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A BIWEEKLY REVIEW OF CLINICAL RADIOLOGIC PRACTICE

# Lucent Lesions of Vertebral Body: Differential Diagnosis

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***This module meets the American Board of Radiology's (ABR's) criteria for self-assessment toward the purpose of fulfilling requirements in the ABR Maintenance of Certification (MOC) program.***

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***After participating in this educational activity, the radiologist should be better able to diagnose the common lucent lesions in the vertebral body based on the imaging features of the lesions and patient characteristics.***

**Category: General Radiology**
**Subcategory: Musculoskeletal**
**Modality: Multiple**

**Key Words:** Lucent Lesions of Vertebral Body, Imaging of Lucent Lesions of Vertebral Body

*Each vertebra has an anteriorly located body of cancellous bone, with a thin layer of surrounding cortical bone; and posterior elements, which are composed largely of cortical bone (pedicles, laminae, and spinous and transverse processes). The spinal canal is between these two components (Figure 1). Cancellous bone lesions often localize in the vertebral bodies, whereas cortical bone lesions preferentially affect the posterior elements. However, some bone lesions may show no preference for either of the two vertebral parts.*

## Malignant Lesions of the Vertebral Body

### Metastasis

Metastasis is the most common vertebral tumor in adults. The spine is the most common site of osseous metastasis (vertebrae are involved in 30%–70% of patients with osseous metastatic disease[1]). Vertebral metastasis usually first seeds in the posterior half of the vertebral body and subsequently enlarges to involve the anterior part of the body, laminae, and pedicles. Most osseous metastatic tissues produce lucent metastases, except for prostate and breast, which may have a sclerotic pattern. Common primary malignant tumors producing lucent vertebral metastasis include lung, gastrointestinal tract, kidney, and thyroid.

**Vertebral metastasis usually first seeds in the posterior half of the vertebral body and subsequently enlarges to involve the anterior part of the body, lamina, and pedicles.**

Conventional radiography has relatively low sensitivity for detection of vertebral metastasis unless it causes a pathologic fracture. Frontal radiographs may show an absent pedicle, which has been called "winking owl sign."

CT is often the preferred imaging method for evaluation of osseous vertebral metastasis. CT typically shows lytic or soft tissue attenuation lesions with irregular margins, usually breaching the cortex (Figure 2A). The vertebrae can be targeted for CT-guided biopsy; however, easier nonspinal sites generally are preferred for biopsy.

MRI is superior to CT for detection and extent of osseous vertebral bony metastasis, and MRI is preferable to assess

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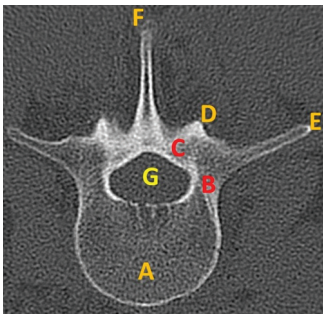


**Figure 1.** Normal lumber vertebral anatomy. Axial, CT bone window shows parts of a typical lumber vertebra, including (*A*) the vertebral body; the posterior elements—(*B*) pedicle, (*C*) lamina, (*D*) facet, (*E*) transverse process, and (*F*) spinous process—and (*G*) the vertebral canal.

complications such as spinal cord compression. T2-weighted (T2W) STIR MR sequences show lesions with mixed (hypo-/iso-/hyper-) signal intensity within the marrow due to the presence of edema, hemorrhage, or necrosis (Figure 2B). T1-weighted (T1W) MR sequences show lesions with iso-/hypointense signal to muscles. There are varying enhancement patterns after gadolinium administration.

### Multiple Myeloma/Plasmacytoma

Plasmacytoma (solitary plasma cell tumor) is an isolated monoclonal plasma cell tumor. Multiple myeloma is multifocal malignant proliferation of monoclonal plasma cells within bone marrow. Multiple myeloma is the most common primary malignant bone neoplasm in adults and accounts for 10% of all hematologic diseases.[2] Multiple myeloma typically affects patients age 40 years and older, with a male-to-female ratio of 2:1. Eighty percent to 90% of patients with multiple myeloma have skeletal (mostly axial skeleton) involvement. Initial patient evaluation may involve whole body skeletal survey radiographs. CT is more sensitive than radiography, and CT is used in guiding tissue sampling for histopathologic confirmation. Multiple myeloma lesions are well-circumscribed, lytic or multicystic-appearing masses, which may have vertical dense striations and are usually nonenhancing to slightly enhancing with contrast agent. CT also may show compression fracture, cortical destruction, bone demineralization, and associated soft tissue mass. There can be involvement of adjacent vertebrae with sparing of the discs. Lesions show no periosteal reaction (Figure 3A). Rarely, multiple myeloma may manifest with osteosclerosis, in which case POEMS syndrome (*p*olyneuropathy, *o*rganomegaly, *e*ndocrinopathy, *M*-protein, and *s*kin changes; including skin thickening, hyperpigmentation, hypertrichosis, and angiomas or hemangiomas) should be suspected. MR patterns in multiple myeloma range from normal to focal lesion(s) or diffuse infiltration, or combined focal lesion(s) with diffuse infiltration ("salt-and-pepper") appearance. T1W sequences show marrow lesions that are iso-/hypointense to muscle, with a characteristic "mini brain" appearance of thick cortical struts in an expanded vertebral body. There may be associated compression fracture or extension into the posterior elements. Soft tissue spread may produce the "draped curtain" sign in the spinal canal (Figure 3B). Fat-saturated T2W and STIR images show heterogeneous signal, focally hyperintense to fat, which may have curvilinear signal voids representing fractures. Lesions show mild to moderate diffuse enhancement with gadolinium, and the lesions may be of peripheral, rim-enhancing type.[2,3]

**Multiple myeloma is the most common primary malignant bone neoplasm in adults.**

The 2014 International Myeloma Working Group criteria for diagnosis of multiple myeloma requires three findings: a histopathologic diagnosis (>10% monoclonal plasma cells in bone marrow and/or a biopsy-proven plasmacytoma); a laboratory diagnosis (monoclonal protein in the serum or urine); and at least one of the "CRAB" (*c*alcium [elevated], *r*enal failure, *a*nemia, *b*one lesions) criteria for myeloma-related organ dysfunction, including hypercalcemia, renal insufficiency, anemia, and at least 5 mm lytic bone lesions.[2]

### Lymphoma

Lymphoma affects long bones much more frequently than the spine. However, in addition to vertebral osseous involvement, lymphoma may involve the vertebral disc,[4] spinal epidural space, and surrounding soft tissues.

**Lymphoma affects long bones much more frequently than the spine, but in addition to vertebrae, it may involve the vertebral disc, spinal epidural space, and surrounding soft tissues.**

Radiographs may show lytic bone destruction of the vertebrae, but rarely may present with a sclerotic pattern termed "ivory vertebra." CT demonstrates lytic or permeative bone destruction of multilevel involvement that may cross the disc

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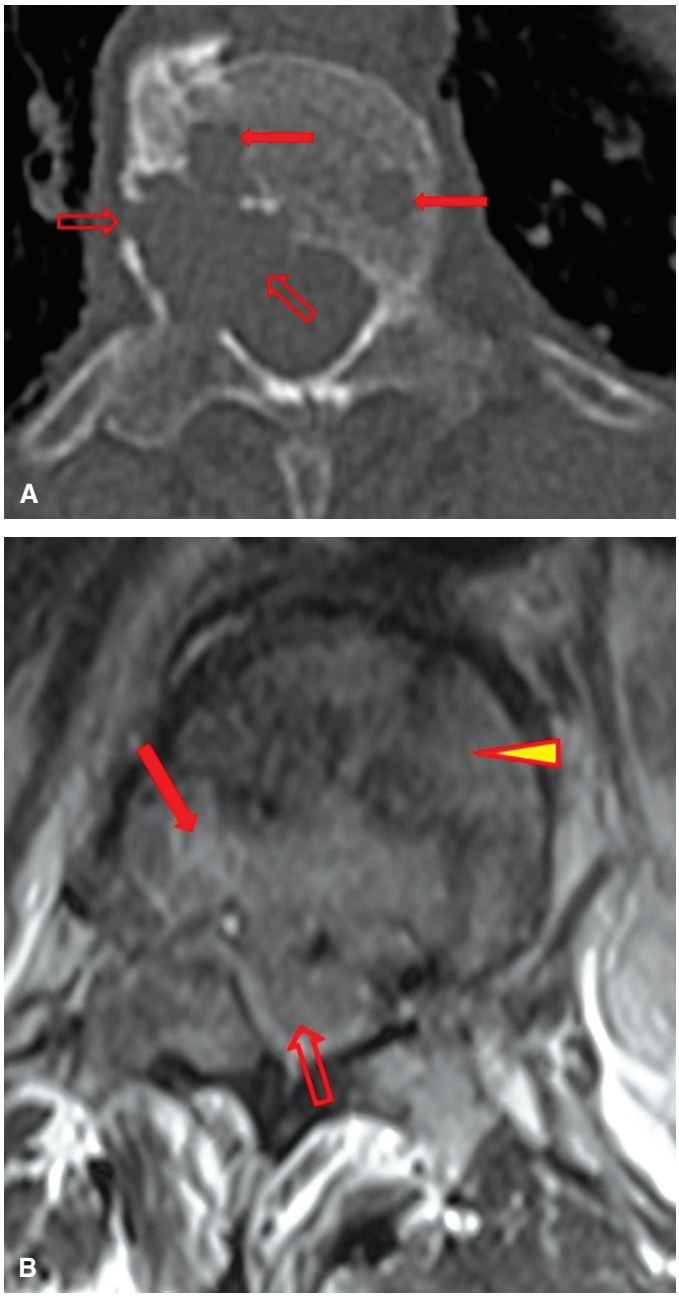


**Figure 2.** Vertebral body metastasis. *A*: Axial, CT scan of T12 thoracic vertebra shows lytic lesions of soft tissue attenuation (*closed arrows*), with irregular margins, and breaching the cortex (*open arrows*). *B*: Axial, T2W MR image through T12 vertebra of the same patient shows intermediate intensity lesion (*closed arrow*) with posterior extraosseous extension, encroachment on the anterior epidural space, and ventral compression on the spinal cord (*open arrow*). This detail is not appreciated on the CT scan. *Arrowhead* identifies the normal marrow space.

spaces and spread to local soft tissue (Figure 4). On MRI, vertebral lymphoma typically demonstrates T1-hypointense signal compared with normal marrow with diffuse contrast enhancement, and a variable (iso-/hyperintense) T2/STIR signal. Many types of lymphoma show high fluorodeoxyglucose (FDG) uptake on FDG-PET/CT, which is useful for disease staging.[4]

### Ewing Sarcoma

Ewing sarcoma is the second most common primary malignant bone tumor in children and adolescents (second only to osteosarcoma, which is the most common primary malignant bone tumor of childhood), with peak prevalence at age 10 to 15 years. There is spine involvement in 4% to 6% of patients, with a higher predilection for the sacrum. Typical presentations are spinal pain and mass, fever, elevated erythrocyte sedimentation rate, with or without neurologic symptoms. Lesions contain aggressive round blue cells histologically, and typically they involve the anterior and middle spinal columns with perineural spread. Ewing sarcoma may originate in soft tissues.

Radiographic presentation includes a permeative or moth-eaten pattern, centered in the vertebral body or sacrum with a wide zone of transition. There may be presence of vertebra plana, and involvement of adjacent vertebrae with sparing of the associated vertebral disc. A sclerotic pattern is rare, occurring in fewer than 5% of cases. In addition, CT may demonstrate a permeative intramedullary mass with or without a nonossifying soft tissue mass and heterogeneous enhancement due to necrotic regions within the lesion (Figure 5A). Lesions show infiltrative pattern on MRI and may demonstrate a "smudged" bone cortex. On T1W images, lesions are hypointense to vertebral disc and muscle; T2W/STIR images show iso-/hyperintense signal to red marrow. There is a heterogeneous contrast enhancement pattern (Figure 5B). Lesions are FDG-avid on FDG-PET/CT, which is used for identifying metastatic disease.[5]

**On CT, Ewing sarcoma of the spine may demonstrate a permeative intramedullary mass centered in the vertebral body or sacrum, with or without a nonossifying soft tissue mass, and heterogeneous enhancement.**

## Benign Lesions

### Giant Cell Tumor

Giant cell tumor is a locally aggressive benign tumor of osteoclast-like giant cells that accounts for 5% of all primary bone tumors and 20% of benign skeletal tumors. The sacrum is involved in 4% of cases, whereas the remaining vertebrae are affected in about 3% of cases. Osseous giant cell tumor typically affects young adults (age 20–50 years), with peak incidence in the third decade of life. Giant cell tumor is three times more common in females than in males. It may occur in association with aneurysmal bone cyst and Paget's disease of bone.[6]

Radiographs show a lytic, expansile lesion with a narrow, nonsclerotic transition zone. Giant cell tumors typically lack bone matrix but may have residual bone trabeculae within them. In spinal lesions, CT demonstrates a lytic region with soft tissue attenuation that may breach the vertebral cortex (Figure 6). Lesions may also contain fluid-attenuation regions due to necrosis. Contrast enhancement may mimic the bony matrix on CT. Presence of fluid-fluid levels suggests associated aneurysmal bone cyst. MRI is the best modality for evaluating epidural spread of disease. Lesions typically appear as expansile, sharply demarcated masses, often with soft tissue extension demonstrating hypo-/isointense signal on T1W images and iso-/hyperintense signal on T2W images. Hypointense, thin, curvilinear bands on all sequences typically represent residual bone trabeculae or fibrous septa.

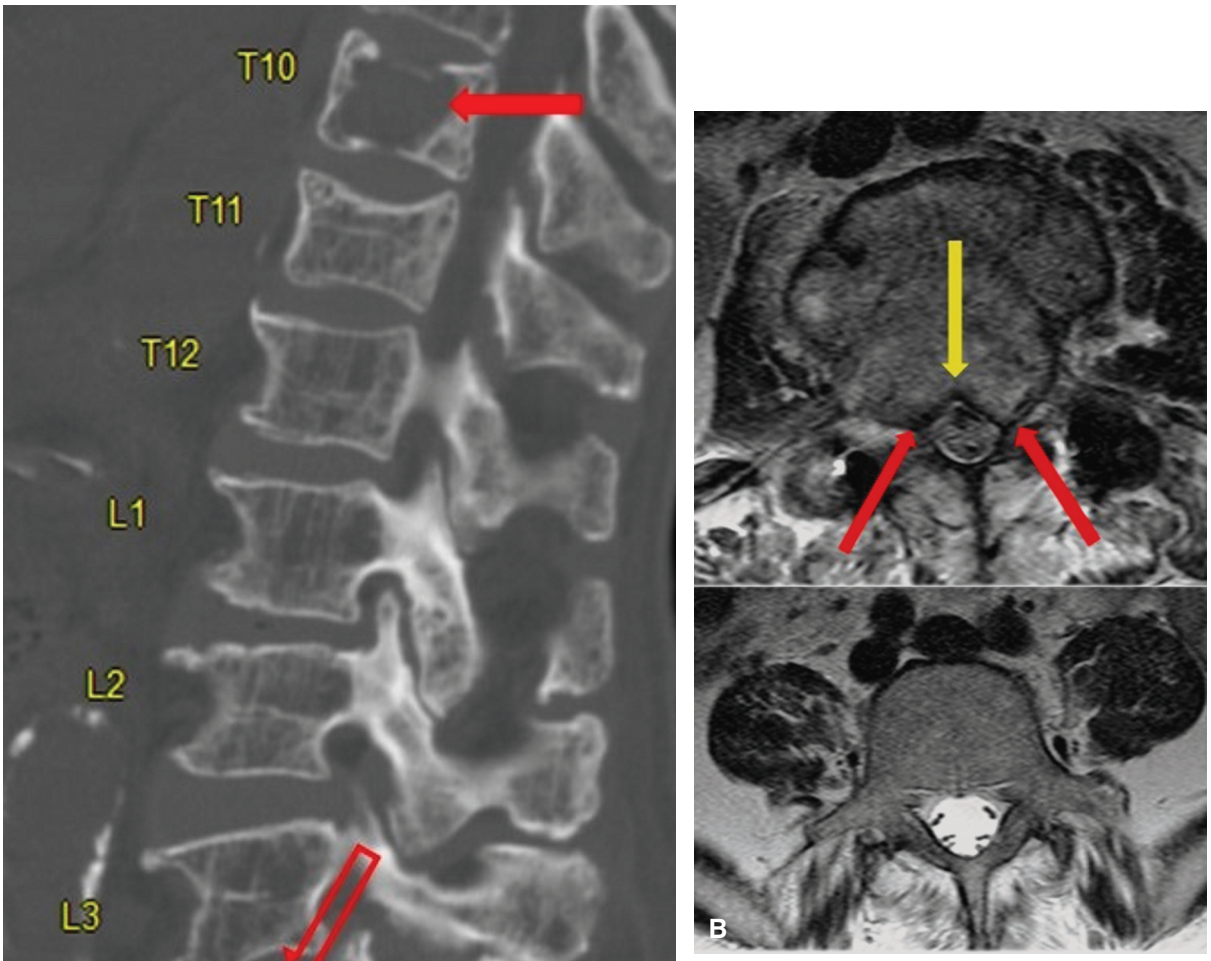


**Figure 3.** Multiple myeloma. *A*: Sagittal, CT scan of thoracolumbar vertebrae of a patient with multiple myeloma shows punched-out lytic lesion of T10 (*closed arrows*), and vertebra plana of L4 with preserved disc spaces (*open arrows*). *B*: Draped curtain sign. Axial, T2W MR image (*upper row*) in a different patient at the level of a lumber vertebral body shows a plasmacytoma with posteriorly extending soft tissue mass (*red arrows*) that protrudes into the anterior epidural space on both sides of the firmly attaching posterior longitudinal ligament (*yellow arrow*), thereby producing the characteristic "draped curtain" appearance. Upper image shows the draped curtain appearance. Lower image shows an unaffected lumbar vertebra for comparison.

Lesions demonstrate heterogeneous enhancement with gadolinium due to the presence of nonenhancing areas of necrosis. MRI also may show hemosiderin deposition and fluid-fluid levels when associated with aneurysmal bone cyst. Nuclear bone scans show increased radiotracer uptake on all three phases.[6]

**On CT, presence of fluid-fluid levels in a giant cell tumor of bone suggests an associated aneurysmal bone cyst.**

### Vertebral Osteomyelitis

Vertebral osteomyelitis is a relatively common disease, with a mean prevalence of 2.4 cases per 100,000 population that increases with age; from 0.3/100,000 at 20 years or younger to 6.5/100,000 at older than 70 years. In pyogenic vertebral osteomyelitis, *Staphylococcus aureus* is the most frequently isolated agent, followed by *Escherichia coli*. Tuberculosis or fungi often cause the less common granulomatous type. Inoculation can be either hematogenous, direct (from penetrating trauma or surgery), or spread from contiguous soft tissue. Vertebral osteomyelitis often is associated with underlying chronic medical conditions or diseases such as diabetes, coronary heart disease, immunosuppression, cancer, end-stage renal disease on hemodialysis, or IV drug abuse. When involving the adjacent vertebral disc, it is termed discitis-osteomyelitis. Neurologic complications are common, occurring in up to 38% of patients, and often are attributable to nerve impingement from epidural or paravertebral abscess, or pathologic fracture.[7]

Conventional radiographs usually are negative during the initial 2 to 8 weeks of disease, but they eventually may show endplate osteolysis followed by sclerosis (chronic vertebral osteomyelitis), paraspinal soft tissue density and loss of fat planes, and fusion across disc space in late stage of the disease. CT is less sensitive than MRI, especially in the acute stage. CT shows poorly defined osteolytic changes (Figure 7).

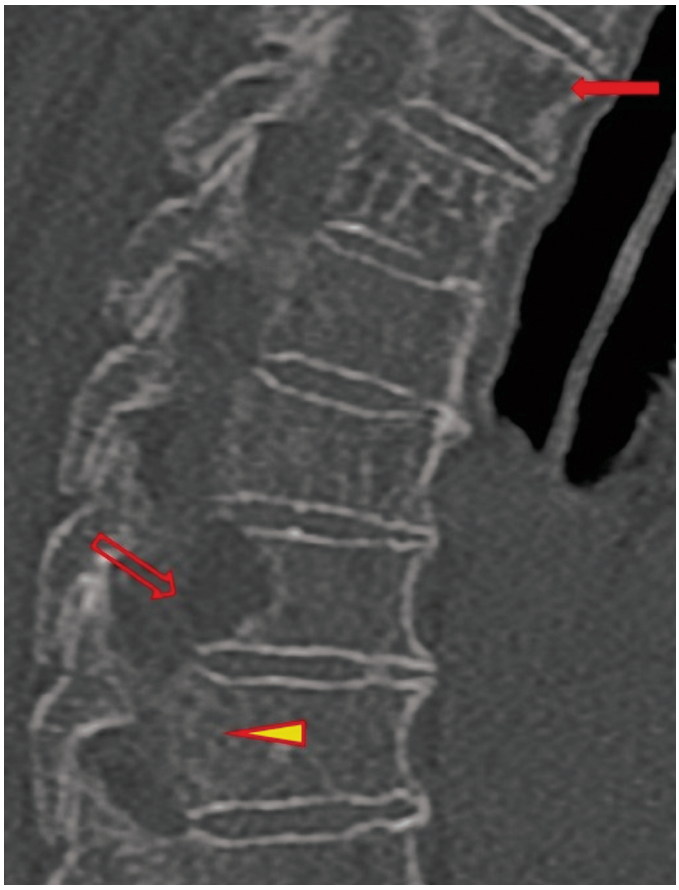

**Figure 4.** Vertebral lymphoma. Sagittal, CT scan of thoracic vertebrae shows *multilevel involvement* of lytic bone destruction (*closed arrow*) with extension into the vertebral canal and vertebral disc (*open arrow*), and permeative bone destruction (*arrowhead*).

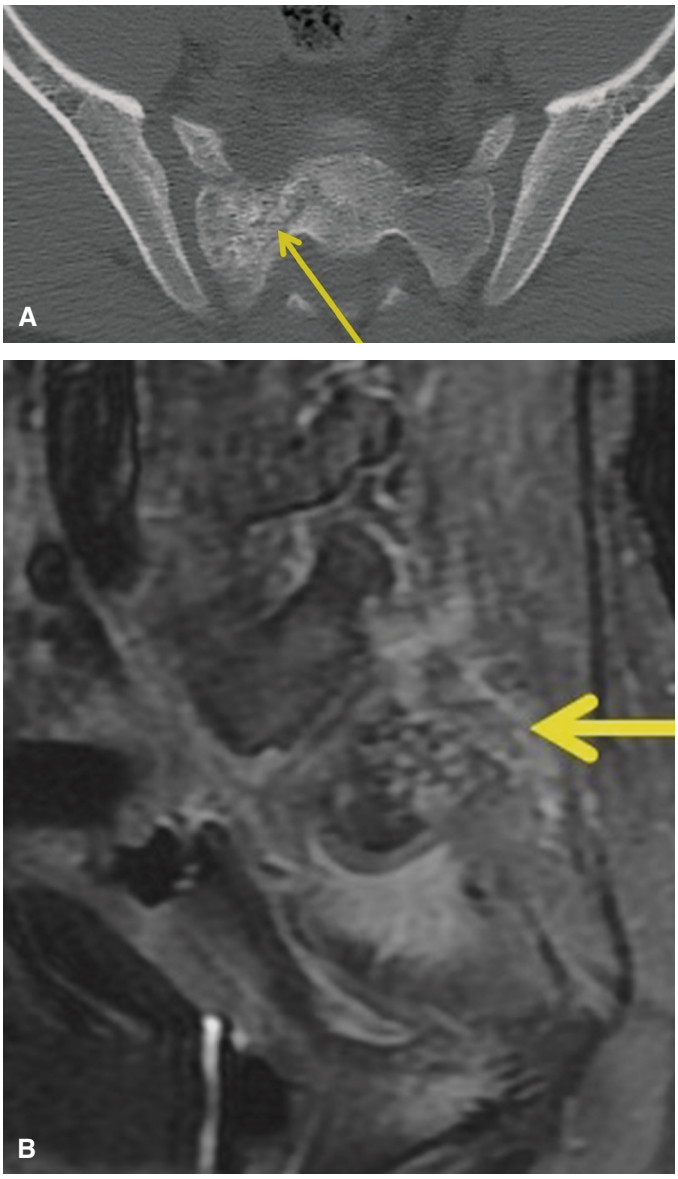


**Figure 5.** Vertebral Ewing sarcoma. *A*: Axial, CT scan with bone window shows a mixed lytic and sclerotic lesion predominantly involving the right side of S2 vertebral body (*yellow arrow*). No new bone formation is present. *B*: Sagittal, contrast-enhanced, fat-saturated MR image shows heterogeneously enhancing lesion centered within the right side of S2 vertebral body (*yellow arrow*). (Images courtesy of Vinay Kandula, MD, Nemours Alfred I. duPont Hospital for Children, Wilmington, Delaware.)

There also may be a spinal deformity, which is best seen on coronal and sagittal reformation; increased paraspinal soft tissue; or enhancing intervertebral disc, bone marrow, and paravertebral soft tissue. MRI is the best diagnostic imaging examination, with about 96% sensitivity, 92% specificity, and 94% accuracy.[7] MRI can show the complete extent of disease including soft tissue and spinal canal involvement and cord compression. T1W images demonstrate hypointense marrow signal, may show loss of disc height, or reveal paraspinal/epidural isointense mass (phlegmon/abscess). Fat-saturated, T2/STIR shows hyperintense marrow signal and paraspinal/epidural collections. Loss of disc height also may be evident. Contrast enhanced MRI is particularly helpful for diagnosis of associated paraspinal/epidural collections. MRI is the preferred modality for evaluation of disease progression; however, imaging improvement typically lags behind clinical improvement.[7]

### Langerhans Cell Histiocytosis

Langerhans cell histiocytosis also is known as eosinophilic granuloma. It is a rare disease that usually affects children age 1 to 15 years, with peak incidence between age 1 and 3 years, and a male-to-female ratio of 2:1. Its annual incidence is three to five cases per million children aged 5 to 10 years and one to two cases per million adults. Vertebral involvement occurs in 7.8% to 25% of patients with Langerhans cell histiocytosis.[8]

Radiography reveals lytic, destructive, vertebral lesions and in advanced cases, vertebra plana (termed pancake vertebra). Langerhans cell histiocytosis may result in scoliosis or kyphosis. Compared with conventional radiographs, CT better demonstrates these bone lesions of Langerhans cell histiocytosis (Figure 8A). Adjacent vertebral discs and posterior elements often are spared. There may be enhancing soft tissue with paraspinal or epidural extension. MRI better demonstrates soft tissue and spinal cord involvement. T1W images demonstrate hypointense vertebral soft tissue mass, which may be associated with pathologic fracture. On T2W images, the lesion is heterogeneously hyperintense, usually with normal disc spaces. Langerhans cell histiocytosis lesions show homogeneous enhancement (Figure 8B) after contrast administration.[8]

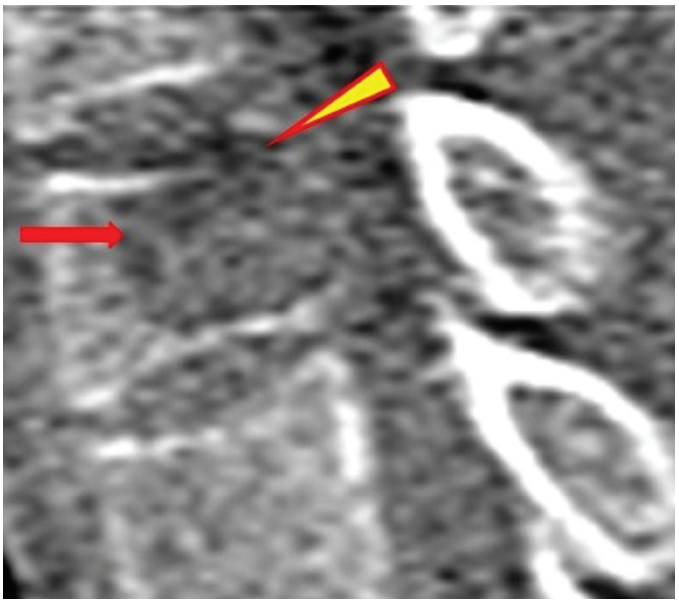

**Figure 6.** Vertebral giant cell tumor. Sagittal, CT scan of lumbar vertebra shows expansile vertebral body lesion with narrow, nonsclerotic transition zone (*arrow*) and some cortical breaching (*arrowhead*).

**Advanced Langerhans cell histiocytosis involving the vertebral body may develop vertebra plana, but adjacent vertebral discs and posterior elements often are spared.**

### Intraosseous Hemangioma

Intraosseous hemangioma is the most common benign vertebral neoplasm. It is a hamartoma composed of thin-walled, endothelium-lined sinusoidal channels and fatty tissue with interspersed bony trabeculae. It is usually asymptomatic and an incidental finding. Intraosseous hemangioma is slightly more common in females than in males and less common in children. Symptoms are more likely to occur with thoracic lesions and increased physical activity. The most common presentation is back pain, but pathologic fracture and cord/nerve compression are possible.[9]

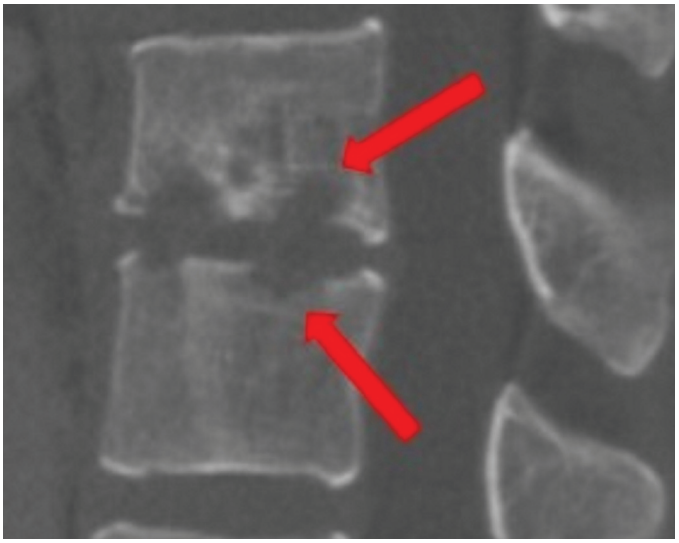

**Figure 7.** Vertebral discitis-osteomyelitis. Sagittal, CT scan of two lumbar vertebral bodies shows poorly defined, lytic changes at the contiguous endplates (*arrows*) and extending into the disc space representing discitis-osteomyelitis.

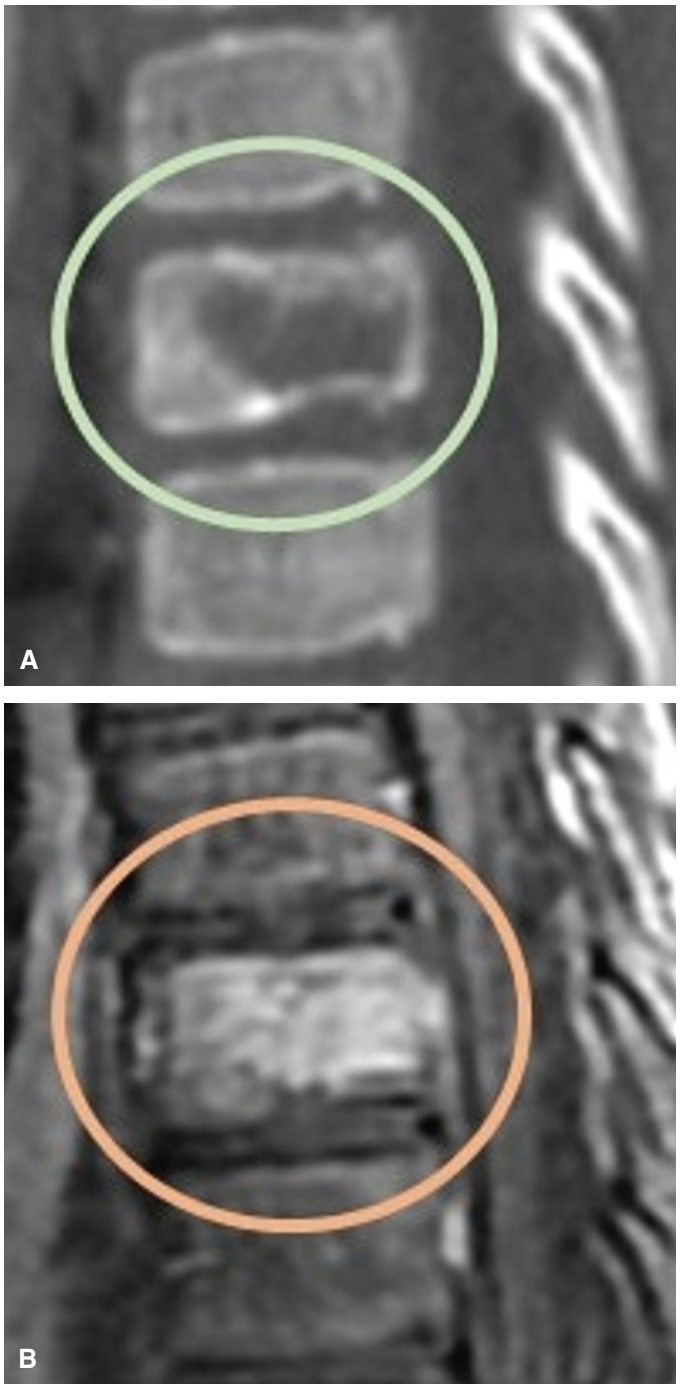


**Figure 8.** Vertebral Langerhans cell histiocytosis. *A*: Sagittal, CT scan, bone window, shows an osteolytic lesion of T9 vertebra (*circle*). *B*: Sagittal, T1W MR image with contrast shows homogeneous and intensely enhancing lesion of the vertebral body of T9 (*circle*) consistent with marrow infiltration. (Images courtesy of Vinay Kandula, MD, Nemours Alfred I. duPont Hospital for Children, Wilmington, Delaware.)

Radiographs demonstrate coarse vertical trabeculae with a corduroy/honeycomb pattern. CT is more sensitive than radiographs, showing well-circumscribed hypodense lesions with thickened vertically aligned trabecula seen on sagittal and coronal reconstructions, termed "corduroy sign" (Figure 9A). These thickened trabeculae are represented by thick, white, "polka dots" on axial views (Figure 9B). On MRI, lesions are typically hyperintense on T1W images due to fatty stroma. Atypical lesions (with more vascular

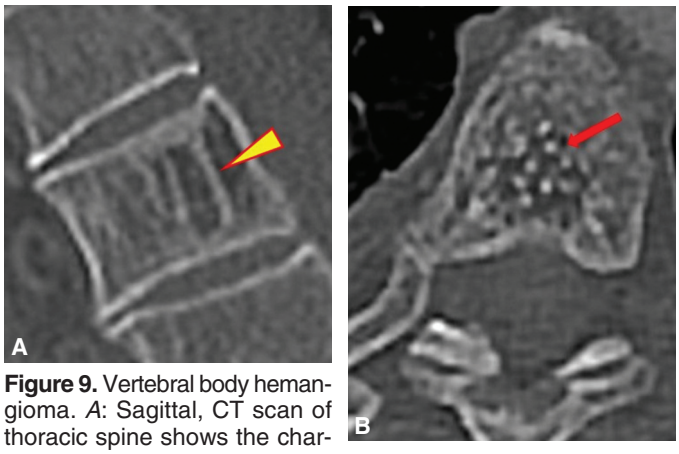


**Figure 9.** Vertebral body hemangioma. *A*: Sagittal, CT scan of thoracic spine shows the characteristic "corduroy pattern" (*arrowhead*). *B*: Axial, CT scan of thoracic spine shows the characteristic "polka dots" pattern (*arrow*).

elements) are iso-/hypointense on T1W images. T2W/STIR sequences demonstrate hyperintense or intermediate intensity signals. Typical lesions only mildly enhance after contrast administration.[9]

### Brown Tumor

Brown tumor also is known as osteoclastoma, osteitis fibrosa cystica, or von Recklinghausen disease of bone. Brown tumor is a nonneoplastic, metabolic lesion that occurs in the setting of chronic hyperparathyroidism with strongest association with tertiary hyperparathyroidism, followed by secondary hyperparathyroidism. Due to much higher prevalence of secondary hyperparathyroidism than other forms, most cases of brown tumor are encountered in the setting of secondary hyperparathyroidism.[10] Vertebral brown tumors are rare and may occur in patients with chronic end-stage renal disease. The lesion equally affects both the vertebral body and posterior elements without preference. Radiographs show a lytic, expansile, and well-defined vertebral lesion without matrix production or cortical penetration (Figure 10). Usually other features of hyperparathyroidism are seen, including osteopenia, "rugger-jersey spine," subperiosteal resorption/cortical thinning, endplate erosions, Schmorl's nodes, and soft tissue calcification. The bones of the hands may show subperiosteal bone resorption, cortical thinning, and acro-osteolysis. CT is more sensitive than radiographs and demonstrates soft tissue-to-blood attenuation of the expansile mass. MRI may show cystic, solid soft tissue or mixed components. Brown tumors demonstrate iso- or hypointense signal on T1W images, iso- or hyperintense signal on T2W images, and fluid-fluid levels may be present.

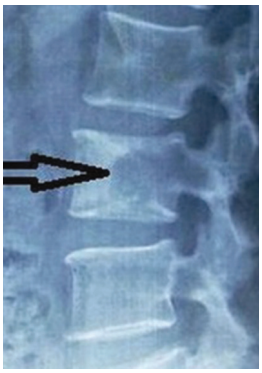

**Figure 10.** Vertebral brown tumor. Lateral radiograph of the lumbosacral spine shows an osteolytic lesion in the L-3 vertebral body (*arrow*). (Images courtesy of Vaishya R, Agarwal AK, Singh H, Vijay V. Multiple "brown tumors" masquerading as metastatic bone disease. *Cureus*. 2015;7[12]).

There is enhancement of solid components of the lesion after contrast administration. Nuclear Tc99m-MDP bone scan shows intense radiotracer uptake.[10]

## Conclusion

Differential diagnostic considerations of lucent vertebral body lesions range from benign inflammatory, infective and metabolic lesions to malignant metastatic and primary lesions. Imaging features on CT and other problem-solving imaging modalities such as MRI and bone scanning are important for correct identification and diagnosis of these lesions. However, due to overlap of imaging features, tissue biopsy remains cardinal for diagnostic confirmation in some cases and for identification of the primary site of metastatic lesions.

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**1.** In conventional frontal radiographs of vertebrae, the "winking owl sign" can be the result of metastatic disease involving
- **A.** lamina
- **B.** spinous process
- **C.** transverse process
- **D.** pedicle
- **E.** vertebral body

See Reference No. 1 for further study

**2.** All of the following vertebral body lesions can extend into the adjacent vertebral disc, *except*
- **A.** lymphoma
- **B.** osteomyelitis
- **C.** multiple myeloma
- **D.** giant cell tumor of bone

See Reference No. 3 for further study

**3.** All of the following are radiographic features of vertebral lymphoma, *except*
- **A.** predominant lytic lesion
- **B.** permeative bone destruction
- **C.** multilevel involvement
- **D.** rare "ivory vertebra" appearance
- **E.** absent disc space involvement

See Reference No. 4 for further study

**4.** On axial CT scan of a vertebral body, the cause of the "polka dot" sign is
- **A.** metastatic renal carcinoma
- **B.** intraosseous hemangioma
- **C.** multiple myeloma
- **D.** giant cell tumor of bone
- **E.** secondary hyperparathyroidism

See Reference No. 9 for further study

**5.** Which one of the following is the usual *initial* location of vertebral metastatic disease?
- **A.** Lamina
- **B.** Spinous process
- **C.** Pedicle
- **D.** Posterior half of the vertebral body
- **E.** Transverse process

See Reference No. 1 for further study

**6.** All of the following are radiographic features of vertebral multiple myeloma lesions, *except*
- **A.** exuberant periosteal reaction
- **B.** well-circumscribed lesion
- **C.** vertebra plana
- **D.** lytic lesions predominate
- **E.** bone demineralization

See Reference No. 3 for further study

**7.** Which one of the following is the *most* common vertebral tumor in adults?
- **A.** Plasmacytoma
- **B.** Metastasis
- **C.** Lymphoma
- **D.** Multiple myeloma
- **E.** Giant cell tumor

See Reference No. 2 for further study

**8.** All of the following are radiographic features of vertebral Ewing sarcoma, *except*
- **A.** permeative pattern
- **B.** predilection for the sacrum
- **C.** presence of vertebra plana
- **D.** sclerotic more common than osteolytic pattern
- **E.** sparing of vertebral discs

See Reference No. 5 for further study

**9.** Which one of the following primary malignancies is *least* likely to produce osteolytic metastases in a vertebral body?
- **A.** Lung
- **B.** Gastrointestinal tract
- **C.** Prostate
- **D.** Kidney
- **E.** Thyroid

See Reference No. 10 for further study

**10.** Which one of the following bone tumors may occur in association with giant cell tumor of bone?
- **A.** Ewing sarcoma
- **B.** Aneurysmal bone cyst
- **C.** Langerhans cell histiocytosis
- **D.** Plasmacytoma
- **E.** Lymphoma

See Reference No. 6 for further study