Imaging Approach to Malignant Bone Tumors

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Introduction

Primary malignant bone tumors are quite rare, whereas metastatic disease to the bone is common. For a number of years, conventional radiology played a major role in the diagnosis. With the advanced imaging techniques ultrasound, color Doppler, MDCT, MRI and PET-CT scans (Tables I & II), early diagnosis, extent of the disease, staging of the disease and follow up imaging do help a great deal.

C.T. in Malignant Bone Lesions – Table I

- Cross sectional images
- Soft tissues
- Early calcifications
- Tissue characteristics
- Medullary cavity
- Vessels & nerves

Role of M.R.I – Table II

- Transitional zone
- Skip areas
- Tissue characteristics
- Soft tissues – necrosis, hemorrhage
- Marrow involvement
- Neurovascular bundles
- M.R. Angiography

Team work involving the orthopedic surgeon, oncologist, pathologist and imageologist goes a long way in dealing with malignant tumors. A modified WHO classification is listed in table III.

Primary Malignant bone tumours (modified who classification)

Table III

- Bone Forming – Osteosarcoma & Variants, Ewing's
- Cart. Forming – Chondrosarcoma
- Marrow Tumours – Multi.myeloma,
- Lympho-sarcoma, leukemia
- Fibrous Tissue – Fibrosaroma, Malignant fibrous Histiocytoma
- Giant Cell – Mgt. Giant Cell Tumour
- Vascular – Angiosarcoma, kaposi's sarcoma
- Miscellaneous –Neurosarcoma, Chordoma, Adamantinoma

A mnemonic is prepared to study the criteria of malignancy, namely STAMPS. S-stands of the site whether epiphysis, metaphysis or diaphysis. T-stands for transitional zone that is the border between normal and abnormal bone. A-stands for age of the patients and aggressive nature of the lesion. M-stands for matrix, whether that is lucent, or calcified or ossified. Ossified matrix is usually cloudy whereas cartilaginous calcification shows punctate, arc like or circular. Vascular matrix may suggest hemangioma. Fatty matrix indicates lipomatous tumor. P-stands for periosteal reaction which can be linear, multilaminated, spiculated, velvety type or presence of Codman's triangle. In benign lesions the periosteal reaction is generally unilaminar. Multilaminar

periosteal reaction is often encountered in Ewing's sarcoma. Spiculated or Sunburst type of periosteal reaction is noted both in Ewing's sarcoma and osteosarcoma. S- stands for soft tissue swelling and associated calcifications. This is listed in table IV

Imaging Criteria of Malignant Bone Tumors – Table IV

- Site
- Transitional zone
- Aggressive nature
- Matrix
- Periosteal reaction
- Soft tissues

Primary malignant tumors such as Ewing's sarcoma, osteosarcoma and lymphosarcoma are common in younger age group. Fibrosarcomas and chondrosarcoma occur in adults whereas myeloma and metastasis usually occur in older people. Table V

Primary Malignant Bone Tumors – Table V

- Ewing's sarcoma & Ewing's family of tumors
- Osteosarcoma - Several varieties
- Chondrosarcoma – Several varieties
- Lymphoma – Leukemia
- Fibrosarcoma, malignant fibrous histiocytoma
- Plasmacytoma - Multiple myeloma - Poems syndrome

Other primary tumors include hemangioendothelioma, angiosarcoma, Kaposi's sarcoma, rhabdomyosarcoma, liposarcoma etc.

Ewing's sarcoma

The age ranges between 3-30yrs. Slight predominance in males is noted, about 50% of them occur in diaphysis of long bones. The transitional zone is wide and the matrix may be ossified. The Saucerization of cortex is one of the typical radiological findings (fig. 1). The periosteal reaction is onion peel in most of the cases (fig. 2). However, spiculated, sunburst and Codman's triangles of periosteal reaction may be seen. Moth eaten or gross lytic areas may be noted. The soft tissue swelling is pronounced when it occurs in the flat bones such as scapula, ileum etc. The sclerosis may be prominent and when it occurs in the vertebral body it is called ivory vertebra (fig. 3). These are listed in table VI

Radiological features – Table VI

- Common in long bones – diaphysis
- Permeative destructive lytic pattern in medulla
- Wide zone of transition
- Saucerization of cortex
- Lamellar type of periosteal reaction
- Onion peel appearance
- Flat bones permeative destruction with large soft tissue swelling
- Ivory vertebra
- Vertebra plana

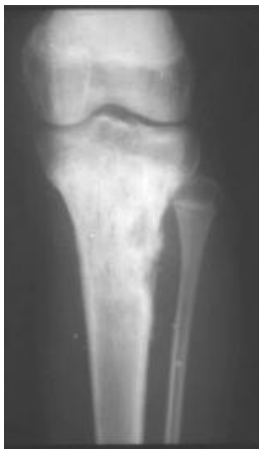


Fig 1: Ewing's sarcoma of diametaphysis of tibia with sclerosis simulating osteosarcoma. However, the saucerization of the cortex is typical of Ewing's sarcoma.

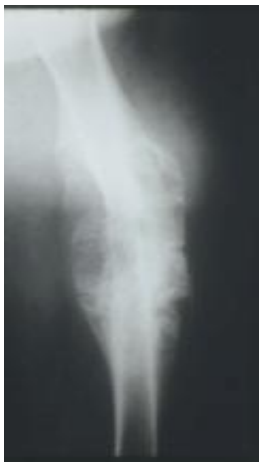


Fig. 2: Ewing's sarcoma of femoral shaft in a 10 yr old boy. Note the Codman's triangles and periosteal reaction.

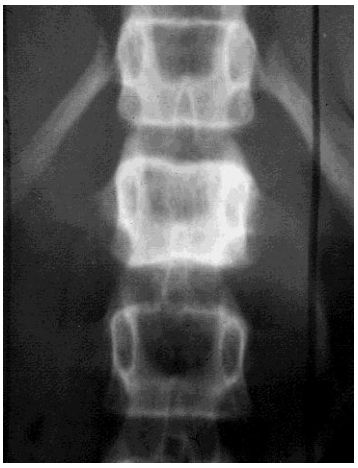


Fig. 3: Ewing's sarcoma of L1 – Ivory vertebra

Plain films are helpful in noting the types of periosteal reaction in the long bones. However, in flat and short bones periosteal reaction is not appreciable. Soft tissue swelling is large and is better identified on MRI and CT (fig. 4). Necrotic areas are also well seen in the advanced imaging techniques.

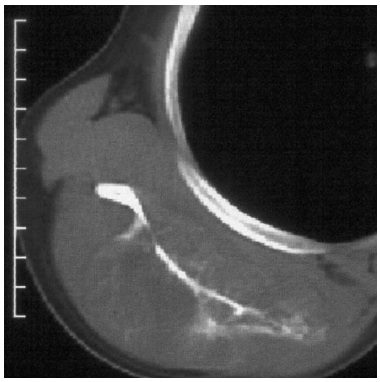


Fig. 4: Ewing's sarcoma CT. Note the soft tissue swelling and spiculated periosteal reaction.

Metastasis from Ewing's sarcoma often occurs in the bones and lungs. There is a group of Ewing sarcoma family of tumors which includes Askin tumor, PNET (Primitive Neuroectodermal Tumor, soft tissue Ewing's sarcoma etc.)

Osteosarcoma - Several varieties

Several varieties of osteosarcoma exist. Osteogenic sarcoma radiologically is metaphyseal in origin with multiple lucent areas, cortical brake and spiculated periosteal reaction. A large soft tissue mass is associated. Codman's triangle is often present. Extensive pluffy type of new bone formation is noted. Purely osteolytic type of osteosarcomas are also seen, one of which is telangiectatic osteosarcoma. It is encountered in the second and third decades. This is often very aggressive with multiple lytic areas and minimal new bone formation. Table VII consists of these lesions with osteoid matrix

Osteosarcoma - Osteoid Matrix – Table VII

- Conventional
- Telangiectatic
- Chondroblastic
- Paraosteal
- Periosteal
- Multicentric

Classic osteosarcoma generally occurs in late 1st and 2nd decades. Male predominance is

noted. It is metaphyseal and rarely extends to the epiphysis. There is diffuse new bone formation with areas of lysis. The periosteal reaction is spiculated sunburst or Codman's triangles. It is important to identify osteoid matrix which is cloudy and cumuls (fig. 5ab & 6). Type of osteosarcoma are listed in table VIII

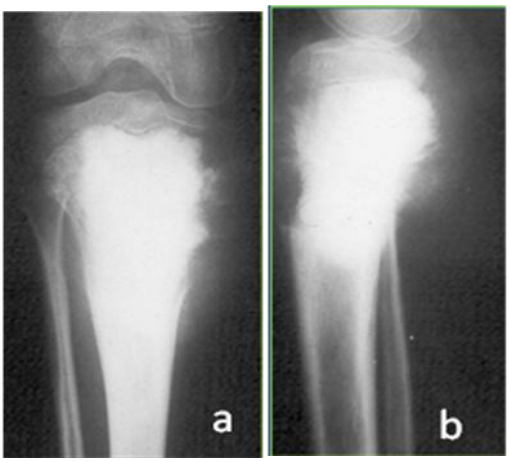


fig. 5ab: Sclerosing type of osteosarcoma in the metaphysis of the tibia. Note the cloud like ossifications and periosteal reaction.

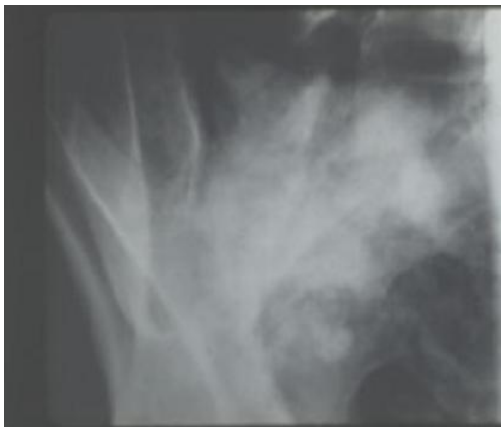


Fig. 6: Osteosarcoma of the sacrum with cloud like matrix

Osteosarcoma - Table VIII

- **Intramedullary**
  - **High grade**
  - **Telangiectatic**
  - **Low grade**
  - **Small cell**
  - **Osteosarcomatosis**
  - **Gnathic**
- **Surface**
  - **Intracortical**
  - **Paraosteal**
  - **Periosteal**
  - **High grade surface**

High grade

It is very aggressive with areas of new bone formation and necrosis. Pathological fractures do occur (fig. 7).

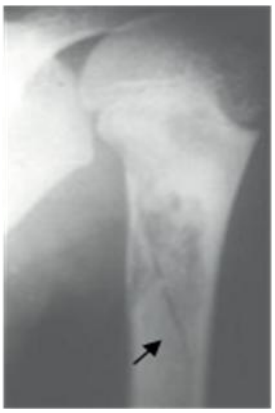


Fig. 7: Lytic type of osteosarcoma with a pathological fracture

Telangiectatic

This is mostly lytic and not much of new bone or periosteal reaction (fig. 8ab). Occasionally, fluid – fluid levels are seen on MRI.

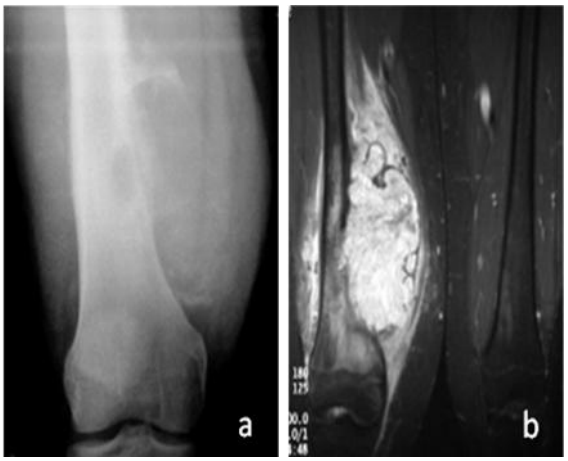


Fig. 8ab: Telangiectatic osteosarcoma lower end of femur.

Low grade
Simulates osteoma or osteoblastoma

Small cell
No definite imaging characters are noted.

Osteosarcoma metastasizes to bones and lungs. MRI reveals the skipped metastasis. Radionuclide scan identifies all the osteoid producing lesions.

Osteosarcomatosis
There are two verities. One in children and another in adolescence, they are multiple, dense sclerotic areas in the metaphysis as well as in the epiphysis. Sometimes it is mistaken for metastasis from osteosarcoma.

Gnathic
Osteosarcoma of the mandible is a specific entity. It occurs in 3rd or 4th decade. A mixture of sclerotic and lytic areas are noted. Prognosis is better.

Surface osteosarcoma – Intracortical

These occur in the diametaphyses of young adults. Multiple layers of periosteal reaction may be noted which are circumscribed (fig. 9ab). No other radiological findings are noted.

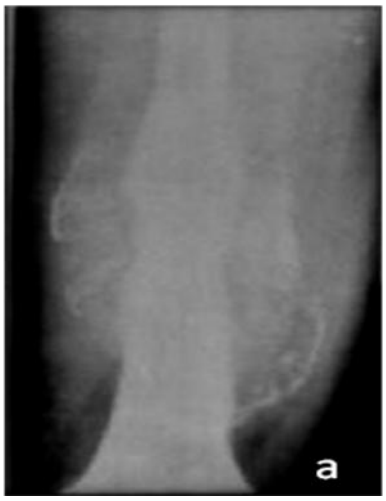


Fig. 9a: Surface osteosarcoma. Note the periosteal reaction & saucerization

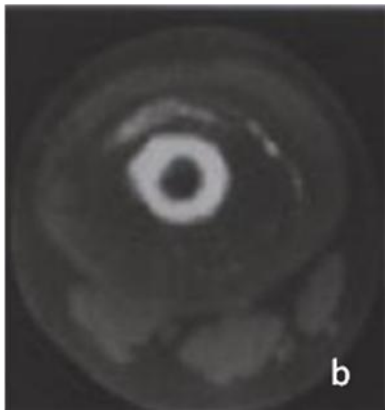


Fig. 9b: Surface osteosarcoma. Note the circumscribed periosteal new bone.

Paraosteal osteosarcoma

The age is generally at 3rd and 4th decades. There is a long history of pain and swelling. Radiologically a lump of bone occurs in the juxta cortical plane. The peripheral border is lobulated. In some cases it is separated from the host bone by a translucent line. In advanced cases the cortex may be invaded and extend into the medulla. CT is best to identify the involvement of the cortex and medulla. The degree of malignancy is lower than that of classical osteosarcoma (fig. 10 &11).

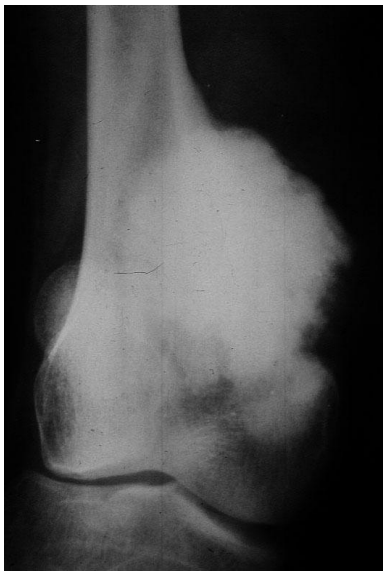


Fig. 10: Paraosteal osteosarcoma arising from the lower end of femur

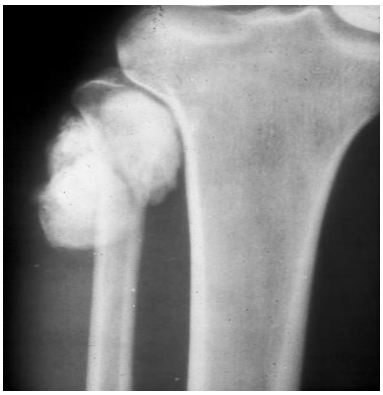


Fig. 11: Paraosteal osteosarcoma surrounding the fibula.

Periosteal osteosarcoma

This occurs 2nd and 3rd decades. Long bones of the lower extremities are involved. Initially the cortex is involved with marginal osseous spiculations. Most lesions are diaphyseal and linear periosteal may be seen. In the soft tissues calcified cartilage may be noted, which may lead to a mistaken diagnostic of chondrosarcoma radiologically (fig. 12abcd).

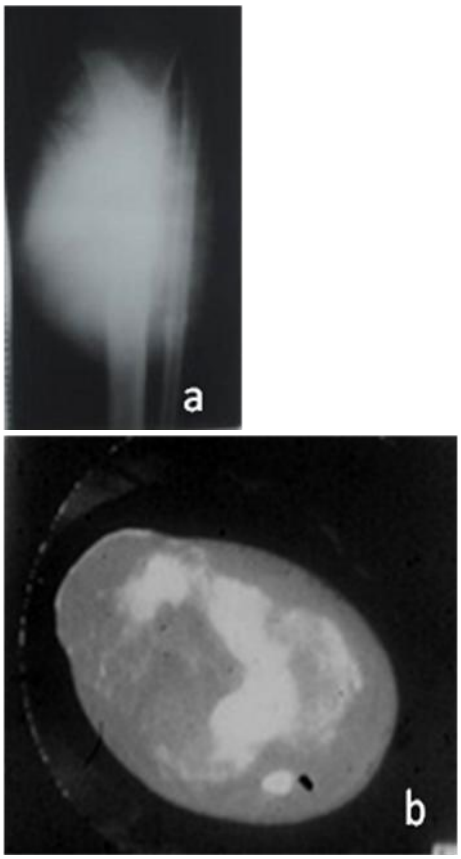


Fig. 12ab: Periosteal osteosarcoma of diaphysis of tibia. CT shows the extent of the tumor.

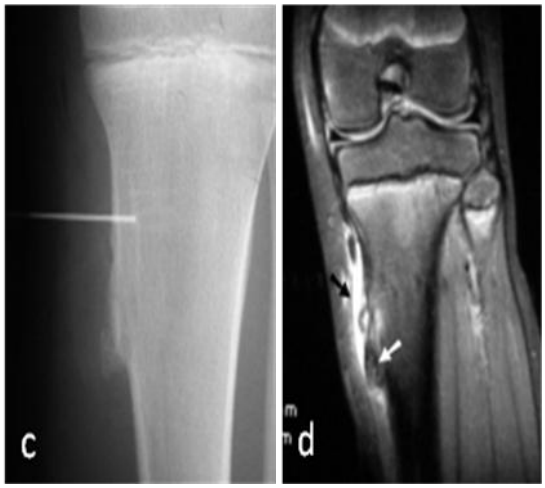


Fig. 12cd: Perioseal osteosarcoma- c. Plain film, d. MRI

Multicentric osteosarcomatosis

These are often encountered in children with multiple dense lesions in most of the bones. This has to be differentiated from osteoblastic metastasis from osteogenic sarcoma (fig. 13ab)

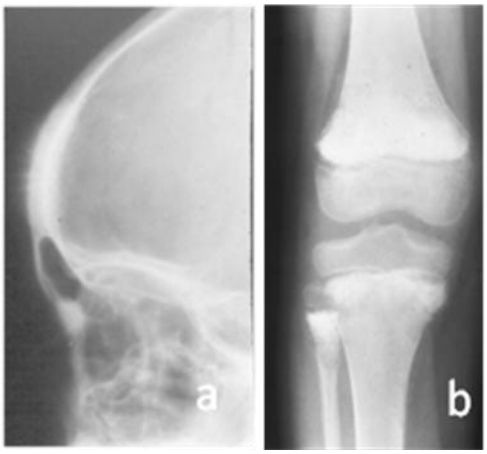


Fig. 13ab: Multicentric osteosarcomatosis in a 5 yr old child. Note the dense lesions around the knee and skull.

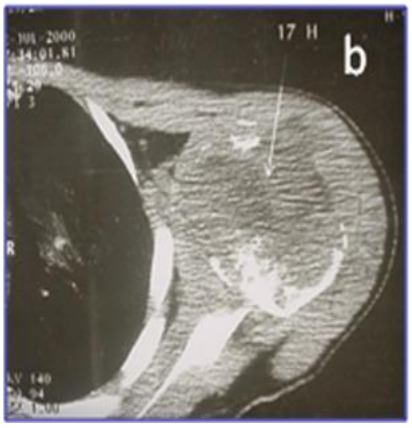


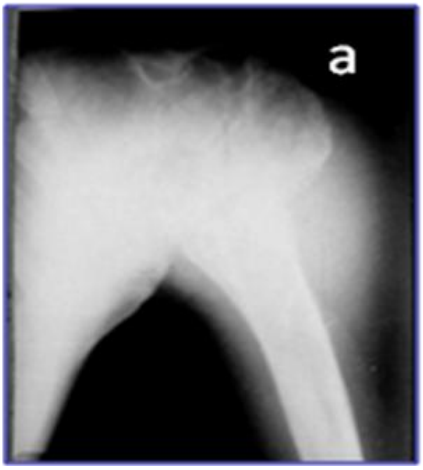
Fig. 14ab: Post radiation osteosarcoma- a. Plain radiography & b. CT.

Most of the lesions are osteolytic. However, radiation osteitis may be seen in the adjacent bones

Secondary osteosarcoma can occur in Paget's disease or fibrous dysplasia

Post radiation osteosarcoma

Secondary osteosarcoma may be encountered subsequent to radiation, particularly following treatment of carcinoma of breast (fig. 14ab).



Primary Chondrosarcoma – Several Varieties

It is rarely seen in children, the age range is between 4th and 6th decades. The primary chondrosarcoma arises centrally in the medulla. Radiologically, an osteolytic area with smooth scalloped endosteal erosion is seen (fig. 15). The transitional zone may vary. Fusiform thickening of cortex with a velvety periosteal reaction iss present. Central calcifications indicative of cartilaginous origin are present (fig. 16). In chondrosarcoma of the flat bones such as ileum and scapula, a large soft tissue mass is noted with calcifications. CT helps in identifying the mass and the involvement of soft tissue structures. On MRI T2 weighted images show bright signals with lobulations.

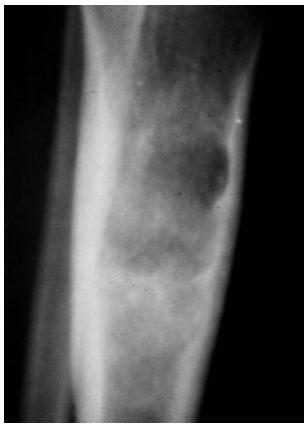


Fig. 15: Chondrosarcoma of the tibia in a 40 yr old man. Note the lytic lesion with endosteal scalloping and thickened cortex.

Juxta cortical chondrosarcoma

It is encountered in 3rd and 4th decades. Radiologically a large soft tissue mass extends outward from the cortex. Calcifications are noted in the matrix.

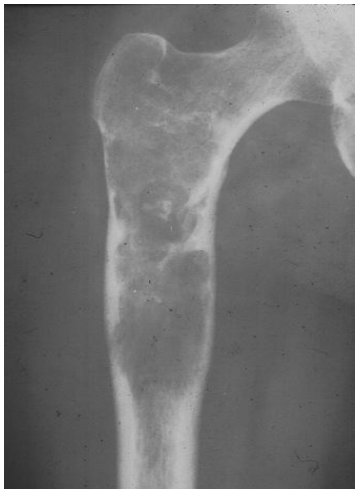


Fig. 16: Chondrosarcoma of the femur with endosteal scalloping and multiple calcifications

De-differentiated Chondrosarcoma

This is encountered in 5th and 6th decades. This generally occurs in long standing chondroid lesion. Pathological fractures may occur. The large soft tissue mass shows the dedifferentiated portion which is of greater malignancy. Depending upon the site of biopsy, it may show low grade chondrosarcoma, fibrous histiocytoma or osteosarcoma.

Clear cell chondrosarcoma

It may be encountered in 3rd to 7th decades. The sites of predilection include proximal end of femur and humerus. Radiologically, large osteolytic lesion is noted with a narrow zone of transition. This may extend to epiphysis. Calcification is rare (fig. 17a).

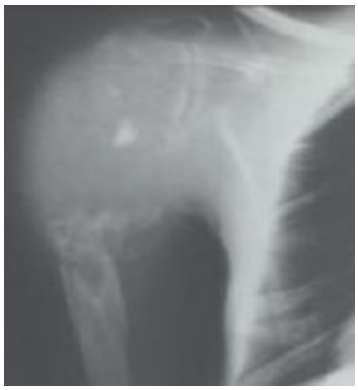


Fig. 17a: Clear Cell chondrosarcoma in the proximal end of humerus extending into the epiphysis.

Mesenchymal chondrosarcoma

It is encountered in 2nd and 3rd decades (60%). Facial bones, ribs and long tubular bones may be affected. Approximately 1/3rd of the cases originate in soft tissues. Radiologically, most of the cases show calcifications both in the bone and in the soft tissues (fig. 17b).

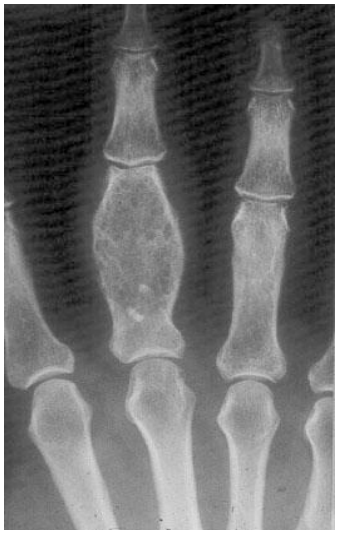


Fig. 17b: Mesenchymal chondrosarcoma in a 32 yr old involving the proximal phalanx of middle finger.

Secondary chondrosarcoma occurs in 1% of enchondromas, 10-15% of hereditary multiple exostoses and 25-30% of Maffucci syndrome (fig. 18). CT often helps in depicting soft tissue involvement (fig. 19)

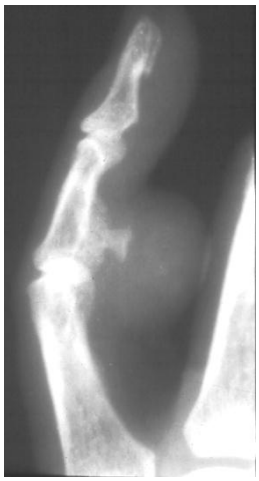


Fig. 18: Chodnrosarcoma in exostosis of middle phalanx of index finger

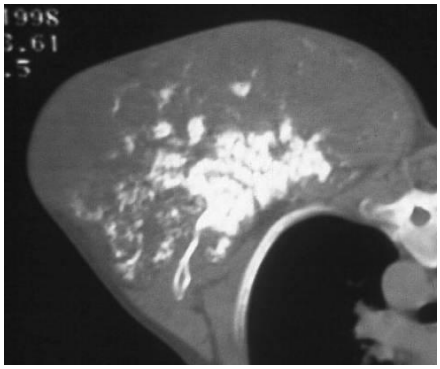


Fig. 19: Secondary chondrosarcoma arising from exostosis of the scapula. Note the scattered calcifications.

On occasion, difficulty arises to note the changes occurring in the transformation of a benign lesion into malignant lesion. The thickness of the cartilage, when it is more than 3cms, malignancy must be considered. Another criterion is the more the scatter of the calcifications the more possibility of malignancy. The third criterion is disappearance of previously noted calcifications.

Extra osseous Chondrosarcoma

It occurs in 3rd to 6th decades. Cricoid cartilage, thyroid cartilage and other soft tissues are targets. A large mass with calcification gives a clue.

Lymphoma – Leukemia

Two major categories are noted. 1. Hodgkin's lymphoma and 2. Non Hodgkin's lymphoma.

Hodgkin's lymphoma

It is encountered in 3rd and 4th decades. It is more common in males. Four histological sub types are noted. Radiologically, osteolytic lesions occurs in 2/3rd of cases. Mixed and sclerotic lesions in 30% and purely sclerotic lesions 5-10%.

Non-Hodgkin's lymphoma

It is almost the same age group of Hodgkin's lymphoma and it is more common than the Hodgkin's. Lytic and mixed lesions are more common. Minor periosteal reactions may be noted (fig. 20).

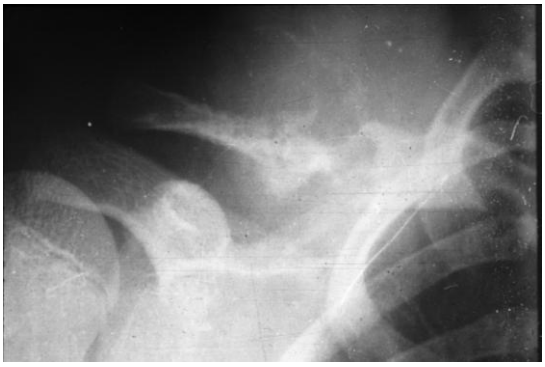


Fig. 20: 12 yr old boy – Histiocytic lymphoma. Mixed lesion of clavicle with pathological fracture

Leukemia

It is common in childhood. In the first two decades diffuse osteoporosis is noted in the vertebrae with compression fractures. In the long bones horizontal radiolucent bands

occur in the metaphysis. Multiple small lucencies and moth eaten pattern may be seen with mild periosteal reactions.

In adults it is usually chronic. Generalized osteopenia is noted. In chronic myelogenous and lymphatic leukemias the radiological findings are purely defined. Osteolytic area with mottling is noted particularly in the spine (fig. 21).

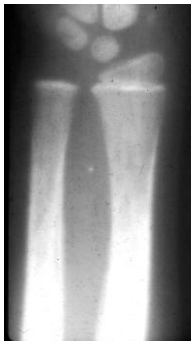


Fig. 21: 6 yr old boy with acute lymphatic leukemia. Note the moth eaten appearance

Fibrosarcoma

It generally occurs in 3rd to 4th decades. Most of the lessions occur in the lower limbs. Diametaphysis is the common site. Radiologically a lytic moth eaten area is noted in the medullary cavity with wide zone of transition. No calcification or new bone is present. Minor periosteal reaction may be seen.

Malignant fibrous histiocytoma is a histological diagnosis and may develop secondary to bone infarct, Paget's disease or post radiation area. Radiologically, a well defined lytic area with cortical destruction is noted. Occasionally, soft tissue calcification may be seen. Very little periosteal reaction is observed (fig. 22ab).

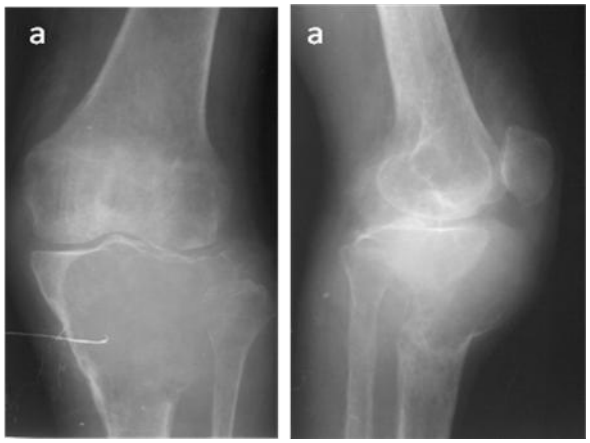


Fig. 22a: Malignant fibrous histiocytoma in the proximal tibia. Large osteolytic lesion extending to the articular margin simulating Giant Cell Tumor

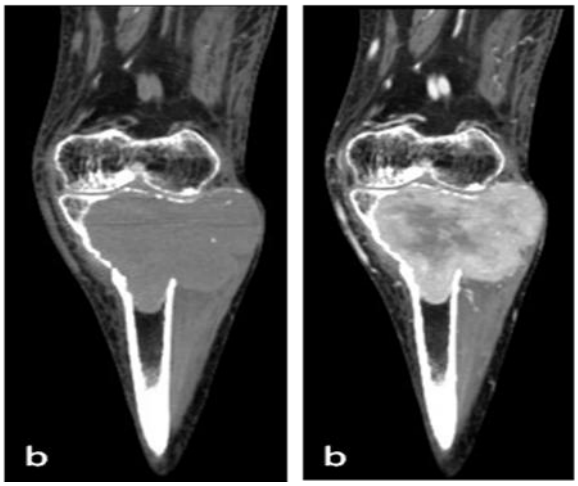


Fig.22b: Malignant fibrous histocytoma in 62 yr old. MRI shows the soft tissue component

Plasmacytoma - Multiple Myeloma

This is encountered around 50 years of age. It a solitary focus of myeloma. An expanding lytic lesion with wide zone of transitions and a soft tissue mass are characteristic. Spinal lesions are associated with large soft tissue masses. CT and MRI are of help. It often simulates solitary metastasis from carcinoma of the lung, breast and kidney. The patient may present with a pathological fracture (fig. 23, 24ab and 25).

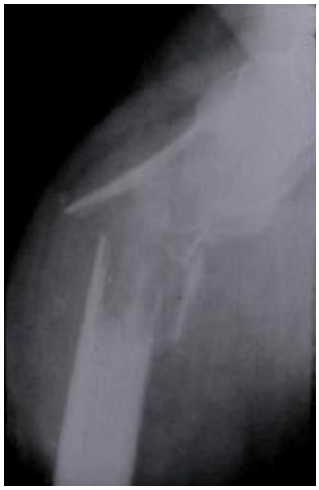


Fig.23: Plasmacytoma of femur with a pathological fracture

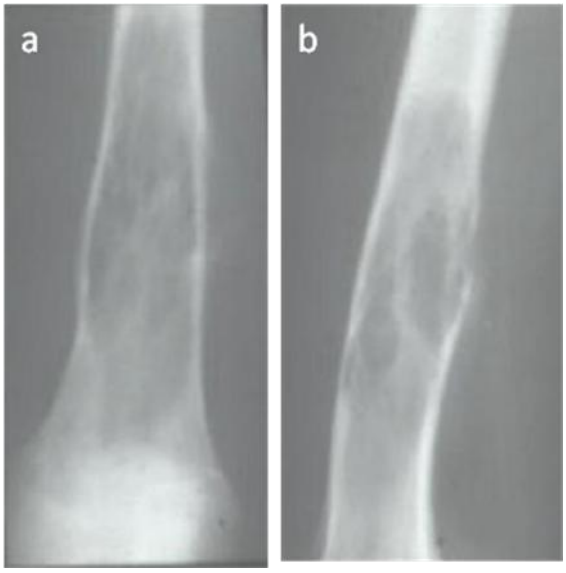


Fig. 24ab: Plasmacytoma of lower end of femur in a 60 yr old

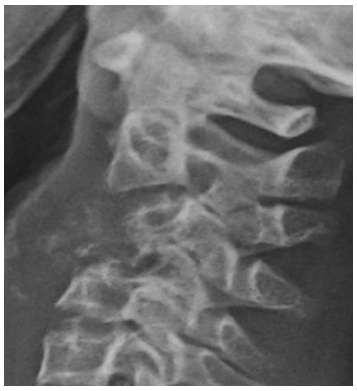


Fig.25 : Plasmacytoma of C3 body with lysis and soft tissue swelling

Multiple myeloma

There are about eight radiological patterns described in the literature. Multiple punched out lesions in the skull are seen only in 30% of the cases. However, it may be only the radiological finding. Generalized osteopenia with compression of the fracture of the spine are noted. Permeative mottled pattern of lysis is another finding. Some of the lesions may be expanded and some may be small lytic areas. Bence Jones proteins in the urine are noted in about 60% of the cases (fig. 26 & 27).

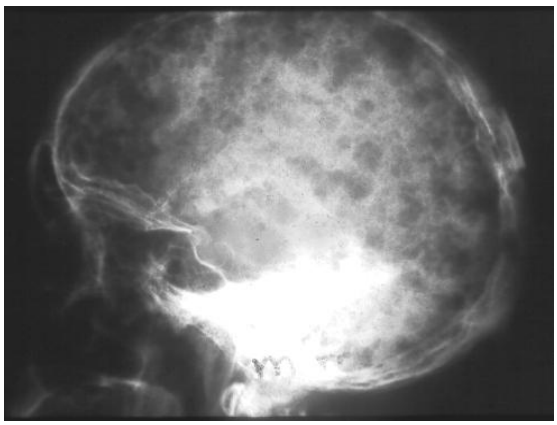


Fig.26: Multiple myeloma. Note the several lytic lesions in the skull

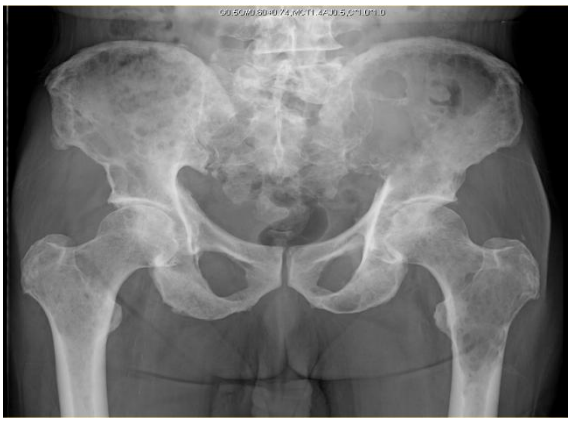


Fig. 27: Multiple myeloma with several osteolytic lesions simulating metastasis

Poems syndrome

This mnemonic represents 'P' for peripheral neuropathy, 'O' for organomegaly, 'E' for endocrinal changes such as diabetes, 'M' for myeloma spike and 'S' for soft tissues changes.

Radiologically, the bone lesions are osteosclerotic. However, in rare cases osteolytic lesions may also be noted (fig. 28).

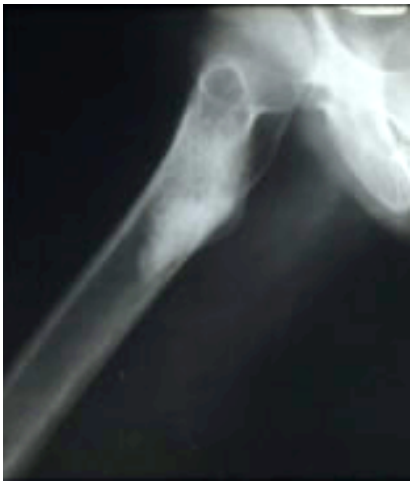


Fig. 28: Poems syndrome – Sclerotic lesion in femur

Giant cell tumors may be malignant de novo are a benign tumor may become malignant. However, benign giant cell tumors may also produce pulmonary metastasis (fig. 29).

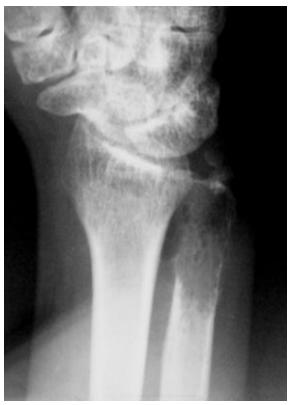


Fig.29: Malignant GCT of lower end of ulna Histological proof

Bone Metastases

These can be osteolytic, osteosclerotic or a combination of these. The common primaries producing metastasis include carcinoma of the lung, thyroid, breast in females. In males prostate is the most primary site in producing sclerotic metastasis. Mucous secreting adenocarcinoma may produce calcifying or ossifying metastasis. Any soft tissue sarcoma also may produce lytic metastasis.

Gastrointestinal and lower urinary tract lesions produce both lytic and sclerotic metastasis (fig. 30ab). Carcinoids may produce sclerotic metastasis. Sclerotic lesions are listed in table IX.

Osteosclerotic – Table IX

- Irregular islands of sclerosis
- Axial and peripheral skeleton.
- Primaries include prostate in males and breast in women
- Carcinoid tumors

Mixed type of metastasis may occur in any malignancy from a primary in any organ of the body.

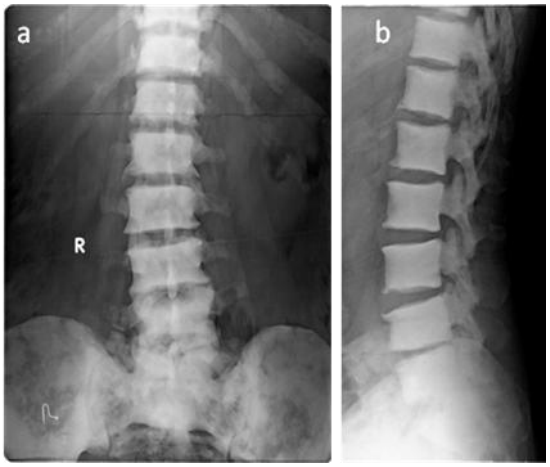


Fig.30ab: Diffuse sclerotic metastasis from carcinoma of the prostate

For the final diagnosis, evidence should be based on histological characteristics Table X

BONE TUMOURS - Pathological Diagnosis – Table X

- FNAC +56%
- Excision Biopsy
- Special stains
- Immunohisto Chemisty
- Electron Microscopy
- Cytogenetics
- Flow cytometry

Conclusion

To sum up primary malignant bone tumors are rare and can be diagnosed by plain films most of the time. However, CT & MRI would help in further analyzing and malignancy. Finally, histopathology would be the answer. Secondary malignant bone tumors are common and the primary site should be investigated. Rarely, the primary may be unknown.

Further Reading

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