, true in STSs, it can predict tumor grade, and is of value in staging, restaging, and prognosis [9]. STS are generally staged according to Memorial Sloan Kettering Cancer Center (MSKCC) staging system [10, 11]. 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.

The purpose of this study was to evaluate the role of MRI in cases of primary malignant bone tumors and to determine the MRI characteristics of different primary malignant bone tumour and correlate and compare the imaging findings with surgical and gross pathological findings wherever possible.

Material and methods

We prospectively evaluated forty patients of suspected primary malignant skeletal neoplasms for two year period starting from august 2010 to September 2012. The age ranged from 8 years to 71 years (mean 40 years). There were 21 males and 19 females. In all patients, data on history, clinical examination and clinical diagnosis was obtained.

Plain radiographs were taken in all. Both anteroposterior and lateral projections were taken. Once the tumor was diagnosed on plain radiography, MRI was performed. Magnetic Resonance Imaging (MRI) was performed in forty consecutive patients with malignant bone tumors. On radiography and MRI, the following parameters were analyzed - the transitional zone, intra medullary extent, soft tissue extent, mineralization of matrix, periosteal response, cortical involvement, joint involvement and epiphyseal involvement. Involvement of neurovascular bundle and signal characterization was studied on MRI. Contrast was administered in 10 patients. The degree and pattern of enhancement was noted. Involvement of adjacent structures was also noted.

All patients were subjected to surgery and a detailed operative finding with their histopathology report was taken. The MR morphology was correlated with surgical and histopathological features.

Staging was done separately on both modalities (radiographs and MRI) according to Enneking's system of staging bone sarcomas and Giant cell tumours were staged according to Enneking's staging for giant cell tumors.

Results

The study "Multiplanar MR Imaging of primary malignant bone tumors with surgical and histopathological correlation" comprised of 40 patients in a two year period starting from august 2010 to September 2012. The age ranged from 8 years to 71 years (mean 40 years). There were 21 males and 19 females (**Table – 1**).

Table - 1: Demographic distribution study group.

Diagnosis	No.	Male	Female	Age range (years)	Median age
Osteosarcoma	13	7	6	8-22	15
Ewing's sarcoma	8	4	4	9-29	19
Chondrosarcoma	6	3	3	28-71	49
Chordoma	3	3	0	34-64	49
GCT	8	2	6	21-50	35
Multiple myeloma	2	2	0	54-65	60

The common clinical symptoms were pain in the region of tumour and swelling lasting for 2-3 months on average. Three cases gave history of antecedent trauma. All the patients were investigated with plain radiographs and MRI and were confirmed with gross surgical and histopathological findings.

Out of the 40 cases, thirteen were Osteosarcomas, eight were Ewing's sarcomas, six were Chondrosarcomas, eight were Giant cell

tumours, three were Chordomas, and two were multiple myelomas. Of the eight Giant cell tumours, one case was malignant. Site of lesion was as per **Table – 2**.

Table - 2: Site of the lesion.

Osteosarcoma	**No.**
Lower end of Femur	4
Upper end of Tibia	3
Upper end of Femur	2
Upper end of Humerus	3
Thigh	1
Ewing's sarcoma	
Shaft of femur	3
Ilium	2
Femur upper end	1
Humerus upper end	1
Rib	1
Chondrosarcoma	
Pelvis	3
Femur	2
Humerus upper end	1
Radius lower end	2
Humerus upper end	2
Femur upper end	1
Tibia upper end	1
Tibia lower end	2
Chordoma	
Sacrum	3

Out of the total 40 cases cortical break was detected on MRI in 33 cases. It was absent in 7 cases. Thus 82.5% cases demonstrated cortical break and 17.5% did not show cortical break on MRI. It is best demonstrated on T1W imaging. Thirty one cases were operated and nine cases were not operated due to the presence of distant metastasis. Out of the thirty one cases operated, cortical involvement was seen in 27 cases and was absent in 4 cases.

Thus sensitivity, specificity, positive predictive value and negative predictive value of MRI in detecting cortical involvement in our study were 96.2%, 100%, 100% and 80% respectively.

Out of total forty cases, 12 cases showed joint involvement on MRI. The joint was uninvolved in 27 cases. Thus 32.5% cases demonstrated involvement of joint and 67.5% cases did not show joint involvement on MRI. Surgery could only be performed in 31 of these patients due to presence of metastasis in nine cases**.** The sensitivity was 100%, specificity 90.4%, positive predictive value 83.3% and negative predictive value 100%.

Out of a total of forty cases, MRI showed neurovascular bundle involvement in four cases. It was uninvolved in 36 cases. Thus 10% cases demonstrated involvement of neurovascular bundle and 90% cases did not show involvement of neurovascular bundle on MRI. Surgery could be performed in 35 of these patients. Five patients could not be operated due to the presence of metastasis. The sensitivity in our study was 100%, specificity 96.2%, positive predictive value 100 % and negative predictive value was 96.2%. MRI and surgical pathological findings in study were as per **Table – 3**.

Discussion

The need for accurate preoperative local staging techniques to allow planning of limited or limb saving surgery in patients with primary bone sarcomas has fostered an interest in radiological staging techniques. Preoperative treatment planning is based largely on these imaging studies because the local tumour extent determines how a tumour-free margin can be accomplished. Accurate local staging allows for a high percentage of successful local resections or limb saving procedures.

In our study, we tried to prospectively analyze the accuracy of MRI in relative to conventional radiography. We studied forty cases of primary malignant bone tumours (thirteen Osteosarcomas, eight Ewing's sarcomas, six Chondrosarcomas, three osteoclastomas, three chordomas and two multiple myelomas) by radiography and MR imaging and analysed the findings.

Out of the thirteen cases of Osteosarcoma, narrow zone was noted in three and the ten cases showed wide zone of transition on plain radiography. All the cases of Ewing's sarcoma and Chondrosarcoma showed wide zone of transition. All the eight cases of giant cell tumour showed narrow zone of transition.

Table - 3: MRI and surgical pathological findings in study.

Cortical involvement	**MRI findings**	**Surgical pathological findings**
Present	26/31 (84%)	27/31 (87%)
Absent	5/31 (16%)	4/31(13%)
Soft tissue involvement		
Present	24/31 (77.4%)	25/31 (80.6%)
Absent	7/31 (19.3%)	6/31 (16%)
Joint involvement		
Present	12/31 (38.7%)	10/31 (32.2%)
Absent	19/31 (61.2%)	21/31 (67.7%)
Neurovascular involvement		
Involved	4/31 (12.9%)	5/31 (16%)
Uninvolved	27/31(87.1%)	26/31 (84%)

In our study marrow involvement was seen in all the forty cases. It was confirmed by surgical and pathological findings in 31 cases. The extent of marrow involvement was best shown by T1W images, STIR coronal or saggital sequences Tateishi U, et al. [12] and Iagaru A, et al. [13] studied the accuracy of MR imaging for estimating intra osseous extent of osteosarcoma. They compared how well T1W images and STIR images revealed the extent of longitudinal intra osseous involvement in osteosarcoma. R Golfieri, et al. [14] studied the role of STIR sequence in MRI examination of bone tumours and found that the STIR sequence suppress the high signal from fatty bone marrow giving a clear depiction of tumour extent in its intra medullary component.

Soft tissue involvement was seen in 34 out of 40 cases .Two cases of Ewing's sarcoma did not show any obvious soft tissue component. Extra osseous involvement was best shown by T2 weighted axial images. Charest M [15] evaluated 25 patients with Osteogenic sarcoma and Ewing's sarcoma with MRI and found that tumour involvement of the soft tissue is best shown by T2 weighted sequences.

Cortical break was detected on MRI in 33 cases. It was absent in 7 cases. It is best demonstrated on T1 longitudinal and T1 axial images. Thirty one cases were operated. Nine cases could not be evaluated due to the presence of metastases. Out of thirty one cases operated cortical involvement was noted in 26 cases and absent in 5 cases. The sensitivity, specificity, positive predictive value and negative predictive value of MRI in detecting cortical involvement in our study are 96.2%, 100%, 100% and 80% respectively.

The presence or absence of joint involvement is particularly important in preoperative evaluation of tumour extent which will subsequently decide the appropriate surgical procedure (intra or extra articular resection). MRI is highly sensitive for detecting joint diagnosis may lead to overstaging of tumour and result in unnecessarily radical surgical procedures [16].

In our study MRI showed joint involvement in 12 cases, it was uninvolved in 19 cases. Surgery was performed in 31 cases due to the presence of metastasis in nine cases. The sensitivity was 100%, specificity 90.4%, positive predictive value 83.3% and negative predictive value 100%.

The results in our study were quite similar to Van Rijswijk CS, et al. [17] who found sensitivity, specificity, positive predictive value and negative predictive value to be 100%, 70%, 86.4% and 100% respectively.

On MRI involvement of neurovascular bundle was present when tumour is surrounding these structures or containing at least one half the circumferences and obliterating the associated fat plane. The relationship of neurovascular bundle to the tumour was best shown on T2 weighted axial images and T1weighted post contrast axial images. Fat saturated T1 weighted post contrast images are superior to T2 weighted images in defining the proximity of soft tissue tumour mass to the neurovascular bundle Messerschmitt PJ, et al. [18] found that it is easier to evaluate neurovascular bundle proximity to tumour with fats at T1 post contrast images than with T2W for 64% of cases. In our study MRI showed neurovascular bundle involvement in four cases. It was uninvolved in 36 cases. Surgery could be performed in 31 cases. Nine patients could not be operated due to the presence of metastasis.

One case was detected false positive on MRI. The sensitivity in our study was 100%, specificity 96.2%, positive predictive value 100 % and negative predictive value is 96.2%. The result in our study is comparable to Kornaat PR, et al. [19] who found sensitivity, specificity, positive predictive value and negative predictive value to be 100%, 98%, 98% and 100% respectively.

Despite great value of MR imaging in the staging of the bone lesions, it is of relatively little value in specific histological diagnosis. There are specific diagnoses however that have a relatively characterstic MR appearance. Cofield RH [20] 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. This MR appearance in chondroid lesions reflects underlying high ratio of water content to mucopolysaccharide component within hyaline cartilage. 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. In our study, six cases of chondrosarcomas were correctly characterised with MRI. They were profoundly hyperintense on T2 weighted images because of high water content of cartilaginous elements. Rest of the tumours had a non specific appearance on MRI. Enneking W F, Spanier S S, Goodman M A [21] proposed a system for the surgical staging of musculoskeletal sarcomas. The malignant tumours were staged according to the Enneking's Staging of Musculoskeletal Neoplasms [21]. Eight cases had distant metastasis (Stage lll), 22 cases were of Stage IIB and ten cases were in Stage IIA.

The Giant Cell Tumors were staged according to Enneking's modified staging system: According this staging system six cases were in stage II and two cases were in stage III in our study. The discrepancy of staging between plain radiography and MRI was mainly due to the cortical invasion and soft tissue swelling evident on MRI alone. According to Murali Sundaram, et al. [22] when radiographic depiction of tumour permits assessment of its morphology, matrix and probable histologic nature, MRI ought to be the next examination solely for staging purposes. Bloem, et al. also concluded in their study of 56 patients with bone sarcomas that MR imaging was the modality of choice for local staging of primary bone sarcoma.

Conclusion

MRI is the preferred modality to image musculoskeletal tumours and should be obtained after radiographic evaluation. The multi planar imaging capability of MRI helps delineation of tumour and its extent in bone and soft tissues with high contrast resolution. MRI is excellent modality for determining the extent of the tumour within the medullary canal and in showing the extent of extra-osseous soft tissue

involvement. T1 weighted images give information regarding intra medullary extent and T2 weighted images, the soft tissue extent. MRI is very sensitive in detecting cortical involvement but less sensitive in detecting the periosteal reaction, tumour osteoid and calcification when compared to plain radiography. Both T1 and T2 weighted images are equally sensitive in detecting the cortical break. Joint involvement, neurovascular involvement are detected on MRI. Axial T2 weighted images are the best for the evaluation of Joint and Neurovascular involvement.

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