CHAPTER 43

RADIOGRAPHIC EVALUATION OF BONE TUMORS

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The plain film radiograph is commonly the first objective evidence to suggest a bone tumor. However, a definitive diagnosis is rarely made with a plain radiograph alone, and must be correlated with clinical data and the results of pathologic examination of the specimen.

Radiographs of the area in question will assist the pathologist in making the diagnosis. Errors in biopsy technique, bone infection, fracture callus formation, and poorly differentiated lesions may complicate making the correct diagnosis. Proper evaluation of the x-ray is the first step toward diagnosis, and a systematic approach is suggested to evaluate the bone lesion.

The basic method of evaluating a bone tumor on x-ray is to describe the morphological characteristics, assess the aggressiveness of the lesion, and combine this data with clinical information in order to form a differential diagnosis. Important clinical information to obtain includes the patient's age, chief concern, symptoms, and medical history. The single most helpful portion of the history, in narrowing the differential diagnosis, is the age of the patient. Certain bone tumors tend to appear in specific age ranges of patients (Table 1).

Table 1

PATIENT AGE RANGES FOR DIFFERENTIAL DIAGNOSIS OF BONE TUMORS

First and Second Decade

Benign	Malignant
Aneurysmal Bone Cyst	Adamantinoma
Chondroblastoma	Ewing's Sarcoma
Desmopolastic Fibroma	Osteosarcoma
Enchondroma	
Giant Cell Tumor	
Neurilemmoma	
Osteoblastoma	
Osteoid Osteoma	
Osteochondroma	
Osteoma	
Simple Bone Cyst	

Third through Fifth Decade

Benign	Malignant
Aneurysmal Bone Cyst	Adamantinoma
Chondroblastoma	Chondrosarcoma
Chondromyxoid Fibroma	Ewing's Sarcoma
Desmoplastic Fibroma	Fibrosarcoma
Giant Cell Tumor	
Hemangioma	
Lipoma	
Neurilemmoma	
Non-ossifying Fibroma	
Osteoblastoma	
Osteoma	
Osteoid Osteoma	
Osteochondroma	
Simple Bone Cyst	

Greater than Sixth Decade

Benign	Malignant
Lipoma	Chondrosarcoma

RADIOGRAPHIC CATEGORIES

Lodwick developed a computer-assisted approach to formulate a differential diagnosis for the evaluation of bone tumors. He described four categories of information to be obtained from the plain radiograph: type of bone destruction, proliferation of bone, mineralization of tumor matrix, and location including dimensions of the tumor. Each category helps to define the morphologic characteristics of the bone tumor in order to formulate a reasonable differential diagnosis.

Destruction of Bone

There are three types of bone destruction that may be present in bone tumors: geographic, moth-eaten, and permeative. A geographic pattern of bone destruction is characterized by complete destruction of bone to the boundary between tumor and normal bone. There is a well-defined focal margin with a sharp transition zone between the lesion and normal bone. Geographic bone

destruction is most often associated with benign tumors. The differential diagnosis should include lipoma, osteoblastoma, osteoid osteoma, chondroma, osteoma, fibrosarcoma, giant cell tumor, and osteomyelitis (Table 2).

Table 2

PATTERNS OF BONE DESTRUCTION

Geographic
- Chondroma
- Osteoma
- Fibrosarcoma
- Lipoma
- Osteoid Osteoma
- Osteoblastoma

Moth-Eaten
- Chondrosarcoma
- Ewing's Sarcoma
- Fibrosarcoma
- Osteosarcoma

Permeative
- Chondrosarcoma
- Fibrosarcoma
- Ewing's Sarcoma

The moth-eaten pattern of bone destruction is more aggressive than that seen in the geographic variety. It is characterized by multiple, small, confluent holes involving the outer cortex and inner structure. There is a large transition zone between the lesion and normal appearing bone with a poorly-defined margin. Unfortunately, lesions demonstrating this type of bone destruction are often rapidly-growing, malignant bone tumors. The differential diagnosis of a lesion demonstrating this pattern of bone destruction must include fibrosarcoma, chondrosarcoma, osteosarcoma, Ewing's sarcoma, but also osteomyelitis.

A permeative pattern of bone destruction is characterized by many tiny holes throughout the cortex of the bone overlying the lesion. The transition zone is faint and often indistinguishable. The margins of the lesion tend to blend with the surrounding normal bone. Complete discontinuity in the cortex may result in a secondary pathologic fracture. This complication may also occur as a result of moth-eaten patterns of destruction. This type of bone destruction is usually associated with very aggressive and rapidly growing malignant lesions. The differential diagnosis includes Ewing's sarcoma, fibrosarcoma, chondrosarcoma, and osteomyelitis.

Combinations of the above patterns can exist, and a particular pattern may be distinguished by location within the bone. Geographic destruction is primarily located centrally, while moth-eaten and permeative types of destruction are located peripherally.

Proliferation of Bone

Proliferative changes usually take one of two forms: changes which reflect encapsulation, such as an expanded cortical shell with a sclerotic rim, or changes demonstrating a disseminated tumor without effective encapsulation, such as mottled proliferation. Both forms of proliferation are associated with periosteal and endosteal responses. Trabeculation of the tumor may also occur.

Periosteal proliferation occurs as the addition of layers of new bone are added to the exterior, creating an expanded osseous contour. The ultimate thickness of the surrounding cortical bone is dependent upon the extent of endosteal erosion and the degree of periosteal proliferation. Five types of periosteal responses have been described: buttressing, onion-skinning, Codman's triangle, sunburst, and hair-on-end appearance.

Periosteal buttressing occurs when the interface between normal and expanded cortex is "filled in" with bone. Bony proliferation merges with the underlying cortex producing an appearance of dense cortex. An onion-skin pattern is characterized by multiple layers of new bone formation. These multiple concentric layers of periosteal bone create a lamellated, or "onion peel" appearance, and may be associated with a more rapidly growing tumor. Codman's triangle is a triangular elevation of periosteum at the periphery of a bone tumor. This type of periosteal reaction may be seen with an aggressive lesion, as well as osteomyelitis.

These patterns appear as delicate rays of periosteal bone formation, separated by blood vessel-containing spaces. When the rays extend away from the bone in a radiating pattern from a single focus, it is described as a sunburst pattern. When the rays extend perpendicular to the underlying bone, a hair-on-end periosteal pattern is described. Sun-burst and hair-on-end periosteal reactions are associated with aggressive tumors such as Ewing's Sarcoma and osteosarcoma.

Trabeculation represents new bone formation as a secondary response to a nearby neoplasm. Such proliferation is frequently located at the interface between the endosteal and periosteal envelope. Descriptors of trabeculated lesions include thin, thick, delicate, coarse, loculated, striated, and radiating. Examples of tumors with trabeculated lesions include giant cell tumor, chondromyxoid fibroma, non-ossifying fibroma, aneurysmal bone cyst, and hemangioma.

Mineralization of Tumor Matrix

Visible tumor matrix is associated with neoplastic bone, but must be differentiated from calcifications that may develop in regions of necrotic or degenerative tissue, callus formation, or as a sclerotic response to non-neoplastic bone. Calcified tumor matrix is suggestive of cartilaginous tumors and may include chondromas, chondroblastomas, chondrosarcomas, and chondromyxoid fibromas. The matrix is usually centrally located, with concentric, flocculent, or random fleck-like radiodense areas.

Osseous tumors which may demonstrate a visible matrix include osteosarcoma, parosteal osteogenic sarcoma, ossifying fibroma, osteoma, and osteoblastoma. The matrix is variable in size, and in comparison to cartilaginous tumor matrix, demonstrates increased density, larger distribution, and a homogeneous consistency.

Lodwick states that a mature bone-forming tumor, such as a low-grade osteosarcoma or parosteal sarcoma, will show radiographic patterns of large, uniform densities with regular, sharply-defined edges. Less mature osseous lesions may demonstrate lumps, clouds, or scattered wisps of calcific density on the radiograph.

Location, Size and Shape

The location of certain tumors is often very specific and may provide important clues for correct diagnosis. It is important to consider that lesions present in the transition zone between one anatomic area and another are more difficult to diagnose based on anatomic location.

The location of a lesion may be described in two planes: transverse and longitudinal. Transverse plane position is determined based on the tumor's center, and can be described as central, eccentric, cortical, or parosteal. Examples of lesions located centrally within the medullary canal are enchondromas, solitary bone cysts, and chondroblastomas. Eccentrically-located lesions are positioned to one side of the central axis, usually appear in the medullary canal, and include giant cell tumors, osteosarcomas, chondrosarcomas, fibrosarcomas, chondroblastomas, and chondromyxoid fibromas. Cortically-located lesions are also found to one side of the central axis, but are primarily within the cortex. This location is typical for a non-ossifying fibroma or osteoid osteoma. When a lesion appears on the outer surface of the cortex, it is considered parosteal or juxtacortical, i.e., osteochondroma, parosteal osteogenic sarcoma, and juxtacortical chondroma.

Location within the epiphysis, metaphysis, or diaphysis determines the longitudinal position. Epiphyseal lesions include chondroblastoma, osteoma, intraosseous ganglion, osteoblastoma, and osteoid osteoma. Metaphyseal lesions include chondromyxoid fibromas, desmoplastic fibroma, osteoma, Ewing's sarcoma, giant cell tumor, lipoma, malignant fibrous histiocytoma, non-ossifying fibroma, osteoblastoma, osteochondroma, osteoid osteoma, chondromasarcomas, fibrosarcomas, osteosarcomas, and simple bone cyst. Diaphyseal lesions include adamantinoma, aneurysmal bone cyst, desmoplastic fibroma, enchondroma, fibrous dysplasia, non-ossifying fibroma, osteoblastoma, osteoid osteoma, Ewing's sarcoma, and simple bone cyst.

In general, primary malignant bone tumors measure greater than six centimeters and are larger than benign tumors when first identified. Elongated lesions with a diameter 1.5 times greater than another dimension of the lesion may also be indicative of malignancy.

It is important to appreciate that the possible malignant potential of a lesion is difficult to ascertain from a plain-film radiograph alone. Rather, a lesion is most accurately described as appearing to be aggressive or non-aggressive.

CONCLUSION

When a bone lesion is observed on a plain-film radiograph, the clinician should use a systematic approach of evaluation. This approach includes evaluation of morphological characteristics, including bone destruction, bone proliferation, tumor matrix mineralization, and location of the lesion. This information must be correlated with clinical data to determine the aggressiveness of the lesion, as well as a differential diagnosis.

BIBLIOGRAPHY

Lodwick GS: A probalistic approach to the diagnosis of bone tumors. *Radiol Clin North Am* 3:487, 1965.

Mankin HJ: Advances in diagnosis and treatment of bone tumors. *Medical Intelligence* 300:543, 1979.

Posteraro RH: Radiographic evaluation of pedal osseous tumors. *Clin Podiatr Med Surg* 10:633, 1993.

Resnick D, Niwayama G: Tumors and tumor-like lesions of bone. In Resnick D, Niwayama G (eds): *Diagnosis of Bone and Joint* Disorders, Vol. 3, Philadelphia, W. B. Saunders, 1981.

Schajowicz F: Current trends in the diagnosis and treatment of malignant bone tumors. *Clin Orthop* 180:220, 1983.

Watt I: Radiology in the diagnosis and management of bone tumors. *J Bone Joint Surg (Br)* 67(B):520, 1985.