A Compartmental Approach to the Radiographic Evaluation of Soft-Tissue Calcifications

Kevin P. Banks, MD,* Liem T. Bui-Mansfield, MD,*†‡ Felix S. Chew,§ and Frank Collinson, MD†

Musculoskeletal radiology, like most areas of diagnostic radiology, has seen a dramatic increase in the use of cross-sectional imaging techniques over the last decade. However, conventional radiography remains a vital role in the evaluation of disease involving the spine and extremities. Given its widespread availability and low cost, radiography should be the initial examination obtained when imaging is clinically indicated. Therefore it is essential that the practicing radiologists be able to maximize the diagnostic value of this common study to aid the clinicians with a focused differential diagnosis, if not a definitive diagnosis. While much emphasis has been placed on radiographic interpretation of osseous lesions, similar diagnostic yield can be often obtained about calcified or ossified soft-tissue lesions. Detailed evaluation of the distribution and morphology of the soft-tissue calcifications, combined with a thorough knowledge of the entities that may occur at the site of the noted abnormality, provides significant interpretive value to provide a definitive diagnosis or accurately recommend the next most effective management step. We provide a compartmental-based approach to the interpretation of soft-tissue calcifications.

In the evaluation of osseous lesions, location is often the most important characteristic in determining the differential diagnosis. A lytic lesion in the epiphysis of the wrist quickly focuses the differential diagnosis of chondroblastoma or giant cell tumor. A similar appearing lesion in the metaphysis of the phalanges is highly suspect for an enchondroma. Similarly, location can provide essential information about calcified or ossified soft-tissue lesions.

Calcium deposition in the soft tissues is a common finding on conventional radiographs. The differential diagnosis of these calcifications is broad and includes vascular, inflammatory, infectious, metabolic, and neoplastic entities (Tables 1 and 2). While abnormal calcifications in the subcutaneous tissues of the appendicular skeleton generate one differential list of diseases, similar densities in a periarticular distribution or the axial skeleton produce a distinct list of pathology. Therefore, the first step in the evaluation of soft-tissue calcifications involves a fundamental knowledge of the assorted compartments in which these various entities may arise.

Depending on the portion of the body being assessed, appendicular or axial skeleton, these compartments differ. In the appendicular skeleton we subdivide the soft tissues into subcutaneous, neurovascular, fascial, muscular, and periarticular compartments (Figs. 1 and 2). In the case of the lower leg, the subcutaneous tissues are thickest along the sides and posteriorly, with only a thin layer present anteriorly over the tibia. As elsewhere, it comprises predominantly fatty tissue with small components of connective, vascular, and nervous tissue. Just deep to this is the thin fascial compartment separating the subcutaneous and muscular compartments. Composed of tough, fibrous tissue, the fascial compartment also extends into the muscular compartment where, in the case of the lower leg, it divides the muscular compartment into anterior, lateral, posterior superficial, and posterior deep compartments. The muscular compartment is defined as the space occupied by the muscles of that extremity and supporting tissues. It extends from the fascia superficially down to the underlying bones. In this example, major contributors to

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this compartment include the gastrocnemius, soleus, and tibial muscles. Interspersed within the muscular compartment are vessels such as the anterior tibial and peroneal arteries, which comprise the vascular compartment. Finally, there is the periarticular compartment that is defined by the capsule surrounding the joint and includes all internal structures. In the shoulder joint (Fig. 2), this entails the articular cartilage covering the humeral head and glenoid, labrum, synovium, glenohumeral ligaments, and tendons.

Distinct from those of the extremities are the compartments of the axial skeleton (Fig. 3). In the spine, the soft-tissue compartments comprise the anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), intervertebral disk, interspinous and supraspinous ligaments, and paravertebral soft tissues. Unlike the compartments of the extremities, these tissues and subsequent calcified disease entities within these compartments are more singular in nature.

This anatomic approach allows for practical differentiation of soft-tissue calcifications. In the evaluation of musculoskeletal diseases, this entails the subcutaneous, fascial, muscular, and periarticular compartments, as well as the axial skeletal compartment and the vascular compartment, which is unique in that it is a subcompartment of each of the aforementioned compartments.

### Table 1: One Approach to Developing a Differential Diagnosis of Soft-Tissue Calcifications Using VINDICATE (Vascular, Infectious, Neoplastic, Drug, Autoimmune, Traumatic, and Extraneous Etiologies of Disease)

<table>
<thead>
<tr>
<th>Vascular</th>
<th>Phleboliths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection</td>
<td>Cysticercosis</td>
</tr>
<tr>
<td>Neoplasm</td>
<td>Extraskeletal osteosarcoma or chondrosarcoma</td>
</tr>
<tr>
<td>Drugs</td>
<td>Vitamin D</td>
</tr>
<tr>
<td>Autoimmune</td>
<td>Dermatomyositis or polymyositis</td>
</tr>
<tr>
<td>Trauma</td>
<td>Tendonitis</td>
</tr>
<tr>
<td>Extra</td>
<td>DISH</td>
</tr>
</tbody>
</table>

### Table 2: Common Causes of Soft-Tissue Calcifications, Their Appearance, and Their Relative Prevalence (not accounting for vascular calcifications)

<table>
<thead>
<tr>
<th>Causes</th>
<th>Typical Appearance</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dystrophic calcifications</td>
<td>Small to large amorphous calcifications, may progress to ossification</td>
<td>95-98</td>
</tr>
<tr>
<td>CPPD</td>
<td>Chondrocalcinosis</td>
<td>1-2</td>
</tr>
<tr>
<td>HADD</td>
<td>Single glob of calcification at tendinous insertion</td>
<td>1-2</td>
</tr>
<tr>
<td>Metastatic calcifications</td>
<td>Finely speckled calcifications</td>
<td>1-2</td>
</tr>
<tr>
<td>Tumoral calcinosis</td>
<td>Multilobulated calcifications, predominantly near large joints</td>
<td>&lt;&lt;1</td>
</tr>
<tr>
<td>Metastatic osteosarcoma</td>
<td>Amorphous, fluffy, confluent collection of calcifications</td>
<td>&lt;&lt;&lt;&lt;1</td>
</tr>
<tr>
<td>Primary extraskeletal osteosarcoma</td>
<td>Amorphous, fluffy, confluent collection of calcifications</td>
<td>&lt;&lt;&lt;&lt;1</td>
</tr>
</tbody>
</table>

### Appendixicular Skeleton

#### Subcutaneous

The subcutaneous compartment of the extremity comprises predominantly adipose tissue with small amounts of intermixed connective, vascular, and nervous tissue. It is bordered superficially by the dermis and deep by the fascial compartment. Given its predominantly fatty composition, it is usually of little diagnostic interest on radiographs. The presence of abnormal calcifications is one of the exceptions and their presence is quite conspicuous on the relative lucent background of the subcutaneous tissue. When seen, they often represent one of four etiologies: tumoral calcinosis, end-stage renal disease (ESRD), scleroderma, or venous insufficiency. A thorough knowledge of the typical appearance of calcifications associated with these entities, as well as the clinical context in which they present, is central to diagnostic accuracy and avoiding any unnecessary and potentially harmful testing.
Tumoral Calcinosis

Tumoral calcinosis is an uncommon entity first described in 1943 by Inclan and coworkers.\(^1\) It is a disease characterized by the presence of large masses of metastatic calcifications located in the subcutaneous juxta-articular soft tissues and extensor aspect of the extremities.\(^2\) The cause is thought to be due to an inborn error of phosphorus metabolism that results in hyperphosphatemia and an associated high calcium-phosphate product ($>75 \text{ mg}^2/\text{dL}^2$).\(^3\) The disease typically is first seen in individuals by age 20 with a slight male predominance in some reports.\(^4,5\) Black individuals are most frequently afflicted and about a third of cases have a familial history with the remainder appearing to be sporadic.\(^2\) While the majority of individuals are asymptomatic, diminished range of motion is a known complication from large juxta-articular masses as well as neuropathic symptoms due to compression of nearby nerves.\(^4\)

The characteristic imaging findings of tumoral calcinosis are calcified masses found in the subcutaneous tissues adjacent to joints or along the extensor aspects of the extremities. They are often multiple in numbers. When juxta-articular, the lesions most often occur adjacent to large joints such as the hips and shoulders with their presence having also been reported around the elbows, knees, and joints of the feet\(^2,3\) (Fig. 4). Radiographically, they are lobulated masses ranging in size from 1 to 20 cm\(^2\). They are composed of radiodense calcified material with intervening radiolucent bands of fibrous septa, which has been called “chicken wire” in appearance.\(^3\) The radiodense regions may be homogeneous or occasionally show sedimentation on upright radiographs, but is most readily demonstrated on computed tomography (CT) or magnetic resonance (MR) imaging.\(^4\) If imaged early in the course of the disease, juxta-articular lesions may be misdiagnosed as calcific bursitis. Subsequent studies will often demonstrate maturation of the lesion to an appearance more suggestive of tumoral calcinosis. This feature, as well as the frequent occurrence of multiple lesions, aid in proper diagnosis. It should be noted that the lesions can grow slowly over

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time and have also been known to cause pressure erosions of underlying bones and therefore these findings may mimic malignancy.

**End-Stage Renal Disease**

ESRD is an extremely common disease in the United States with approximately 8000 renal transplants being performed each year and over 10 times that number of people undergoing dialysis. It is the common end result of numerous entities, with common etiologies including diabetes and longstanding hypertension. The systemic manifestations of this disorder are widespread with musculoskeletal involvement being one of the more recognized expressions. With continued advances in hemodialysis and transplantation leading to improved survival, the radiographic findings of this disease are encountered with increasing frequency. It is an inappropriately high level of calcium and phosphorus that result in the soft-tissue calcifications commonly seen in these individuals. Like patients suffering from tumoral calcinosis, the lesions are not generally seen unless the calcium-phosphorus product exceeds 75 mg²/dL² and there is a direct correlation between their prevalence and duration of ESRD. While many cases are asymptomatic, large lesions have been reported to cause decreased range-of-motion as well as neuropathic symptoms from the compression of adjacent nerves.

Given their similar etiology, it is not unexpected that the calcified masses of tumoral calcinosis are closely related radiographically to the soft-tissue lesions found in ESRD. The lesions are found in the subcutaneous tissues in a juxta-articular distribution as well as less commonly along the extensor aspect of the extremities. When occurring near a joint, the masses are typically polyarticular and symmetric. On radiography, they appear as well-defined, lobulated, calcified masses with interwoven fibrous septa (Fig. 5). As in tumoral calcinosis, fluid-calcium levels can be seen on upright films or cross-sectional imaging. In addition to soft-tissue calcifications, cases of ESRD often have associated bone resorption (subchondral, subligamentous), vascular calcifications, and abnormal bone density (Fig. 6).

**Scleroderma**

Scleroderma is an idiopathic disorder of the connective tissues with a wide range of systemic effects. It is a result of the deposition of abnormal collagen, which initiates a cascade of inflammation, fibrosis, and eventual atrophy that accounts for its features. Women are most commonly affected with onset of disease usually seen in the third and fourth decades of life. Many of its clinical and radiographic manifestations are quite characteristic, such as the Raynaud phenomenon or the finding of a dilated esophagus with lower esophageal sphincter incompetence during barium swallow examination. Because of this, many patients already carried a diagnosis of scleroderma when soft-tissue manifestations in the extremities are first noted. The calcinosis of scleroderma comprises calcium apatite crystals and is frequently, but not exclusively, found in areas of sclerodactyly. It is not associated with any underlying abnormality of calcium metabolism.

The subcutaneous soft-tissue calcifications of scleroderma have been termed calcinosis. On radiographic evaluation, the lesions are present in the hands and feet as well as areas of the extremities such as the elbow that frequently rub or experience other forms of mild trauma. Unlike the typical findings of tumoral calcinosis or ESRD, the soft-tissue calcifications of scleroderma may be either focal or diffuse with an irregular morphology. A cobblestone appearance is often noted, which may seem similar to ESRD or tumoral calcinosis; however, they are homogenously dense without the associated septa or calcium-fluid levels (Fig. 7). Another key diagnostic feature of scleroderma-related soft-tissue calcifications are their unique predilection for the hands, being seen in over 50% of afflicted individuals, a location rarely involved in their radiographic mimics. This, combined with the common presence
of acroosteolysis and distal phalangeal soft-tissue wasting, aids in the correct interpretation of these lesions.

**Venous Insufficiency**

While it would first seem that venous insufficiency should be considered in the same category as the other vascular compartment calcifications, in the extremities, they are generally seen in the superficial venous system and therefore mostly limited to the subcutaneous compartment. Their development occurs in the presence of long-standing varicosities and/or thrombus formation. These factors result in venous stasis, which in turn leads to calcium deposition along the venous intimal layer. Due to this mechanism, it is apparent that their incidence mirrors that of varicose veins, with women more commonly afflicted than men and the lower extremities almost exclusively affected except in cases of arm venous stasis due to prior trauma, surgery, or other condition that alters normal venous drainage.

On radiographs of the extremities, the calcifications of chronic venous insufficiency most frequently appear as phleboliths in the subcutaneous tissue. These have a characteris-
tic ring shape with central lucency that represents foci of calcified thrombi. A second well-recognized appearance is that of small, linear calcifications oriented along the long axis of the extremity (Fig. 8). In these instances, numerous calcifications are typically present and often parallel each other or show a branching or reticular pattern\textsuperscript{10} (Fig. 9). Associated evidence of chronic venous stasis may be present such as soft-tissue edema or even periosteal reaction of the bones.

Vascular

A subcompartment of the three aforementioned soft-tissue compartments, the arteries are also subject to the development of abnormal calcifications and are an extremely common radiographic finding in middle-aged and elderly individuals. Due to their common nature, they are radiographically identical whether they arise in the subcutaneous tissues or within the muscular portion of the extremities, and therefore, we consider these lesions as a separate group from those arising in their surrounding compartment. The calcium deposits seen associated with arteries can be classified into two subgroups, atherosclerotic plaques and Monckeberg's arteriosclerosis.\textsuperscript{10} Their distinct pathogenesis and subtle differing radiographic expression are illustrated below.

Atherosclerotic Peripheral Vascular Disease (ASPVD)

Atherosclerotic plaque is the entity responsible for the well-known disorder of peripheral vascular disease. It is a disease of the arterial intima that arises from the abnormal deposition of fatty substances, cellular waste, cholesterol, and calcium. It typically involves the large- and medium-size arteries and results in narrowing and possible occlusion of the vessel lumen. Additionally, like in the torso, arterial aneurysms are subject to plaque deposition and its associated calcifications allowing for their identification on radiography. The typical clinical picture is of vascular insufficiency with claudication, diminished pulses, pallor, and decreased extremity warmth. In instances of aneurysms, patients may experience “blue toe syndrome” due to distal embolus of microthrombi.

The presence of calcifications is what allows for the visualization of atherosclerotic plaque at time of imaging. They present as patchy, irregular, plaque-like or even tubular densities of variable shape and size distributed along the path of large- and medium-sized arteries. The calcifications usually do not encircle the entire vessel lumen and this trait can aid in distinction from the small artery calcifications associated with diabetes mellitus.\textsuperscript{10} In instances of aneurysms, an oval- or round-shape outline of calcium can be seen, often with associated densities of diseased arteries leading to and from the site of vascular dilation (Fig. 10).

Diabetes Mellitus (DM)

Diabetes is an extremely prevalent disease, being diagnosed more and more frequently, and afflicting over 120 million
individuals worldwide with a 33% increase in incidence seen in the United States from the period of 1990 to 1998.11 Subsequently, its sequela is also being encountered more often to include calcified arteriosclerosis. In addition to an increased incidence of ASPVD, individuals with DM are also prone to the development of Monckeberg’s medial arteriosclerosis. As the name implies, it involves the formation of calcified plaques in the medial layer of the blood vessels.12 While these lesions do not cause vaso-occlusion, they do cause diminished distensibility of the vessel with decreased pulses and a “pipe stem” characteristic on physical examination and are often associated with neuropathic symptoms.13

Radiographically, the soft-tissue calcifications of Monckeberg’s medial sclerosis predominate in the small arteries of the distal extremities, particularly the feet. They are seen as a series of concentric rings that may or may not be connected.10 When connected, they are seen as two parallel lines following the arterial path, similar to that seen in ASPVD, but finer in morphology and more continuous (Fig. 11).

Fascia

Deep to the subcutaneous tissue lays a thin, but tough layer of fibrous tissue that constitutes the fascial compartment. It encompasses the underlying muscle compartment and, while rarely a focus of imaging studies, when the fascia is involved in a disease process, the findings can be quite distinctive. This is particularly true of calcium deposition in the fascia.

Dermatomyositis/Polymyositis

Fascial calcifications are almost invariably secondary to the closely related diseases of dermatomyositis and polymyositis. Each of these entities is an uncommon idiopathic inflammatory myopathy found in both juvenile and adult forms with women affected twice as often as men. The two diseases share the main clinical features of chronic weakness and muscle inflammation, though dermatomyositis also has prominent cutaneous manifestations.14 The main difference between the two disorders is seen in their underlying pathogenesis. Dermatomyositis seems to be due to immune-complex deposition within small vessels, while polymyositis appears related to immune-mediated muscle injury.15,16

It is in the chronic phase of these diseases that calcium deposition in the soft tissues first occurs. During healing from episodes of myositis, calcifications develop in areas of necrosis involving the fascial planes and sometimes the subcutaneous tissues.17 Radiographically, this manifests as numerous small densities in the appendicular skeleton that go on to coalesce and become sheet-like in appearance17,18 (Fig. 12). It is this sheet-like configuration of calcium at the interface of the subcutaneous and muscular compartments that is highly specific for these entities. The findings are located predominantly in the proximal portions of the extremities and occasionally, punctate calcifications also form in juxta-articular sites that go on to become macronodules.17 The accompanying sheet-like calcifications and their proximal greater than distal distribution in the extremities help distinguish these

Figure 11 Lateral radiograph of the foot ankle in a diabetic male shows parallel linear calcifications of the posterior tibial artery due to Monckeberg arteriosclerosis.

Figure 12 Lateral radiograph of knee in a patient with dermatomyositis shows sheet-like calcifications along fascial planes and subcutaneous tissue, soft-tissue atrophy, and osteoporosis. (Reprinted with permission.39)
juxta-articular lesions from those seen in scleroderma or tumoral calcinosis.

**Muscle**

The largest soft-tissue compartment of the extremities, the muscular compartment, is bordered superficially by the fascia and deep by the periosteum and joint capsules. As its name implies, it is composed predominantly of myocytes, but also has a rich supply of neurovascular tissue that is central to many of the disease entities encountered in this region. Numerous entities can lead to calcifications within the intramuscular compartment, such as vascular diseases, connective tissue disorders, and myopathies; however, these disorders will frequently present with distinctive or at least suggestive calcifications in the previously discussed compartments and will not be further covered in this section. More commonly, when evaluating intramuscular calcifications, other pathologic processes are present and must be considered during radiographic interpretation. These include infection, neoplasms, and myositis ossificans.

**Infection**

Skeletal muscle is relatively resistant to infection and therefore infectious myositis is uncommon. In the past, it was generally encountered primarily in tropical regions. Increasingly, however, it is now being seen in temperate climates, particularly in immunocompromised individuals such as those with diabetes, AIDS, or undergoing chemotherapy. When caused by bacterial or viral pathogens, the radiographic findings are almost always limited to soft-tissue swelling or obliteration of fat planes, with the rare exception being calcium deposition secondary to a chronic intramuscular abscess. More likely, if an infectious pathogen results in intramuscular calcifications, it is the result of a parasitic infection. The most common helminth responsible is the *Taenia solium*, which is better known as cysticercosis. It is found worldwide and infection occurs following ingestion of the tapeworms' eggs, usually secondary to fecal contamination of food and water. Patients are most likely to present with neurological symptoms, particularly seizures, while muscle involvement is usually asymptomatic and is diagnosed incidentally.

Correct radiographic assessment of the location, shape, and size of these calcifications is integral to distinguishing this entity from the calcium deposits seen in noninfectious entities such as scleroderma or dermatomyositis. Viable cysts are not appreciated during routine radiographic assessment. When the larvae die, an inflammatory response ensues and the cysts calcify, making them apparent during conventional radiography. The dead larvae of cysticercosis produce numerous small oval or linear intramuscular calcifications that measure 5 to 7 millimeters in size. These findings are nearly pathognomonic of this disease, and when encountered in a patient without history of helminthic infection, it is important that the patient’s clinician be notified so that definitive evaluation and treatment be initiated.

**Neoplasms**

Several benign and malignant tumors produce mineralization that results in intramuscular calcifications. While often unrewarding, radiography remains the initial imaging evaluation of these lesions and can in some cases provide valuable information that is highly suggestive if not diagnostic of certain entities. While a review of all calcified or ossified soft-tissue tumors of the extremities is beyond the scope of this article, certain lesions warrant mentioning since they have characteristic appearance. These tumors include intramuscular hemangiomas, leiomyoma or leiomyosarcoma, giant cell tumor of soft tissue (GCT-ST), synovial sarcoma, and extraskeletal chondrosarcoma or osteosarcoma.

**Hemangioma.** Hemangiomas are benign vascular lesions that histologically resemble normal blood vessels. Though soft-tissue hemangiomas are commonly diagnosed in radiologic practice, they are most frequently encountered in solid organs, with intramuscular hemangiomas accounting for only 1 to 4% of all such vascular tumors. When they do occur, it is most likely to occur in children and adolescents with boys and girls equally affected. Rarely, they may be found in association with an enchondroma, known as Maffucci’s syndrome (Fig. 14).

Radiographs of hemangiomas demonstrate a soft-tissue mass containing phleboliths, which are seen as round densities ranging from 2 to 8 mm in size with a characteristic central lucency. Phleboliths are present in up to 90% of intramuscular hemangiomas and is highly specific for this entity (Fig. 14). Uncommonly, curvilinear or amorphous cal-

Figure 13 Oblique and lateral views of the ankle demonstrate numerous “rice-shaped” calcifications in the muscles of the lower leg. The long axes of the calcifications are oriented along the direction of the muscle bundles. This finding is consistent with cysticercosis. (Courtesy of MedPix, Dr. Glenn Richard, D.O., National Naval Medical Center, Bethesda, MD).
Giant Cell Tumor of Soft Tissue. GCT-ST is a rare tumor with a much less typical appearance than its more recognized counterpart, GCT of bone. Comprising giant cells of osteoclast type, the tumor is clinically similar to its osteogenic relative with a generally benign course and good response to surgical excision. A wide age range of individuals is afflicted with median age at diagnosis being 43 years. Men and women are equally affected with the tumors occurring in the lower extremities approximately 50% with the upper extremity only seen in 10% of cases.

As with many soft-tissue tumors, the radiographic findings are nonspecific. An infiltrative soft-tissue mass is seen with dense dystrophic calcifications often noted, due to the presence of osteoclasts, aiding in its radiographic conspicuity (Fig. 16). Malignant fibrous histiocytoma (MFH) is its most frequent mimicker, usually necessitating biopsy.

Synovial Sarcoma. Synovial sarcoma is one of the more common malignant soft-tissue tumors encountered in the extremities. Synovial sarcoma is a misnomer because it does not arise from the synovium but is usually located near a joint; intraarticular synovial sarcomas are extremely rare. Synovial sarcoma is highly aggressive with 25% of patients having metastases by the time of diagnosis and median survival being only 33 months. Synovial sarcoma is seen predominantly in the second through fourth decades of life with patients most commonly presenting with a palpable mass. When encountered, the tumor is located in the legs in 60 to 70% of cases.

A nonspecific mineralized mass is seen on radiography in up to a third of synovial sarcoma cases. The dystrophic calcifications are generally near a joint and many times are associated with bone.
with adjacent bony changes that suggest a malignant process. No further characterization is usually possible with the tumor being radiographically indistinguishable from an extraskeletal osteosarcoma; however, typical location in a young adult can suggest the correct diagnosis27 (Fig. 17).

**Extraskeletal Chondrosarcoma and Osteosarcoma**

Extraskeletal chondrosarcomas and osteosarcomas are both rare variants of their osseous counterparts. They occur late in life and are often encountered in the lower extremity.27 Prognosis is generally worse with recurrence and metastasis being the rule rather than the exception. Their nonspecific radiographic appearance and generic clinical presentation yield very little diagnostic value and a broad differential must be applied at time of radiographic interpretation to include MFH and other soft-tissue sarcoma.

Extraskeletal chondrosarcoma may present as either a noncalcified or a calcified soft-tissue mass. Calcified masses are common findings in extraskeletal chondrosarcoma, often showing stippled and ring- or arc-like calcifications (Fig. 18). These rare malignancies grow slowly and have a favorable prognosis. In large joints, they can arise from the synovium as a primary neoplasm or as a result of malignant transformation of synovial chondromatosis.

Extraskeletal osteosarcoma has a predilection for the lower extremity, especially the thigh, and as many as 6% may have a history of previous radiation therapy. Although osteosarcomas, in general, show calcified tumor, these soft-tissue lesions often do not demonstrate any visible calcific compo-
nent. Their imaging features are nonspecific (Fig. 19) and the diagnosis must be obtained by biopsy.

**Myositis Ossificans**

Myositis ossificans (MO) is the term used to denote a specific form of heterotopic ossification that occurs in muscle. The term “myositis” is a misnomer because the disorder is not an inflammatory process. MO has no age, gender, or ethnic predilection and may or may not be precluded by a history of trauma. Patients may be asymptomatic or can present with pain, swelling, or a palpable mass (usually in the large muscle groups of the extremities) and it may be confused with an infectious or neoplastic process. Certain precursors have been noted in approximately 50% of individuals and include trauma, neurologic injury, or bleeding disorders.

Radiographically, myositis ossificans undergoes a typical course of maturation that is key to its diagnosis. During the acute and subacute phases (up to 4 to 8 weeks), MO often is seen as a soft-tissue mass with ill-defined mineralization that can often be confused with a sarcomatous lesion. While nonspecific-appearing during this period, a key radiographic feature is that the mass is not in continuity with the adjacent bone, nor with any associated cortical destruction or periosteal reaction. These findings are suggestive of the diagnosis, which can be confirmed with short-term follow-up radiography. Once mature (usually by 2 months following initial presentation) the lesion will demonstrate the diagnostic findings of a soft-tissue lesion with a rim of calcification (Fig. 20).

**Periarticular**

The periarticular space is the most complex compartment of the extremities, being composed of a variety of tissue types and structures to accomplish the complex requirements of functional motion combined with load bearing. It is defined by its external boundary, the joint capsule, and contains fibrocartilage, hyaline cartilage, tendons, tenosynovium, and synovial fluid. For the purpose of our compartmental approach, we include the nearby bursa, which are closely related to the function and pathology of the intraarticular structures. Given the distinct components that make up this anatomical compartment, it is readily apparent that each of the structures may be affected by different disorders.

**Hydroxyapatite Deposition Disease—Tendons and Bursae**

Hydroxyapatite deposition disease (HADD), also known as calcific tendinitis, is a common disorder that manifests itself by the deposition of crystals in tendons and occasionally
Initially, hydroxyapatite is deposited in tendons. Subsequently, the calcification may rupture into the adjacent bursa, joint, or bone. Its pathogenesis is unclear with proposed theories including degenerative changes due to recurrent trauma, local hypoxia leading to alterations in pH, or occult neurologic factors. HADD can have a varied clinical appearance from asymptomatic to acute or chronic pain with fever, redness, swelling, and diminished range of motion. When tendons are affected, the disorder most commonly strikes the shoulder, hip, elbow, wrist, and knee in decreasing order of frequency. Afflicted bursae include the olecranon and subacromial.

On conventional radiographs, the calcium deposits of HADD have a distinct appearance. The calcifications typically appear as homogeneous, discrete, and nodular densities. They may be linear, oval, or rounded in shape and are most commonly found at the site of tendon insertions or origins. The supraspinatus is the most frequently encountered site of occurrence and bilateral involvement may be present. The calcifications may change with time, either enlarging or occasionally resolving. On MR imaging, bone marrow edema can be seen without cortical destruction, mimicking more ominous entities such as tumor and infection.

Calcium Pyrophosphate Deposition Disease—Hyaline Cartilage and Fibrocartilage
Hyaline cartilage and fibrocartilage can mineralize due to a variety of disorders, resulting in dystrophic calcifications that may be seen on radiography. When present, this is termed chondrocalcinosis, a general term used to relate the presence of radiographically evident cartilage calcifications (Fig. 22). CPPD is a specific inflammatory condition that is widespread in the elderly population. It has a highly variable clinical presentation from asymptomatic to acute episodes of severe pain (known commonly as pseudogout) due to its associated destructive arthropathy.

The crystal deposition of CPPD is typically noted on radiographs as thin, linear, or wedge-shaped foci of increased density that parallels the articular surfaces of the joint. The most often affected sites include the triangular fibrocartilage complex (Fig. 23), lunotriquetral ligament, symphysis pubis, and articular cartilage of the glenoid. While it can radiographically mimic numerous other intraarticular disorders, its involvement of non-weight-bearing joints helps differentiate the chondrocalcinosis of this disease from that of other arthritides such as osteoarthritis.

Synovial/Tenosynovial Osteochondromatosis—Joint Space and Tenosynovium
Synovial osteochondromatosis is a benign metaplastic proliferative disorder of the synovium, which can affect the joints, tendons, and bursae. In this disease, the connective tissue of the synovium undergoes cartilaginous metaplasia with the resultant formation of multiple loose bodies. The loose bod-

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**Figure 21** AP view of right elbow shows an amorphous calcification (arrowhead) corresponding with origin of ulnar collateral ligament. While this finding could be concerning for mineralization associated with neoplasm, radiographic findings and location of lesion are consistent with HADD.

**Figure 22** CPPD. (A) AP view of the knee shows chondrocalcinosis within the lateral meniscus. (B) Lateral view of the knee shows synovial calcification and patellofemoral osteoarthritis, which is worse than the other compartments.
ies go on to calcify or ossify, leading to the disorder’s characteristic radiographic findings. Patients often present with nonspecific symptoms of pain, decreased range of motion, or a locking/catching sensation. While any joint may be afflicted, the knee, hip, elbow, and shoulder are most commonly involved. With the extraarticular form of tenosynovial osteochondromatosis, involvement of the hands (Fig. 25), feet, and wrists have been reported.

The radiographic appearance of synovial osteochondromatosis is often diagnostic with numerous rounded calcified bodies within the joint space associated with an effusion (Fig. 26). The bodies may be anywhere from 1 to 20 mm in size, but tend to be relatively uniform in size inside an individual joint. Unfortunately, up to a third of patients may have minimal or no calcification of the nodules, making advanced imaging necessary. When tenosynovial osteochondromatosis is present, the radiographic findings are much less specific and further evaluation with cross-sectional imaging is more commonplace.

**Heterotopic Ossification**

Heterotopic ossification (HO) is due to the abnormal presence of extraskeletal osteoblastic cells and occurs in patients with fractures, burns, joint replacements, paraplegia, and
poststroke hemiplegia. It is commonly seen in the region of large joints and can result in limited range of motion as well as pain and swelling.

As in cases of myositis ossificans, there is rapid development of soft-tissue calcifications. Unlike MO, HO is not confined to skeletal muscle and no distinctive zone of peripheral mineralization is demonstrated (Fig. 27). It will take up to 6 months to radiographically mature and thus interval radiographic change during this period should be anticipated as a benign feature of this lesion.

Axial Skeleton

Anterior Longitudinal Ligament

Diffuse idiopathic skeletal hyperostosis (DISH) is an idiopathic disease manifest by noninflammatory ossification of the spinal ligaments. Also known as Forestier’s disease, the disorder afflicts individuals greater than 40 years of age with a male predominance. Those affected may be asymptomatic or present with spinal pain and decreased range of motion. Severe cases of cervical involvement have resulted in dysphagia due to the bulk effect of the osteophytes impinging of the esophagus.

The classical radiographic appearance of DISH is that of ossification of the anterior spinal longitudinal ligament involving four or more contiguous vertebrae and hyperostosis of some of the ligamentous attachments. Radiographs of the axial skeleton reveal an undulating ribbon of bone along a portion of the spine involving several intervertebral discs of normal or near normal height. Most commonly, this is seen in the thoracic spine (Fig. 28); however, abnormalities may also be present in the cervical and lumbosacral spine. The classic appearance is flowing linear density along the anterolateral aspects of the vertebral bodies that continues across the disc space. A lucency is often seen separating the ossified anterior longitudinal ligament and the anterior margin of the adjacent vertebral body. Involvement in the spine and lumbar region is usually more prominent on the right side of the spine, due to the pulsation effects of the aorta on the left.

Posterior Longitudinal Ligament

Often seen in conjunction with cervical DISH is an entity termed ossification of the posterior longitudinal ligament (OPLL). It is detected in approximately 50% of cases of cervical DISH and may result in spinal canal narrowing and neurologic deficits. OPLL almost exclusively involves the cervical spine with other regions involved less than 10% of the time.

The findings are striking and distinct enough on radiographs to be diagnostic. A thick, smooth ribbon of increased density is seen corresponding with the path of the posterior longitudinal ligament (Fig. 29). Though degenerative changes may be seen of the disk and intervertebral joints, these findings are not necessarily part of the disorder and are frequently a manifestation of concurrent chronic degenerative changes disorder given the advanced age of most patients. Associated spinal...
canal stenosis is seen, which may result in finding of cord impingement on CT or MR evaluation.

**Intervertebral Disk**

Intervertebral disk calcifications (IDC) are a well-known radiographic entity, often being incidentally encountered during plain film evaluation of the chest and abdomen.\(^{42}\) It has a large number of predisposing systemic conditions that result in biochemical alterations (eg, hemochromatosis, CPPD, hyperparathyroidism, acromegaly, ochronosis, and amyloidosis) or altered mechanics of the spine (eg, Klippel–Feil, juvenile rheumatoid arthritis, ankylosing spondylitis, and post-traumatic/operative vertebral fusion, advanced degenerative changes).\(^{42,43}\) The disorder is seen more commonly in men than women and increases steadily in prevalence with advancing age.\(^{42}\)

Radiographic evaluation of the torso will depict IDC in 5 to 6% of individuals with the lower thoracic spine most commonly affected.\(^{42}\) The typical appearance is of dense, amorphous calcification in the disk space. It is usually located at the disk’s margin, entailing the annulus fibrous, though calcification of the nucleus pulposus and entire disk can also be seen\(^{42}\) (Fig. 30). Given the typical afflicted individual and predisposing conditions, it is readily apparent that concurrent degenerative changes are often seen.

**Perispinal Ligaments**

Mineralization of the interspinous and supraspinous ligaments can be a diagnostic clue to the presence of AS. A well-known member of the seronegative spondyloarthropathies, AS is a disease of young individuals with onset between 15 and 35 years of age.\(^{46}\) Its musculoskeletal manifestations are numerous, but clinically it often presents with chronic back pain associated with decreased range of motion and loss of thoracic expansion.

Calcification and ossification of the interspinous and supraspinous ligaments are prominent radiographic features that increase in conspicuity as disease advances. On frontal views of the chest or abdomen, a central radiodense stripe may be identified, known as the dagger sign\(^{46,47}\) (Fig. 32).
This is often seen in conjunction with other typical findings such as sacroiliac joint disease, syndesmophytes, and ankylosis, aiding in proper radiographic interpretation.

**Conclusion**

While MR imaging has become the imaging technique of choice in the evaluation of soft-tissue lesions, conventional radiography remains vital in the initial assessment of such abnormalities given their inexpensive cost and widespread availability. Given this, it is necessary that practicing radiologists maximize the diagnostic utility of conventional radiography to aid the clinician in improved patient management and the avoidance of unnecessary interventions. We provide a review of many of the common soft-tissue calcifications encountered in clinical practice with a compartmental-based approach to their interpretation to illustrate the subtle, but important information that can be yielded about these lesions from radiographs. While not designed to be all-inclusive, it is felt that with sound knowledge of the entities discussed and their most characteristic features, one should be able to assess the majority of soft-tissue calcifications encountered during routine radiographic assessment of the extremities.

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**Figure 31** Reiter syndrome. AP radiograph of lumbar spine shows ossification in the left L3-4 paraspinal soft tissues leading to a bridging phyte. (Reprinted with permission.38)

**Figure 32** Ankylosing spondylitis. (A) Lateral radiograph of cervical spine shows syndesmophytes bridging the entire cervical spine and ankylosis of the posterior elements. (B) AP radiograph of lumbar spine shows syndesmophytes and ossification of the posterior ligamentous structure, the “dagger” sign. The sacroiliac joints have fused. (Reprinted with permission.38)
References