



# Common Primary Tumors of Bone

Primary bone tumors are a relatively rare occurrence, however, they can have serious deleterious consequences. Many possess the ability to degenerate into malignant metastatic cancers. A systemic approach to radiographic analysis can facilitate an early diagnosis, and ensure timely treatment.

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**P**Primary bone tumors are a relatively rare neoplasm, however, they are a source of significant patient morbidity. Many, in fact, possess the ability to degenerate into malignant metastatic cancers. Early detection, from patient history and radiographic analysis, is of the utmost importance in identifying potential cancerous bone lesions. Using a systematic approach with radiographic analysis, it is possible to identify potential problematic lesions, and reduce patient morbidity.

## Background

Cancer is second only to heart disease and stroke as the leading cause of death in North America. Cancer deaths accounted for over

27% of all deaths in Canada in 1995, with lung cancer by far the most prevalent neoplasm, having both the highest incidence and mortality.<sup>1</sup> In comparison, primary malignant bone tumors are relatively rare, occurring at a rate of about one in 100,000. Secondary malignant bone tumors are 35 times more likely to occur, usually as an end-stage, serious complication of cancer at other body sites.<sup>2,3</sup>

Although relatively uncommon, primary bone tumors are a significant clinical problem, with high rates of patient morbidity and the potential for malignant degeneration. Early detection, as is the case with all neoplasms, is extremely important in determining the eventual course and prognosis. As many tumors are asymptomatic until a seem-



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ingly trivial insult has serious sequelae (*i.e.*, pathologic fracture), however, it is important to be able to find and categorize bone lesions in the early stages of their development. In this article, a systematic approach to locating and categorizing common primary bone tumors will be explored.

### Identification of Bone Tumors: Diagnostic Options

Proper diagnosis of bone tumors requires careful examination of all available sources of information, including patient history, physical examination, plain films and other imaging techniques, such as computed tomography (CT) and magnetic resonance

imaging (MRI). Each imaging option has its own strengths, which must be considered during analysis.

Plain films remain the chief diagnostic tool for the initial assessment of suspected bone lesions,<sup>4</sup> as they provide the most crucial and reliable information regarding the nature, progression, location and aggressiveness of potential bone lesions. CT scans are useful for analysis of the spine and other regions of anatomical complexity, while MRI is useful for demonstrating abnormalities of bone marrow, and to illustrate soft-tissue reactions to cancerous growths.<sup>4,5</sup> MRI is limited, however, in that it cannot show calcification, ossification, cortical destruction or periosteal reactions—changes best viewed using plain films.<sup>4</sup>

Additional diagnostic options such as nucleotide bone scans lack specificity, but are very useful in detecting the early presence of metabolic disease.<sup>4,5</sup> These options include laboratory tests, which, while useful, do not provide definitive information, and, therefore, should be used as an adjunct to imaging analysis. Most benign tumors and many malignant



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tumors, show normal values on the majority of laboratory tests.<sup>4</sup> Some lab tests, however, are useful in specific cancerous processes; for example, serum calcium levels are elevated with advanced bone destruction, as seen in many lytic bone diseases. Serum alkaline phosphatase levels are increased in osteosarcoma, osteoblastic metastasis and other bone proliferating diseases, while multiple myeloma shows characteristic changes with serum electrophoresis.<sup>3-5</sup>

The most accurate diagnostic tool available to the clinician is the bone biopsy. Biopsy provides histologic evidence, which can provide an accurate diagnosis of the tumor or lesion in question. However, it provides no evidence as to the progression or aggressiveness of the lesion.<sup>3,4</sup> Biopsy, therefore, is best used in conjunction with plain films to provide the most complete diagnosis.

Finally, patient information and characteristics of the lesion, as viewed on plain radiographs, are important in diagnosing bone tumors. Table 1 provides a list of important diagnostic information that can facilitate a presumptive diagnosis. Careful examination of such findings can provide the information necessary to make a rapid, accurate diagnosis; for example, the reaction of the host bone can narrow the field of possible diagnoses significantly. Periosteal and/or endosteal reactions occur in many different bone diseases, but do not necessarily occur in the same manner. A thick, wavy periosteal reac-

Table 1

## SIGNS AND SYMPTOMS OF BONE TUMORS

Patient Information	Age Gender Systemic symptoms Local pain, swelling
Plain film Information	Location Size Soft tissue involvement Bone reaction (periosteal, endosteal) Bone destruction pattern Growth rate/progression Margination Matrix characteristics (luscent, opaque, flocculant) Multiplicity (monoostotic, polyostotic)

tion is characteristic of venous stasis, while a layered, lamellar reaction is found in a mildly aggressive underlying condition, such as osteomyelitis.<sup>3,5</sup> Aggressive cancerous growths also can cause periosteal reactions, which occur when the tumor breaks through the periosteum and advances into the soft tissue, as seen in osteosarcoma. Conversely, the characteristic periosteal reaction seen in Ewing's sarcoma involves cyclical periosteal destruction and regrowth, resulting in the classic "onion-skin" periosteal reaction.<sup>6,7</sup>

## Radiographic Analysis

Proper and efficient analysis of radiographs is key in locating and identifying bone lesions. A systematic approach to analyzing radiographs follows the general "ABCs" pattern: "A" stands for alignment of skeletal structures; "B" stands for analysis of bone density and trabecular pattern; "C" stands for inspection of cartilaginous tissue and joint spaces; and "s" stands for soft-tissue reactions and appearance. When presented with a patient with a possible

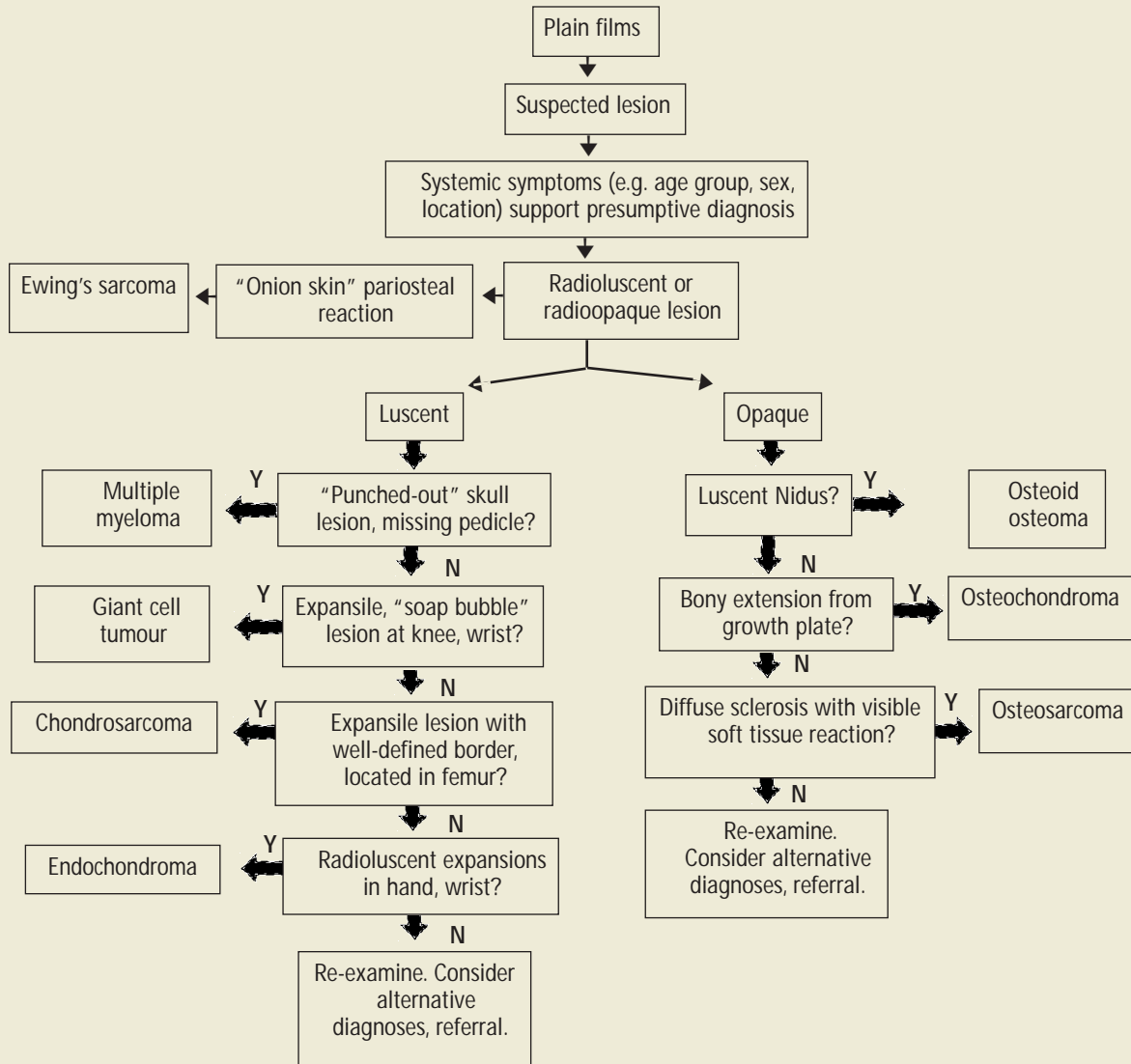


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Figure 1

## RADIOGRAPHIC DIAGNOSIS OF PRIMARY BONE TUMORS

Diagnosis based on radiographic appearance is possible by examining for the characteristic features of each tumor.



bone lesion, all aspects of this search pattern are important, however, the analysis of bone density and trabecular patterns is key in determining the presence of osteolytic and/or osteoblastic lesions. Many cancerous lesions present with distinct radiographic features, and a systematic analysis

can provide a rapid presumptive diagnosis (Figure 1).

Presenting complaints, such as localized pain and soft-tissue swelling, increased skin temperature and decreased range of motion at an affected joint, are key indicators of possible cancerous tumors. These findings alone,



Table 2

## KEY RADIOGRAPHIC FEATURES OF PRIMARY BONE TUMORS

Tumour	Radioluscent/ Radioopaque	Most Common Location(s)	Characteristic Radiographic Feature(s)
<b>Benign</b>			
Osteochondroma	radio-opaque	Distal femur, knee.	Bony stalk capped with cartilage, oriented away from involved joint.
Osteoid osteoma	radio-opaque (luscent nidus)	Femur, tibia.	Luscent nidus surrounded by sclerotic halo ("circle within a circle").
Giant cell tumour	radioluscent, expansive	Knee, radius, humerus.	"Soap bubble appearance" in metaphysis, with some subarticular expansion.
Endochondroma	radioluscent	Tubular bones of the hands.	Luscent expansion with well-defined margins.
<b>Malignant</b>			
Multiple myeloma	radioluscent	Skull, vertebrae (pedicles, bodies)	"Punched-out lesions" of skull, vertebral compression fractures, missing pedicle.
Osteosarcoma (central)	radioopaque (diffuse sclerosis)	Knee, humerus.	Poorly defined border with dense "ivory" regions, soft tissue mass visible on x-ray.
Chondrosarcoma	radioluscent, expansive	Central: femur, humerus. Peripheral: pelvis, shoulder.	Luscent expansive lesion with well-defined border. Associated soft tissue reaction.
Ewing's sarcoma	—	Skeletal long bones.	Periosteal reaction on bone surface gives classic "onion-skin" appearance.

however, are not sufficient to differentiate between tumors and other possible diagnoses, including osteomyelitis, fracture, deep contusion or tumor-like lesion (*i.e.*, fibrous dysplasia, fibrous cortical defect). It is imperative, therefore, that radiographs be obtained and examined. Table 2 provides a synopsis of the major radiographic features of the most common primary bone tumors.

Cancerous bone tumors may present in any bone in the body, however, many common primary tumors are predilected to the appendicular skeleton, especially the knee joint, proximal femur and humerus. Other common locations include the spine, skull, pelvic bones and extremities (especially the metacarpal bones). Lesions may present radi-

ographically as: osteolytic, luscent areas of either epiphyseal, diaphyseal or metaphyseal origin; osteoblastic, sclerotic lesions at these locations; or a combination of luscent and opaque lesions.

## Differential Diagnoses

Primary bone tumors generally present with a specific set of symptoms and radiographic appearances, however, other non-neoplastic diseases of bone also may present with similar symptoms. Table 3 discusses differential diagnoses of the most common primary bone tumors, plus outlines the incidence and likely prognosis for each. Physical examination and



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Table 3

## CHARACTERISTICS OF COMMON PRIMARY BONE TUMORS

Tumour	Malignancy	Age	Sex	Prognosis	Differential Diagnosis
Osteochondroma	benign	<20	M 2:1	Excision of symptomatic lesion is curative.	Parosteal sarcoma, periosteal sarcoma.
Osteoid osteoma	benign	<15	M>F	Complete excision is curative. Can recur if excision incomplete.	Brodie's abscess, stress fracture.
Endochondroma	benign	10-30	M=F	For most, no treatment necessary.	Fibrous dysplasia, unicameral bone cyst, chondroblastoma.
Giant cell tumour	benign	20-40	F 3:2	Curettage associated with a 40 to 60% recurrence rate.	Chondroblastoma, aneurysmal bone cyst, osteochondroma.
	malignant	20-40	M 3:1	Wide resection may be curative, although may compromise the function of the affected limb	
Multiple myeloma	malignant	50-70	M 2:1	Late stage (multiple skeletal lesions) associated with 6-12 month survival. Median survival: 3 years.	Metastatic bone cancer.
Osteosarcoma (Central)	malignant	15-25	M 2:1	Poor as pulmonary metastasis has already occurred when skeletal lesions are found.	Periostitis, osteomyelitis. In older patients: Paget's disease, fibrous dysplasia
Chondrosarcoma	malignant	40-60	M 2:1	Rarely metastasizes, although frequently recurs at initial site.	Osteomyelitis, fibrous dysplasia, metastatic cancer.
Ewing's sarcoma	malignant	10-25	M 2:1	Poor if not detected early. Five year survival rate: 75%.	Osteomyelitis, osteosarcoma.

patient history generally provide the information necessary to provide a differential diagnosis for a certain bone lesion, and are important considerations, as many neoplastic and non-neoplastic bone lesions present with similar radiographic features.

The most common primary bone tumors—those discussed here—are relatively distinct in their radiographic presentation, and are identifiable based on features that are

unique to those tumors. However, the presenting symptoms and signs, such as localized swelling, pain and tenderness, are common for both tumors and infectious diseases, such as osteomyelitis or suppurative tuberculosis.<sup>3,4</sup> Radiographically, several common conditions can mimic the presentation of rare cancerous growths; for example, the radiolucent, well-marginated, distal tibial presentation of Brodie's abscess closely resembles



both the benign conditions of fibrous dysplasia or non-ossifying fibroma, and the more serious chondroblastoma, a benign localization of endochondral ossification.<sup>4,5</sup> Signs and symptoms are also very similar—the key differential factor being the presence of a recent infectious condition in Brodie’s abscess. Similarly, the dense, sclerotic presentation of osteosarcoma can mimic both osteomyelitis and, in older patients, Paget’s disease. Any presumptive diagnosis must include these as differential diagnoses, with the patient history and physical examination providing key information to allow for the elimination of secondary possibilities.

## Common Primary Tumors

There are many different primary bone tumors, most of which are extremely rare and likely not to be encountered in general practice. Several more common tumors, however, may be seen by primary contact physician. The more common tumors include: benign tumors, such as osteochondromas and osteoid osteoma; malignant neoplasms, such as multiple myeloma and osteosarcoma; and the quasi-malignant giant cell tumor, which can present as either benign or malignant. The general characteristics and features of each category are summarized below.

## Common Benign Tumors

Benign tumors are relatively common, and few have either the ability or the tendency toward malignant degeneration. Most benign tumors remain asymptomatic until their presence is indicated by a trivial or accidental

injury. Benign lesions can present as either osteolytic or osteoblastic, however, they are generally well defined with sclerotic margins, which limit their invasiveness or aggressive potential. The most common benign bone tumors include: osteochondroma, a bony stalk-like outgrowth of the epiphyseal growth plate covered by a cartilaginous cap; osteoid osteoma, a dense, sclerotic lesion with a central, lucent nidus; and endochondroma, the most common benign tumor of the hand.

The most common benign skeletal growth is the osteochondroma, which can occur as a single lesion or as multiple lesions.<sup>8</sup> An osteochondroma is an abnormal outgrowth of the epiphyseal growth plate, and occurs during the adolescent growth period, before the growth plate has closed (Figure 2). The majority of patients (75%) are under 20 years of age, with males being affected twice as often as females.<sup>3-5</sup>

Osteochondromas affect the long tubular bones, and are most often found at the knee joint. The lesion is described by patients as a hard, painless mass near

a joint. Osteochondromas present as one of two types: pedunculated, which presents at the hip and knee as a bony stalk covered by a cartilaginous domed cap; or sessile, a broad-based exostosis lacking an elongated portion, which is most common in the metaphyseal/diaphyseal portions of the proximal humerus, femur and scapula.<sup>4</sup> Generally, osteochondromas are asymptomatic, unless they impinge on a surrounding neurovascular structure, or affect local joint

Proper diagnosis of bone tumors requires careful examination of all available sources of information.



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Figure 2. Lateral view radiograph of the knee joint showing an osteochondroma extending in a retrograde direction from the distal femoral region.

function. A fracture through the stalk causes severe pain and localized swelling. A key radiographic finding is that the osteochondroma is oriented almost exclusively away from the involved joint. Solitary osteochondromas do not usually require treatment, while symptomatic ones should be excised. Key differential diagnoses include parosteal sarcoma and periosteal chondrosarcoma, which are similar in that each has a cleavage plane between the normal bone and neoplasm, however, a pedunculated osteochondroma is continuous with the host bone.<sup>5,9</sup>

Osteoid osteoma (or osteoblastoma) is the second most common benign bone tumor, affecting mainly adolescent males (< 15 years). Osteoid osteoma is found most often in the femur and tibia, but also can affect the posterior elements of the vertebral body and, in rarer cases, in the ribs, clavicle and humerus.<sup>3,4</sup> The presentation of osteoid osteoma is key in quickly identifying the

presence of this lesion. Patients present with severe, deep, aching pain, which is worse at night, is not relieved by rest, but is relieved dramatically by acetylsalicylic acid (ASA). Vasomotor responses cause profuse sweating and increased skin temperature at the site, with localized swelling, point tenderness and decreased range of motion. Radiographic analysis shows a sclerotic, expanding lesion with a characteristic lucent nidus. Initially, the central nidus is filled with blood vessels and nerve tissue, and is uncalcified, but may develop a central portion of calcification upon maturation.<sup>3</sup> A calcified nidus is not usually visible on plain films, but is visible using other imaging techniques, such as CT scans (Figure 3). Excision is usually curative, however, this lesion is predisposed to recur if excision is incomplete.

The most common benign tumor of the hand is the enchondroma, which can exist as one isolated lesion, or as many lesions, characteristic of Ollier's disease.<sup>10</sup> Enchondromas affect children and young adults, mainly in the second and third decade. The small tubular bones of the hand and the phalanges are the preferential location for 90% of all enchondromas. They present as painless tumors and are present for some time before a trivial injury results in pathologic fracture. On radiographic analysis, enchondromas appear as radioluscent expansions of the metaphysis, with well-defined margins of cortical bone.<sup>4</sup> Malignant degeneration is rare, however, the closer the tumor is to the axial skeleton, the greater the chance for degeneration.<sup>3-5</sup>

Multiple enchondromas may exist as part of Ollier's disease, an inborn anomaly of endochondral bone formation that results in multiple lucent lesions, predominantly in



the tubular bones of the hand and the iliac crest.<sup>10</sup> As with single endochondromas, the condition is asymptomatic until trivial injury results in pathologic fracture.

## Common Malignant Tumors

Malignant primary bone tumors appear on plain films as either sclerotic or lytic lesions, however, they have the common feature of an aggressive border, lacking a well-defined sclerotic margin. The most commonly diagnosed malignant primary bone tumors include: multiple myeloma, a proliferation of plasma cells that has serious deleterious effects on bone and the bone microenvironment; osteosarcoma (osteogenic sarcoma), the most common malignant tumor in children; chondrosarcomas, a group of tumors noted for their production of neoplastic cartilage;<sup>11</sup> and Ewing's sarcoma, a common tumor in children, characterized by a periosteal reaction distinct on radiographic analysis.

Multiple myeloma is a serious neoplasm of plasma cell proliferation, which originates in the bone marrow and involves several skeletal sites, with some extraosseous involvement.<sup>11</sup> Radiographically, multiple myeloma is recognized by the characteristic lesions found in specific locations within the skeletal system, especially the vertebral bodies and skull. Multiple myeloma can result in the degeneration of one pedicle of a vertebral body, and also can lead to osteopenia of the vertebral body, which



Figures 3a and 3b. Osteoid osteoma. 3a, (left) Anteroposterior radiograph of knee joint shows sclerotic mass located in the cortex of the proximal tibia. The nidus of the osteoid osteoma is not visible on this radiograph. 3b, (right) Computed tomogram of the proximal tibia shows the nidus of the lesion (arrowhead).

causes compression fractures similar to that of idiopathic or post-menopausal osteoporosis.<sup>4,5</sup> The skull lesion of multiple myeloma is the “punched out” lesion, a localized area of radiolucency, occurring as one of several such lesions on any portion of the skull (Figure 4).<sup>4,5</sup>

Multiple myeloma affects patients between the ages of 50 years and 70 years, with a greater predilection for men.<sup>12</sup> Systemic signs, such as anemia, owing to the replacement of hematopoietic tissues with proliferating tumor plasma cells, and the production of abnormal serum and urine proteins, accompanies renal disease. Pain is relieved at night and with rest, and is aggravated during the day and during weight-bearing. The prognosis for multiple myeloma is poor, and the aggressive, polyostotic nature of the disease makes treatment and containment difficult. Key differential diagnoses must include metastatic carcinoma, as metastasized tumors also can cause the “missing pedicle” sign.<sup>13</sup>

Osteosarcomas, the second most common malignant bone tumor, and the most

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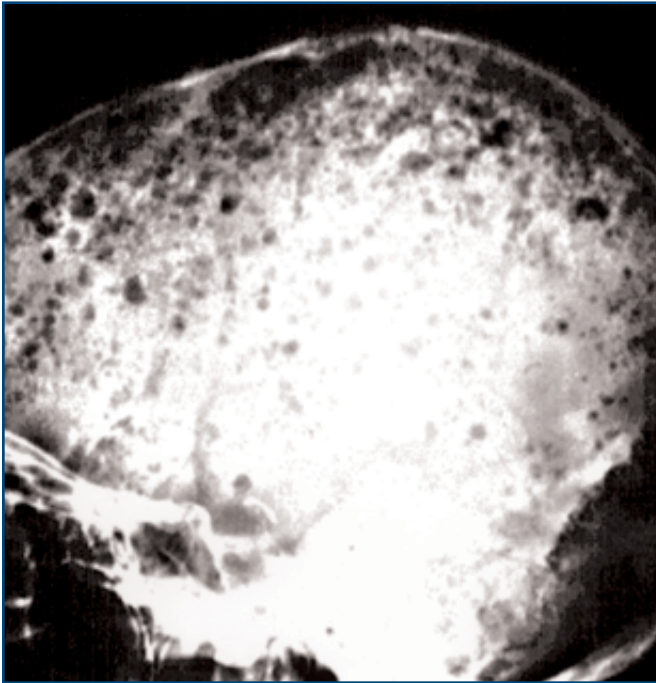


Figure 4. Lateral radiograph of the skull. The classic "punched out lesions" of multiple myeloma are easily seen as distinct, radiolucent lesions.

common malignant bone neoplasm in children, account for 20% of all primary bone tumors.<sup>4,5</sup> Osteosarcomas affect children and young adults before their 25th birthday, with males affected more often than females. Several types of osteosarcomas exist, and are categorized by their locations. Osteosarcomas can be classified as either intraosseous (central), surface (periosteal), extraosseous, secondary and multicentric.<sup>14</sup> The intraosseous or central osteosarcoma is the most common, and will be discussed here.

Signs and symptoms of osteosarcoma include cachexia, weight loss and fever, and painful swelling at the site of the lesion. The site will be firm, but not necessarily hard to the touch in the early stages, and hard to the touch in the later stages, once ossification has occurred.<sup>4</sup> Osteosarcomas most often affect the knee and shoulder, and present on x-ray

as a dense, ivory sclerotic lesion in the metaphysis of the affected bone (Figure 5). A soft-tissue reaction is common, and periosteal new bone formation can result in a "sunray" radiation pattern. As with multiple myeloma, the prognosis for osteosarcoma is poor, as all types are highly aggressive and malignant.<sup>4,5</sup> Often, pulmonary metastasis has already occurred at the time the primary osseous lesion is discovered.

The third most common malignant bone tumor is chondrosarcoma, a heterogeneous group of bone neoplasms that is comprised of cartilaginous neoplastic tissue.<sup>4,15</sup> Chondrosarcomas can be subdivided into groups based on histologic subtype, grade or location.<sup>15</sup> Generally, however, classification as either being central or peripheral is sufficient in a clinical setting. All chondrosarcomas predominantly affect men between 40 years and 60 years, most often affecting the pelvis and proximal femur.<sup>4,5</sup>

Chondrosarcomas present as a painful, palpable mass, and radiographically, they present as lucent, expansive lesions with a well-defined sclerotic margin. A soft-tissue reaction also may be present. The central chondrosarcomas occur mainly in the femur and humerus, as a metaphyseal or diaphyseal lesion. The peripheral chondrosarcoma affects mainly the pelvis and shoulder girdle, and has a characteristic soft-tissue mass associated with the tumor.<sup>3-5</sup> The prognosis for each depends on the grade, size and site of the lesion, although recurrences are common and metastasis is rare.<sup>4</sup>

Ewing's sarcoma is a relatively uncommon bone neoplasm found predominantly in patients under 25 years.<sup>4,5</sup> There is a slight predilection for men, and a strong frequency in white men.<sup>4</sup> Ewing's sarcoma



primarily affects the long bones of the skeleton, with additional involvement of the pelvis and innominate bone.<sup>4</sup> Localized pain, swelling, fever (local temperature elevation) and anemia are common signs and symptoms, which closely resemble infection in presentation.<sup>3,4,7</sup>

Radiographically, Ewing's sarcoma has a characteristic periosteal reaction that results in radio-opacity and periosteal irregularity, which has been coined the "onion skin" reaction.<sup>4,5</sup> Constant disruption and rebuilding of the periosteal regions accounts for this appearance.

Ewing's sarcoma is a serious condition, which has a poor prognosis if not detected early. Patients usually present with a history of diffuse pain and swelling at the affected site, which may indicate the disease has progressed to the late stages.<sup>4,5,7</sup>



Figure 5. Lateral radiograph of the knee joint shows the characteristic "ivory" pattern of osteosarcoma in the proximal tibia. A soft-tissue mass is visible on this plain film (arrowhead).

### Quasi-malignant Tumors

Giant cell tumors (GCTs), or osteoclastomas, are primarily a benign neoplasm. They also have a strong potential for malignant degeneration, however, such that GCTs are considered quasi-malignant.<sup>5</sup> GCTs comprise 15% of all benign bone tumors, but also account for 5% to 8% of all malignant bone tumors.<sup>16</sup> The key factor in their potentially malignant degeneration is their ability to invade adjacent structures, facilitated by a relatively thin cortical margin surrounding the primary tumor. GCTs are found primarily in the third to fifth decade, after closure of the growth plate.<sup>4,16</sup> The overall incidence in men and women is similar, however, men are slightly more predisposed to the

malignant tumor, whereas women are predisposed to the benign tumor.<sup>5</sup>

GCTs mainly affect the long tubular bones of the appendicular skeleton—generally the knee—but also can be found in the sacrum and patella. Initial signs and symptoms include swelling around the affected joint, with decreased range of motion, and a dull, aching pain. On x-ray, the GCT appears as a radiolucent lesion of the metaphysis, adjacent to the articular surface of the bone (Figure 6).<sup>4,5</sup>

The key radiographic factor to differentiate between malignant and benign tumors is the nature of the radiolucency. Aggressive tumors will be purely lytic, and will demonstrate cortical breakthrough and some soft-tissue reaction. Conversely, benign tumors



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Figure 6. Anteroposterior radiograph of the knee. A giant cell tumour is visible in the proximal tibia, at the tibio-fibular joint. The sclerotic border of the lesion (arrowhead) suggests a benign, non-aggressive lesion, however, a small percentage of giant cell tumours have malignant potential.

will demonstrate a “soap bubble” appearance, created by the tumor removing numerous trabeculae, resulting in the remaining trabeculae reinforcing each other.<sup>4,5</sup> A valuable additional diagnostic method for differentiating benign from malignant tumors is to use CT scans to determine the staging of the tumor.<sup>17</sup> The prognosis for a benign GCT is extremely good, however, an invading GCT does so slowly, with the tumor expanding slowly into adjacent structures. The survival rate for malignant GCTs is only 10%.<sup>5</sup>

### Summary

Primary bone tumors are a relatively rare occurrence, however, they can have serious

deleterious consequences if they are not detected and treated early. Many common bone neoplasms have characteristic features, both radiographically and upon physical examination, which allow for a rapid diagnosis. Treatment usually involves surgery, chemotherapy or radiation, or any combination thereof. Surgical treatment can range from simple curettage to resection to amputation in extreme cases.<sup>4</sup> Early detection is of utmost importance in preventing the drastic measures that are sometimes necessary to stop the damage and spreading of bone tumors. A systemic approach to radiographic analysis can facilitate an early diagnosis, and ensure timely treatment. **Dx**

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