Original Research Article

MR imaging of primary malignant bone tumors with surgical and histopathological correlation

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Abstract

Background: A bone tumor is a neoplastic growth of tissue in bone. Abnormal growths found in the bone can be either benign (noncancerous) or malignant (cancerous).

Aims and objectives: The purpose of this study was to evaluate the role of MRI in cases of primary malignant bone tumors and MRI characteristics of different primary malignant bone tumors, to compare the imaging findings with surgical and gross pathological findings, Staging of tumor on MRI, correlating them with operative and histopathological findings.

Materials and methods: This was a prospective study done in Department of Radiodiagnosis of NRIGH comprising of 40 patients 21 male and 19 female who were suspected or proven cases of the malignant bone tumor. Plain radiographs in AP and Lateral views (including the adjacent joint) were taken in all cases. The primary pulse sequences included T1 and T2 WI using spine echo and gradient echo techniques with TR of 600 msec. and TE 30msec. for T1WI and TR of 2740 msec. and TE of 85 msec. for T2 WI . The MR morphology was correlated with surgical and histopathological features.

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.

Conclusion: MRI in combination with plain radiography is an excellent modality for evaluation of the musculoskeletal pathologies especially differentiating a malignant from a benign lesion. The multiplanar imaging capabilities place a major role in delineation of tumour extent in to the bone and

soft tissues with high contrast and resolution with additional information of neurovascular bundle involvement, joint involvement and staging.

Key words

Bone tumors, Osteosarcoma, Osteoblastoma, Giant cell tumor, Enchondroma, Chondrosarcoma, Chondroma histopathology, Radiographic features, MRI features, CT findings.

Introduction

A bone tumor [1] is a neoplastic growth of tissue in bone. Abnormal growths found in the bone can be either benign (noncancerous) or malignant (cancerous). Cross sectional imaging had improved the diagnostic accuracy of both benign and malignant bone tumors. The ability to characterize tumors, the differential diagnosis of primary osseous neoplasm remains based on the radiographic appearance. Radiographs provide information regarding the location, margin, matrix mineralization, cortical involvement and adjacent periosteal reaction. But MRI is superior to plain radiography due to its delineation of local extent and local staging of the disease and also in assessing the intraarticular extension and the presence of intra tumoral necrosis and hemorrhage in assessing the treatment effectiveness and follow-up.

Materials and methods

This was a prospective study done in Department of Radiodiagnosis of NRIGH comprising of 40 patients 21 male and 19 female who were suspected or proven cases of the malignant bone tumor. Plain radiographs in AP and Lateral views (including the adjacent joint) were taken in all cases. MRI was performed on a 1.5 Tesla GE system. The primary pulse sequences included T1 and T2W1 using spin echo and gradient echo techniques. The additional sequences used include the fat saturated SE and short Tau Inversion-Recovery (STIR) sequences.

MRI was performed on a 1.5 Tesla GE (General electricals) Signa Excite. The primary pulse sequences include T1 and T2 WI using spine echo and gradient echo techniques with TR of 600 msec. and TE 30msec. for T1WI and TR of 2740 msec. and TE of 85 msec. for T2 WI. Additional sequences used include the FS SE and STIR sequences.

The spinal cord is imaged in sagittal, coronal and axal planes. Images are obtained with multi slice technique using slice thickness using a slice thickness of 5 mm, inter slice gap of 6mm and matrix of size of 512 x 512. The MR morphology was correlated with surgical and histopathological features.

All the Giant cell tumors were included in the study because it was not possible to predict the malignancy on plain radiography.

The findings to be noted were given in **Table – 1**.

Features seen on both plain radiography and MRI
1. The transitional zone
2. Intramedullary extent
3. Soft tissue extent
4. Mineralization of matrix
5. Periosteal response
6. Cortical involvement
7. Joint involvement
8. Site of lesion
9.Epiphyseal involvement
Features seen only on MRI
1. Involvement of neurovascular bundle
2. Signal characteristics.

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 November 2017 to January 2019 the age ranged from 6 years to 71years (mean 40 years) (**Figure – 1**). There were 21 males and 19 females (**Table – 2, Figure - 2**).

Table – 2: Sex distribution.

Diagnosis	No.	Male	Female	Age range	Median age
Osteosarcoma	13	7	6	6-22	14
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

Figure – 1: Age distribution.

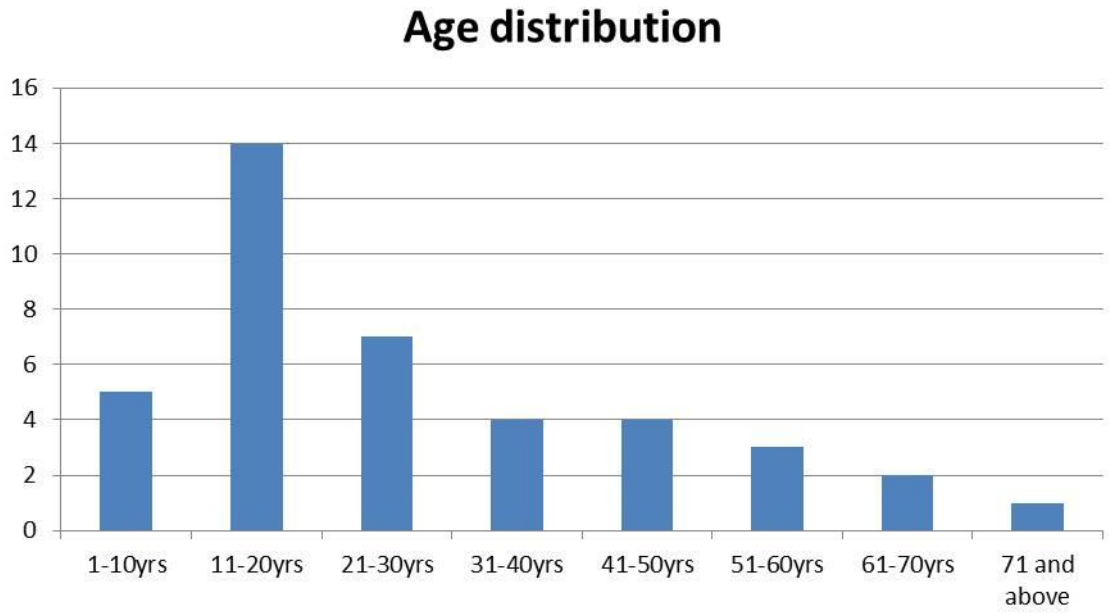
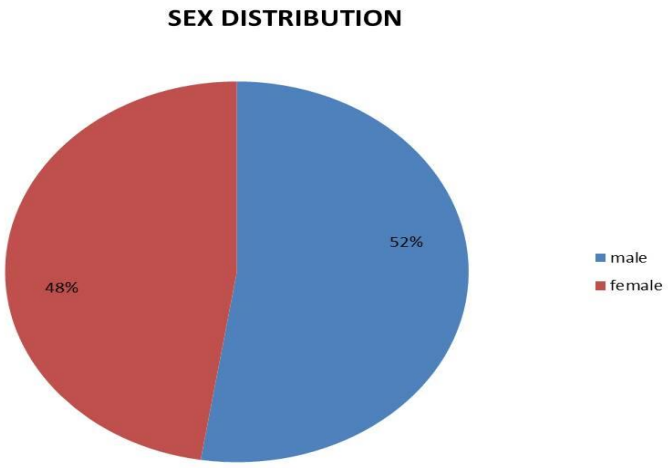


Figure – 2: Sex distribution.



Study group

The common clinical symptoms were pain in the region of tumor 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.

Of the 40 cases, thirteen were Osteosarcomas, eight were Ewing's sarcomas, six were Chondrosarcomas, eight were Giant cell tumors, three were Chordomas, and two were multiple myelomas. Of the eight Giant cell tumors, one case was malignant (**Table – 3, Figure - 3**).

Table – 3: Histopathological classification.

Osteosarcoma	13
Ewing's sarcoma	8
Chondrosarcoma	6
GCT	8
Multiple Myeloma	2
Chordoma	3

Figure – 3: Characterization of tumor.

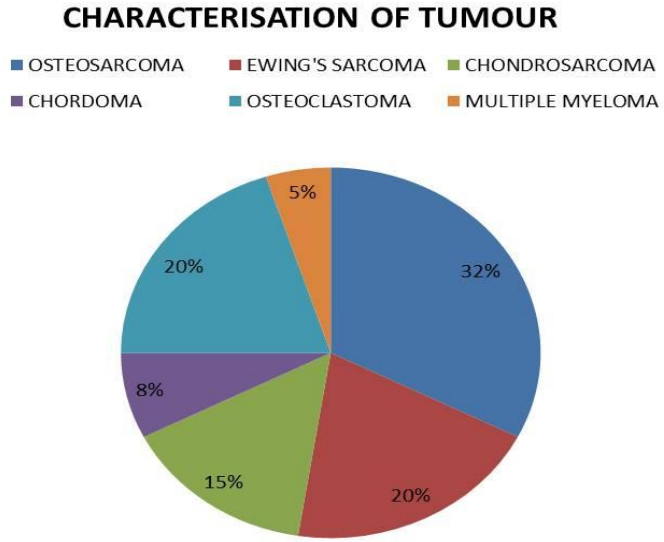


Table – 4: Site of lesion.

Osteosarcoma	
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
Giant cell tumor	
Radius lower end	2
Humerus upper end	2
Femur upper end	1
Tibia upper end	1
Tibia lower end	2
Chondrosarcoma	
Pelvis	3
Femur	2
Humerus upper end	1
Chordoma	
Sacrum	3

Site of lesions were as per **Table – 4.**

MRI findings in malignant bone tumors

Signal Characteristics

Most of the tumors were hypo intense on T1W images and heterogeneously hyper intense on T2W images. In general most tumors had a non-specific appearance on MRI except for cartilaginous tumors. The cases of chondrosarcoma were profoundly hyper intense on T2W images because of high water content of cartilaginous elements.

Cortical break

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 (**Table – 5, Figure - 4**).

Table – 5: MRI findings and surgical findings.

Cortical involvement	MRI findings	Surgical findings
Present	26/31 (84%)	27/31 (87%)
Absent	5/31 (16%)	4/31(13%)

Figure – 4: Cortical break.

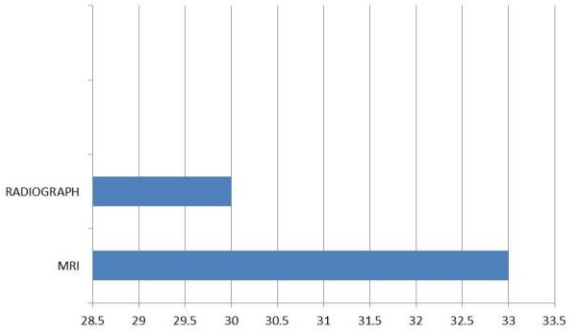
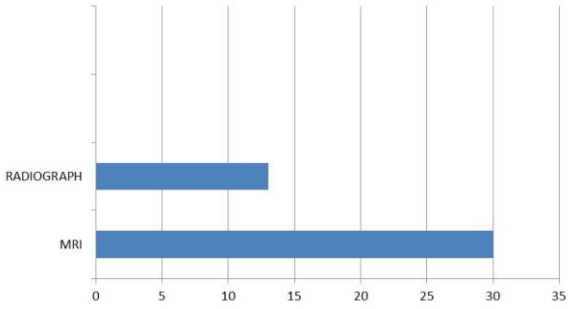


Table – 6: Soft tissue involvement.

Soft tissue involvement	MRI findings	Surgico-pathological findings
Present	24/31 (77.4%)	25/31 (80.6%)
Absent	7/31 (19.3%)	6/31 (16%)

Figure – 5: Soft tissue involvement.



Thus 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.

Marrow involvement

Marrow involvement was seen in all cases on MRI which was confirmed on surgery in thirty one cases. The extent of marrow involvement was best shown by T1W images and STIR coronal or sagittal sequence. It was confirmed by surgical and pathological findings in thirty one cases.

Soft tissue involvement

Extra osseous soft tissue involvement was seen in 34 cases out of 40 cases. Soft tissue involvement is not seen in 4 cases of GCT, two cases of Ewing's sarcoma. Extraosseous soft tissue involvement was best shown by T2W axial images (**Figure – 5, Table – 6**).

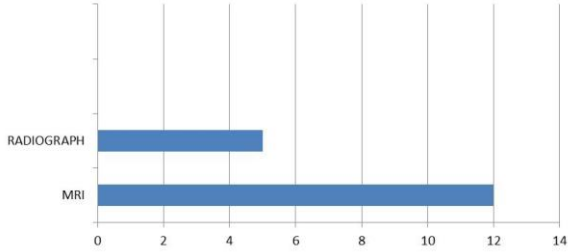
Joint involvement

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 (**Table – 7, Figure – 6**).

Table – 7: Joint involvement.

Joint involvement	MRI findings	Surgico-pathological findings
Present	12/31 (38.7%)	10/31 (32.2%)
Absent	19/31(61.2%)	21/31 (67.7%)

Figure – 6: Joint involvement.



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%.

Neurovascular bundle involvement

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

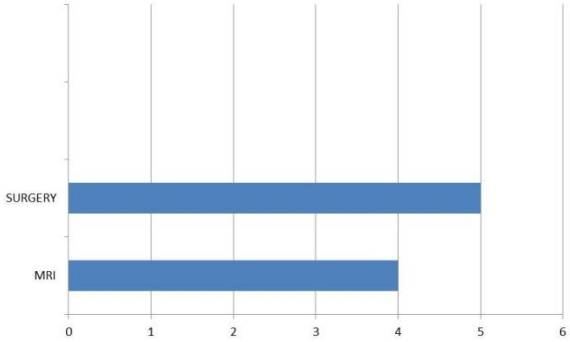
be performed in 31 of these patients. Nine patients could not be operated due to the presence of metastasis.

MRI and surgical/pathological correlation out of 35 patients who were operated was as per **Table – 8, Figure – 7**.

Table – 8: Neurovascular involvement.

Neurovascular involvement	MRI findings	Surgical/ pathological findings
Involved	4/31 (12.9%)	5/31 (16%)
Uninvolved	27/31(87.1%)	26/31 (84%)

Figure – 7: Neurovascular involvement.



The sensitivity in our study was 100%, specificity96.2%, positive predictive value 100% and negative predictive value was 96.2%.

Discussion

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

On plain radiography and MRI, the parameters mentioned in the **Table - 1** were evaluated in all the and staging was done separately.

Transitional zone

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 tumor showed narrow zone of transition.

On MRI, all the lesions showed clear demarcation between the involved zone and normal fat in the marrow. The giant cell tumors showed a clear hypo intense rim corresponding to the sclerosis on plain radiograph.

Marrow Involvement

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 sagittal sequences.

Ella Onikul, David Parham, et al. in 1996 [2], studied the accuracy of MR imaging for estimating intraosseous extent of osteosarcoma. They compared how well T1W images and STIR images revealed the extent of longitudinal intraosseous involvement in osteosarcoma.

R Golfieri, et al. [3] in 1990 studied the role of STIR sequence in MRI examination of bone tumors and found that the STIR sequence suppress the high signal from fatty bone marrow giving a clear depiction of tumor extent in its intramedullary component.

Soft tissue 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.

Orest B Boyko, David A Cory [4] 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 sequences.

Cortical Break

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.

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 may lead to overstating of tumor and result in unnecessarily radical surgical procedures [5].

We evaluated the relationship of the tumor to adjacent joint and involvement of the intrasynovial 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 peritumoral inflammatory changes may lead to false positive diagnosis of joint involvement which may be followed by unnecessary radical en bloc resection of joint [6].

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 are quite similar to Van Trommel, et al. [7] who found sensitivity, specificity, positive predictive value and negative predictive value to be 100%, 70%, 86.4% and 100% respectively.

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 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 neurovascular bundle to the tumor 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 tumor mass to the neurovascular bundle. Suzanne, William Kaufman [8] in 1997 found that it is easier to evaluate neurovascular bundle proximity to tumor with fat sat 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 is 100%, specificity 96.2%, positive predictive value 100 % and negative predictive value is 96.2%. The result in

our study is comparable to Bloem JL, et al. [9] who found sensitivity, specificity, positive predictive value and negative predictive value to be 100%, 98%, 98% and 100% respectively.

Signal intensity pattern

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 characteristic MR appearance. Cohen, et al. [10] 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 characterized with MRI. They were profoundly hyper intense on T2 weighted images because of high water content of cartilaginous elements. Rest of the tumors had a non-specific appearance on MRI.

Staging of tumors

Enneking WF, Spanier SS, Goodman MA [11] proposed a system for the surgical staging of musculoskeletal sarcomas (**Table – 9**).

Table – 9: Staging of tumors.

Stage	Grade	Site	Metastases
IA	G1	T1	M0
IB	G1	T2	M0
IIA	G2	T1	M0
IIB	G2	T2	M0
IIIA	G1-2	T1	M1
IIIB	G1-2	T2	M1

Characteristics

G – Grade T- site

G0- benignT1- Intracompartmental

G1-low grade malignancy T2 - extracompartmental

G2-high grade malignancy

M- Metstasis

M0-no regional or distant metastasis

M1- regional or distant metastasis present.

The malignant tumors were staged according to the Enneking's Staging of Musculoskeletal Neoplasms [11]. Nine cases had distant metastasis (Stage III), 21 cases were of Stage IIB and 2 cases were in Stage IIA.

Holger Pettersson, Thurman Gillespy, et al. [12] compared the informative value of MRI with that of plain radiography, angiography, scintigraphy and computed tomography in 176 cases of primary musculoskeletal tumors. Olson, et al. [13] proposed an algorithm for the management of bone tumors.

The Giant Cell Tumors were staged according to Enneking's modified staging system:

Stage 1: asymptomatic and latent Radiographically with benign histologic pattern.

Stage 2: May be symptomatic but there is "active" radiographic appearance (the GCT has expanded the affected bone but is still confined by the overlying cortex), there is no radiographic evidence of distant metastasis with benign histology.

Stage 3: is symptomatic and radiographs show rapid and aggressive growth (permeative bone destruction, extracortical extension with accompanying soft tissue mass, extension to the subcortical cortex and/or associated periosteal reaction). The histologic pattern is benign and distant metastases are rare but acceptable for this stage.

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. when radiographic depiction of tumor permits

assessment of its morphology, matrix and probable histologic nature, MRI ought to be the next examination solely for staging purposes [20] (**Figure – 1 to 5**).

Figure - 1: 8 years/M child with complaint of swelling in the right shoulder since 3 months. **A:** X-ray Rt. shoulder shows Fracture neck of right humerus with large soft tissue opacity noted in the upper end of humerus with calcifications, sclerosis and periosteal reaction which are confirmed by the axials of CT (**B, C**) and axial ,sagittal and coronal MR Images (**D, E, F**). HPE was given as osteosarcoma.

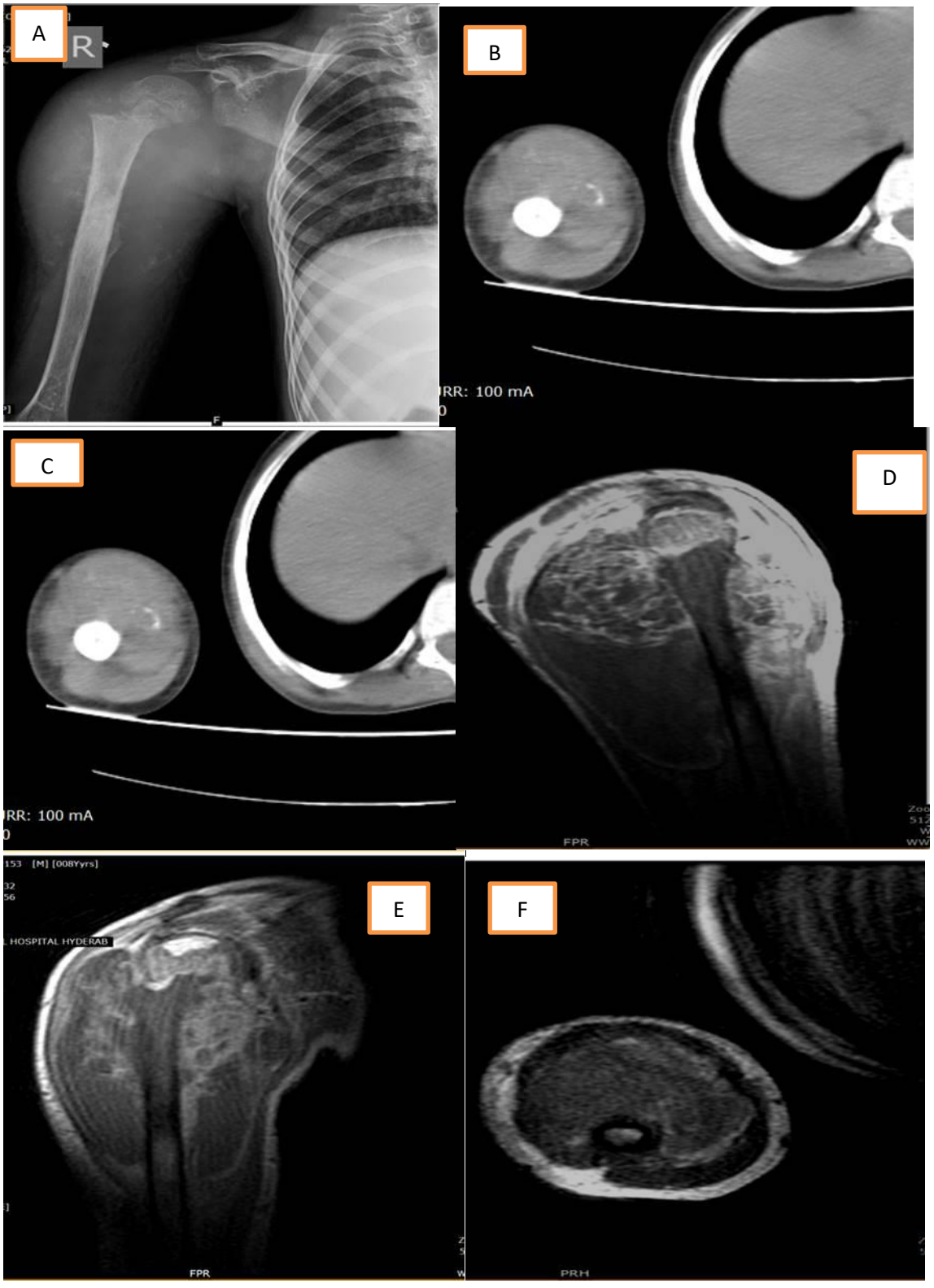
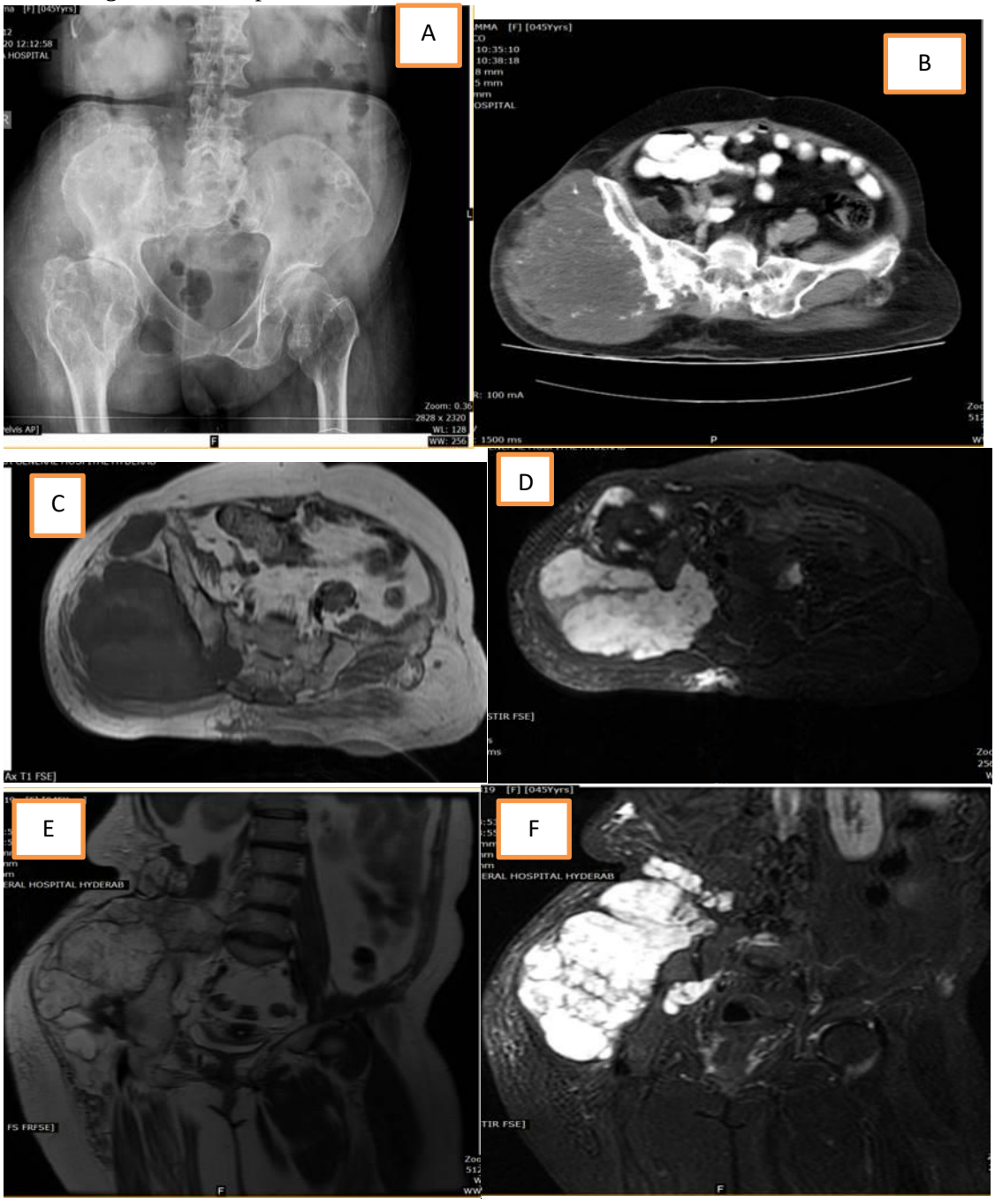


Figure - 2: 45 years/F with complaint of swelling in the right hip since 5 months. **A:** X-ray Pelvis with both hips shows Right iliac blade shows ill-defined lytic areas with a large soft tissue component with calcifications. **B:** CT axial section shows Ill-defined lytic lesion with significant soft tissue component and multiple calcifications. **C to D** (Axial T1, STIR and Coronal GR and STIR): Large multilobulated lesion noted replacing the right iliac bone with high signal intensity on fat suppressed STIR images. HPE was proven chondrosarcoma.



Conclusion

MRI in combination with plain radiography is an excellent modality for evaluation of the musculoskeletal pathologies especially differentiating a malignant from a benign lesion. The multiplanar imaging capabilities place a major role in delineation of tumor extent in to the bone and soft tissues with high contrast and resolution with additional information of neurovascular bundle involvement, joint involvement and staging.

Figure - 3: 17 years/F with complain of pain in right ankle since 3 months. **A:** X-ray –Right ankle (AP)- a well-defined subarticular lytic lesion with narrow zone of transition noted in the lower end of right tibia. There is no evidence of periosteal reaction – consistent with Osteoclastoma. **B to E** (T1 SAG & COR, T2 SAG and Coronal): A well-defined altered signal intensity lesion noted in the lower end of tibia which is hypo intense to marrow on T1WI and hyper intense on T2WI extending into the subchondral region. **F:** A high power view reveals the giant cell nuclei and stromal cell nuclei to be similar, characteristic of GCT.

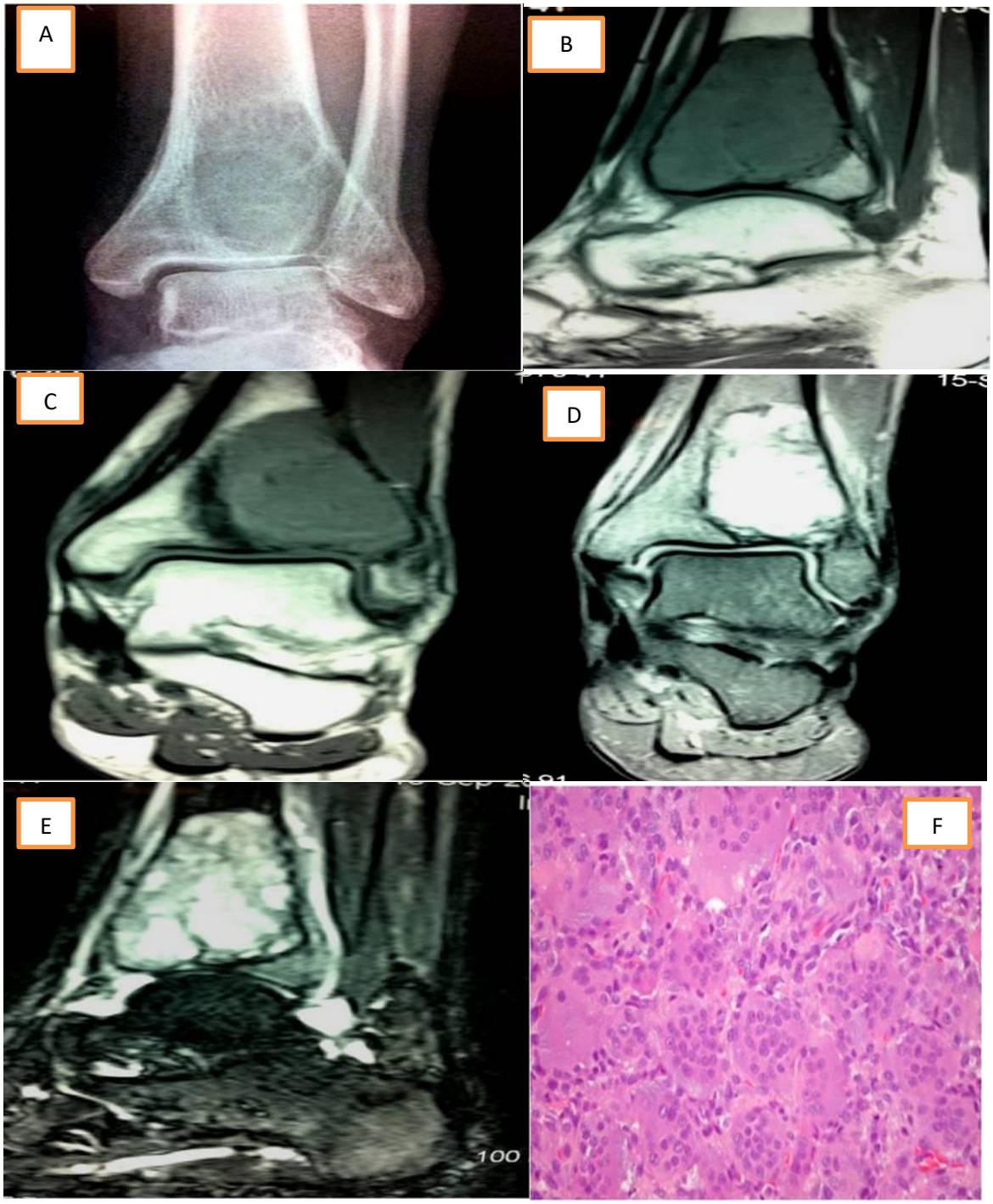


Figure - 4: 14 years/M with complaint of pain and swelling in left thigh since 2 months. **A:** X-ray – Left thigh (AP) - mild expansion with lytic and sclerotic areas with new bone formation and thick periosteal reaction with codman's triangle s/o osteogenic sarcoma. **B to E** (COR T2 FS, AXA T1 & T2 FS and COR T1): Mildly widened with marrow showing iso to hypo intense signal intensity on T1WI and heterogeneous (predominantly hyper intense) signal intensity on T2WI and STIR with areas of bone destruction showing spiculated periosteal reaction and new bone formation. **F:** H&E stained slide shows sheets of cells with atypia and mitoses with areas of atypical osteoid and few giant cells – s/o Osteosarcoma.

Figure - 5: 15 years/F with complaint of pain and swelling in right thigh since 2 months. **A:** X-ray – Left thigh (AP) - expansile lesion with permeative type of bone destruction and onion peel like periosteal reaction with a soft tissue swelling. Features s/o Ewing's sarcoma. **B to E** (COR T2WI, AXA T1WI& T2WI and SAG T1WI): Mild expansion with altered signal intensity in the marrow with lamellated periosteal reaction giving an onion peel appearance and a large lobulated soft tissue component associated with the lesion which shows heterogeneous signal intensity on both T1 and T2WI with areas of haemorrhage and necrosis. **F:** shows solid sheet of small round cells with indistinct cell borders, scant cytoplasm round to oval nucleus with vesicular chromatin with small nucleoli –s/o Ewing's sarcoma.

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