Malignant Bone Tumors in the Dog

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- Osteosarcoma
- Parosteal Osteosarcoma (Juxtacortical Osteosarcoma)
- Chondrosarcoma
- Fibrosarcoma
- Hemangiosarcoma (Malignant Hemangioendothelioma)
- Liposarcoma
- Plasma Cell Myeloma (Plasmacytoma, Multiple Myeloma)
- Lymphosarcoma
- Giant Cell Tumor of Bone (Osteoclastoma)

The classification of tumors arising from bone is based on the predominant matrix formation and differentiation of cells. The majority of bone tumors in the dog are malignant; they arise mainly from the osseous tissue as osteosarcomas and parosteal osteosarcomas, or from cartilage as chondrosarcomas. The most commonly encountered bone tumors are primary tumors that arise from the mesenchymal elements associated with bone, the fibrous connective tissue (fibrosarcoma), the fat cells (liposarcoma), the blood vessels (hemangiosarcoma), and the hematopoietic cells of the bone marrow (plasma cell tumor, lymphosarcoma). (8,11,12,20,25,26,33,34,41)

The incidence of primary bone cancer in the dog is low when compared with that of tumors arising in other organs. (28) In a retrospective study of animal neoplasm Dorn and co-workers (14) found that the incidence of primary bone tumors in the dog was 7.9 per 100,000 animals. In the dog the most common tumors are osteosarcomas, which account for about 80% of bone tumors. Chondrosarcomas (10%) and fibrosarcomas and hemangiosarcomas (7%) are encountered less frequently. Parosteal osteosarcoma, lymphosarcoma, plasma cell myeloma, and liposarcomas are seen only rarely.

Osteosarcoma

Osteosarcoma is a malignant primary tumor of bone consisting of malignant stroma with evidence of malignant osteoid, bone, and/or cartilage formation. (43)

Osteosarcoma of medullary origin is the most common primary bone tumor in the dog. Brodey collected data on 1462 cases of primary osteosarcoma from various sources, which included cases from the Veterinary Medical Data Program, Animal Medical Center, New York SPCA, Utrecht University, Ontario Veterinary College, veterinary literature, and the University of Pennsylvania School of Veterinary Medicine.*

The sites of origin of osteosarcoma in 1215 dogs are shown in Figure 74-1. The data include all dogs of all breeds for whom this information was available. Eighty-two percent of these tumors involved the appendicular portion of the skeleton, and 18% involved the axial skeleton. Overall the sites of highest incidence were the distal radius and proximal humerus. However, this information can be subdivided further on the basis of site of involvement, weight, and height of the dog.

FIG. 74-1 Site of origin of 1215 primary osteosarcomas in the dog.

Kistler (21) using the information gathered by Brodey, subdivided the 1215 cases of canine osteosarcoma into four groups. The basis for each subdivision was the dog's standard weight and height, as indicated in the Complete Dog Book, an official publication of the American Kennel Club that contains current breed standards.

Giant breed dogs, weighing more than 90 lb, accounted for 29% of the cases of osteosarcoma. Ninety-five percent of these osteosarcomas were of appendicular origin, and 5% were of axial origin. The most common site of involvement was the distal radius (41.8%) and proximal humerus (15%), with a forelimb to hindlimb ratio of 2.5:1.

Large breed dogs, weighing 60 lb to 90 lb, accounted for 55% of the cases of osteosarcoma. Seventy-nine percent of these tumors were of appendicular origin, and 21% were axial in origin. The most common sites of involvement were the proximal humerus (19%) and the distal radius (14%), with increased numbers involving the hindlimb; the proximal femur (6.2%); the distal femur (8.2%); the proximal tibia (6.6%); and the distal tibia (6.2%). A forelimb to hindlimb ratio of 1.5:1 was found.

Medium breed dogs weighing 30 lb to 60 lb accounted for 11% of the cases of canine osteosarcoma. Sixty-seven percent were of appendicular origin, and 33% were of axial origin. The most common sites of involvement were the proximal humerus (18.4%), the distal radius (10%), and the proximal tibia (8.5%). A forelimb to hindlimb ratio of 1.7:1 was noted.

Small breed dogs weighing less than 30 lb accounted for 5% of all the cases of canine osteosarcoma. Forty-one percent were of appendicular origin, and 59% were of axial origin. A hindlimb to forelimb ratio of 1:1 was noted.

These findings, because they are based on a large data pool, are more meaningful than previous studies. (11,49)

In 879 of the purebred animals in his study, Kistler (21) found five long bones to be involved at either the proximal or distal end: the humerus, the radius, the ulna, the femur, and the tibia. In dogs weighing more than 90 lb, 50% of the tumors affected the radius; in lighter dogs, only 20% did so. When the specific area of bone involvement was examined, 90% of radial and ulnar tumors occurred on the distal end, and 90% of humeral tumors occurred on the proximal end, while tumors involving the tibia and femur were less likely to show a predilection for either end. These findings differ from those of Wolke and Neilsen, (49) who reported that distal ends of the femur and tibia had two to three times the tumor frequency of the proximal ends of these bones.

Overall, an increased proportion of appendicular involvement was noted in dogs taller than 16 inches, with a proportionate increase in tumor numbers with an increase in the height of the dog. However, although there was a higher incidence of forelimb involvement in dogs weighing more than 90 lb, no significant change in the proportion of forelimb tumors was noted with increased height.

The breed of dog is an important factor in determining the incidence of osteosarcoma. In the study by Kistler (21) the German shepherd had the highest incidence, followed by the Great Dane, Saint Bernard, boxer, Irish setter, Labrador retriever, Doberman pinscher, and collie. However, when these data are compared with the relative risk of any dog of any breed developing osteosarcoma, the Saint Bernard has a relative risk of 12.77 followed by the Great Dane (7.27), golden retriever (5.27), Irish setter (4.34), Doberman pinscher (4.03), and German shepherd (2.52). (39) These findings are similar to those of Tjalma. (45)

The above descriptions of incidence by breed and site of origin do not convey the marked differences in the site predilection for particular breeds. The Saint Bernard and Great Dane develop mainly osteosarcoma of the distal radius and proximal humerus and rarely of the flat bones or skull. The boxer, however, has a predisposition to develop osteosarcoma in the skull and flat bones, but rarely of the appendicular skeleton. (16) The role of stress due to skeletal mechanics may cause increased cell turnover at these sites and may in turn result in an increased opportunity for cell mutations to occur at these sites. This could perhaps account for the high incidence of tumors of the distal radius in giant breed dogs.
The average age of onset of osteosarcoma in the dog is about 71/2 years, with a range of 1 to 15 years. The age incidence and breed weight can be seen in Figure 74-2. Giant breed dogs have a peak incidence at 4 to 7 years of age. However, osteosarcoma of the ribs is found more frequently in young adult dogs, while osteosarcoma of the skull is seen mainly in older dogs. (16)

Previous reports have shown that male dogs are affected by osteosarcoma more frequently than females. (11,20,25) Kistler found that overall, 53% of the dogs affected were males and 47% were females. He also found that females of the giant breeds and males of the large breeds had a greater incidence of osteosarcoma compared with the opposite sex in the same weight range. Specifically, in German shepherds, Labrador retrievers, and Old English sheep dogs, there is an increased frequency of osteosarcoma in males, while in Saint Bernards, rottweilers, and Great Danes there is a higher incidence in females.

Genetic factors may also be important in the etiology of osteosarcoma. Bech-Nielsen and Co-workers found that tumors developed in two Saint Bernard siblings and an uncle, with a familial aggregation for a number or generations. They found that osteosarcoma in Saint Bernards can be transmitted as an autosomal recessive gene or by a more complex mode of inheritance involving interaction between genetic and environmental factors. However, vertical transmission of an infectious agent could not be excluded.

Osteosarcoma developing at the site of external radiation is well documented in humans. (24) Two such cases of osteosarcoma, which developed on the maxilla and proximal ulna, are known to have occurred in the dog. (45,46)

There is convincing evidence that osteosarcoma may develop at sites of prior fracture. In such cases many of the fractures had been repaired by internal fixation with the Jonas pin and Steinmann pin or by external fixation. (2,4,18,22,29,42*)

* Herring ME, Nunamaker D: Personal communication, 1982.

**FIG. 74-2** Graph showing age of onset of osteosarcoma in relation to weight of the dog.

**CLINICAL DATA**

In the dog, a species in which osteosarcoma frequently affects the longbones of the appendicular skeleton, the most common sign is lameness due to pain. The pain may be localized to the metaphyseal area of the bone by a thorough clinical examination and palpation. Lameness is followed by palpable swelling and visible enlargement of the affected area, usually one or more weeks after the initial onset of signs. The initial enlargement of the affected metaphyseal area is usually cool, but as the lesion increases in size the swelling becomes warm and painful as a result of periosteal elevation and stretching. Expansion of the tumor is accompanied by congestion, edema, fibroplasia, and periosteal new-bone formation. (37) As the size of the lesion increases, limitation of motion of the adjacent joint will be noted. When pain becomes very severe, there will be total loss of function of the limb accompanied by muscle atrophy. Initially the animal will be in good health, but with onset of pain and early metastatic spread to the lungs, the animal's condition will deteriorate rapidly. Pathologic fractures at the tumor sitemap be the initial sign in the early stage of development of an aggressive osteolytic tumor or may be found in the later stages of the disease.

Osteosarcomas arising from the ribs, cranial vault, and jaws first appear as firm bony swellings. Those arising from the nasal cavity present as unilateral or bilateral nasal hemorrhages or purulent nasal discharge. Osteosarcoma of the vertebral column will initially present with neurologic signs.

The duration of clinical signs is variable depending on the site of involvement. Tumors arising from flat bones of the head have a longer clinical course and a longer survival time than those arising from the appendicular skeleton. Osteosarcoma arising from the appendicular skeleton may have a rapid course of disease with death in as short a period as one month, while some animals survive 6 months or longer. Eighty-five percent of dogs surgically treated for osteosarcoma by limb amputation are dead within 8 months post surgery (7) owing to metastatic spread to the lungs via the hematogenous route at an early stage of the disease. Hypertrophic pulmonary osteoarthropathy is commonly found in dogs with pulmonary metastasis. (11)

**GROSS PATHOLOGY**

Although osteosarcoma of the appendicular skeleton arises in the medullary cavity of the metaphyseal region, in many instances the cortex and surrounding soft tissue are invaded prior to clinical presentation or surgical intervention. Often
osteosarcoma produces a Codman's triangle as a result of periosteal new-bone formation, which maybe seen on cross section of the affected bone (Figs. 74-3 and 74-4).

Osteosarcomas have variable amounts of cartilaginous, fibroblastic, and bone-producing areas. The gross appearance of the lesion will vary depending on the proportions of these elements. Based on the gross appearance of the sectioned lesion, two major morphologic groups of osteosarcomas have been recognized in the dog.(37) The first group destroys the bone architecture, but tumor cells fail to produce much calcified matrix. These are the osteosarcomas that produce osteolytic pattern radiographically. Occasionally these lesions may be highly vascular with marked hemorrhage on the surface; these are referred to as telangiectatic osteosarcomas(16) and may be difficult to differentiate grossly from hemangiosarcomas or aneurysmal bone cysts.(38)

The second group destroys normal bone and produces varying amounts of tumor bone with or without neoplastic cartilage. These tumors tend to have an osteoblastic pattern radiographically. Rapidly growing and invasive tumors frequently invade the cortical bone, producing little periosteal new bone but eliciting a severe soft tissue response. More slowly growing tumors may produce extensive periosteal and endosteal new bone. Long-standing tumors will also breach the normal barrier of hyaline cartilage of the growth plate and articular surface and extend into the joint.

**FIG. 74-3** Thick section of osteosarcoma of distal radius. Note origin in medulla, invasion of cortical bone, and subperiosteal new-bone formation. (Courtesy of Dr. Wayne Riser)

**FIG. 74-4** Thick section of osteosarcoma of distal femur. Note extension of tumor into soft tissue and subcortical new-bone formation. (Courtesy of Dr. Wayne Riser)

**MICROSCOPIC PATHOLOGY**

Histologically the tumor shows proliferation of neoplastic osteoblasts with the formation of tumor osteoid and bone. Occasionally the production of a fibrillar stroma and neoplastic cartilage will be encountered. (31)

Pool(37) has further classified osteosarcomas in the dog into simple, compound, fibroblastic, osteoblastic, chondroblastic, and pleomorphic types. Attempts to correlate these various morphologic types with clinical behavior and prognostic implications, as has been possible in humans, have not proven successful in the dog.

Simple osteosarcomas may produce tumor osteoid and bone in varying amounts (Fig. 74-5). Compound osteosarcomas form tumor osteoid and bone and varying amounts of neoplastic cartilage. The tumor cells of fibroblastic osteosarcomas are fusiform in appearance and produce an abundant collagenous stroma, with varying amounts of tumor osteoid and bone being formed directly by the neoplastic cells. Osteoblastic osteosarcomas produce a variable amount of tumor osteoid and bone. The tumor cells resemble osteoblasts, with a varying degree of cellular pleomorphism. Multinucleated tumor giant cells may be found scattered throughout the tumor. The majority of canine osteosarcomas are of this type.

Chondroblastic osteosarcomas show the formation of tumor osteoid, bone, and cartilage directly by the tumor cells, but in this type the cartilaginous component predominates. These tumors may be difficult to differentiate from chondrosarcomas.

For a more complete and detailed description of the histopathologic appearance of canine osteosarcomas, the reader is referred to the excellent work of Pool.(37)

**FIG. 74-5** Osteosarcoma. Proliferation of neoplastic osteoblasts and formation of tumor osteoid.
BIOLOGIC BEHAVIOR
Most tumors will continue to grow, invading and destroying the surrounding tissues. Tumors arising in the metaphysis of long bones show early venous invasion with metastasis to lungs and subsequent spread via the systemic circulation to other organs. Tumors arising from the skull show local invasion and destruction, with less vascular invasion by tumor cells and slower incidence of pulmonary metastasis. (17) Lymph node metastasis is found in fewer than 5% of canine osteosarcomas.

Parosteal Osteosarcoma (Juxtacortical Osteosarcoma)

Parosteal osteosarcoma arises on the surface of the bones, primarily the long bones, and has a histologic pattern of well-differentiated but malignant fibrous, osseous, and cartilaginous tissue. All three mesenchymal tissue types may be present in a single tumor. (37)

This tumor arises in bone-forming periosteal connective tissue and not in the extraskeletal tissue adjacent to the bone, (37) thus differing considerably from the intramedullary osteosarcoma, which is the more common tumor in the dog. Parosteal osteosarcoma, because it is rare in the dog, requires further investigation to provide better clinical-pathologic information.

This sarcoma accounts for only about 1% of the total cases of osteosarcoma that we have seen. The largest number of cases in the dog were described by Jacobson (19) as parosteal osteomas, a designation considered inappropriate for this tumor and should be termed parosteal osteosarcomas. (37) A single case was reported by Banks. (1)

The tumor may arise in dogs of any age; the mean age is 7 years. (19) Most dogs are of giant or large breeds. Twice as many males as females are affected.

CLINICAL DATA
In the dog the clinical course of parosteal osteosarcoma is considerably longer than that of osteosarcoma arising in the medullary cavity of long bones. The lesion appears as a firm, slowly growing mass on the surface of a bone; it can result in lameness or loss of range of motion of the affected joint. These tumors may arise on the long bones of the limbs or the head. (19)

GROSS PATHOLOGY
Parosteal osteosarcomas usually form a large, irregular, firm mass intimately attached to the periosteum (Fig. 74-6). A thick connective tissue capsule covers the surface. The tumor tissue on the cut surfaces shows foci of osseous, fibrous, and cartilaginous tissue. With time and increasing size, the tumor invades the cortex of the underlying bone and eventually penetrates into the medullary cavity.

FIG. 74-6 Parosteal osteosarcoma attached to periosteum of femur.

MICROSCOPIC PATHOLOGY
There is proliferation of neoplastic cells resembling neoplastic osteoblasts and fibroblasts. Foci of neoplastic osteoid, bone, and cartilage, any one of which may be predominant, are present within the stroma (Fig. 74-7). At the periphery a thick connective tissue capsule will be evident.

FIG. 74-7 Parosteal osteosarcoma. Proliferation of fibroblast-like cells with formation of osseous foci.

BIOLOGIC BEHAVIOR
Parosteal osteosarcomas continue to grow on the surface of the bone. Invasion of the underlying cortex and medulla occurs with time. It is our opinion that recurrence at the site of excision is frequent. Metastasis to the lungs may eventually occur via the hematogenous route. However, because these tumors grow more slowly and invade vessels at a later stage in their development, they have a better prognosis than osteosarcomas of medullary origin.
Chondrosarcoma

Chondrosarcoma is a malignant tumor in which the cells produce a neoplastic chondroid and fibrillar matrix but never directly produce neoplastic osteoid or bone. If neoplastic osteoid or bone is produced, the tumor is classified as an osteosarcoma.

Chondrosarcomas may be primary, arising within bone (central) or from the periosteum (peripheral), or secondary, arising by malignant change in osteochondromas. (43)

Chondrosarcomas account for about 10% of all bone sarcomas. (9, 12, 25) Large breed dogs are affected most frequently. (9, 25) In Brodey's study, (9) boxers accounted for 25% of all cases of chondrosarcoma; a high incidence was also found for German shepherds and mixed-breed dogs. These findings differ considerably from the reports of Ling (25) and from our own experience, in which we failed to find any cases of chondrosarcoma in boxers.

In the dog, flat bones of the body are more commonly affected by chondrosarcoma. (9, 25) Brodey (9) reported that the major sites of origin were the ribs (29%), nasal cavity (26%), and pelvis (14%). These results differ from our own experience and that of Ling, (25) who found that the majority of chondrosarcomas arose from the nasal cavity (50%), with fewer cases arising from the ribs and pelvis.

The age of dogs affected by chondrosarcoma ranges from 1 to 12 years, (25) with an even distribution throughout.

CLINICAL DATA
The clinical signs caused by the tumor vary considerably depending on the area of involvement and the size the tumor attains prior to surgical removal. Nasal chondrosarcomas present with sneezing and unilateral or bilateral nasal discharge, which may be purulent or hemorrhagic. Difficulty in breathing may be noted, but deformities of the nasal bone are rarely produced. Rib tumors produce hard, painless swelling at the costochondral junction. Chondrosarcomas of the pelvis are large, hard, lobulated tumors palpable externally and per rectum; hindlimb lameness and difficulty in defecation will be noted clinically. Tumors of the vertebrae cause compression of the spinal cord and present with neurologic signs.

GROSS PATHOLOGY
At the time of surgical excision, chondrosarcomas tend to be large masses, ranging in size from 2 cm to 20 cm in diameter. On cut section the tumor is lobulated, firm, and bluish white and may contain small calcified areas of tumor tissue, which have a chalky texture. Nasal chondrosarcomas are locally infiltrative and destructive, with ill-defined borders and, frequently, a myxoid appearance.

Central chondrosarcomas of long bones arise in the medullary cavity and may penetrate the cortex and invade the parosteal tissue. (37) Parosteal-reactive new bone may be laid down around the tumor.

MICROSCOPIC PATHOLOGY
Chondrosarcomas vary considerably in their histologic appearance. Well-differentiated chondrosarcomas may be difficult to distinguish from chondromas. They show uniformity of cell type with few mitotic figures, and in some cells, double nuclei. Undifferentiated chondrosarcomas show marked nuclear pleomorphism and a high mitotic rate (Fig. 74-8). Many of the undifferentiated chondrosarcomas show proliferation of fusiform cells lying in myxomatous matrix, with small foci of differentiation to an aneurysmal matrix.

FIG. 74-8 Chondrosarcoma. Neoplastic chondrocytes show moderate pleomorphism.

BIOLOGIC BEHAVIOR
Chondrosarcomas show less propensity to metastasize than osteosarcomas. Metastasis via the hematogenous route to the lungs is found later in the course of the tumor and occurs in about 10% of the cases. (9)
**Fibrosarcoma**

Fibrosarcoma arises from malignant fibrous connective tissue elements that produce a collagenous matrix but no neoplastic cartilage or bone. The tumor may be central, arising from the medulla of bone, or peripheral, arising from the periosteal connective tissue. Care should be taken to differentiate primary fibrosarcomas of bone from fibrosarcomas of soft tissue origin, which may invade adjacent bony structures. Differentiation maybe especially difficult when the tumors arise in the oral cavity, where soft tissue fibrosarcomas of gingival and palatine origin are locally invasive of adjacent bony structures.

Fibrosarcoma is rare in the dog. It occurs mainly in mature, medium and large breed male dogs. The central fibrosarcoma will vary in its rate of growth but may be a very rapidly growing mass. It arises mainly in the metaphyseal area of long bones. Periosteal fibrosarcomas arise mainly from the mandible and maxilla. They are slowly growing tumor masses, intimately attached to the bone surface, that with time will erode and destroy the adjacent bony tissue.

**GROSS PATHOLOGY**

Gross pathology varies considerably from a firm, grayish white mass, which may appear whorled and lobulated and which is locally invasive and destructive (Fig. 74-9), to a soft, reddish mass with areas of cystic degeneration, hemorrhage, and necrosis (Fig. 74-10).

![FIG. 74-9 Fibrosarcoma arising from maxillary bone.](image1)

**FIG. 74-10 Thick section of fibrosarcoma with extension through cortex into surrounding tissue. (Courtesy of Dr. Wayne Riser)**

**MICROSCOPIC PATHOLOGY**

The histologic appearance of this tumor is the same as that of tumors arising from soft tissue. There may be extensive collagen formation by fusiform cells, with little pleomorphism or mitotic activity, or the cells may be extremely pleomorphic, with numerous mitoses and little collagen formation. An interwoven pattern can usually be recognized within these tumors (Fig. 74-11).

![FIG. 74-11 Fibrosarcoma. Interwoven bundles of fusiform cells.](image2)

**BIOLOGIC BEHAVIOR**

Tumors that are welldifferentiated on microscopic examination may show recurrence at the site of surgical excision but infrequently show metastatic disease. Highly anaplastic fibrosarcomas tend to have a more rapid clinical course and are more likely to show metastatic disease. It is our experience that these tumors, even though locally invasive of the vessels within the area of the primary tumor, can show evidence of pulmonary metastasis up to one year after surgical removal of the affected limb.

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**Hemangiosarcoma (Malignant Hemangioendothelioma)**

Primary hemangiosarcoma is a malignant tumor arising from the endothelium of blood vessels. The tumor is rare, and
with fibrosarcomas constitutes about 7% of primary bone sarcomas in the dog. Five percent of cases of hemangiosarcoma in the dog are found arising from bone. The tumor may arise in young adult dogs, with an age range of 3 to 16 years and a peak incidence at 7 years. (5,40) Medium and large breed dogs of either sex may be affected. It is our opinion that this tumor is most common in German shepherds.

Signs of tumor in the bone are pain, lameness, and swelling, with destruction of the bone. The tumors arise in the medullary area and erode the cortical bone, extending through the periosteum into the surrounding soft tissue. Pathologic fractures at the tumor site are common.

The tumor most frequently involves the proximal and distal ends of the long bones. The flat bones of the axial skeleton are involved less frequently.

**GROSS PATHOLOGY**
The affected area of the bone shows loss of normal architecture and replacement by a friable, dark red, bloody tissue (Figs. 74-12 and 74-13). Some specimens may show a less well-differentiated vascular architecture and appear light gray and more solid in section. Extension through the cortex into the soft tissue may be observed.

*FIG. 74-12 Hemangiosarcoma in the ulna, with extension into surrounding tissue.*

*FIG. 74-13 Thick section of hemangiosarcoma. (Courtesy of Dr. Wayne Riser)*

It is important to differentiate the tumor from an aneurysmal bone cyst and telangiectatic osteosarcoma, which have a similar gross appearance.

**MICROSCOPIC PATHOLOGY**
Hemangiosarcomas show proliferation of malignant endothelial cells, which form the lining of blood-filled vascular channels of varying size (Fig. 74-14). The fibrous stroma supports malignant endothelial cells. Occasionally cases may be encountered in which tumor cells are more fusiform and the tumor solid, with the formation of few vascular channels. These cases may be difficult to differentiate from fibrosarcoma or malignant synoviomas. (37)

*FIG. 74-14 Hemangiosarcoma. Proliferation of neoplastic endothelial cells lining vascular channels.*

**BIOLOGIC BEHAVIOR**
The tumors are locally destructive and frequently show vascular invasion and metastasis prior to the time when clinical signs become apparent. Metastasis is to the lungs and then to internal organs, particularly the spleen, liver, and right atrial appendage. When metastatic disease is widespread throughout these organs, it is frequently impossible to ascertain whether the tumor in the bone is a primary or secondary tumor.

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**Liposarcoma**

Liposarcoma is a malignant tumor that arises from the adipose tissue of the bone marrow cavity. Very few cases have been reported in the dog, but those cases reported arose in the medullary cavities of long bones. (6,10,13,30) The tumor, which is locally destructive (Fig. 74-15), may lead to the formation of periosteal new bone and swelling of the surrounding soft tissue.

On gross examination the tumor is soft and yellow white (Fig. 74-16). Histologically the tumor cells have multiple vacuolated areas within the cytoplasm of the cells. Nuclei are ovoid and vesicular, with a variable number of mitotic figures (Fig. 74-17).
Plasma Cell Myeloma (Plasmacytoma, Multiple Myeloma)

Plasma cell myeloma presents as neoplastic proliferation of plasma cells of the bone marrow cavity. It is rare in the dog and arises as a multicentric tumor. (27, 32, 36) The sites affected most commonly are the flat bones of the head, the vertebrae, the ribs and pelvis, and the proximal femur and humerus. (32) Pathologic fractures may occur at the site or sites of involvement and may be the primary presenting sign. Other clinical manifestations of plasma cell myeloma are related to the overproduction of immunoglobulins by the tumor cells and include such disorders as bleeding diathesis, hyperviscosity syndrome, nephrotoxicity, anemia, increased susceptibility to infections, and hypercalcemia. (27)

On gross examination of the affected bones, the tumorous areas are red, soft, and well demarcated from the surrounding bony tissue (Fig. 74-18). Clinical pathology usually shows a hypergammaglobulinemia and the presence of Bence Jones protein in the urine. Pathologic confirmation of the tumor may be made by needle aspiration or biopsy of the affected areas. Normal marrow elements are replaced by sheets of closely packed cells resembling plasma cells (Fig. 74-19), with eccentric nuclei and an extensive dense cytoplasm. The degree of cellular and nuclear pleomorphism is variable, as is the number of mitotic figures. Binucleated cells are found occasionally.

The biologic behavior of this tumor depends on the degree and sites of osseous involvement. The majority respond well to chemotherapy.

FIG. 74-18 Myeloma. Multiple foci of tumor in medullary cavity of femur.

FIG. 74-19 Myeloma. Neoplastic plasma cells in medullary cavity.
**Lymphosarcoma**

Primary Lymphosarcoma of bone in the dog is exceedingly rare, whereas bone marrow involvement is frequently encountered as part of the multicentric tumor in the dog. Primary lymphosarcoma arising within the medullary cavity of the axial or appendicular skeleton presents with pain but little swelling of the affected areas. Multiple bones may be involved. Radiographically the lesion resembles plasma cell myeloma, and there may be pathologic fractures of the affected bone.

The more frequently encountered cases of marrow involvement seen with generalized multicentric Lymphosarcoma rarely produce clinical or radiographic signs related to bone disease.

On gross examination primary lymphosarcoma shows as soft whitish foci in areas of bone destruction (Fig. 74-20), whereas cases of multicentric lymphosarcoma show replacement of the marrow by a homogenous, soft, white mass. Pathologic examination of aspirates or biopsy specimens shows replacement of normal marrow elements by sheets of neoplastic lymphoid cells (Fig. 74-21).

The primary tumor of bone often progresses to involve lymph nodes and internal organs, particularly the liver and spleen.

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**Giant Cell Tumor of Bone (Osteoclastoma)**

Giant cell tumor of bone develops within bone and arises from mesenchymal cells that differentiate into fibroblast-like stromal component and multinucleated cells resembling osteoclasts. Great care must be taken in making the diagnosis of giant cell tumor of bone because osteosarcoma may contain numerous giant cells, which may aggregate in some areas of the tumor. However, within the giant cell tumors little or no matrix will be produced.

This tumor is extremely rare in the dog, arising in both the appendicular and axial skeletons. Too few cases have been reported to identify any age, breed, or sex predilection. The diagnosis of giant cell tumor is made initially on the basis of specific radiographic findings and is confirmed by histopathologic examination of the affected area. The histopathology shows avascularized stroma with extensive proliferation of ovoid-shaped cells regularly interspersed with giant cells (Fig. 74-22). Because so few cases have been recognized, the biologic behavior of this tumor is poorly understood.

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