

# CHAPTER 7

## ORTHOPAEDIC RADIOGRAPHY

DARRYL BIERY

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### GENERAL PRINCIPLES

Radiography is one of the most useful diagnostic tools in veterinary medicine for the detection and diagnosis of suspected musculoskeletal disease. Radiographs permit localization and characterization of a lesion, which together with the animal's history, clinical signs, and physical and laboratory findings are used to achieve a tentative or specific diagnosis.

Technically excellent radiographs must be made. Fortunately the bony structures provide excellent subject contrast for imaging normal and abnormal structures. Certain body parts, such as the skull and spine, may require greater radiographic detail for examination. A variety of fine-detail screens or film techniques exist for these purposes. A comprehensive description of radiographic and subject factors that affect radiographic quality is beyond the scope of this chapter; the reader is referred to other excellent texts for a discussion of this subject ([21,28,33](#)).

Failure to perceive a lesion is commonly related to radiographs that are unsatisfactory as a result of underexposure, overexposure, improper positioning of a body part, or an insufficient number of radiographic views. With technically excellent radiographs, most skeletal lesions will be detected. It should be remembered that since a radiograph is only a two-dimensional image, a minimum of two views, preferably perpendicular to each other, is usually necessary for examination of a part ([Fig. 7-1](#)). Occasionally, a lesion is seen on only one of two or more radiographic views. Sometimes special radiographic views or a contrast study is necessary to adequately localize or characterize a disease process ([Fig. 7-2](#)).

The radiographic image is a composite of superimposed subject densities consisting of cancellous and cortical bone, fat, and soft tissue structures such as muscles, ligaments, and tendons. Therefore, body parts such as bones and joints have a wide spectrum of radiographic densities and contrast.

The basis of radiographic interpretation is the recognition of an altered size, shape, contour, position, or radiographic density. Thus it is imperative that the observer understand and recognize the normal, a task made difficult by the variety of species and breeds (e.g., different sizes and shapes) that the veterinarian must treat. A thorough study and search of all structures on the entire radiograph are essential. Fortunately the sharp contrast that exists between the cancellous and cortical bone and surrounding soft tissue structures usually provides visualization of an abnormality, including subtle changes. The radiographs should be viewed in a consistent manner on a radiographic viewbox using a bright light and, when indicated, with other aids such as a magnifying or minifying lens.

All components of a bone should be examined, including the subchondral bone, epiphysis, physis, metaphysis, diaphysis, apophysis, cortex, and medullary cavity. Occasionally it will be difficult to determine whether a specific structure is normal or abnormal. In such cases, it is frequently helpful to make a radiograph of the contralateral part for comparison or to refer to textbooks, a radiographic atlas, or radiographs of other animals of similar age and breed. Numerous anatomical variants of the skeletal system exist that can easily be diagnosed erroneously as disease ([Fig. 7-3](#)).

When a radiographic finding is equivocal, additional follow-up radiographs may be helpful; bone is metabolically active, and lesions such as a bone tumor change in appearance, sometimes in a relatively short period of time. It is also very important to remember that the musculoskeletal system may appear normal even in the presence of disease. For example, as much as 70% of the bone mineral may be removed before a bone is radiographically appreciated to be more radiolucent than normal.

When a lesion is detected, its radiographic appearance and alterations should be characterized in order to establish the most likely diagnosis or differential diagnosis. ([2,4,20,26,28](#))



FIG. 7-1 A pathologic fracture and displacement of the distal fracture fragment are



visible only on the craniocaudal view (A) and not on the lateral view (B). The pathologic fracture is secondary to infiltration by a synovial sarcoma. Also note the adjacent soft tissue mass and alterations in the contour, size, and shape of the femur, patella, and proximal tibia.



FIG. 7-2 A dorsopalmar stress radiographic view of a carpus accentuates the abnormal radiocarpal-second carpal joint widening (A) compared with the nonstress view (B). The dog had a torn medial collateral ligament.

The radiographic spectrum of bone and soft tissue alterations is limited. For example, bone can change only in its morphologic appearance (size, shape, and contour) or density. These alterations in appearance reflect the nature of the disease process and usually are not pathognomonic. Although a histologic examination is required for a definitive diagnosis, many of the radiographic patterns of bone disease are relatively diagnostic of a specific disease when evaluated in context with a specific history, clinical signs, or laboratory data. However, there may be a poor correlation between the clinical and radiographic findings. Radiographic alterations may lag behind the onset of clinical signs (e.g., osteomyelitis), or the radiographic alterations may have been present prior to the onset of clinical signs (e.g., malignant bone tumor). Some bony changes such as spondylosis deformans frequently have no associated clinical signs or clinical significance.

## RADIOGRAPHIC ALTERATIONS

The alterations of each bone lesion should be characterized according to the following: (1) change in density; (2) change in size, shape, or contour; (3) type of margination between normal and abnormal bone; (4) type of periosteal reaction; (5) location and distribution of lesion or lesions; and (6) change in soft tissues. Each of these alterations will be described below, since the spectrum of the change will permit the radiographic categorization of the lesion. Many times it is possible to decide whether a lesion is benign or malignant based on the categorization of bony or soft tissue alterations.

## DENSITY

Change in density is one of the more common alterations and may be either increased (more radiopaque than normal) or decreased (more radiolucent than normal). A bone's radiopacity decreases as the result of osteolysis, osteomalacia, and osteoporotic processes. A localized area of decreased bone density is known as osteolysis and is due to an increased rate of bone resorption, which may be the result of an increased blood supply, increased osteoclastic activity, or soft tissue invasion. The osteolytic lesion may be present in a variety of bone diseases including malignant tumor, abscess, or benign cyst. Three distinctive types of bone lysis have been described: circumscribed or geographic (Fig. 7-4, A), regional or moth-eaten (Fig. 7-4, B), and diffuse or permeative bone lysis (Fig. 7-4, C). Circumscribed bone lysis has a single or confluent area of complete bone destruction, which usually represents a nonaggressive and benign process. Moth-eaten lysis appears as multiple holes of moderate size that tend to coalesce and is usually an aggressive lesion. The most aggressive pattern of lysis is permeative and commonly represents an infiltrative neoplasm.



FIG. 7-3 A sesamoid bone in the ulnar collateral ligament is visible on the lateral aspect of the elbow. This sesamoid bone is more commonly present in larger-breed dogs and should not be erroneously diagnosed as a chip fracture or other disease.

Osteomalacia, a disease process that results from inadequate osteoid mineralization, also produces lysis. The lesions are usually localized to a specific area of bone, such as the metaphysis in dogs with hypertrophic osteodystrophy (Fig. 7-5). Osteomalacic diseases are usually accompanied by osteoporosis, such that the two lytic processes are frequently indistinguishable radiographically.

Osteoporosis, or bone atrophy, is a generalized loss of radiographic opacity, usually affecting more than one bone. This radiographic appearance is associated with many factors, including disuse (e.g., posttraumatic), congenital abnormalities (e.g., osteogenesis imperfecta [Fig. 7-6]), hormonal aberrations (e.g., Cushing's disease), and dietary intake (Fig. 7-7).

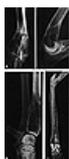


FIG. 7-4 (A,B) A bone cyst in the distal humerus has a circumscribed and sharply margined lytic lesion. (B) An osteosarcoma of the distal radius has a regional lytic lesion with a poorly demarcated margin. (C) Lymphosarcoma involving the entire radius is characterized by permeative lysis.

Increase in radiopacity of cortical or cancellous bone is referred to as osteosclerosis. Osteoblastic, myelosclerotic, and osteopetrotic processes produce the radiographic appearance of osteosclerosis.



FIG. 7-5 Radiolucent or lytic areas in the distal metaphysis of the radius and ulna represent the earliest and one of several radiographic abnormalities seen in hypertrophic osteodystrophy.



FIG. 7-6 Marked osteoporosis with pathologic fractures, bone deformity, and soft tissue swelling are present in a dog with osteogenesis imperfecta.



FIG. 7-7 Generalized osteoporosis of the pelvis and femurs is present in a young dog with nutritional osteoporosis. Note the pathologic fracture of the femur (closed arrow) and compression-type fracture of the left ilium (open arrow).

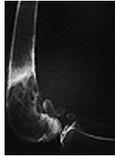


FIG. 7-8 An osteosarcoma of a dog's distal femur has a combination of osteoblastic, osteolytic, and periosteal alterations.



FIG. 7-9 Myelosclerotic appearance of bone infarcts in the distal femur and tibia of a dog. The dog also has an aggressive bony lesion of the proximal tibia, which was an osteosarcoma.



FIG. 7-10 Canine panosteitis with myelosclerosis involving the femur.

Osteoblastic lesions represent an increased osteoblastic activity and are usually associated with bone tumors and infection. Some diseases such as osteosarcoma present with a combination of osteoblastosis and osteolysis (Fig. 7-8).

Myelosclerotic alterations appear as abnormal, increased radiographic opacities in the medullary cavity of bone and may be localized or generalized in one or more bones. Diseases that may cause myelosclerosis include bone infarcts (Fig. 7-9), canine panosteitis (Fig. 7-10), medullary osteomyelitis, tumors such as plasma cell sarcoma and lymphoma (Fig. 7-11), and other reticular endothelial diseases of bone marrow. Osteopetrosis is manifested radiographically by a strikingly increased medullary opacity and obliteration of normal bone architecture(27)

#### SIZE, SHAPE, AND CONTOUR

Almost any disease of bone, joint, or soft tissue can cause an alteration in size, shape, or contour of a bone. These alterations are commonly associated with abnormal stress or load distributions of continually remodeling bone. Most size, shape, and contour alterations are secondary to diseases such as physis injury with uneven or premature closure (Fig. 7-12), previous fracture with malunion, congenital anomalies such as medial patella luxation, and occasionally tumors. (See Fig. 7-1.)

#### LESION MARGIN

The sharpness or distinctness of the margin of a bone lesion is one of the most helpful radiographic alterations to evaluate. The sharper and better demarcated the lesion margin or transition zone between normal and abnormal bone, the more likely is the disease process to be benign. (See Fig. 7-4, A). Conversely, the less sharp or the more poorly demarcated a lesion margin is, the more likely is the lesion to be malignant. (See Fig. 7-4, B,C). Many lesions will have a spectrum of sharp to hazy margins; the least sharp aspect of a margin should be considered the more valid finding for suggesting the type of underlying disease process.

Occasionally a sharp margin is present in a benign lesion such as pathologic fracture of bone cyst; conversely, a malignant tumor may have a sharp area of transition between normal and abnormal bone.



FIG. 7-11 Lymphosarcoma of one femur (arrow) in a cat is seen as a myelosclerotic alteration. Note the density compared with the opposite normal femur

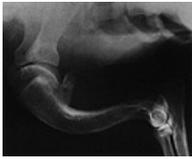


FIG. 7-12 A previous fracture with premature closure of the caudal proximal humeral physis in a dog resulted in abnormal size, shape, and contour to the bone

## PERIOSTEAL REACTION

The type of periosteal reaction is extremely helpful in defining the disease process. In general, the more organized and smooth the periosteal reaction, the more likely that the lesion is benign. Those periosteal changes that appear most active and are least organized are most compatible with a malignant tumor. Again, as with the other alterations, a spectrum and admixture of responses can be present. In general, the spectrum of periosteal changes ranges from the most benign appearing (non-aggressive) one of solid lamina, through others such as amorphous or lacy, laminated, or onion skin, to sunburst (most aggressive) (Fig. 7-13, A-F). Classic examples include the following: fracture callus, solid laminar reaction; hypertrophic osteopathy, amorphous to lacy appearance; an intermittent active process of infection or tumor, laminated appearance; a malignant bone tumor such as osteosarcoma, sunburst reaction.

Another type of periosteal reaction, known as Codman's triangle, represents elevation of the periosteum from the cortex. The presence of a Codman's triangle, previously thought to be indicative of a primary bone tumor, is not helpful in characterizing a bone lesion but is seen commonly with many diseases such as subperiosteal hemorrhage, fracture healing, infection, and tumors (Fig. 7-14).

## LOCATION AND DISTRIBUTION

Defining the location and distribution of one or more bony lesions is also very helpful in making a diagnosis. Most diseases (benign and malignant) have a predilection for certain bones or parts of a bone. For example, panosteitis involves the diaphysis of only the long tubular appendicular bones, whereas osteochondrosis, another benign and self-limiting disease, involves the epiphyses, such as the proximal humerus, humeral condyles, and femoral condyles. In general, primary bone tumors are usually monostotic, metaphyseal, and in the appendicular bones. Polyostotic lesions are usually metastatic tumors, fungal osteomyelitis, or systemic and metabolic diseases. The preferential sites and distribution of specific diseases are described in subsequent chapters of this text.

## SOFT TISSUES

The radiographic appearance of the soft tissues adds valuable information about a disease process. (4,20,26,28) Soft tissue alterations may be present with or without radiographic evidence of a bony lesion. The soft tissue disease may represent a musculoskeletal lesion limited to only the soft tissues or it may be the result of underlying bone disease such as osteomyelitis in which soft tissue changes occur prior to bony changes. Less exposed radiographs or viewing with a bright light may be necessary to better evaluate the soft tissues. Common radiographic findings of soft tissue alterations include swelling, atrophy, and displacement or obliteration of normal structures such as fascial planes (Fig. 7-15). Other radiographic soft tissue abnormalities that may be seen are the presence of mineralization, a radiopaque foreign body, a lipoma, or emphysema due to infection, fistulous tract, or puncture wound (Fig. 7-16).



FIG. 7-13 Periosteal reactions reflect the underlying disease process in the most nonaggressive to the most aggressive types of disease: Solid laminar periosteal reaction of a healed fracture (A) and panosteitis (B). Amorphous to lacy periosteal reaction in hypertrophic osteopathy (C) and bacterial osteomyelitis (D). Laminated periosteal reaction in osteomyelitis (E). Sunburst periosteal reaction in an osteosarcoma (F).



FIG. 7-14 Codman's triangle, which represents elevation of the periosteum, is seen in a healing fracture (A), coccidioid osteomyelitis (B), and osteosarcoma (C). The healing fracture callus is irregular and large secondary to incomplete immobilization.

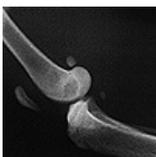


FIG. 7-15 Cranial cruciate rupture in a cat in which the patella, tibia, and popliteal sesamoid bones are displaced. The infrapatellar fat pad is also obliterated.

One or a combination of these soft tissue changes may suggest the cause or site of a disease process. For example, if the soft tissue swelling is poorly marginated, the disease process is more likely to be an aggressive lesion such as an infiltrative tumor rather than an organized process such as hematoma, abscess, or benign tumor.

## LESION CHARACTERIZATION

If one or more of the many bony or soft tissue alterations appear active, infiltrative, and not confined to the bone, the lesion is termed aggressive, (14,26,28) indicating that the lesion is more likely to be malignant rather than non-aggressive and benign. The more aggressive-appearing lesions are commonly primary or metastatic malignant tumors. Conversely, lesions appearing nonaggressive include diseases such as fracture and fracture healing, bone cyst, and most infections. Osteomyelitis may have a multitude of appearances varying from nonaggressive to aggressive.

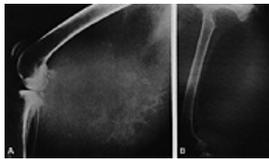


FIG. 7-16 Soft tissue alterations of dystrophic soft tissue mineralization within a squamous cell carcinoma (A) and an oblong radiolucent density within the quadriceps representing a submuscular lipoma (B).

It should be remembered that many variations exist in the spectrum of aggressive- to nonaggressive-appearing lesions and that the radiographic findings are not pathognomonic. For example, a healing traumatic fracture with incomplete immobilization and infection can mimic an aggressive lesion such as tumor ([Fig. 7-14](#)).

Although a biopsy or culture is necessary to establish a definitive diagnosis for treatment and prognosis, there is less urgency for lesions that appear nonaggressive.

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## FRACTURES

Radiography is essential for identifying and defining a fracture. ([29](#)) A fracture is present when there is a complete or incomplete discontinuity of bone or cartilage. Although most fractures are visible as an abnormal radiolucent line, some fractures have no visible line, particularly those due to a compression or an underlying pathologic process. ([See Fig. 7-7](#)). Many nondisplaced fractures will have a fracture line that becomes more visible days later when resorption and healing are occurring at the fracture site. Occasionally a compression fracture will create a fracture line that is more opaque than normal.

When assessing a fracture radiographically, at least two views should be made. Radiographs of a fracture site should include the entire bone and the adjacent joints. A fracture should be classified according to its radiographic appearance as to (1) type (e.g., spiral, comminuted, Salter-Harris); (2) location (e.g., middiaphysis); and (3) position of fracture fragments. Further radiographic evaluation can be augmented by assessing distraction, impaction, joint involvement, soft tissue disease, and possible underlying disease process. The margins of a fresh fracture of otherwise normal bone are sharp, whereas a fracture through a bone affected by an underlying disease process is usually poorly demarcated.

Radiography is also very important in assessment of fracture reduction and fixation and progressive evaluation of fracture healing such as progressive normal healing, delayed union, nonunion, and malunion.

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## JOINTS

Injuries and diseases of joints, like those of bones, are readily evaluated with radiography. ([4.7.20.24.28](#)) High-quality radiographs, appropriate positioning, and adequate number of views are essential in the thorough evaluation of a joint. One must also be familiar with normal anatomy, variants of normal, and the location and radiographic appearance of various joint diseases. The epiphyses, physes, and metaphyses of the bones adjacent to the joint being evaluated should be included on the radiographs. Special radiographic views such as coned down and stress or dynamic radiographs ([see Fig. 7-2](#)) are occasionally necessary.

The radiographic assessment of a joint should include evaluation of alignment, subchondral bone, joint space, and adjacent periarticular soft tissues. ([See Chapter 87.](#)) Many of the joint tissues such as cartilage, synovial membrane, fibrous capsule, and collagenous structures are not visible on survey radiographs and therefore cannot be evaluated. Survey radiographic alterations include loss of calcification of the articular cartilage, distention of joint capsule (effusion or fibrosis), subchondral bone sclerosis or cysts, formation of bone spurs, and abnormal joint space ([Figs. 7-2](#) and [7-17](#)). A joint space may be abnormally increased or decreased as a result of disease processes such as effusion or loss of cartilage, respectively. For valid radiographic assessment of joint space, the joint should be radiographed during weight bearing, with the x-ray beam perpendicular to the joint of interest. The radiographic alterations usually are not pathognomonic but are compatible with any one of the causes of noninflammatory or inflammatory arthritides. Frequently there is a poor correlation between the radiographic findings and clinical signs. Early rheumatoid arthritis or ruptured cruciate ligament may show no radiographic abnormalities but the animal is very lame. Conversely, there may be extensive alterations, such as degenerative joint disease in a dysplastic hip, yet no lameness is present. Multiple joints may need to be radiographed if a polyarthritis is suspected or if a radiographic finding is equivocal.



FIG. 7-17 Disease of the carpal and metacarpophalangeal joints is characterized by a loss of joint space, subchondral sclerosis, subchondral cysts, bone spurs, and para-articular soft tissue swelling.

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## IMAGING MODALITIES FOR ASSESSMENT OF MUSCULOSKELETAL DISEASE

Although clinically used less commonly in animals than in humans, the following methods offer additional types of imaging for evaluation of the musculoskeletal system. The use of some of these imaging modalities has been limited in veterinary medicine owing to the cost and the need for specialized types of equipment.

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## RADIOGRAPHIC TOMOGRAPHY

The specially designed equipment used in radiographic tomography can produce a sharp image of a single narrow plane within a body part. This is achieved by a coordinated reciprocal movement of the x-ray tube and film about a pivot point during the exposure. The pivot point can be adjusted, and at this point the structures are visualized with body parts above

and below this level obscured by motion blurring. In the musculoskeletal system tomography is useful in the study of the skull, particularly the cranium, and temporomandibular joints, spine, and appendicular joints. (10,12,33) Early lesions such as bone necrosis, intra-articular cartilaginous or osseous bodies, and articular fracture are demonstrable (Fig. 7-18).



FIG. 7-18 A dorsoplantar tomographic view of the tarsus demonstrates a fracture (arrow) that extends from the lateral tracheal of the tibial tarsal bone into the joint. The fracture was not visible with conventional radiography.

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#### MAGNIFICATION RADIOGRAPHY

High resolution can maximize information visible on a radiograph. This can be achieved with two types of magnification. The first method is to optically enlarge the image on a fine-grain film. The other method is to do direct radiographic magnification by increasing the object-film distance. With a small x-ray tube focal spot (usually less than 0.6 mm size) and air gap to reduce scatter, twofold to fourfold geometric enlargement can be obtained. This technique has been useful in enhancing radiographic visualization of small-image details for the diagnosis of bone and joint disease. (13,16,23)

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#### ARTHROGRAPHY, TENOGRAPHY, AND BURSOGRAPHY

Arthrography, tenography, and bursography utilize contrast media for the opacification of a joint cavity, tendon sheath, or bursa. (26,31) Articular and surrounding structures can be evaluated for osteochondrosis, meniscal tears, soft tissue mass, and integrity of joint capsule, tendon sheath, or bursa (Fig. 7-19).

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#### TRANSOSSEOUS VENOGRAPHY

Transosseous venography is a radiographic contrast study that allows visualization of intraosseous and parosseous veins. (8,15,18,25,34) Contrast media is injected directly into a bone, after which serial radiographs are usually made. Although used more for assessment of vertebral disease in veterinary medicine, the technique can be useful in assessment of fracture complications such as nonunion, delayed union, or ischemic necrosis.

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#### ANGIOGRAPHY

Angiography, a radiographic contrast study that permits visualization of blood vessels, is useful for the diagnosis of thrombosis, arteriovenous fistula, bleeding site, and as an aid in differentiating benign from malignant masses (Fig 7-20) (9,26)



FIG. 7-19 Tenography demonstrates an intact gastrocnemius tendon and extravasation of contrast material around the gastrocnemius muscle. The head of the gastrocnemius muscle was torn



FIG. 7-20 An arteriogram demonstrates arterial obstruction of the cranial tibial artery associated with necrosis and infection at the site of a previous injury. Only collateral small arteries are present at the disease site.

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#### MYELOGRAPHY

Myelography, a radiographic contrast study, allows visualization of the subarachnoid space for detection and localization of a pathologic process. (1,17,32) This contrast study usually permits the lesion origin to be pinpointed as extradural, intradural-extramedullary, or intramedullary (Fig. 7-21).

Lymphangiography, a radiographic contrast study, allows visualization of the lymphatic vessels and nodes. (30,38) This contrast study can aid in the differential diagnosis of lymphatic diseases (e.g., traumatic rupture), tumors (e.g., lymphoma and lymphangioma), and congenital disease (e.g., lymphoedema) (Fig. 7-22).

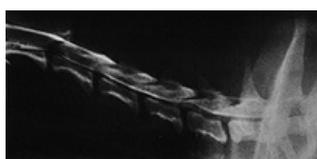


FIG. 7-21 A myelogram demonstrates an extradural lesion due to protrusion of an intervertebral disk at C5-6.



FIG. 7-22 (A) Normal lymphangiogram of a dog's rear leg. (B) Abnormal lymph vessels and absence of popliteal lymph node in the rear leg in a dog with lymphoedema.



FIG. 7-23 Craniocaudal xeroradiograph of a normal dog's foreleg.



FIG. 7-24 A left lateral scintigram demonstrates focal pulmonary uptake of a bone scanning agent  $^{99m}\text{Tc-MDP}$ . The lung mass was a primary pulmonary osteosarcoma.

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## XERORADIOGRAPHY

Xeroradiography, an electrostatic imaging system, uses x-rays to produce a latent image on a plate containing selenium-charged particles. The resultant powder image is transferred to paper and fused thermally for a permanent opaque image (Fig. 7-23). Xeroradiography provides a broader latitude and greater edge enhancement than radiography (22,26). Its advantage of making possible the recording of many tissues of varying densities and thicknesses, however, is offset by a relatively higher radiation exposure.

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## NUCLEAR MEDICINE

Nuclear medicine (scintigraphy) is the use of radiation-detection instruments to image the distribution of radio-active drugs such as technetium-99m diphosphonate, which is incorporated into the hydroxyapatite crystals of bone. Any disease process that disturbs the normal balance of bone production produces an abnormal bone scan in which activity appears either increased or decreased. Bone scans permit localization of bone and joint diseases such as infection, tumor, trauma, arthritis, and vascular diseases (3,5,6,35,37). Bone and joint scans are more sensitive than radiography for detection of an abnormality but are not as helpful in distinguishing between various disease processes (Fig. 7-24).

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## X-RAY COMPUTED TOMOGRAPHY

X-ray computed tomography (CT) is an imaging system that gives cross-sectional displays of body structures. The system, composed of a pencil-like transmitted x-ray beam, scintillation detector, and computer for image reconstruction, improves tissue-density resolution over conventional radiography (11,19,26). Radiographic differences in various tissues such as blood, brain gray and white matter, and cerebral spinal fluid are imaged as separate entities.

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