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Comparative role of CT scan and MR imaging in primary malignant bone tumors

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Abstract:
Aims:

- *To discuss the role of C.T. scan and M.R.I. in evaluation of primary malignant bone tumors.*
- *To determine the imaging characteristics of different primary malignant bone tumors.*
- *To correlate imaging with surgical and histological findings.*

Materials and methods:
This prospective study of 13 cases was conducted in Shri M. P. Shah Medical College and G.G .Hospital, Jamnagar.

Observations: *A total of 13 patients with primary malignant bone tumors were evaluated primarily with plain radiography followed by C.T. scan and M.R.I .Contrast study was performed as and when deemed necessary. Following* ***observations were made:*** *There were 4 cases of Ewing's sarcoma, 5 cases of osteosarcoma, a single case of each – bone lymphoma, malignant haemangioendothelioma, malignant giant cell tumor and chondrosarcoma.*
CT scan was better than MRI in evaluation of cortical destruction in 2 cases and both were equally efficient in 10 cases. Matrix mineralization was present in 5 cases and CT scan detected it with higher accuracy.MRI was better for evaluation of extent of bone marrow involvement in 5 cases and equal to CT scan in 5 cases. The soft tissue extent of tumor was better evaluated with MRI in 7 cases and both modalities were equally good in 6 cases. Joint involvement was present in 4 cases and was better evaluated with MRI in all of them.MRI was superior in evaluation of neurovascular bundle in 9 cases and equal to CT in 4 cases. Although MRI could demonstrate different components of tumor, there was no difference in signal intensity patterns of different histological types of tumors.

Conclusions: *MRI is the preferred modality to image musculoskeletal tumors and should be obtained after radiographic evaluation. Its multiplanar imaging capability helps delineation of tumor and its extent in bone and soft tissues with high contrast resolution. It is an excellent modality to determine neurovascular bundle involvement, joint involvement, local extent and staging.*

Key words: *CT scan, MRI, Imaging, malignant bone tumors.*

I. Introduction:

Evaluation of bone tumors involves a multimodality approach and although cross-sectional imaging has extraordinarily improved the ability to characterize tumors, the differential diagnosis of primary osseous neoplasm remains based on their radiographic appearance. Radiographs provide critical information regarding lesion location, margin, matrix mineralization, cortical involvement and adjacent periosteal reaction. But MRI is the best modality for focal extent and local staging. The excellent contrast resolution and multiplanar capabilities of MRI lead to improved evaluation of both intracompartmental and extra compartmental extent of bone. This is particularly true with regards to invasion of muscle, neurovascular structures and adjacent fat planes and degree of marrow involvement. MRI has also been shown to be superior in assessing intraarticular extension and the presence of intratumoral necrosis and hemorrhage. MRI is the best technique to detect skip lesions (small metastasis separated from primary tumor by healthy tissue) which are often missed by other imaging means. MRI also plays an important role in evaluation of effectiveness and follow up of treatment .In these days of managed care, cross sectional imaging is limited to one modality and most centres will chose MRI in this regard[1].

II. Materials and methods:

The study was conducted in Shri M.P.Shah Medical college and G.G.Hospital, Jamnagar. It comprises of 13 patients of primary malignant bone tumors. Proven or suspected cases of bone tumors were included. All the patients first underwent plain Xray, followed by CT scan and MRI. Contrast study was performed as and when required.

Methodology:

Xray: 300 and 500 m.A. Philips M.R.S.

CT scan: G.E. 16 slice CT scanner

MRI: Siemens' Magnatom Essenza 1.5 T.

All patients underwent MRI scan with 1.5 Tesla machine (Siemens' Essenza, 16 channel scanner). Various region of interest were scanned with T1w (600/ 30) (TR/TE) T2w (4300/100), STIR (3200/75, TI – 220) sequences in Sagittal, coronal and axial planes with 3-4 mms slice thickness. A matrix size of 358 x 448 used with a 24-30 cm sized FOV for coronal and sagittal scans and 14- 16 cms for axial scans.

III. Results:

There were 4 cases of Ewing's sarcoma, 5 cases of osteosarcoma, a single case of each – bone lymphoma, malignant haemangioendothelioma, malignant giant cell tumor and chondrosarcoma. The youngest patient was 9 years old and the eldest was 45 years. Maximum patients were in their second and fourth decades. Males were more commonly affected than females with a ratio of 8: 5.

CT scan was better than MRI in evaluation of cortical destruction in 2 cases and both were equally efficient in 10 cases. Matrix mineralization was present in 5 cases and CT scan detected it with higher accuracy.MRI was better for evaluation of extent of bone marrow involvement in 5 cases and equal to CT scan in 8 cases. The soft tissue extent of tumor was better evaluated with MRI in 7 cases and both modalities were equally good in 6 cases. Joint involvement was present in 4 cases and was better evaluated with MRI in all of them.MRI was superior in evaluation of neurovascular bundle in 9 cases and equal to CT in 4 cases. Although MRI could demonstrate different components of tumor, there was no difference in signal intensity patterns of different histological types of tumors.

On correlation with operative and histopathological follow up – neurovascular bundle involvement was found in 10cases – all of which were also picked up by MRI – thus MRI showed 100% sensitivity for neurovascular bundle involvement .In one patient MRI showed false positive involvement-thus specificity of MRI was 75 percent. Positive predictive value of MRI for neurovascular bundle involvement was 90.9 percent and negative predictive value was -100 percent.

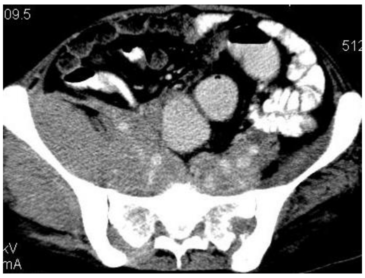
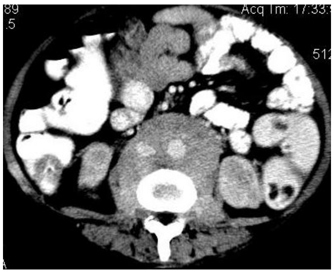
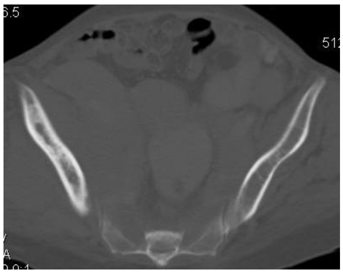
Joint involvement was detected in 4 cases on surgery – all of which were also diagnosed by MRI- therefore sensitivity and negative predictive value was 100 percent. In 2 patients MRI showed joint involvement but on surgery joints were normal –therefore, specificity of MRI was -81 percent and positive .predictive value was 66.66 percent.

Thus, MRI is a highly accurate imaging modality for staging of bone tumors.

IV. Discussion:

4.1. Soft tissue extent of mass lesion

The inherent contrast between a soft tissue mass and skeletal muscle by x-ray transmission and CT is low. This often makes definition of lesion margins difficult. On the other hand, T2 weighted MR images show high intrinsic contrast and readily delineate tumor-muscle interfaces owing to the low signal intensity of muscle and the generally high signal intensity of pathologic soft tissue .MR imaging is particularly helpful in certain areas, such as the arms and legs, where fat planes are poorly shown by CT .Soft tissue masses surrounded by fat are well shown by CT. TI weighted MR images also show clear demarcation of soft tissue masses from adjacent fat, since fat produces a signal of high intensity, and soft tissue produces a signal of low intensity. T2 weighted images, however, frequently obscure tumor-fat borders since tumor and fat signals may be equal in intensity. Therefore, both TI and T2 weighted sequences are usually necessary for complete lesion definition. In our study, MRI was found to be better than CT scan in evaluation of soft tissue extent in 7 cases and equal to CT in 6 cases.

1A.  1B.  1C. 

Figures 1 –Bone lymphoma

A,B **-** CECT abdomen, pelvis – soft tissue window – Enhancing soft tissue mass lesion along right iliac bone. .The lesion encases right sided iliac vessels. B. Lymph node mass noted in pre and Para-vertebral space and causing encasement of bilateral iliac vessels. C. Bone window showing sclerotic lesion involving right iliac bone.

4.2. Intra medullary extent of mass lesion:

Definition of intra medullary lesion extent by CT requires the recognition of a subtle increase in marrow attenuation. Normal marrow on TI weighted MR images have uniformly high signal intensity owing to its high fat content. Replacement of normal marrow by tumor of low signal intensity is easily discernible on TI weighted images, even when the marrow space is small. Small isolated lesions, such as “skip” metastases from osteogenic sarcoma, can also be detected by such images **[2].**Large lesions or calcified lesions in the marrow space are well shown by CT. Coronal MR Images help to define the vertical extent of marrow involvement .In our study, 13 cases showed marrow involvement – out of which MRI was found to be better in 5 cases.

2A.  2B. 

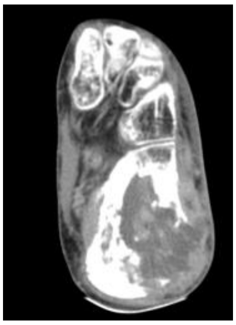
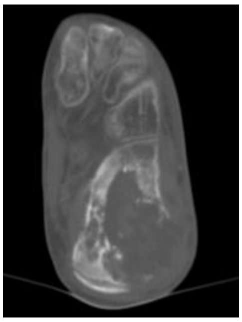
3A  3B.  3C.  3D. 

Figure 2: Osteosarcoma

A.T1W Sagittal image shows hypointense lesion involving the upper shaft of humerus with large perihumeral soft tissue component displacing the adjacent muscles.Note that the vertical extent of the lesion is very well evaluated on this sagittal T1WI..B. Plain radiograph shows permeative lytic sclerotic lesion with wide zone of transition involving the upper shaft of humerus.Associated periosteal elevation in the form of Codman’s triangle and assosciated soft tissue swelling.

Figure 3 : Ewing’s sarcomas

A,B.CECT ankle – coronal reformatted image showing ill defined heterogenously enhancing lesion involving calcaeum causing irregular destruction of underlying bone (giving moth eaten appearance) with cortical destruction (more on lateral aspect) and associated soft tissue extension of the mass lesion. C.Expansile lytic destructive lesion involving the calcaneum on plain radiograph. D.T1 contrast enhanced image showing heterogenosuly enhancing soft tissue lesion involving the calcaneum

4.3. Lesion calcification:

Calcification or ossification is an important finding in characterizing musculoskeletal masses. CT clearly demonstrates both soft tissue and intra medullary mineralization. On MRI, these foci appear as regions of absent signal. Although large calcifications are shown by MRI, detection of small areas of calcification is limited because the spatial resolution of MRI is less than that of CT. Contrast resolution also influences the detection of calcification by MRI. The visibility of dark areas (calcification) depends on the signal intensity of the tissue surrounding them. Therefore, the detection of calcification depends on the MR imaging sequence. An additional disadvantage of MRI is the lack of specificity of signal void areas which may be due to flowing blood, fibrous tissue, metal artifact or air as well as calcification .In our study, matrix mineralization was noted in 5 cases – all of which were better evaluated on CT scan.

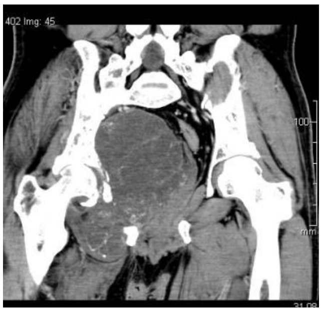
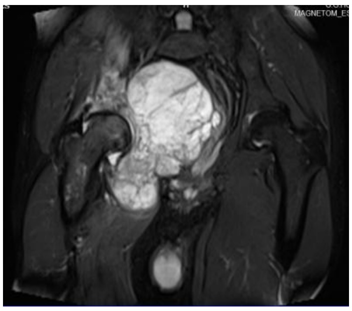
4A  4B  4C 

Figure 4: Chondrosarcoma

A,B: Sagittal and coronal reformatted CT images showing a large lytic lesion with internal punctuate and arc like calcification in right iliac bone, anterior and posterior column of right acetabulum and superior and inferior pubic rami. C:PDFS coronal MR image showing intensely hyperintense mass lesion (characteristic of chondroid matrix) in right iliac bone. Note that the lesion calcification is much more conspicuous on CT scan than on MRI.

4.4. Cortical bone involvement:

Cortical bone is particularly well shown by CT because of its high attenuation. With MR imaging, normal bone cortex produces virtually no signal and appears black. Cortical bone may show some increase in signal intensity when involved by a neoplasm. Because of its superior spatial resolution, CT shows early tumor involvement of cortical bone better than MR imaging Gross cortical destruction is demonstrated on MR images as interruption of the cortical signal void. CT scan was found to be better in evaluation of cortical bone destruction in 2 cases and equal to MRI in 10 cases.

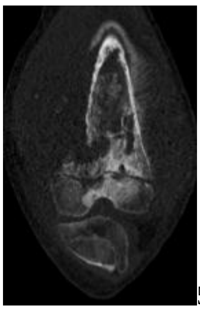
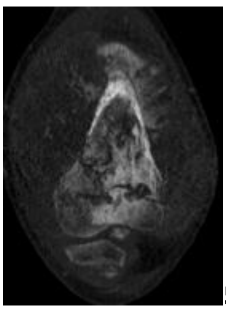
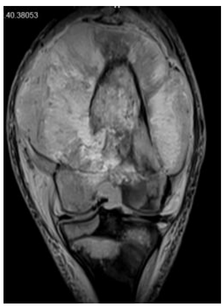
5A  5B  5C  5D 

Figure 5: Osteosarcoma

A,B :CT images ,coronal reformatted ,bone window – shows mixed lytic and sclerotic lesion with bony matrix mineralization, subperiosteal new bone formation and pathological fracture ;C,D : PDFS MRI :transmetaphyseal and transarticular spread with marrow edema ,soft tissue mass formation. Note that the cortical bone destruction and matrix mineralization is better evaluated on CT images while joint involvement and soft tissue mass formation are better seen on MRI.

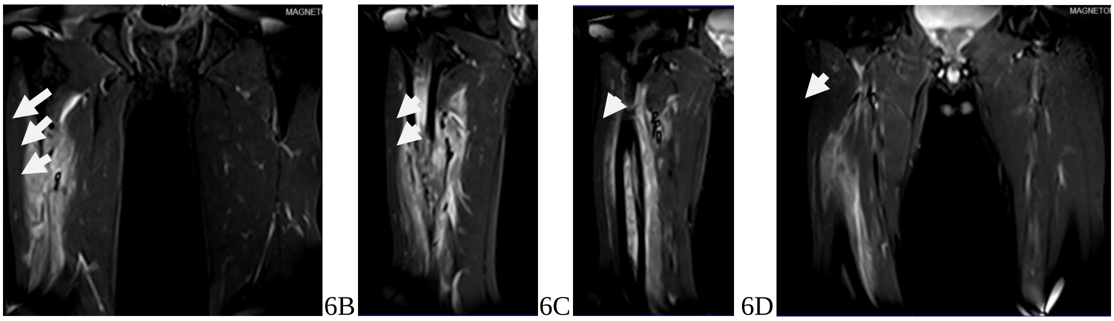
4.5. Neurovascular bundle involvement:

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 containing at least one half the circumferences and obliterating the associated fat plane. The relationship of NV bundle to the tumor was best shown on T2W axial images and T1W post contrast axial sections. Fat saturated T1 weighted post contrast images are superior to T2 weighted images in defining the proximity of soft tissue tumor mass to neurovascular bundle Suzanne ,William Kaufman7 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.

Contrast enhanced CT studies vary in their ability to identify normal vessels, although dynamic CT generally shows vessels well.

In our study, MRI was found to be better to CT scan in evaluation of neurovascular bundle in 9 cases and was equally good in 4 cases.



6A 6B 6C 6D

Figure 6: Ewing's sarcoma

PD-FS MR images in coronal plane show heterogeneous signal intensity noted in medulla of mid shaft of right femur and extending into upper third of femur Also noted is presence of heterogeneously hyperintense signal with multiple flow-voids noted involving into vastus medialis, intermedius and lateralis muscle, adductor magnus muscle, lateral intermuscular septum and profunda femoris vessels upto its origin
Encasement of the Profunda femoris artery is well seen on above images.

4.6. Joint involvement:

The presence or absence of joint involvement is particularly important in preoperative evaluation of tumor extent which will subsequently decide the appropriate surgical procedure (intra or extra articular resection). MRI is highly sensitive for detecting joint involvement in malignant tumors .However false positive diagnosis may lead to over staging of tumor and result in unnecessarily radical surgical procedures.(Wolfgang Schima 1994)[3]

We evaluated the relationship of the tumor to adjacent joint and involvement of the intra synovial 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 the articular cartilage, if present. Joint involvement was also presumed in cases of tumor extension into the cruciate ligaments which are intracapsular but extrasynovial. 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 1994)[3]. MRI was found to be better than CT scan in evaluation of all 4 cases of joint involvement.

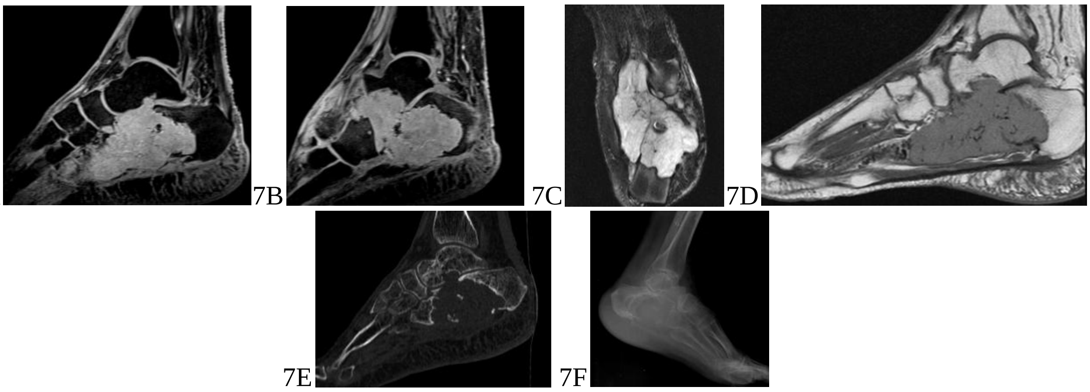


Figure 6: Malignant Haemangioendothelioma

A, B, C : Gadolinium enhanced vibe MR images in Sagittal and coronal planes ; D-Non contrast T1WI Sagittal image **--** Well defined, lobulated, non-capsulated soft tissue lesion which appears hyperintense on PD FAT SAT and hypointense on T1WI and shows post contrast enhancement arising from calcaneum and extending to involve talus, navicular, lateral cuneiform with involvement of calcaneo-navicular joint and sparing of Talonavicular, talo-calcaneal joint.

E : CT scan Sagittal reformatted image bone window **-** Expansile Lytic destruction of calcaneum with associated soft tissue mass and bony fragments and extension into surrounding tarsal bones and calcaneo navicular joint.

F: Plain radiography lateral view : Expansile Lytic destruction of calcaneum with associated soft tissue mass and bony fragments

4.7. Signal intensity pattern:

Despite great value of MR imaging in the staging of bone lesions, it is of relatively little value in specific histological diagnosis. There are specific diagnoses however that have a relatively characteristic MR appearance. Cohen et al [4] 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 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. They were profoundly hyperintense on T2W images because of high water content of cartilaginous elements. Rest of the tumors had a non specific appearance on MR.

V. Conclusion:

Conventional radiography is the first line of diagnosis for bone tumors. The radiograph can localize the lesion and determine its degree of aggressiveness enabling the radiologist to make an informed differential diagnosis and in many cases a specific diagnosis.

MRI is the preferred modality to image musculoskeletal tumors and should be obtained after radiographic evaluation.

Its multiplanar imaging capability helps delineation of tumor and its extent in bone and soft tissues with high contrast resolution. MRI is an excellent modality to demonstrate marrow involvement by the tumor, involvement of neurovascular bundle and joint invasion. MRI can demonstrate cortical breach but false positive results may occur if cortex is markedly thinned out. MRI is the modality of choice for local extent and tumor staging [5].MR imaging usually defines the extent of soft tissue masses better than CT. This is particularly true in areas such as the arm, leg and foot where fat planes are poorly identified by CT. Although MRI does not permit definite histologic diagnosis of a significant proportion of lesions. MR imaging features combined with plain radiographic findings, the age of the patient and other relevant clinical information allow the radiologist to categorize many lesions as benign or malignant.

CT is superior to MR for detecting small areas of mineralization and early cortical bone erosion. Visibility of small mineralized areas by MRI is dependent on the MR imaging Sequence.

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