Diagnostic Imaging of Solitary Tumors of the Spine: What to Do and Say

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Metastatic disease, myeloma, and lymphoma are the most common malignant spinal tumors. Hemangioma is the most common benign tumor of the spine. Other primary osseous lesions of the spine are more unusual but may exhibit characteristic imaging features that can help the radiologist develop a differential diagnosis. Radiologic evaluation of a patient who presents with osseous vertebral lesions often includes radiography, computed tomography (CT), and magnetic resonance (MR) imaging. Because of the complex anatomy of the vertebrae, CT is more useful than conventional radiography for evaluating lesion location and analyzing bone destruction and condensation. The diagnosis of spinal tumors is based on patient age, topographic features of the tumor, and lesion pattern as seen at CT and MR imaging. A systematic approach is useful for recognizing tumors of the spine with characteristic features such as bone island, osteoid osteoma, osteochondroma, chondrosarcoma, vertebral angioma, and aneurysmal bone cyst. In the remaining cases, the differential diagnosis may include other primary spinal tumors, vertebral metastases and major nontumoral lesions simulating a vertebral tumor, Paget disease, spondylitis, echinococcal infection, and aseptic osteitis. In many cases, vertebral biopsy is warranted to guide treatment.

Abbreviations: ABC = aneurysmal bone cyst, H-E = hematoxylin-eosin, SAPHO = synovitis, acne, pustulosis, hyperostosis, osteitis

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**Introduction**

Metastatic disease, myeloma, and lymphoproliferative tumors of the spine commonly cause multiple lesions, which, in association with the clinical data, usually allow the diagnosis to be easily made. In contrast, primary spinal tumors must be considered in cases of a solitary spinal lesion. A wide variety of primary neoplasms can involve the spine. Spinal tumors can be classified according to their tissue of origin (Table). Patients’ symptoms are often nonspecific.

In this article, we review the clinical features of spinal tumors and the use of various imaging modalities in the evaluation of these tumors. We then discuss and illustrate the imaging findings of primary tumors of the spine, with emphasis on the important role the radiologist plays at the time of diagnosis in evaluating lesion topography and extension. The radiologic appearances of these lesions can sometimes suggest a specific diagnosis, thereby helping guide our clinician colleagues in the complex treatment of affected patients.

**Clinical Features**

Clinical data, such as patient age, symptoms, history, and laboratory findings, help make the radiologic diagnosis. A prior history of radiation therapy suggests radiation-induced tumors. Some tumors have a predilection for specific age groups. In patients under 30 years of age, tumors of the spine are fairly uncommon and are generally benign except for Ewing sarcoma and osteosarcoma (1). In patients over 30 years of age, most tumors are malignant except for vertebral hemangiomas and bone islands. Metastases are the most common lesions. Sometimes, clinical data are so typical for a certain disorder that they allow the final diagnosis. For example, in a young adult patient, bone pain that occurs mainly at night and is promptly relieved with salicylates is highly suggestive of osteoid osteoma. In many cases, however, clinical data are not specific, with back pain being the most common complaint. In some patients, initial symptoms may simulate disk herniation. Vertebral fracture sometimes reveals spinal tumors. Radicular or spinal cord compression depends on the location and extension of the spinal lesion in the foramina and spinal canal. The growth rate of the tumor may also be a factor in differentiating high-grade malignant tumors (usually fast growing) from low-grade malignant and benign tumors (usually slow growing).

**Imaging Modalities**

Conventional radiography is complementary to magnetic resonance (MR) imaging and computed tomography (CT) even if they play a less significant role. CT and MR imaging are needed for evaluation of both the intraosseous extent of the tumor and soft-tissue involvement. We have found CT to be the most accurate method for evaluating the extent of osseous involvement and the degree of cancellous and cortical bone loss. CT helps evaluate the risk for vertebral body collapse. MR imaging is the best imaging modality for the evaluation of the epidural space and neural structures. Nevertheless, weight-bearing full-spine x-rays may help the surgeon in making a decision regarding overall spinal balance and the need for stabilization.

Multidetector CT is performed in most cases with a large field of view and no contrast medium. With an isotropic volume acquisition, it is possible to obtain axial, sagittal, and coronal reformatted images that are of the same quality as the source images. Two-dimensional multiplanar reformatted images are useful in the evaluation of the epidural space and neural structures.
of cortical bone destruction and calcified tumor matrix.

Our MR imaging protocol includes sagittal and axial images in all cases. Coronal images may be helpful for the evaluation of paravertebral soft-tissue extension. T1-weighted images are helpful for delineating normal bone marrow architecture, fat content within masses, and subacute hemorrhage and for evaluating tissue enhancement after the intravenous administration of contrast material containing gadolinium–diethylenetriaminepentaacetic acid. The administration of gadolinium-based contrast material results in enhancement proportional to soft-tissue vascularity and is helpful for differentiating cystic lesions from cystlike solid masses. It is also useful for biopsy in that it allows differentiation of enhanced viable tumor from areas of nonenhanced necrosis. In addition, gadolinium-based contrast material is frequently used to better demonstrate epidural extension. Contrast material enhancement is best evaluated on fat-saturated T1-weighted MR images. Inhomogeneous suppression of the fat signal can impair the quality of images obtained in the cervical and thoracic spine because of phase-encoded motion artifacts. Thus, contrast material–enhanced non-fat-suppressed T1-weighted images are reliable and remain valuable. Dynamic contrast-enhanced MR imaging may provide information about the rapidity of the enhancement (2). Most pathologic processes are often highlighted on T2-weighted images due to their increased fluid content. T2-weighted images delineate spinal canal stenosis and high-signal-intensity areas resulting from myelomalacia in spinal cord compression. Short inversion time inversion-recovery imaging is very sensitive for detecting most types of soft-tissue and marrow abnormalities and is recommended if the exploration requires a large field of view, which may result in inhomogeneous suppression of fat signal with T2-weighted sequences. Full-spine and whole-body MR imaging are also very useful in the assessment and diagnosis of multifocal lesions of the skeleton.

Bone scintigraphy can be performed when multifocal lesions with increased radionuclide uptake are suspected. However, bone scintigraphy is limited in its capacity to depict detailed surgical anatomy, particularly compared with CT or MR imaging (3).

Decision making before surgical treatment in patients with spinal tumors requires accurate delineation of possible vascular involvement. CT angiography and MR angiography are commonly used to depict the relationship of cervical spinal tumors to the supraaortic trunks. These modalities are useful in the evaluation of the artery of Adamkiewicz in the thoracic region (4) but may not always replace conventional angiography in determining the precise relationship between the tumor and the spinal vessels. Moreover, some vascular tumors may require embolization prior to surgery.

**Evaluation of a Spinal Lesion**

**Topographic Features**

The common distribution of spinal tumors is summarized in Figure 1. The site of origin of a lesion within a vertebra can be difficult to determine in slow-growing and large lesions. The distribution of hematopoietic marrow plays an important role in the distribution of metastatic disease and hematologic malignancies in the vertebral bodies. Some tumors have a distinct predilection for the ends of the spinal column. Chordoma is the most common primary distal tumor of the upper cervical spine. It should be differentiated from pseudotumoral lesions of the foramen magnum such as calcium pyrophosphate dihydrate deposits, synovial pannus, and craniovertebral junction tuberculosis. Chordomas that develop from remnants of the primitive notochord.

![Figure 1. Chart shows the common distribution of tumors of the spine.](chart.png)
are also frequently found in the sacrococcygeal region. Giant cell tumors commonly involve the sacrum. The sacrum, as a site of hematopoietic or red marrow in the adult, is also a common site of metastatic disease as well as of hematologic malignancies including plasmocytoma, myeloma, lymphoma, and Ewing sarcoma.

**Type of Matrix**

As in the peripheral skeleton, the type of tumor matrix can help the radiologist diagnose bone- or cartilage-forming tumors and fibrous dysplasia.

Osteoblastic tumors can display amorphous ossifications at radiography or CT. The matrix most often appears amorphous or cloudlike because it is less dense than normal bone and lacks an organized trabecular pattern. The amount and degree of matrix mineralization is widely variable; thus, the radiographic appearance of osteoblastic tumors may range from densely blastic to nearly completely lytic. Dense osteoblastic lesions display a low T1-T2 signal intensity pattern at MR imaging. The differential diagnosis of osteoblastic tumors includes osteoblastic metastasis, bone island, lymphoma, and osteosarcoma. Osteoblastic tumors should be differentiated from reactive bone sclerosis adjacent to osteoid osteoma and osteoblastoma.

Cartilage-forming tumors typically exhibit punctate commalike or annular calcifications at radiography and CT. These calcifications appear as low-signal-intensity foci at MR imaging. Cartilage lobulations display high signal intensity on T2- and short inversion time inversion-recovery–weighted images owing to the high water content of the hyaline cartilage. A pattern of enhancing rings and arcs is seen in cartilaginous tumors on postcontrast images. The differential diagnosis of cartilage-forming tumors includes osteochondroma, chondroblastoma and chondrosarcoma, ABC, and chordoma.

Fibrous tissue is nonspecific, with low to intermediate signal intensity on T1-weighted images and variable signal intensity on T2-weighted images. Fibrous dysplasia is easily diagnosed with CT, manifesting as ground-glass attenuation.

**Other Differential Features**

Fluid-fluid levels were initially described at CT. MR imaging is now the most sensitive method for detecting fluid-fluid levels and may also help differentiate liquid from hemorrhage. The imaging finding of prominent fluid-filled hemorrhagic spaces in a vertebral lesion is suggestive of ABC but has also been described in telangiectatic osteosarcoma (5,6). Moreover, the high prevalence of a secondary ABC should indicate the possibility of finding fluid-fluid levels in a coexisting tumor. Vertical striations or a “honeycomb” pattern are highly suggestive of vertebral hemangioma. Fat content within lesions can be found in vertebral hemangioma, fibrous dysplasia, Paget disease, and Schmörl node.

**Margins and Limits**

Benign tumors usually exhibit geographic bone destruction and sclerotic margins without soft-tissue extension (except ABC, aggressive hemangioma, and eosinophilic granuloma). Conversely, malignant tumors usually exhibit poorly defined margins, permeative bone destruction, and a soft-tissue mass. Marrow and, more particularly, soft-tissue edema, is frequently seen adjacent to primary bone tumors.

**Locoregional Extension**

Cervical spinal tumors require CT angiographic or MR angiographic evaluation to depict their relationship to the supraaortic trunks. Thoracic spinal tumors require accurate delineation of the relationship of the lesion to the pleura, mediastinum, and ribs. In the lumbar region, spinal tumors may involve the retroperitoneum. For sacral tumors, it is important to delineate lesion extension to the sacroiliac joints and pelvis.

**Bone-forming Tumors**

**Bone Island**

Bone islands, or enostoses, are asymptomatic lesions that are discovered incidentally in patients of all ages. They are not true neoplasms and represent dense compact bone within spongiosa (developmental abnormality) (Fig 2). Radiography and CT demonstrate round osteoblastic lesions with “brush border” at their periphery (Fig 3). Enostoses have low signal intensity at T1- and T2-weighted MR imaging. They may show activity at bone scintigraphy in less than 10% of cases, and most lesions remain stable. Enostoses vary in size, and some giant enostoses have been reported in the literature. The primary alternative in the differential diagnosis is osteoblastic metastasis.

**Osteoid Osteoma**

Osteoid osteoma is a benign osteoblastic lesion characterized by a nidus of osteoid tissue or even mineralized immature bone, often surrounded by sclerotic reactive bone. At histologic analysis,
At radiography, the complex anatomy of the spine makes the detection and localization of a radiolucent nidus obscured by reactive sclerosis much more difficult than that of a nidus located in a long bone. Bone scintigraphy is almost invariably positive and has been advocated for localizing the vertebral level in patients with clinically suspected osteoid osteoma. Subsequent targeted CT is generally regarded as the preferred cross-sectional technique for the demonstration and precise localization of the nidus. Osteoid osteoma characteristically manifests as a low-attenuation nidus with central mineralization and varying degrees of perinidal sclerosis (Fig 4). The nidus of osteoid osteoma can have a very heterogeneous, variable appearance at MR imaging, making detection and characterization difficult. Most tumors have low to intermediate signal intensity.
The role of imaging in osteoid osteoma is to help identify and accurately localize the tumor prior to surgical or percutaneous treatment (excision, laser treatment, or thermocoagulation).

**Osteoblastoma**

The histologic similarities between osteoid osteoma and osteoblastoma are striking, but their clinical manifestations and natural histories differ (11). Osteoblastoma causes dull, localized pain or is asymptomatic (12). It tends toward progression and may be locally aggressive, whereas osteoid osteoma tends toward regression (11). Osteoblastoma accounts for 1% of all primary bone tumors, with a male-female ratio of 2:1. Between 32% and 46% of osteoblastomas involve the spine (13). Ninety percent of osteoblastoma...
mas manifest in the 2nd and 3rd decades of life. Osteoblastomas originate in the neural arch and often extend into the vertebral body. Spinal osteoblastomas appear with more or less equal frequency in the cervical, thoracic, and lumbar segments.

At bone scintigraphy, osteoblastoma demonstrates marked radionuclide uptake. Reactive sclerosis adjacent to the lesion is common at conventional radiography. The radiologic features of osteoblastoma are a lesion diameter greater than 2 cm, osseous expansion, soft-tissue components, and multifocal matrix mineralization (Fig 5) (14). Tumors that are mainly lytic at CT with little evidence of matrix mineralization are hypointense at T1-weighted MR imaging and hyperintense at T2-weighted imaging (15). Lesions showing little matrix mineralization at CT but diffuse osteoid production at histologic analysis have low signal intensity at T2-weighted MR imaging (Fig 6) (16). Depending on the degree of tumor matrix mineralization, T2-weighted imaging may show areas of mixed low and high signal intensity, or the tumor may be mainly of low signal intensity (17). All tumors enhance following the injection of gadolinium-based contrast material, as would be expected given the vascular nature of the lesion. Soft-tissue invasion with cortical destruction must be differentiated from the severe inflammatory response involving several adjacent bones and soft tissue (Fig 7). The so-called flare phenomenon can cause marked overestimation of lesion size and lead to sampling error (18). The variable appearance of the tumor and the adjacent

Figure 6. Aggressive osteoblastoma of the L5 vertebral body in a 34-year-old woman with low back pain and neurologic symptoms. (a) CT scan shows a destructive expansile lesion with osteoid matrix extending into the spinal canal. (b) Axial T2-weighted MR image shows a mass with low signal intensity. (c) Axial contrast-enhanced fat-saturated T1-weighted MR image shows marked enhancement of the lesion. (d) Photomicrograph (original magnification, ×40; H-E stain) reveals a bone-forming tumor with irregular anastomosing trabeculae (T) lined by regular osteoblasts and osteoclasts (arrowheads) and with rich vascularity (a).
and lumbar segments are involved with equal frequency, followed by the sacrum and the cervical column (5). In 79% of cases, the tumor arises in the posterior elements with partial vertebral body involvement (5). Involvement of two vertebral levels is seen in 17% of cases (5). Patients may present with pain, signs of neurologic compression, or a palpable mass.

Conventional osteosarcoma is a high-grade malignant osteoblastic lesion with varying amounts of osteoid production, cartilage, or fibrous tissue. In 80% of cases, CT demonstrates matrix mineralization (Fig 8). Rarely, tumors with marked mineralization originating in the vertebral body may manifest as an “ivory vertebra” (sclerosing osteoblastic osteosarcoma). A

Figure 8. Osteoblastic osteosarcoma of the sacrum in a 20-year-old man with sacral pain, neurologic symptoms, and a palpable mass. (a) CT scan shows permeative bone destruction and osteoid matrix. (b) Axial T2-weighted MR image shows a slightly hypointense lesion with cystic foci (arrowheads). (c) Axial contrast-enhanced fat-saturated T1-weighted MR image shows enhancement of the lesion with cystic foci (arrowheads). (d) Photomicrograph (original magnification, ×40; H-E stain) reveals a high-grade osteoblastic osteosarcoma with a thin net of immature osteoid matrix (arrowheads) interwoven between neoplastic osteoblasts.
purely lytic pattern is also seen in various subtypes such as telangiectatic osteosarcoma (predominant cystic architecture simulating ABC). MR imaging signal intensity characteristics are usually nonspecific. Fluid-fluid levels have been described in association with telangiectatic osteosarcoma (5,6,19). As opposed to ABCs, telangiectatic osteosarcomas with prominent fluid-filled hemorrhagic spaces are characterized by thick, solid nodular tissue surrounding the cystic spaces, matrix mineralization, and a more aggressive growth pattern (6).

Patients with osteosarcoma of the spine should be treated with a combination of chemotherapy and at least marginal excision (assuming the tumors are surgically accessible) (20). Postoperative radiation therapy may be of benefit in selected patients (6).

**Cartilage-forming Tumors**

**Osteochondroma**

Osteochondroma represents the most common bone tumor and is a developmental lesion rather than a true neoplasm (21). This lesion is caused by the separation of a fragment of growth plate cartilage, which grows as a result of progressive enchondral ossification, leading to a subperiosteal osseous excrescence with a cartilage cap that projects from the bone surface (21). Osteochondromas enlarge as a result of growth at the cartilage cap, identical to a normal physeal plate. Enchondral ossification leads to medullary bone with a fatty or hematopoietic marrow. After skeletal maturity, osteochondromas usually exhibit no further growth (21). Most osteochondromas are solitary and sporadic lesions, although some are multiple, usually with an autosomal dominant inheritance. Although only 1.3%–4.1% of solitary osteochondromas originate in the spine, approximately 9% of patients with multiple osteochondromas have spinal lesions (22). Solitary lesions affect males more frequently than females (1.9:1 ratio), and the average age at diagnosis is 33 years (23). Osteochondromas can arise from any part of the vertebral column, but the cervical spine is commonly involved, with a predilection for the atlantoaxial area, followed by the thoracic spine and the lumbar spine (22–24). In cases of multiple exostoses, the thoracolumbar spine is more commonly involved. Most spinal lesions occur near the tip of spinous or transverse processes. They can also develop in the vertebral body, a pedicle, or, more rarely, the articular facet (23). Radiation-induced osteochondromas occur within or at the periphery of the radiation field and are usually solitary. The prevalence following irradiation for childhood malignancy is approximately 12%.

Because of overlapping of osseous structures of the spine, conventional radiography is often insufficient (23). CT is the modality of choice for demonstrating the diagnostic appearance of marrow and cortical continuity with the underlying vertebra (Fig 9) (21,23). At MR imaging, the lesion manifests with a peripheral rim of low signal...
Chondroblastoma

Chondroblastoma is a benign cartilaginous tumor with a predilection for the growing skeleton (28). It is composed of sheets of chondroblasts admixed with reactive giant cells and variable amounts of chondroid matrix. “Chicken wire” calcification of the matrix is highly typical of chondroblastoma. Only 1.4% of all chondroblastomas originate in a vertebra (29). Most patients present during the 3rd decade of life (28–30). The tumor involves the vertebral body and posterior elements. Back pain is the most common symptom (28,30). However, neurologic symptoms may occur when the spinal canal or foramina are invaded.

Given the difficulty of diagnosing these spinal lesions, the difficulty of clinical and radiologic follow-up, and the risk of malignant transformation, systematic surgical resection is warranted in all cases of diagnosed spinal osteochondroma (23,27).

The tumor shows aggressive features at imaging, with bone destruction and a soft-tissue mass but no surrounding bone edema (28,29). In other cases, CT may demonstrate a geographic lesion with sclerotic borders (Fig 10) (30). Most lesions have hypointense areas on T2-weighted MR images. Low signal intensity on T2-weighted images is associated with immature chondroid matrix, hypercellularity, calcifications, and hemosiderin at histologic analysis (31).
Treatment options for this benign tumor include local curettage or resection. Because of the high rate of local recurrence, total vertebrectomy is the most commonly used technique (30).

**Chondrosarcoma**

Chondrosarcoma is the second most common nonlymphoproliferative primary malignant tumor of the spine in adults (32). Peak prevalence occurs between 30 and 70 years of age (33). Men are affected two to four times more frequently than women (32). The thoracic and lumbar spine are most frequently affected, with the sacrum being affected only rarely (32,33). Chondrosarcoma originates in the vertebral body (15% of cases), posterior element (40%), or both (45%) at presentation (14). The clinical course of primary chondrosarcoma originating in the spine is usually long because most tumors are low-grade lesions (14,33).

Chondrosarcomas of the spine usually manifest as a large, calcified mass with bone destruction (14,33,34). True ossification may also be present, which sometimes corresponds to residual osteochondroma in cases of secondary chondrosarcoma (26). Chondroid matrix mineralization is better demonstrated with CT. Calcified matrix is detected as areas of signal void at MR imaging. The nonmineralized portion of the tumor has low attenuation on CT scans, low to intermediate signal intensity on T1-weighted MR images, and very high signal intensity on T2-weighted images due to the high water content of hyaline cartilage (Fig 11). An enhancement pattern of rings and arcs at gadolinium-enhanced MR imaging reflects the lobulated growth pattern of these cartilaginous tumors. Extension through the intervertebral disk has been reported in 35% of cases (35).

Chondrosarcoma tends to recur if inadequately managed. En bloc resection provides the best chance of survival and the lowest rate of local recurrence (33).
Eosinophilic Granuloma
Langerhans cell histiocytosis, previously termed histiocytosis X, includes conditions that range from the usually solitary and curable eosinophilic granuloma, to the disseminated process that produces Schüller-Christian syndrome, to the disseminated and rapidly fatal variety known as Letterer-Siwe disease. These three seemingly dissimilar conditions are united by common pathologic features. At histologic analysis, diagnosis of Langerhans cell histiocytosis is made on the basis of identification of Langerhans cells variably admixed with inflammatory cells, eosinophils, lymphocytes, neutrophils, and plasma cells. Langerhans cell histiocytosis is a rare condition (one new case per 2,000,000 persons per year) (36). It usually occurs in children, with a peak prevalence between 5 and 10 years of age. Eighty percent of cases occur before the age of 30 years. In multifocal involvement (10%–20% of cases), osseous lesions appear simultaneously or within 1–2 years. Vertebral involvement is seen in only 7.8%–25% of cases of Langerhans cell histiocytosis (36). Patients with spinal lesions usually have pain, which subsides rapidly after bed rest. Although almost all vertebral lesions involve collapse of the vertebral body, neurologic complications are rare and usually mild. Some patients may present with mild hyperpyrexia, mild elevation of the erythrocyte sedimentation rate, slight eosinophilia, and leukocytosis.

The radiographic characteristics of a typical spinal lesion consist of complete or incomplete collapse of the vertebral body; absence of an osteolytic area; preservation of pedicles, posterior elements, and adjacent disk spaces; absence of adjacent paravertebral soft-tissue shadow; and increased opacity in the collapsed body (Fig 12) (36). In patients with typical vertebral lesions but no suspected malignancy, close observation with clinical and radiologic examination might be more appropriate than vertebral biopsy. Reconstitution of the vertebral height usually occurs. Most of the remaining normal tissue of the collapsed vertebral body is the apophyseal plate, which may be damaged during biopsy, thus precluding reconstitution of the vertebral height (36).

Plasmocytoma
Plasmocytoma represents focal proliferation of malignant plasma cells without diffuse bone marrow involvement. These lesions are considered to represent the early stages of multiple myeloma. Solitary plasmocytoma is an uncommon tumor that occurs in 3%–7% of patients with plasma cell neoplasms. Seventy percent of patients are over 60 years old (26). The vertebral body is the most common site of involvement by plasmocytoma due to its rich red marrow content, but the tumor frequently extends to the pedicles (26,37,38). Plasmocytoma usually manifests with a single collapsed vertebra (26,37). A monoclonal seric immunoglobulin is present at a low seric level in 40% of cases.

In two-thirds of cases, the radiographic appearance is characteristic, with a mixed, predominantly lytic pattern (26). The tumor preferentially replaces the cancellous bone, whereas the cortical bone is partly preserved or even sclerotic, resulting in a hollow vertebral body or pedicle (26). The cortical thickening in the arrangement of plasmocytoma appears to be unique to this tumor and results in a “minibrain” appearance on axial images (Fig 13) (38). In one-third of cases,
Treatment is based on complete surgical excision and radiation therapy, with a theoretic chance of cure following early diagnosis. Radiologic surveillance helps in evaluating treatment efficiency, local recurrences, metastases, or transformation into multiple myeloma.

**Lymphoma**

Primary lymphoma of bone is a rare extranodal manifestation of non-Hodgkin lymphoma, accounting for only about 1%-3% of all lymphomas. Primary bone lymphomas are mainly diffuse large B-cell lymphomas. Peak prevalence occurs in the 5th–7th decades, with a strong male
Lesions may be lytic, sclerotic, or mixed with associated vertebral compression. Nearly all tumors (93%) are lytic and morphologically aggressive. A purely sclerotic pattern is rare and might correspond to necrotic and reactive bone formation. Other unusual imaging findings include vertebral plana, ivory vertebra, and pseudohe-mangioma (41,42). Invasion of the spinal canal is common (91% of cases), often with a large mass. The paraspinal component is often larger than the intraosseous lesion (42).

Vertebral lesions may have a sclerotic, lytic, or mixed appearance. The sclerotic (ivory vertebra) and mixed patterns are more common in Hodgkin disease. The appearance of vertebral lymphoma at CT and MR imaging is usually nonspecific. Bone scintigraphy shows increased radionuclide uptake in nearly all patients. Nevertheless, a focus of bone marrow replacement and a surrounding soft-tissue mass without large areas of cortical bone destruction suggest lymphoma (40). Lymphoma is caused by tumor spread from the medullary cavity along the small vascular channels that run through the cortex. It can be seen with other small round cell tumors such as Ewing sarcoma. Contiguous vertebral involvement has also been reported (40). Pathologic studies of bone biopsy specimens can be difficult due to crush artifacts, and sometimes large biopsies are required.

A combination of chemotherapy and involved-field radiation therapy prolongs event-free survival.

**Ewing Sarcoma**

Although the vertebral column is frequently involved in preterminal metastatic Ewing sarcoma, primary vertebral Ewing sarcoma is quite rare, with a reported prevalence of 3.5%–15% (41). Ewing sarcoma is an undifferentiated high-grade proliferation of uniform small round cells. Necrosis is common. Primary vertebral Ewing sarcoma is usually seen in the 2nd decade of life (mean age, 19.3 years), with a slight male predilection (62% vs 38% of cases) (41). The sacrum is the most frequently involved site (55.2% of cases), followed by the lumbar spine (25%). The cervical spine is the least frequently affected site (3.2% of cases). In the nonsacral spine, the majority (60%) of lesions originate in the posterior elements with extension into the vertebral body. The ala is the most frequently affected sacral site (69% of cases). More than one segment is involved in 8% of cases (41). The disk spaces are usually preserved (42).

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Patients receive a combination of chemotherapy and local radiation therapy. Patients with evidence of instability and neurologic compromise may still require surgical decompression and stabilization.

**Vertebral Hemangioma**

Vertebral hemangioma is considered to be a lesion of bone—usually of dysembryogenetic origin—or a hamartomatous lesion. It is composed of thin-walled vessels lined by flat, bland endothelial cells infiltrating the medullary cavity between bone trabeculae. Spinal hemangiomas are common and frequently multiple. The prevalence of hemangiomas seems to increase with age and is greatest after middle age, with a slight female predilection. Most hemangiomas are seen in
Hemangiomas in vertebrae cause rarefaction with exaggerated vertical striations or a coarse honeycomb appearance. CT shows the pattern as multiple dots (polka-dot appearance) representing a cross-section of reinforced trabeculae. At scintigraphy, the appearance of osseous hemangiomas ranges from photopenia to a moderate increase in radiotracer uptake. The histopathologic features of hemangiomas—high vascularity, interstitial edema, and interspersed fat—dictate the MR imaging appearance. The presence of high signal intensity on T1- and T2-weighted MR images is related to the amount of adipocytes or vessels and interstitial edema, respectively (44). Thick, low-signal-intensity vertical struts may be seen within hemangiomas. Fatty vertebral hemangiomas may represent inactive forms of this lesion (Fig 15), whereas low signal intensity at MR imaging may indicate a more active lesion with the potential to compress the spinal cord (45). The radiographic and CT appearances of compressive vertebral hemangiomas can be misleading, with irregular trabeculae and lytic areas; poorly defined, expanded cortex; and soft-tissue expansion (43,46). Mottled high signal intensity on T1-weighted MR images can be expected in only about 50% of compressive vertebral hemangiomas (Fig 16), and signal voids are the most useful additional MR imaging sign in lesions that are hypointense on T1-weighted images (46).

The differential diagnosis of compressive hemangiomas with a coarse reticular pattern and extradural extension includes rare hemangioblastoma, lymphangioma, and Ewing sarcoma (42,47,48).

Transarterial embolization is an effective treatment for painful intraosseous hemangioma and is useful in reducing intraoperative blood loss before decompressive surgery (49). Rapid tumor growth with spinal cord compression should be managed surgically (50). Highly vascular (cavernous type) hemangiomas may sometimes produce a prominent neurologic deficit despite scant evidence of spinal cord compression. The neurologic deficit in these cases is believed to be attributable to blood flow disturbances in the spinal cord (50). Radiation therapy can yield satisfactory results, with the obliteration of vessels and tumor shrinkage (50).

Chordoma
Chordoma is a rare malignant neoplasm arising from the remnants of the primitive notochord.
At gross examination, chordomas form a soft, white, multilobulated mass delineated by a fibrous pseudocapsule (14,51). The characteristic physaliphorous cells are the hallmark of chordoma (14,51). Chondroid chordoma exhibits cartilaginous differentiation, but this variation in histologic appearance does not affect the biologic behavior of the tumor. Fluid and gelatinous mucoid substance, recent and old hemorrhage, necrotic areas, and, in some cases, calcifications and sequestered bone fragments are found within the tumor (51). Next to lymphoproliferative tumors, chordomas are the most common primary malignant neoplasm of the spine in adults (14,52). Chordomas generally occur in late middle age, with a peak prevalence in the 5th–6th decades (51). Spinal chordomas have a 2:1 male-female ratio (51). Chordomas most commonly arise in the sacroccygeal region (50% of cases), followed by the spheno-occipital region (35%) and the vertebral bodies (15%). Sacrococcygeal tumors usually start in the lower sacrum and coccyx (26). Spinal chordomas arise more frequently in the cervical spine than in the thoracic and lumbar regions (51,53). The most common site of involvement in the mobile spine is the vertebral body with sparing of the posterior elements (51,53,54). Clinical manifestation is often subtle because chordomas are slow-growing lesions (14).

The most suggestive manifestation is a destructive lesion of a vertebral body associated with a soft-tissue mass with a “collar button” or “mushroom” appearance and a “dumbbell” shape, spanning several segments and sparing the disks (51). Areas of amorphous calcifications are noted in 40% of chordomas of the mobile spine and in up to 90% of sacrococcygeal lesions (Fig 17) (14). Most chordomas are iso- or hypointense relative to muscle on T1-weighted MR images. The focal areas of hemorrhage and high protein content of the myxoid and mucinous collections that may be seen in chordomas account for the high signal intensity on T1-weighted images (14). On T2-weighted images, most chordomas have a high signal intensity that reflects their high water content (Fig 18). The fibrous septa that divide the gelatinous components of the tumor are seen as areas of low signal intensity on T2-weighted images. The presence of hemosiderin also accounts for the low signal intensity seen on T2-weighted images. This MR imaging feature has been reported in 72% of sacrococcygeal chordomas but is rare in spinal chordomas (55). After the injection of gadolinium-based contrast material, most tumors demonstrate moderate heterogeneous enhancement, but ring and arc enhancement and peripheral enhancement have also been described (51).

Chordoma is a low-grade and slow-growing tumor but generally has a poor long-term prognosis despite its low tendency to metastasize. Death is often related to local recurrence. Prognosis depends on the possibility of margin-free en bloc resection (56). Radiation therapy may also be used as an adjunct treatment.

Chordoma should be differentiated from giant notochordal rest, which may also show physaliphorous cells at biopsy. Unlike in chordoma, radiography and CT fail to demonstrate a distinct lesion in giant notochordal rest, instead showing either normal bone or a variable degree of sclerosis (57). Bone scintigraphic findings are typically normal, whereas MR imaging shows a lesion with low T1 and high T2 signal intensity and no soft-tissue involvement. If the lesion is found incidentally, periodic imaging studies help ensure that the lesion is not progressive with evidence of bone destruction, the occurrence of which would indicate that the lesion is malignant (57).

**Aneurysmal Bone Cyst**

ABC is a benign bone lesion of unknown origin. It is a relatively rare lesion that represents 1.4%–2.3% of primary bone tumors. The spine is involved in 3%–20% of cases (58,59). At histologic analysis, ABC is typically characterized by blood-filled cystic spaces separated by a spindle cell stroma with osteoclast-like giant cells and osteoid or bone production (60). Mineralized chondroidlike material is present histologically.
The natural history of ABC has been described as evolving through four radiologic stages: initial, active, stabilization, and healing (62). In the initial phase, the lesion is characterized by a well-defined area of osteolysis. This is followed by a growth phase, in which the lesion has a purely lytic pattern and sometimes ill-defined margins. Later, during the stabilization phase, the characteristic soap bubble appearance develops as a result of maturation of the bony shell. CT and MR imaging typically show a well-defined lesion with internal septation (14,62). Mineralized chondroidlike material may be seen at radiography and CT only when abundant (62). In a series by Hudson (63), 35% of ABCs showed fluid-fluid levels at CT. Hudson emphasized the need to view such scans with a narrow window setting to identify small differences in fluid attenuation and to allow time for the fluid to settle and create fluid levels (63). Fluid-fluid levels within ABCs are indicative of hemorrhage with sedimentation and are better demonstrated with MR imaging. On T1-weighted images, they may have increased signal intensity due to methemoglobin in either the dependent or nondependent component (14). Gadolinium-based contrast material injection demonstrates smooth enhancement of the tumor. Most patients have pain and swelling, and vertebral lesions frequently cause signs and symptoms related to compression of the spinal cord, nerve root, or both (61).

The solid variant of ABC is a rare lesion, accounting for 3.4%–7.5% of all conventional ABCs (60). Spindle cell proliferation is the predominant histologic component of the solid variant of ABC, which can be mistaken for other tumors of the spine. The lack of anaplasia in all the tissue components strongly argues against a malignant tumor (60). The three main hypotheses reported in the literature propose that the lesion is the result of either the improper repair of a traumatic subperiosteal hemorrhage, a vascular disturbance of the bone, or hemorrhage into a preexisting lesion (61). In 29%–35% of cases, a preexisting lesion can be identified. The most common of these is giant cell tumor, which accounts for 19%–39% of cases in which a preexisting lesion is found (62). Other common precursor lesions include osteoblastoma, angioma, and chondroblastoma, whereas uncommon precursor lesions include fibrous dysplasia, fibrous histiocytoma, eosinophilic granuloma, osteosarcoma, and even metastatic carcinoma (62). ABC usually occurs between the ages of 5 and 20 years but can manifest at any age. There may be a slight female predilection (59). The cervical spine is affected in 22% of cases, the thoracic spine in 34%, the lumbar spine in 31%, and the sacrum in 13% (60). Spinal involvement is typically in the posterior elements, although extension into the vertebral body is common (75% of cases) (62). Spinal ABC may extend into the adjacent vertebrae or intervertebral disk, the ribs, and the paravertebral soft tissue (14,62). The symptomatology varies tremendously with the size of the tumor. Most patients have pain and swelling, and vertebral lesions frequently cause signs and symptoms related to compression of the spinal cord, nerve root, or both (61).

Figure 18. Chordoma of the cervical spine in a 50-year-old woman with neurologic symptoms. (a) Sagittal contrast-enhanced T1-weighted MR image shows a heterogeneously enhanced lesion invading the C5 and C6 vertebral bodies and nearly sparing the C5–C6 intervertebral disk. (b) Sagittal T2-weighted MR image shows the lesion with high signal intensity and invading the C6 vertebral body and epidural space. Note the mushroomlike appearance of the lesion. (c) Photomicrograph (original magnification, ×40; H-E stain) reveals sheets of vacuolated cells (the characteristic physaliphorous cells [arrowhead]) within an abundant myxoid background (*).
Figure 19. ABC of the lumbar spine (L3) in a 34-year-old woman with low back pain. (a) CT scan shows a sharply demarcated and multiloculated lesion with peripheral calcifications and fluid-fluid levels due to layering of blood products. (b) Coronal contrast-enhanced T1-weighted MR image shows enhanced septa between cysts. (c) On a coronal T2-weighted MR image, the signal intensity of cysts varies with stage of blood degradation. (d) Photomicrograph (original magnification, ×20; H-E stain) reveals reactive bone (R) and classic “blue bone” (B) in the wall of a cyst.

Giant Cell Tumor

Giant cell tumor is composed of sheets of stromal ovoid mononuclear cells with uniformly distributed osteoblastic giant cells. This tumor occurs in skeletally mature patients in the 2nd–4th decades of life, more frequently in females (64,65). Seven percent of giant cell tumors occur in the spine. The sacrum is affected in 90% of such cases. The tumor is usually located in the upper

Figure 20. Giant cell tumor of the upper sacrum in a 33-year-old woman. Coronal re-formatted CT image shows a well-defined lytic lesion of the right upper part of the sacrum with extension through the right sacroiliac joint and absence of a sclerotic rim.
sacrum and frequently lateralized in a sacral wing (26). Extension to the iliac wing through the sacroiliac joint is possible. Above the sacrum, the lumbar, thoracic, and cervical spine (in decreasing order of frequency) may be affected (64). The tumor usually predominates in the vertebral body, with frequent involvement of the posterior arch (64). The tumor is limited to the vertebral body and pedicles in only 21% of cases (64). Extraosseous involvement of the soft tissues is seen in 79% of cases (64). Giant cell tumors of the thoracic spine can sometimes simulate posterior mediastinal neoplasms (66). Intervertebral disk invasion and extension into an adjacent vertebra is possible (65).

Radiography typically shows a lytic lesion with cortical expansion (26,65). A purely osteolytic pattern is also possible. CT demonstrates absence of mineralization and the lack of a sclerotic rim at the margins of the tumor (Fig 20). Bone scintigraphy shows increased radiotracer uptake in all patients. The tumor usually has low to intermediate signal intensity on T1-weighted MR images. Areas of high signal intensity can suggest relatively recent hemorrhage. More specifically, most giant cell tumors of the spine have low to intermediate signal intensity on T2-weighted images (67,68). This appearance seems to be caused by hemosiderin deposition and high collagen content (Fig 21) (67,68). Enhancement of the lesion reflects its vascular supply. Cystic areas, foci of hemorrhage, fluid-fluid levels, and a peripheral low-signal-intensity pseudocapsule may also be seen (26,67).

Giant cell tumors of the spine should be completely removed; because of their location, however, this usually means excision with an
Metastatic Disease
Metastases are the most common vertebral tumors. Osteolytic metastases occur more frequently than osteoblastic metastases. Some metastases have a mixed pattern, with areas of osteolysis and areas of sclerosis. Typically, metastases are multiple and of variable size with cortical disruption (osteolytic lesions). Vertebral compression fracture and epidural tumor are common in metastases. Some slow-growing metastases may mimic a primary bone tumor with mineralization and sclerotic margins. Osteolytic metastases are most often caused by carcinoma of the lung, breast, thyroid, kidney, and colon and (in childhood) neuroblastoma. Osteoblastic metastases are most commonly caused by prostate carcinoma in elderly men and by breast cancer in women. Other osteoblastic metastases are caused by lymphoma, carcinoid tumors, mucinous adenocarcinoma of the gastrointestinal tract, pancreatic adenocarcinoma, bladder carcinoma, neuroblastoma, and (in childhood) medulloblastoma.

Paget Disease
Paget disease is a chronic metabolic disorder of abnormal bone remodeling in the adult skeleton. It is rare in patients less than 40 years old. Paget disease occurs more frequently in Caucasians of Northern European descent and is rare in Asians and African-Americans. In the spine, the vertebra is expanded. The typical “picture frame” vertebra shows a coarse and sclerotic peripheral trabecular pattern and central osteopenia. Other patterns of pagetic vertebrae include ivory verte-
bra and isolated posterior arch involvement (70). The pagetic bone marrow contains fatty areas with a heterogeneous distribution. Bone scintigraphy demonstrates the extent of Paget disease. Sarcomatous transformation of the lesion is rare (<1% of cases).

**Granulomatous Spondylitis**
In spinal tuberculosis, concomitant pulmonary tuberculosis occurs in approximately 10% of cases. MR imaging typically shows a centrosomatic, rounded, well-limited abscess surrounded by bone marrow edema, with normal disk spaces (71). Large paraspinal abscesses are frequently associated. Brucellosis occurs in the Mediterranean region, South and Central America, and the Middle East and is frequently associated with bilateral sacroiliitis. Sarcoidosis is more common in Northern Europeans and African-Americans, with the presence of systemic disease in all cases of spondylitis.

**Echinococcal Infection**
Echinococcal infection results from accidental ingestion of dog feces containing echinococcal eggs. *Echinococcus* species are common in southern South America, the Middle East, central Asia, and Africa. Endemic geographic regions in the United States are California, Arizona, New Mexico, and Utah. Hydatic cysts cause multiseptated lesions with minimal enhancement (72). Cyst rupture may cause anaphylaxis. A specific blood test is useful in making the diagnosis.

**SAPHO Syndrome**
SAPHO (synovitis, acne, pustulosis, hyperostosis, osteitis) syndrome occurs in young and middle-aged adults in association with rheumatologic and cutaneous lesions (seronegative spondylarthropathy). A delay of several years can separate osseous from cutaneous lesions. Skeletal sites of involvement are the sternoclavicular joints (70%–90% of cases), the axial skeleton (30%), and the appendicular skeleton and joints (30%). Bone scintigraphy is very sensitive and often reveals asymptomatic skeletal lesions associated with various typical sites of involvement. *Propionibacterium acnes*, the micro-organism usually found in acne lesions, has been recovered from specimens of manubriosternal joints involved by SAPHO syndrome. However, blood and bone cultures are usually negative. At histologic analysis, the osteolytic portion of the lesion contains plasma cells. The dominant radiographic feature is sclerosis in combination with a variable amount of osteolysis and periostitis. Hyperostosis is seen in long-standing disease. Both the multiplicity and location of corner lesions may be useful clues to the diagnosis (73).

**Brown Tumor**
Brown tumor, a classic manifestation of hyperparathyroidism, can arise in the spine, causing neurologic compromise related to both collapse of osteolytic vertebral lesions and tumor growth within the spinal canal (74). At histologic analysis, brown tumor cannot be differentiated from giant cell tumor, so that the diagnosis relies chiefly on the presence of hyperparathyroidism (67,74). When located in bone, brown tumor undergoes remineralization after parathyroidectomy (74).

**Schmòrl Node**
Schmòrl nodes represent vertical disk prolapses through areas of weakness in the vertebral endplate. Schmòrl nodes are often multiple and occur predominantly in the thoracolumbar spine. Recently formed Schmòrl nodes can be painful and may be indistinguishable from inflammatory or tumoral disease in terms of signal intensity. The identification of endplate defects or intranuclear cleft bending of the disk at either CT or MR imaging is helpful in making the correct diagnosis of acute Schmòrl nodes (75).

**Schwannoma**
Schwannomas are usually isolated lesions, except when they are associated with neurofibromatosis type 2. They arise from the nerve sheath, and large tumors may be mistaken for spinal tumors. Radiography, CT, and MR imaging may show widening of the affected foramen.

**Conclusions**
A reasonable differential diagnosis can be developed for most spinal lesions on the basis of patient age, lesion location (within the spine and vertebra), and radiologic appearance. Patients with a solitary spinal lesion should be evaluated at an early stage with the appropriate imaging. MR imaging plays a central role in the work-up of a patient who presents with a spinal tumor, although some benign spinal lesions can display a very aggressive and misleading appearance at MR imaging. Consequently, radiography or even CT should be performed when lesions result in extensive signal intensity abnormalities at MR imaging.

**References**


59. Garneti N, Dunn D, El Gamal E, Williams DA, Nelson IW, Sandemon DR. Cervical spondylod-


Page 1020
Some tumors have a predilection for specific age groups. In patients under 30 years of age, tumors of the spine are fairly uncommon and are generally benign except for Ewing sarcoma and osteosarcoma. In patients over 30 years of age, most tumors are malignant except for vertebral hemangiomas and bone islands. Metastases are the most common lesions.

Page 1021
Chordoma is the most common primary distal tumor of the upper cervical spine. It should be differentiated from pseudotumoral lesions of the foramen magnum such as calcium pyrophosphate dihydrate deposits, synovial pannus, and craniovertebral junction tuberculosis.

Page 1022
Osteoblastic tumors can display amorphous ossifications at radiography or CT. The matrix most often appears amorphous or cloudlike because it is less dense than normal bone and lacks an organized trabecular pattern. The amount and degree of matrix mineralization is widely variable; thus, the radiographic appearance of osteoblastic tumors may range from densely blastic to nearly completely lytic.

Pages 1023
Bone scintigraphy is almost invariably positive and has been advocated for localizing the vertebral level in patients with clinically suspected osteoid osteoma. Subsequent targeted CT is generally regarded as the preferred cross-sectional technique for the demonstration and precise localization of the nidus. Osteoid osteoma characteristically manifests as a low-attenuation nidus with central mineralization and varying degrees of perinidal sclerosis. The nidus of osteoid osteoma can have a very heterogeneous, variable appearance at MR imaging, making detection and characterization difficult.

Page 1039
MR imaging plays a central role in the work-up of a patient who presents with a spinal tumor, although some benign spinal lesions can display a very aggressive and misleading appearance at MR imaging. Consequently, radiography or even CT should be performed when lesions result in extensive signal intensity abnormalities at MR imaging.