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Research Article

HOW ACCURATE IS MRI IN CHARACTERIZATION OF PRIMARY BONE TUMORS – A PROSPECTIVE EVALUATION

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ABSTRACT

The purpose of this study is to determine Magnetic Resonance Imaging (MRI) characteristics of different primary bone tumors and to evaluate the role of MRI in prediction of malignancy and delineation of anatomic extent of primary bone tumors. Fifty three patients either suspected or proven cases of bone tumors were first evaluated with radiograph, followed by MRI examination. In our study of 53 cases, MRI detected marrow involvement, soft tissue involvement (37%), joint involvement (23%) and cortical break (45%), thus helped in staging and management. MRI is the best modality to evaluate the osseous as well as extra-osseous component, marrow involvement, exact extent and neurovascular involvement. It is very helpful in staging of the tumor.

INTRODUCTION

Primary neoplasms of the skeleton are rare, amounting to only 0.2% of the overall human tumor burden. Evaluation of bone tumors involves a multimodality approach. While cross sectional imaging has extraordinarily improved the ability to characterize primary osseous tumors, radiography remains the cornerstone for the differential diagnosis of skeletal tumors and tumor like lesions due to its higher specificity in detecting tumor morphologic hallmarks[1].

Radiographs provide critical information regarding lesion location, margin, matrix mineralization, cortical involvement and adjacent periosteal reaction[2]. MRI is maximally sensitive to the presence of musculoskeletal soft-tissue lesions and also provides exquisite definition of their features. Categorization of the many distinct attributes of the lesions is the key to differentiation of benign from malignant processes. Combining the observations concerning the architectural details with the location and pattern of growth, and finally with the specific MR signal characteristics and contrast enhancement patterns, will produce the most limited differential diagnosis possible.

Objectives

1. To determine MRI characteristics of different primary bone tumors.
2. To evaluate the role of MRI in prediction of malignancy and delineation of anatomic extent of primary bone tumors.

MATERIALS & METHODS

This is a prospective study conducted in the Department of Radiodiagnosis, Bapuji Hospital, Davangere, for duration of two years. Fifty three patients either suspected or proven cases of bone tumors were first evaluated with plain film examination. MRI was performed on a 1.5 Tesla Philips system (Achieva). Sequences and planes used were T1W and STIR sequence in coronal plane using body coil followed by T1W and T2W sequences in axial plane supplemented by sagittal and coronal planes using surface coil, second plane of imaging included STIR sequence and post contrast fat sat T1W images.

RESULTS

In our study, 21 cases (39.62%) were in the age group of 11 -20 years followed by 9 cases (16.98%) in 21-30 age groups. Primary bone tumors were more common in males (60.37%) than in females (39.62 %). Multiple bone involvement was seen in 10 cases, which included 3 cases of multiple myeloma, 3 cases of multiple osteochondroma/ diaphyseal aclasis, 1case of lymphoma, 1case of multiple enchondromatosis / Ollier's disease, 1 case of chordoma and 1 case of non-ossifying fibroma (NOF).

In the current study, most of the primary bone tumors were observed in the appendicular skeleton (n=39) than in axial skeleton (n=14). A case of multiple myeloma showed involvement of both axial and appendicular skeleton. Out of 39 cases of long bone involvement, most of the bone tumours were observed in the meta-diaphyseal region, comprising of 10

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cases (25.6 %). Second most common site was metaphyseal (9 cases) and third most common site was epiphysio-metaphysio-diaphyseal (8 cases).

Table 1 Comparison of the margin of bone tumor with its benign and malignant characteristics

Margin of Bone Lesion	Benign	Malignant	Total
Well defined	29	6	35
Ill defined	0	18	18
TOTAL	29	24	53

In our study, 35 cases (66%) had well-defined margins, of which 29 cases (54.7 %) were benign and 6 cases (10 %) were malignant lesions. The 6 cases of malignant lesions with well-defined margins were chondrosarcoma (n=2), multiple myeloma (n=2), sclerotic osteosarcoma (n=l)and parosteal osteosarcoma(n=1). (Table -1). 18 cases (33.9 %) had irregular/ ill-defined borders of which 18 cases (33.9%) were malignant.

Table 2 Comparison of the zone of transition of bone tumor with its benign and malignant characteristics

Zone of Transition of Bone Lesion	Benign	Malignant	Total
Wide	0	19(35.84%)	19(35.85%)
Narrow	29 (54.71 %)	5(9.43%)	34 (64.15 %)
TOTAL	29 (54.71 %)	24 (45.29 %)	53(100%)

In our study, 19 cases (35.84 %) hade wide zone of transition and all these cases were malignant. While 34 cases (64.15 %) had a narrow zone of transition of which 29 cases (54.71 %) were benign and 5 cases (9.43 %) were malignant (Table - 2). The five cases with malignant lesions with narrow zone of transition were of multiple myeloma (n=3), chondrosarcoma (n=1) and chordoma (n=1).

In our study, 19 cases (35. 84%) revealed soft tissue involvement on radiographs and MRI. In 1of the cases (4%), soft tissue involvement was not identified on the radiographs, while MRI revealed the soft tissue involvement and assisted the diagnosis and hence the management of the patient. The lesion was a case of Ewing's sarcoma.

Out of 53 patients of bone tumors, 14 cases (26%) revealed calcification/ matrix mineralization within the lesion. 8 cases (15%) revealed trabeculae or internal septations within these lesions. Out of these, 3 cases were of giant cell tumor, 2 cases of aneurysmal bone cyst, and one case each of chordoma, osteochondroma and non ossifying fibroma.

Joint involvement was identified on MRI in 12 cases (23%) cases. MR imaging determined cortical involvement in 24 cases (45.28%).

On MR imaging, 46 lesions (87%) were hypointense on T1-weighted images. 6 lesions (11%) were isointense and 1 lesion (2%) was hyperintense on T1-weighted images. Isointense lesions were 5 cases (9.4%) of osteochondroma and 1case (1.8%) of multiple enchondromatosis. Hyperintense lesion was a case of chondroblastoma involving humeral head.

Out of 53 cases, n=48(91 %) lesions revealed hyperintense signal intensity on T2-weighted images and n =46(87%) on STIR sequences. (n=5)9% lesions revealed hypointense signal intensity on T2 and (n=7) 13% on STIR sequences. T2 hypointense lesions identified in our case study were one case each of osteochondroma, chondroblastoma, ossifying fibroma, sclerotic osteosarcoma and non ossifying fibroma.

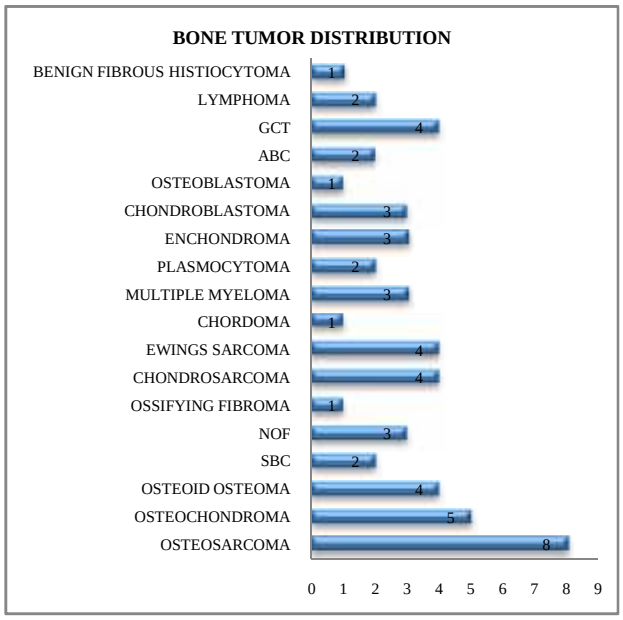


Chart 1 Distribution of pathologies

In our study group of 53 cases, osteosarcoma was the most common pathology, observed in 8 cases (15%) followed by 5 (9.43%) cases of osteochondroma and followed by osteoid osteoma, GCT, chondrosarcoma, Ewing's sarcoma each comprising 4 cases (7.54%). The distribution of other pathologies is as shown in the chart – 1 above.

In our study of 53 cases, 29 cases (55%) cases were benign and 24 cases (45%) were malignant lesions (based on imaging characteristics). Histopathological examination was carried out in 43 cases out of 53cases. Our imaging diagnosis correlated with the histopathological diagnosis in 42 cases (98%). In 1 case (2 %) the imaging diagnosis did not correlate with the histopathological diagnosis. This was a case of benign fibrous histiocytoma.

DISCUSSION

In our study, 53 cases of either suspected or diagnosed primary bone tumors were studied. All patients were first evaluated with plain film examination followed by MRI. These patients were then followed up with regard to histopathological correlation, in which ever cases possible.

Demographic Data

In our study group, most patients were in the age group of 11 - 20 years, comprising of 39.62 % of cases followed by 21-30 years (16.98%). Lesions were more common in males (60.3%) than in females (39.6 %).

In 2010, Obalum DC *et al*[3] retrospectively reviewed cases of primary bone tumors in twenty five years at three different hospitals. The age range of cases was 6 to 85 years with a mean of 25.8 years and peak frequency in the 11-20 year age group. 60.6% were males and 39.4% were females giving a male to female ratio of 1.5:1.

Distribution of pathologies

Out of 53 cases of primary bone tumors, osteosarcoma was most common pathology, observed in 8 cases (15%) followed by 5 (9.43%) cases of osteochondroma and followed by osteoid osteoma, GCT, chondrosarcoma, Ewing's sarcoma each comprising 4 cases (7.54%).

In a retrospective review by Obalum DC *et al*[3], three hundred and fifty-six (51.0%) were benign while 342 (49.0%) were malignant. The commonest types were osteosarcoma 197 cases (28.2%), osteochondroma 106 cases (15.2%) and osteoclastoma 78 cases (11.2%).

Benign Bone Tumours

Osteoid osteoma

In our study, 4 cases (7.54%) were of osteoid osteoma. Three cases were males and one was a female patient. Out of four cases, three lesions were located in the femoral neck and one in tibia. Of these four appendicular osteoid osteomas, two were intracortical in origin, one revealed an endosteal location and other was an intramedullary (cancellous) location. One case of endosteal osteoid osteoma was associated with periosteal reaction.

Kransdori *et al*[4] had stated that the cortical variety is the most common type followed by cancellous (medullary) and Subperiosteal varieties being rate.

Four lesions were lytic with surrounding sclerosis and central nidus. Nidus was visualized on radiograph in two cases while MR imaging demonstrated the nidus in four cases.

P.Goswami *et al*[5] stated that MR imaging can reliably demonstrate the nidus of the osteoid osteoma, which has a variable appearance related to its position relative to the cortex of bone, size and amount of calcification or fibrous tissue present. Also MR imaging is better than CT in diagnosing osteoid osteoma, when the nidus is in cancellous location.

In three cases of osteoid osteoma (two involving femur and one involving tibia) MR imaging also demonstrated adjacent synovial thickening and joint effusion.

NA. Pendse *et al*[6] stated that MR imaging could delineate adjacent soft tissue due to synovial thickening and inflammation and reactive joint effusion.

Osteoblastoma

In our study, 1.8% (n=1) case of osteoblastoma was identified. In our case, it was found in a 10 year old boy and was located in the spinous process of cervical vertebra. It presented as expansile lytic lesion with sclerosis. Spine is the most common site and occurs in 30% of cases Tripathy P. *et al*.[7]

Osteochondroma

Osteochondroma represents the most common bone tumor and constitutes 20%-50% of all benign bone tumors and 10%-l 5% of all bone tumors. In our study, osteochondroma represented 9.43% (n=5) of all bone tumor cases evaluated by MR imaging. **Meyerding**[23] stated that MR imaging is indicated in cases of suspected malignant transformation where patients present with pain or increase in size after puberty and in cases of multiple hereditary exostosis or diaphyseal aclasis.

Enchondroma

In our study, 5.7% (n=3) cases were of enchondroma. In one case, a 15 year old boy presented with multiple swellings in the hand and was diagnosed to have multiple enchondromatosis or Ollier's disease affecting small bones of right hand. None of the lesions showed calcification within. Also periosteal reaction was seen adjacent to the lesion showing cortical break. Clyde Helms[8] in his book had stated that calcified chondroid matrix is found invariably in enchondroma, except when in phalanges. Periostitis should not be seen in enchondromatosis except when associated with a pathological fracture.

Chondroblastoma

We studied 3 cases of chondroblastoma in our study. Two cases were in males and one in a female. All cases were in the 2nd – 3rd decades. All lesions presented as mixed lytic sclerotic epiphysio metaphyseal lesions. On MR imaging these lesions showed varied appearances. In two cases, lesion was hypointense on T1-weighted images and hyperintense in third case. On T2-weighted images, lesion appeared hyperintense in two cases and hypointense in one case. In all cases on MR imaging lesions showed heterogeneity, fine lobular margins and well defined margins with surrounding bone edema.

PT. Weatherall *et al*[9] studied various appearances of chondroblastoma on MR imaging. In his study, T2-weighted MR imaging revealed low to intermediate heterogeneous signal intensity, lobular internal architecture, and fine lobular margins.

Benign fibrous tumors

Five benign fibrous tumors were studied, one each of ossifying fibroma, fibroxanthoma (benign fibrous histiocytoma) and three cases of fibrous cortical defect (non-ossifying fibroma).

Ossifying fibroma of the right fronto-ethmoid region was incidentally detected lesion on MR Brain study in a 36 year old female patient presenting with headache. It was causing sinus outflow tract obstruction resulting in obstructive sinusitis and causing her symptoms. This was well delineated on MR imaging. This sclerotic lesion on radiography appeared hypointense on all MR imaging sequences. Depending on the appearance of tumor matrix**,** R. Kumar *et al*[10] classified these lesions as a) ossifying fibroma when bone predominates in the matrix of the lesion b) cementifying fibroma when spheroid calcification is present c) cementifying fibroma when both bone and calcification is present.

Aneurysmal bone cyst

In our study, two cases of aneurysmal bone cysts were identified. Both cases were in 2nd – 3rd decade and presented as eccentric expansile lytic lesions in meta diaphyseal region. Both cases showed multiple internal trabeculations. MR imaging revealed the multilocular nature of the lesion, however no fluid-fluid levels were noted in either of our cases. Lesions were heterogeneous, which were indicative of different relaxation parameters of the content and additionally both these lesions demonstrated low signal intensity rim.

J.Beltran *et al*[11] studied the MR imaging features of aneurysmal bone cyst. Findings included multiple internal septations, cysts

with fluid-fluid levels of varying intensity and an intact rim of low signal intensity completely surrounding the lesion.

Giant cell tumor

We studied four cases (7.54%) of giant cell tumor, affecting the long bones. All of them appeared as expansile lytic lesions with internal septations. Three lesions in our study showed a cortical break with associated periosteal reaction and fourth lesion showed cortical break with no periosteal reaction. They were all heterogeneously hypointense on T1-weighted images and hyperintense on T2 weighted images. MR imaging could delineate the exact extent of the lesion with intra-articular extension of the lesion in 2 cases and associated cortical break in all four lesions.

Shaligram Purohit *et al*[12] stated that giant cell tumor show low intensity on T1-weighted images and heterogeneously high intensity on T2-weighted images. Therefore intramedullary extension of the tumor is best seen on T1-weighted images while it's extraosseous extent, best appreciated on T2-weighted images.

Malignant Bone Tumours

Osteosarcoma

There were 8 cases (15%) of histologically proven osteosarcoma in our study. The tumors involved long bones namely femur (n=7), fibula (n=1). Most of these lesions were primarily metaphyseal with either extension into epiphysis or diaphysis or both and one case was diaphyseal in location. Five patients were females while three were males and all cases were in the age group of 5-25 years.

Of the eight lesions, five presented as predominantly lytic lesions, two as mixed lytic-sclerotic and one was predominantly sclerotic in appearance. All the cases revealed wide zone of transition. All lesions showed presence of extensive periosteal reaction. On MR imaging, all lesions were hypointense on T1-weighted images and hyperintense on T2-weighted images. However, in one case which presented as sclerotic lesion, MR imaging revealed a predominantly hypointense appearance on all sequences. Cortical break was identified in six of these cases and soft tissue extent could rightly be identified on MR imaging in all cases.

14 cases of histologically proven osteosarcoma were evaluated by MR imaging by Redmond *et al.*[13] They stated that MR imaging provides excellent correlation of intramedullary tumor extent with the pathological findings. T2 weighted images could optimally demonstrate soft tissue bulk and breach of epiphysis or cortex.

Chondrosarcoma

Four cases (7.5%) of chondrosarcoma, were in our study. Male to female distribution was equal in our study with three cases in age group of 4th to 6th decade while a single case was seen in an 18 year old boy. Two cases were situated in the epiphysio-metaphyseal region of the long bones while two cases were located in the pelvis. One case (1.88%) presented as lytic destructive lesion, and another (1.88%) presented as predominantly lytic and two cases (3.8%) presented as mixed lytic sclerotic lesion. All lesions showed matrix mineralization. Three cases revealed wide zone of transition. Three cases were associated with soft tissue involvement on the radiographs while MR imaging confirmed the finding in all these cases. Joint involvement was present in three cases as was rightly identified on MR imaging and correlated with surgical findings. C.ortical break was identified in three cases on MR imaging which was confirmed on surgical findings. All the tumors in our series appeared heterogeneously hypointense on T1-weighted images and hyperintense on T2-weighted images.

Ewing's sarcoma

Four cases of Ewing"s sarcoma were studied. One case (n=1) was located in the diaphysis of femur, two cases involved the pelvis and one was located in scapula. All lesions presented as lytic lesions with ill-defined borders and a wide zone of transition with associated periosteal reaction. The characteristic multi-lamellated onion peel periosteal reaction was seen only in one of our cases. These tumors presented in 1st – 2nd decade and male to female ratio of 3:1 was noted in our study.

Vyakant Vohar *et al*[14] studied 27 patients had concluded that pelvic girdle and lower extremities were most common sites. In his study male to female ratio was 2.8:1.

Boyko *et al*[15] studied MRI of nine patients with biopsy proven Ewing's sarcoma and concluded that MR imaging can identify thickening, infiltration and destruction of cortex. In our study cortical involvement was identified in two cases.

Multiple myeloma/ Plasmacytoma

Three cases of multiple myeloma and two cases of plasmacytoma presenting with multiple lesions (myelomatous change) were studied.

Both plasmacytoma cases presented as lytic lesions involving vertebra. The lytic expansile lesion involving the vertebral body showed typical mini brain appearance on axial sections on MR imaging.

Nancy Major *et al*[16] had reported that identification of mini brain sign in an expansile lesion is characteristic of plasmacytoma and it is important to identify this characteristic sign because biopsy can be avoided in patients with this appearance. However in our case the patient was operated and plasmacytoma was confirmed on histopathology examination.

Our three cases of multiple myeloma presented in 5th – 6th decade as multiple compression fractures of the vertebral column and punched out lytic lesions of the skull. MR imaging revealed diffuse involvement of multiple vertebrae with reduced vertebral height. F.Lecouvet *et al*[17] studied the appearances and distribution of vertebral compression fractures on MR imaging in patients with multiple myeloma. They concluded that most vertebral compression fractures in patients with multiple myeloma appear benign at MR imaging, and their distribution is similar to that observed in osteoporotic fractures. In all our cases, diagnosis was confirmed by the presence of M-band on electrophoresis.

Lymphoma

In our study, two (4%) cases of primary bone lymphoma were studied. One case presented as a lytic destructive lesion of the iliac bones in a 60 year old male. It revealed extensive cortical destruction with soft tissue mass on MR imaging. The other is a 17 year old body with involvement of femur. No periosteal

reaction was identified in this case. No soft tissue involvement was identified on MR imaging.

Krishnan *et al*[18] stated that primary bone lymphoma comprises less than 5% of all primary bone tumours. Their radiographic appearances are variable and despite these variability, findings of solitary, permeative, meta-diaphyseal lesion with a layered periosteal reaction on plain radiograph and a soft tissue mass on MR imaging, especially in a patient older than 30 years are highly suggestive of lymphoma.

Chordoma

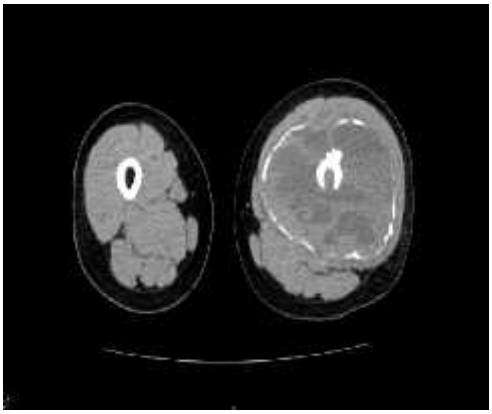
A single case of sacrococcygeal chordoma was studied in our series. It presented as lytic destructive lesion involving the sacrococcygeal region in a 54 year old man. On MR imaging, signal in the mass was predominantly hypointense with scattered areas of hyperintensity corresponding to mucinous or hemorrhagic material. It appeared predominantly hyperintense on T2-weighted images with areas of low signal intensity. Contrast enhanced images showed mild heterogeneous enhancement within the mass.

K.Farsad *et al*[19] reported a similar case of sacral chordoma with similar signal characteristics on MR imaging. He stated that high signal intensity seen on T2 weighted images is a non specific feature; however the combination of high signal intensity and a lobulated sacral mass that contains areas of hemorrhage and calcification is a striking feature of chordoma.

Illustrative cases

CASE 1: A 22 year female presented with pain & swelling of left thigh since 3 months.

a



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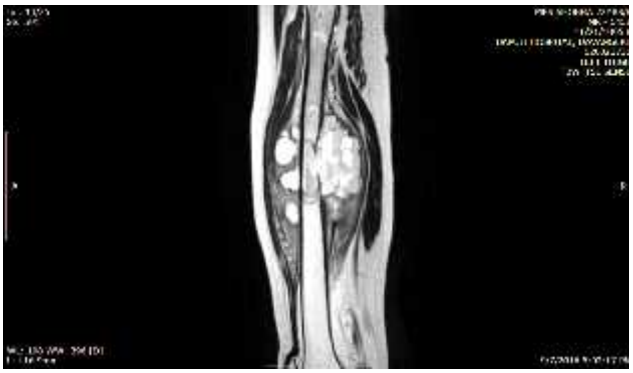

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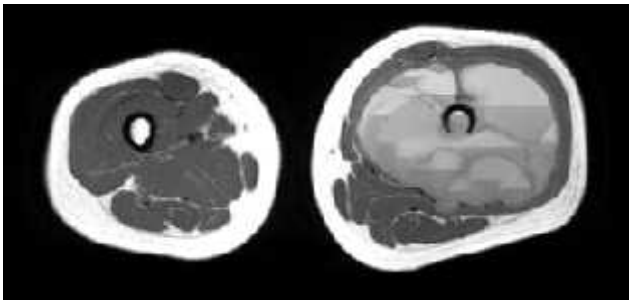

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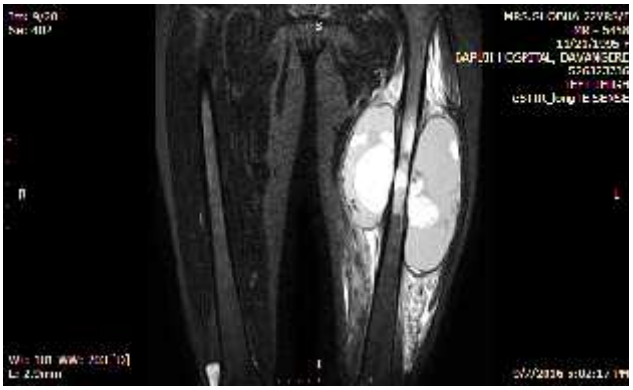

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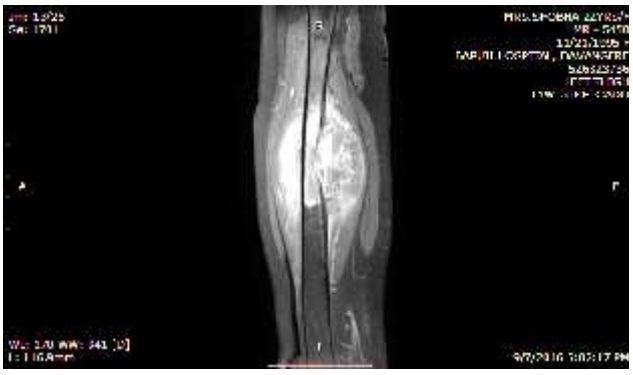
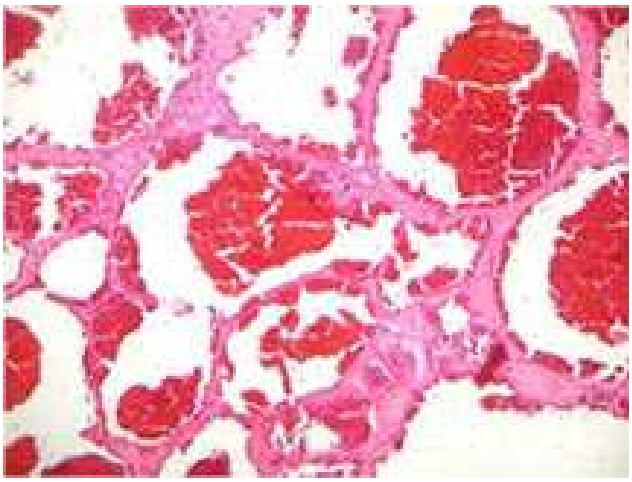


f

CASE 1 (a-f): Telangiectatic osteosarcoma (a) AP and lateral radiograph of femur showing lytic lesion in mid shaft with cortical break and soft tissue component with peripheral and internal calcifications and periosteal reaction (b) axial plain CT image showing intramedullary lesion with posterior cortical break and intramuscuar extension showing multiple fluid levels with peripheral calcification (c) sagittal T2 (d) sagittal STIR weighted images showing intramedullary hyperintense lesion with posterior cortical breech and intra muscular lesion with multiple fluid levels (e) axial T1W showing intramedullary hypointensity (f) sagittal T1 FS contrast showing heterogenous intramedullary,peripheral and septal enhancement.



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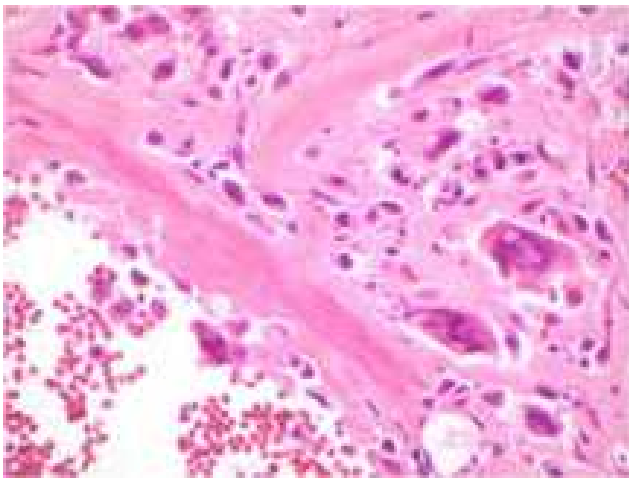
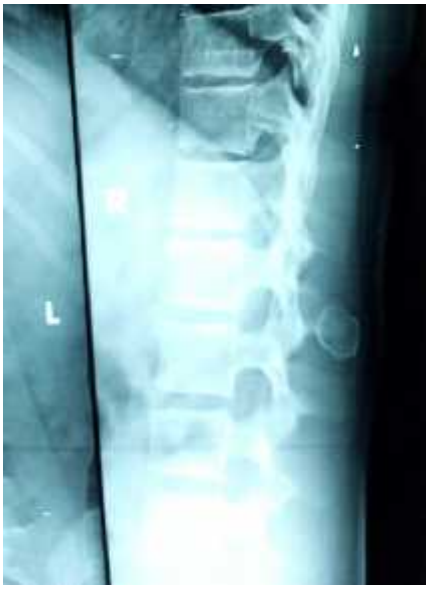


h

CASE 1 (g&h): contd. Telangiectatic osteosarcoma (g) Low power view show multiple blood filled cavities separated by multiple septae (h) High power view show malignant appearing cells with large, hyperchromatic atypical nuclei, scant osteoid.

CASE 2: A 14 year female presented with pain & swelling in the back.



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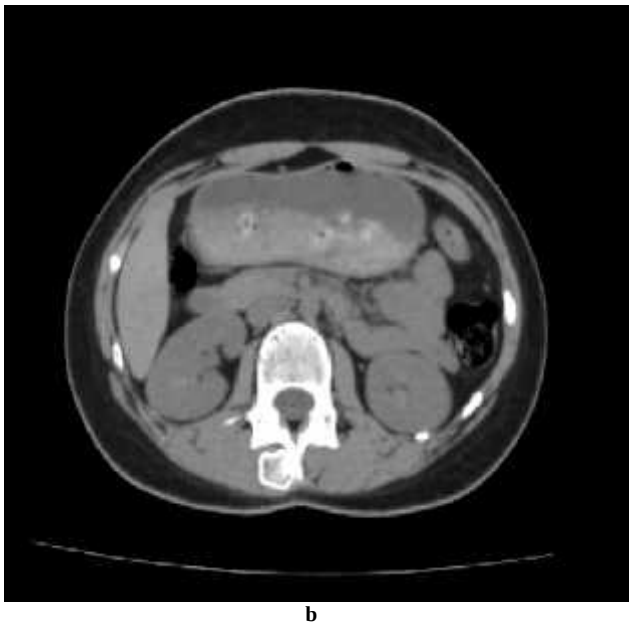

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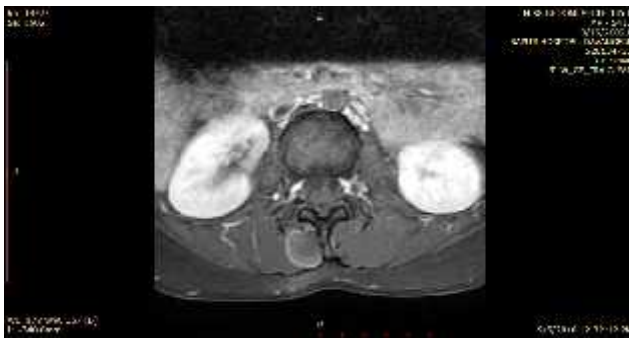

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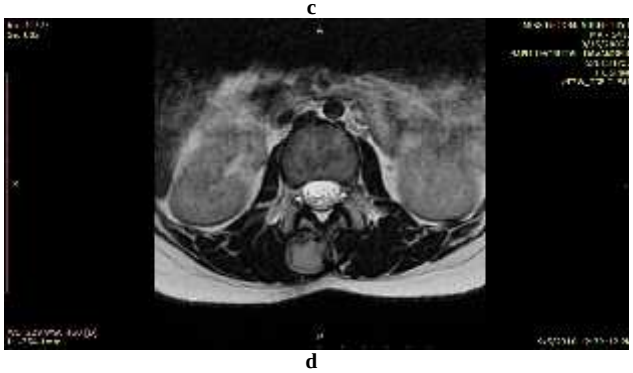

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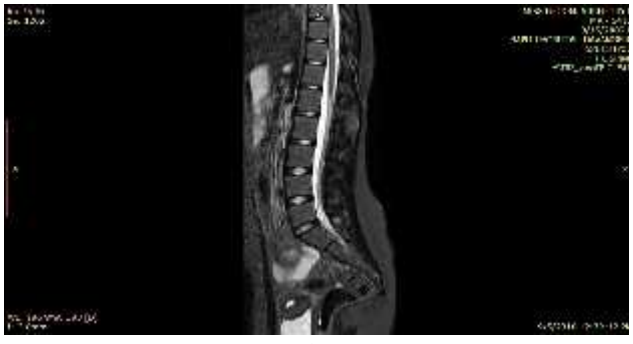
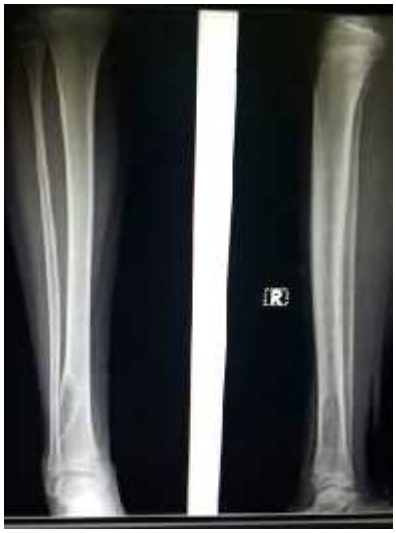


e

CASE 2: Osteochondroma (a) X-ray, (b) axial CT showing exophytic bony lesion which is in continuation with medullary cavity of L2 spinous process. (c) Axial T1, (d) Axial T2 show exophytic bone lesion T1 & T2 hyperintense with hyperintense cartilage cap (thickness <1cm) and no soft tissue component. (e) Sagital STIR image show inversion of signal i.e hypointense.

CASE 3: A 10 year female presented with pain & swelling in distal part of right leg.



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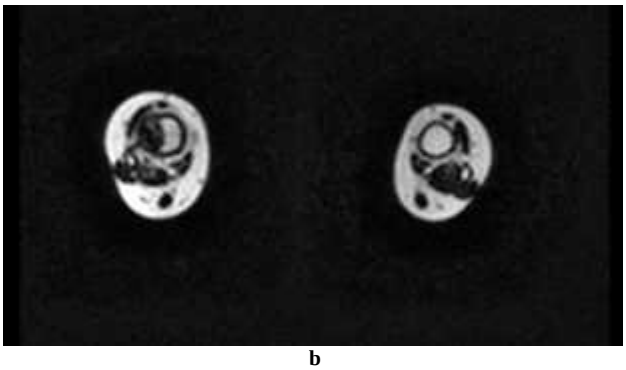

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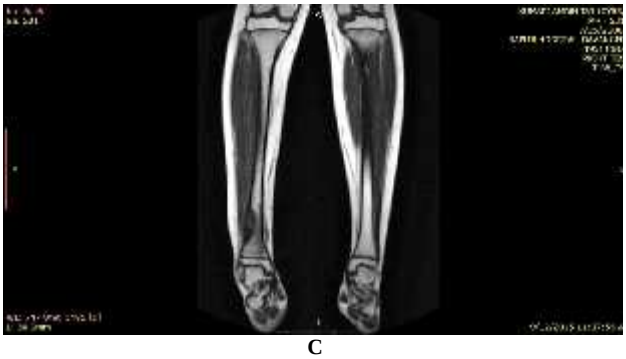

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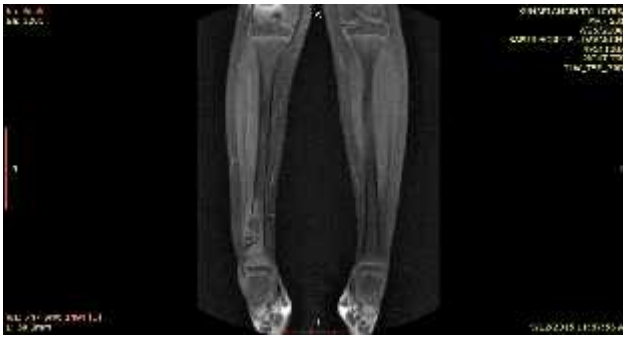
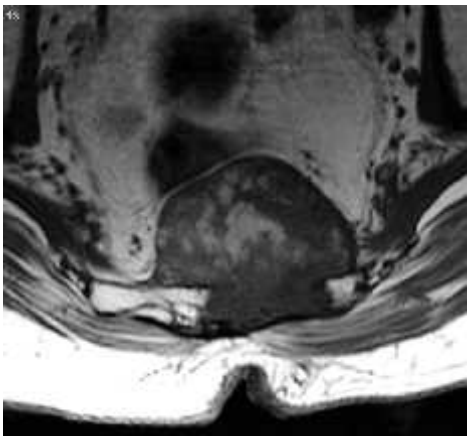


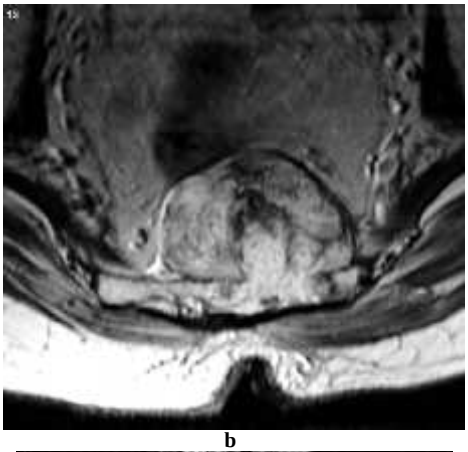
d

CASE 3: Non ossifying fibroma (a) X-ray lateral & AP show a eccentric well defined ovoid lytic lesion with sclerotic margins in distal meta-diaphyseal region of tibia with internal trabeculae (b) Axial T2, (c) Coronal T1 & (d) Coronal T1 FS contrast show well defined intracortical lesion which is hypointense on T1/T2 with minimal to no contrast enhancement.

CASE 4: A 54 year female presented with pain.



a



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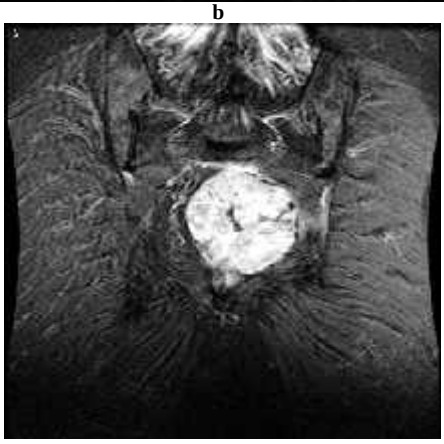

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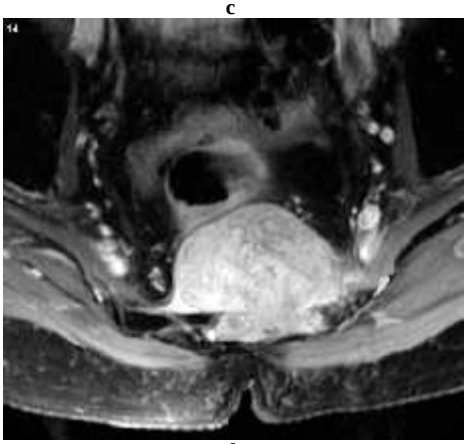
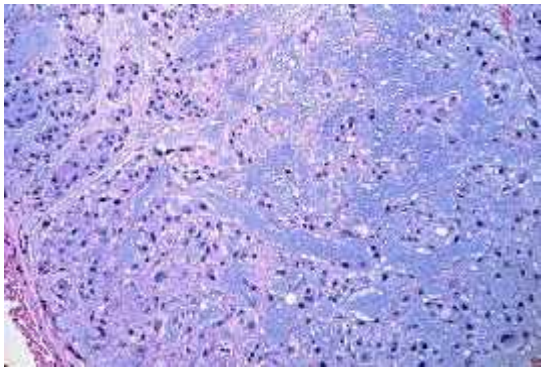
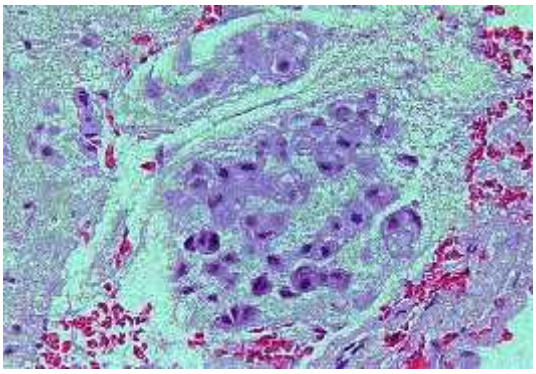


d



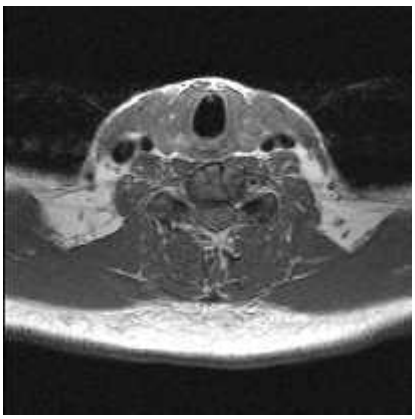
e



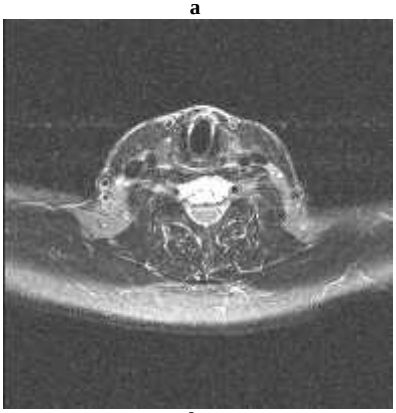
f

CASE 4 Chordoma (a) Axial T1, (b) Axial T2, (c) Coronal STIR, (d) Axial T1 FS contrast shows heterogenous mass arising from the sacrococcygeal vertebra, seen as predominantly hypointense on T1 and hyperintense on T2/STIR with significant contrast enhancement (e&f) Histopathology reveals chordoma showing characteristic physaliphorous cells and mucinous matrix.

CASE 5: A 53 year male presented with neck pain.



a



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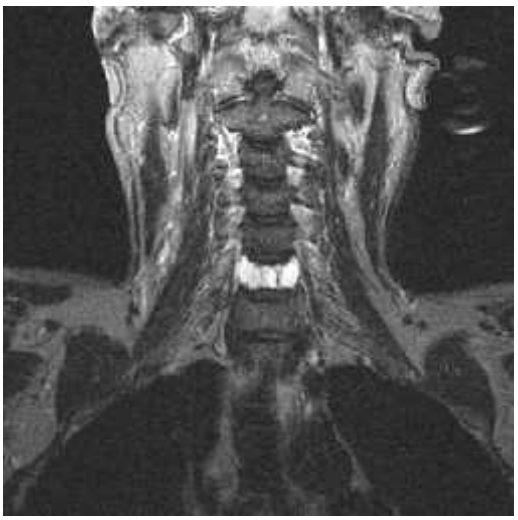
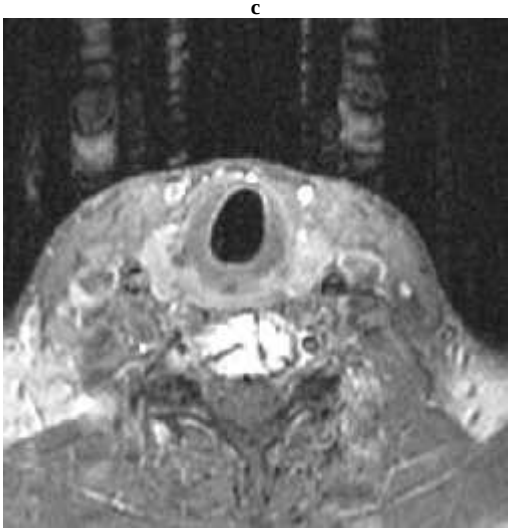


c



d

CASE 5: Plasmacytoma (a) Axial T1, (b) Axial T2 , (c) Coronal STIR , (d) Axial T1 FS contrast showing vertebral body lesion which is hypointense on T, hyperintense on T2 and STIR with significant enhancement on contrast. And it gives typical appearance of 'MINI BRAIN' which is characteristic of vertebral body plasmacytoma.

CONCLUSION

MRI is the preferred modality for identifying the local extent as well as for staging of these tumors. Radiographs provide information regarding lesion location and adjacent periosteal reaction. However, the excellent contrast resolution and multiplanar imaging of MRI enables us to evaluate both intracompartmental and extracompartmental extent of bone, this particularly holds 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 intra-articular extension and the presence of intratumoral necrosis and hemorrhage. MRI is the best technique to detect skip lesions, which may often be missed by other imaging means.

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