NORMAL THORACIC SPINE

There are normally 12 thoracic vertebral bodies. The ribs articulate with the vertebrae both at the disk and at the transverse process. However, the latter articulation occurs only for T1 through T10. On sagittal magnetic resonance imaging (MRI) scans, the exit foramina for the basivertebral veins can be clearly identified posteriorly within the midvertebral body. Epidural fat is prominent posterior to the thecal sac.

The thoracic spine presents several unique problems in regard to MRI, necessitating attention to imaging technique to obtain a high-quality exam. A coronal saturation pulse (or presaturation slab) is routinely used to eliminate motion artifacts from the chest wall and heart. This saturation pulse is used in both sagittal and axial imaging of the thoracic spine. A maximum slice thickness of 3 mm is recommended regardless of imaging plane. Thoracic disk herniations, in particular, are often small and not well visualized when thicker sections are acquired. With conventional T2-weighted spin echo techniques, focal signal loss within the cerebrospinal fluid (CSF) is common. This is due to the strong pulsatile nature of CSF in the thoracic region, which is also present in the cervical spine. Fast spin echo T2-weighted scans suffer substantially less from this problem and are routinely used for sagittal imaging. However, axial T2-weighted scans suffer from CSF flow artifacts regardless of specific technique (conventional or fast). Thus, gradient echo T1-weighted scans are routinely used for axial imaging in the thoracic spine.

Although not strictly “normal,” one finding (indicative of a prior diagnostic exam) that can still be seen in older patients deserves comment: the presence of residual Pantopaque (iophendylate) from a myelogram performed before 1990. Pantopaque was an early contrast agent used for myelography. It is no longer used in part because of the high incidence of arachnoiditis after the exam. Pantopaque is an oily, non-water-soluble substance. It was not uncommon for a small amount to be left within the thecal sac after completion of a myelogram. This persists indefinitely. Currently, on MRI, Pantopaque is still occasionally seen in older patients either free within the thecal sac or trapped within a root sleeve or scar. It is easily recognized because of its appearance on MRI (typically a small globule) with high signal intensity on T1-weighted scans and low signal intensity on T2-weighted scans. Correlation with conventional x-ray films is recommended because Pantopaque is extremely x-ray dense.

CONGENITAL OR DEVELOPMENTAL ABNORMALITY

Butterfly vertebrae have concave superior and inferior end plates with a central osseous defect. In some instances, this is an incidental finding of no clinical significance. However, butterfly vertebrae can be associated with congenital abnormalities such as diastematomyelia, necessitating close review of images.

A lateral meningocele is produced by a protrusion (laterally) of the dura and arachnoid through an enlarged neural foramen. The adjacent pedicles and lamina may be thinned, and the dorsal surface of the vertebral body scalloped. The vast majority of lateral meningoceles (85%) are seen in neurofibromatosis. Thoracic paraspinal masses, when present in neurofibromatosis, are more likely to be meningoceles than neurofibromas. Most lateral meningoceles are right sided, occur in a single foramen, and are seen in the upper thoracic spine (T3-7). Lateral meningoceles are typically asymptomatic. They are easily characterized and diagnosed by MRI, with CSF signal intensity on all pulse sequences.

Neuroenteric cysts are an embryologic remnant. During early embryonic development, a temporary structure (the canal of Kovalevsky) connects the amnion and the primitive yolk sac. Persistence of this canal after embryologic development leads to a fistula from gut, through the vertebral bodies and spinal cord, to the dorsal skin. Persistence of only a portion of the canal is believed to be the origin of mesenteric cysts, enteric diverticula, neuroenteric cysts, diastematomyelia, and spina bifida. Neuroenteric cysts are by definition enteric lined cysts that lie within the spinal canal. There can also be a component outside the canal. Neuroenteric cysts are usually ventral in location to the spinal cord and are most frequently seen at the cervicothoracic junction and conus medullaris. There are frequently associated vertebral body anomalies. The imaging appearance on MRI is varied depending on the blood and protein content, viscosity, and pulsatility. Included in the differential diagnosis is an arachnoid cyst. However, arachnoid cysts are isointense to CSF on all pulse sequences and not associated with vertebral body anomalies.

Epidural lipomatosis is the result of excessive fat deposition in the epidural space. It is seen in morbid
obesity, chronic steroid use, and Cushing's disease. Sixty percent of cases occur in the thoracic spine and 40% in the lumbar spine. In extreme cases, patients can be symptomatic; pain and weakness result from compression of the thecal sac by overabundant fat.

**INFECTION**

**Osteomyelitis**

Vertebral osteomyelitis is often insidious; nonspecific symptoms make diagnosis difficult. Delay in treatment, however, dramatically increases morbidity. In children, osteomyelitis occurs after hematogenous spread of bacteria to the vasculared intervertebral disk. However, in adults, the infection is the result of hematogenous spread to the more vascular end plate, with the disk itself involved secondarily. Plain x-ray films are frequently unremarkable until late in the disease. MRI is the modality of choice for diagnosis; sensitivity is higher for MRI than for radionuclide scintigraphy. Findings on MRI include abnormal low signal intensity on T1-weighted scans and high signal intensity on T2-weighted scans within the vertebral body. These signal abnormalities are due to edema and inflammatory changes. There is typically a paraspinous and epidural soft tissue mass, which enhances after contrast administration. The longer the delay in diagnosis, the greater is the size of the associated abnormal soft tissue. Specific diagnosis is usually possible because of the presence of an irregular very high signal intensity area within the disk space on T2-weighted scans corresponding to fluid. Involvement of the intervening disk space distinguishes this disease (infection) from vertebral metastases.

**Tuberculous Spondylitis**

Tuberculous spondylitis follows a more indolent clinical course than pyogenic infection. It is uncommon in the United States except among immigrants (specifically those from Southeast Asia and South America) and immunocompromised patients. From an imaging perspective, abnormal marrow signal intensity is seen within two or more adjacent vertebral bodies, with accompanying cortical bone destruction and abnormal extralbral soft tissue. Distinguishing features from pyogenic infection include involvement of three or more levels (50% of cases), "skip" lesions, relative sparing of the disk, and a disproportionately large soft tissue mass. Tuberculous spondylitis often spreads along the anterior longitudinal ligament involving multiple contiguous vertebral bodies. The extradural component is typically prevertebral in location, but can extend into the spinal canal. In longstanding disease, there can be extensive bone destruction, a gibbous deformity (vertebral collapse with anterior wedging), and cord compression (resulting from angulation or the soft tissue mass). Computed tomography (CT) clearly depicts the extensive bone destruction and soft tissue (paraspinous) mass. MRI, however, offers superior depiction of both the vertebral and paravertebral involvement. As medical treatment begins to take effect, there is a return to normal in signal intensity (on both T1- and T2-weighted scans) of the vertebral bodies and a decrease in the abnormal enhancement of paravertebral soft tissue.

**AIDS-Related Infection**

AIDS-related infections involving the thecal space in the thoracic area may present as polyradiculopathy or myelopathy. The cause is generally viral but can be direct or indirect in nature. Cytomegalovirus, herpes simplex type 2, varicella-zoster, and toxoplasmosis have been implicated and represent "direct" disease as a result of viral infection. "Indirect" effects include postinfectious demyelination and parainfectious vasculitis. The differential diagnosis should include neoplasia and specifically lymphoma.

**NEOPLASTIC DISEASE**

**Metastases to Bone**

T1-weighted scans are generally the most useful for detection of vertebral body metastases because of their high sensitivity to disease and intrinsic high signal to noise ratio (and thus good image quality). Malignant lesions, with increased cellularity, are low signal intensity on T1-weighted scans and thus quite distinct from the normal high signal intensity marrow (Fig. 7–1). After contrast injection, metastatic lesions usually enhance and are thus less clearly seen unless fat suppression is used. Postcontrast scans can, however, display more effectively the soft tissue extent of disease and canal compromise (Fig. 7–2), although the latter is often also clearly seen on T1-weighted scans. Lytic and blastic lesions appear distinct from one another; the latter is very low signal intensity on T1-weighted scans (Fig. 7–3). With tumors that spread via the lymphatics (e.g., carcinoid), it is important to scrutinize the off-midline sagittal images (and axial scans) for retroperitoneal lymphadenopathy.

In regard to sensitivity, it is well established that MRI is overall more sensitive than radionuclide bone scanning for metastatic disease. MRI may detect lesions despite a normal bone scan. Furthermore, radionuclide bone scans suffer from lower specificity. Degenerative changes, infection, and fractures can all cause a false-positive bone scan. MRI better discriminates between benign and malignant processes.

MRI has replaced myelography in most institutions for the assessment of cord compression by epidural metastatic disease as a result of high sensitivity and low morbidity. Myeloma, prostate, and renal cell carcinoma all have a propensity to develop epidural metastatic disease. However, the highest incidence of epidural metastatic disease is with lung carcinoma; this is the most common cause of metastatic disease to the vertebral column. In terms of symptoms, there is a prodromal phase with central back pain at the level of disease involvement. This is followed by a compressive phase with neurologic deficits, which begin with motor impairment (resulting from anterior cord compression). In lesions causing compression of the conus, autonomic dysfunction may occur without sensory or motor defi-
FIGURE 7–1. Metastatic disease (from lung carcinoma), with mild anterior compromise of the thecal sac. A, On the sagittal T₂-weighted scan, the posterior margins of T7 and T8 bulge in a convex manner posteriorly, encroaching on the spinal canal. The signal intensity of the marrow (of T7 and T8) is misleading on this fast spin echo scan (obtained without fat suppression), appearing isointense with adjacent normal vertebral bodies. Fast T₂-weighted spin echo scans should be acquired with fat saturation to improve their sensitivity to bony metastatic disease. B, The T₁-weighted scan clearly demonstrates the metastatic involvement of T7 and T8. There is replacement of normal marrow in these vertebral bodies by metastatic disease, which demonstrates substantially lower signal intensity. A small focus of metastatic disease (B, arrow) is also present in the anterior superior quadrant of T11.

FIGURE 7–2. Vertebral metastatic disease (from lung carcinoma), with epidural extension and severe cord compression. A, The fast spin echo T₂-weighted midline sagittal image demonstrates compromise of the thecal sac by abnormal soft tissue posteriorly and anteriorly. B, The corresponding T₁-weighted sagittal scan, although not demonstrating as clearly the interface between cerebrospinal fluid (CSF), cord, and soft tissue, clearly depicts the involvement of the posterior portion of both T10 and T11 by metastatic disease. Both the vertebral and epidural lesions demonstrate inhomogeneous enhancement on the postcontrast T₁-weighted sagittal image (C). Contrast enhancement decreases the conspicuity of the vertebral body involvement by metastatic disease but improves the visualization of canal compromise by soft tissue.
FIGURE 7–3. Metastatic disease (from prostate carcinoma) with both lytic and blastic lesions. Metastatic vertebral lesions most often demonstrate decreased signal intensity on T₁-weighted images and increased signal intensity on T₂-weighted scans. Blastic metastases, however, may remain low signal intensity on T₂-weighted images. A, The fast spin echo T₂-weighted scan, obtained with fat suppression, reveals at least two vertebral body lesions with slight high signal intensity (asterisks). Several low signal intensity lesions are also evident (white arrows). B, The T₁-weighted scan better depicts the widespread extent of metastatic disease; the lytic lesions are seen as gray or intermediate low signal intensity (slightly lower in signal intensity than the intervertebral disks), and the blastic lesions as very low signal intensity (almost black). One of the lesions also contains methemoglobin, with abnormal high signal intensity on the T₁-weighted scan. C, The axial section through this lesion reveals abnormal low and high signal intensity. D, A lower axial section demonstrates a focal vertebral body lesion, with additional metastases seen in the ribs (black arrows). A common mistake in film reading is to examine only the midline sagittal scan for metastatic disease. The entire bony skeleton visualized on the scan should be inspected for the presence of metastatic disease, when clinically suspected.
Compression of the thecal sac and cord can occur from any direction, anterior or posterior (Figs. 7–4 and 7–5) or lateral (Figs. 7–6 and 7–7), necessitating close image inspection and acquisition of two perpendicular planes (typically sagittal and axial).

**Leptomeningeal Metastases**

Leptomeningeal metastases can be seen with central nervous system (CNS) tumors (including specifically glioblastoma, ependymoma, medulloblastoma, and pineal tumors) as well as with non-CNS tumors (most commonly lung carcinoma, breast carcinoma, melanoma, and lymphoma). The clinical presentation is varied and includes back pain, leg pain, headache, cranial and spinal nerve deficits, and gait disturbance. The gold standard for diagnosis is CSF cytology. However, this may require multiple samples and a large volume of CSF. The diagnosis of leptomeningeal metastases by CT is based on visualization of nodular filling defects within the CSF and clumping of nerve roots. The advent of high-quality contrast-enhanced spine MRI provided a major advance in the imaging diagnosis of leptomeningeal metastases. MRI is markedly more sensitive than CT for the detection of leptomeningeal metastases when intravenous contrast is used. Small and large enhancing nodules, direct invasion of the cord by metastases, and seeding along the cord surface or exiting nerve roots are all well visualized.

**Hematologic Neoplasia**

Spinal involvement is seen in lymphoma (Fig. 7–8) in 15% of cases. Paravertebral, vertebral, and epidural lesions all occur. Spinal lymphoma is most commonly caused by local spread from retroperitoneal nodes and is thus paravertebral in location. Isolated epidural lesions do occur as a result of hematogenous spread or spread from epidural lymphatics. Epidural disease in lymphoma frequently results in clinically significant cord compression. The appearance of epidural disease is not specific for lymphoma but merely reflects the characteristics of an epidural soft tissue mass. On T₁-weighted scans, a lymphomatous epidural mass is isointense or slightly hyperintense to the spinal cord and on T₂-weighted scans hyperintense to cord. Contrast enhancement is typically homogeneous. Vertebral involvement is also nonspecific in appearance, sharing that of metastatic disease from many causes with inhomogeneous low signal intensity on T₁-weighted scans and intermediate to high signal intensity on T₂-weighted scans.

**Figure 7–4.** Cord compression (in the upper thoracic spine) by expansile bony metastatic disease (from lung carcinoma), revealed on an emergency magnetic resonance imaging scan. A, The fast spin echo T₂-weighted scan with fat suppression reveals extensive abnormal high-signal-intensity bony metastatic disease involving the vertebral bodies and in the upper thoracic spine the spinous processes (posterior elements) as well. The cerebrospinal fluid space surrounding the cord is obliterated, with compression from abnormal soft tissue both anteriorly and posteriorly. B, The T₁-weighted scan clearly depicts the extent of bony metastatic disease but provides a relatively poor view of the canal compromise. Unless intravenous contrast is administered, cord compression is seen best on fast spin echo T₂-weighted scans.
FIGURE 7–5. Cord compression at multiple levels from metastatic colon carcinoma. Just because compression is demonstrated at one level, inspection of the film and the search for other areas of involvement (and possible canal compromise) should not be discontinued. Metastatic disease is typically widespread; therefore, presentation with more than one discrete level of canal compromise is not uncommon. Fast spin echo T₂-weighted (A) and conventional T₁-weighted (B) sagittal scans show severe canal compromise as a result of metastatic involvement of two adjacent vertebral bodies in the upper thoracic spine. However, not to be overlooked is significant anterior cord compression at a level two bodies higher, best seen on the T₂-weighted scan.

FIGURE 7–6. Lateral cord compression resulting from pedicle involvement by metastatic disease. A, The midline sagittal T₁-weighted scan reveals only mild anterior compression of the thecal sac by metastatic disease (which involves both the vertebral body and spinous process). Involvement of the superoposterior quadrant of the adjacent lower vertebral body, with a normal intervening disk space, favors the diagnosis of neoplastic disease as opposed to infection. However, it cannot be concluded from the midline sagittal scan alone that significant canal compromise is not present. Such may occur by involvement of the pedicles laterally, as shown in an adjacent slice (B). Lateral thecal sac compromise was confirmed on the axial scan (not shown).
Metastatic disease from prostate carcinoma, illustrating the importance of both sagittal and axial scans for routine evaluation of canal compromise. On the basis of the sagittal T2-weighted fast spin echo scans (A and B), there is significant cord compression (by abnormal posterior soft tissue) at T4 (only). The lack of fat suppression, however, makes assessment of the extent of bony metastatic involvement difficult. The multiplicity of lesions is readily appreciated from the sagittal T1-weighted scans (C and D). An enlarged lymph node (white arrow), involved by metastatic disease, is also noted anterior to T11. Although the T10 vertebral body is involved in its entirety by metastatic disease, there does not appear to be any substantial canal compromise at this level (on the basis of the sagittal scans alone). However, the axial gradient echo scan at T10 (E) demonstrates substantial anterior and lateral compromise of the canal.
Leukemia is the most common malignancy of childhood and the ninth most common in adults. The disease arises in lymphoid tissue and bone marrow and from a simplistic point of view represents a malignant proliferation of hematopoietic cells. A common symptom is bone pain caused by pressure from rapidly proliferating cells. Bone involvement is most often diffuse but can be focal. The latter is most common in acute myelogenous forms. The CNS serves as a sanctuary for the disease during chemotherapy; thus, the CNS is a frequent site of relapse.

Multiple myeloma is caused by a neoplastic overgrowth of plasma cells. The peak incidence is from 50 to 70 years of age. Vertebral involvement is most common in the thoracic region. MRI is far more sensitive than either plain x-ray films or radionuclide bone scans for disease detection. The most common appearance on MRI is that of diffuse marrow infiltration (Fig. 7–9).
Another not uncommon pattern is that of nodular deposits surrounded by normal marrow. As with other hematologic neoplasias, paravertebral and epidural soft tissue masses can also be seen (Fig. 7–10).

**Astrocytoma/Ependymoma**

The majority of intramedullary spinal cord tumors are either astrocytomas or ependymomas. Astrocytomas are more common in children and ependymomas more common in adults. MRI cannot differentiate an astrocytoma from an ependymoma, although certain imaging features favor one or the other. Involvement of the entire width of the cord, with homogeneous high signal intensity on T₂-weighted scans, favors an astrocytoma (Fig. 7–11). Extensive cord involvement, extending over three or more vertebral segments, also favors an astrocytoma. A small nodular lesion (especially with a cystic component) is more likely to be an ependymoma. Three fourths of all spinal astrocytomas occur in either a cervical or thoracic location.

**Neurogenic Tumors (Nerve/Nerve Sheath Origin Tumors)**

The majority of paraspinal lesions in the thoracic region are neurogenic tumors. These tumors are also the most common cause of a posterior mediastinal mass. In adults, schwannomas and neurofibromas are most common. These two tumors have similar imaging characteristics. In young children, neuroblastoma is most common.

In the radiologic literature, the term schwannoma has been used interchangeably with neurinoma and neurilemmoma. Schwannomas arise from the Schwann cells of the nerve root sheath. Thus, these lesions are seen, at dissection, to be extrinsic (eccentric) to the nerve root. On MRI, schwannomas are hypo- to isointense on T₁-weighted images and hyperintense on T₂-weighted images (Fig. 7–12). On the latter type of scan, schwannomas are also often heterogeneous in appearance; high-signal-intensity areas correspond to small cysts. Enhancement is typically heterogeneous and often more intense peripherally.

Neurofibromas are distinguished from schwannomas by the presence of abundant connective tissue and nerve cells. Neurofibromas enlarge the nerve itself. Neurofibromas are usually associated with neurofibromatosis, even when solitary. Homogeneous contrast enhancement makes the diagnosis of a neurofibroma more likely than that of a schwannaoma.

Three related but different tumors—neuroblastoma, ganglioneuroblastoma, and ganglioneuroma—are thought to arise from primitive sympathetic neuroblasts (the embryonic neural crest). These are differentiated histologically by the degree of cellular maturation. On imaging, the three tumor types are indistinguishable. Neuroblastoma is a malignant tumor composed of undifferentiated neuroblasts. Most neuroblastomas arise in the adrenals and the remainder along the sympathetic chain. The clinical prognosis is worse with increasing age of presentation. The prognosis, however, is better with spinal lesions as opposed to abdominal or pelvic lesions. Extralumbar extension is common with paravertebral lesions. Ganglioneuroblastoma is also a malignant tumor but contains mature ganglion cells in addition to undifferentiated neuroblasts. Ganglioneuroma (Fig. 7–13) is a benign tumor that contains mature ganglion cells. Ganglioneuromas are more common in adolescents and young adults.

**Meningioma**

One third of all spinal meningiomas occur in the cervical region and two thirds in the thoracic region. There is a
Astrocytoma. Sagittal T2- (A) and T1-weighted (B) scans reveal abnormal expansion of the lower cervical and upper thoracic spinal cord. The area involved spans more than three vertebral segments. The lesion is higher in signal intensity than normal cord on the T2-weighted scan and slightly lower in signal intensity than normal cord on the T1-weighted scan. C, Postcontrast there is no enhancement of the mass, which is again demonstrated to be intramedullary in location, expanding the cord to fill the spinal canal.
FIGURE 7–12. Paraspinal schwannoma. T2- (A) and T1-weighted (B) parasagittal images reveal a 3.5-cm paraspinal soft tissue mass at T7. The lesion is high signal intensity, but somewhat heterogeneous, on the T2-weighted scan. Extension into the T7–T8 neural foramen is also noted. C and D, Postcontrast there is intense enhancement of the lesion. Although by imaging appearance the lesion could be either a schwannoma or a neurofibroma, that enhancement is heterogeneous and more intense peripherally favors a schwannoma.

FIGURE 7–13. Ganglioneuroma. A, On the T2-weighted sagittal image to the right of midline, a large paraspinal soft tissue mass is noted. The patient is a 2-year-old child who presented with respiratory distress. The mass extends into and widens the T5–T6 neural foramen. B, On the axial postcontrast T1-weighted image, the mass is noted to enhance. However, the epidural portion enhances more intensely than the remainder of the lesion (the large paravertebral portion). The thoracic spinal cord is severely compressed and displaced to the patient's left.
3:1 female-male incidence. Spinal meningiomas are most often intradural in location but may be extradural. Complete removal can be achieved surgically in 95% of cases. Microsurgical technique is important to minimize neurologic deficits. Despite “complete” removal, 5% recur.

Meningiomas are isointense to the spinal cord on both T1- and T2-weighted scans. This tumor displays marked contrast enhancement, which can improve lesion identification and demarcation (Fig. 7–14). The capping of a meningioma inferiorly and superiorly by CSF is characteristic and demonstrates the lesion to be intradural and extramedullary in location (by far the most common location). On plain film and CT, dense calcification is common.

VASCULAR AND HEMATOPOIETIC DISEASE (NON-NEOPLASTIC)

Arteriovenous Malformation and Fistula

An arteriovenous malformation (AVM) is defined as a nidus of pathologic vessels between enlarged feeding arteries and draining veins. This is to be differentiated from an arteriovenous fistula (AVF), in which the arteries drain directly into enlarged veins. Within this group of lesions, three types are described in the spine: dural AVF (the most common), intramedullary AVM, and intradural extramedullary AVF.

Dural AVFs occur along the dorsal aspect of the lower cord and conus (Fig. 7–15). These feature a single transdural arterial feeder. Dural AVFs are found in elderly men and present with progressive neurologic deficits resulting from venous stasis and infarction.

Intramedullary AVMs occur in young patients and are one cause of intramedullary hemorrhage. They are typically dorsal in location and occur most often in the cervicomedullary region. Multiple feeding vessels lead to a compact vascular plexus, which drains into a tortuous venous plexus surrounding the cord. Intramedullary AVMs present with acute hemorrhagic stroke. The imaging appearance on MRI is that of multiple flow voids within the cord together with enlarged extramedullary feeding vessels (typically anterior to the cord).

Intradural extramedullary AVFs occur in the third to sixth decades. The most common presentation is that of a lesion at the level of the conus but anterior to the cord with supply by the anterior spinal artery. Intradural extramedullary AVFs present with progressive neurologic deficits.

MRI is an important technique for the initial diagnosis of a spinal AVM or AVF. Abnormal large vessels are identified as filling defects on conventional two-dimensional scans. These are best appreciated within the cord on T1-weighted images and within the CSF space on T2-weighted images (see Fig. 7–15). Small lesions are clearly seen postcontrast because of the enhancement of the large draining veins. Associate cord findings include hemorrhage, edema, and myelomalacia.

An important pitfall on image interpretation is that CSF flow artifacts may mimic an AVM on T2-weighted scans. These artifacts can be prominent on conventional spin echo T2-weighted scans but may on occasion also be present on fast spin echo scans. On x-ray myelography, filling defects may be seen as a result of enlarged vessels
and cord atrophy detected, if present. X-ray angiography is used for definitive diagnosis. Selective vessel catheterization, assessing feeding vessels and venous drainage, is performed after initial intra-aortic injection. Spinal AVMs and AVFs are also clearly visualized by contrast-enhanced magnetic resonance angiography, which may with future refinements replace x-ray angiography.

**Spinal Cord Ischemia/Infarction**

There are many causes for spinal cord ischemia and infarction, including atherosclerosis, vasculitis, embolism, infection, radiation, trauma, and surgery (specifically after abdominal aortic aneurysm resection). Infarction and ischemia typically involve the central gray matter of the cord. Anatomically, the lower thoracic cord and conus are most commonly involved. The artery of Adamkiewicz, typically arising from the 9th to 12th intercostal artery, supplies this region. Blood flow is highest to this section of the cord, given the abundance of gray matter and its higher metabolic need. Thus, it is this region of the cord that is most vulnerable to hypoperfusion.

MRI is, without question, the imaging modality of choice for the diagnosis of spinal cord ischemia and infarction. The extent of abnormality as visualized by MRI correlates well with clinical findings and prognosis. The area involved can be minimal (e.g., just the anterior horns). In severe cases, the entire cord is involved in cross-section. In intermediate cases, both the anterior and posterior horns are involved together with the adjacent central white matter. On T2-weighted scans, abnormal high signal intensity is noted in the involved region (Fig. 7–16), corresponding to vasogenic edema in acute and subacute disease. On T1-weighted scans, cord enlargement may be the only finding. Abnormal contrast enhancement of the cord can be present as a result of disruption of blood-cord barrier (secondary to ischemia). There may be associated marrow changes also resulting from ischemia. Differential diagnostic considerations include multiple sclerosis (MS), transverse myelitis, and neoplasia. Recognition of the vascular distribution, both in craniocaudal extent and cross-section, aids in differentiation of spinal cord ischemia/infarction from other disease processes.

**Hemorrhage**

Subarachnoid hemorrhage may be secondary to a spinal aneurysm or AVM or may originate from a cerebral source. With acute hemorrhage, a moderate increase in the signal intensity of CSF on T2-weighted scans may be observed, obscuring the cord and nerve roots. With subacute hemorrhage, high signal intensity is seen on T1-weighted scans because of the presence of methemoglobin.

Epidural and subdural hemorrhage has many causes, including lumbar puncture, trauma, bleeding diatheses, anticoagulant therapy, vascular malformations, vasculitis, and pregnancy. The signal intensity on MRI is dependent largely on the stage of hemorrhage and dilution by CSF. It can be difficult to identify whether a hemorrhage is epidural or subdural in location. When abnormal high signal intensity is seen in the epidural or subdural space,
Spinal cord infarction. The mid- and lower thoracic cord is slightly expanded and has abnormal high signal intensity. These findings correspond to vasogenic edema. Infarcts can be limited to a few vertebral segments or can be very extensive as in this case. With sufficient time, cord atrophy will occur, although the abnormal high signal intensity on T2-weighted scans can persist (as a result of gliosis).

Two other disease processes should be considered in the differential diagnosis. Angiolipomas are rare benign tumors composed of lipocytes and abnormal blood vessels. The latter cause hyperintensity on T2-weighted scans on the basis of slow flow. These tumors are usually epidural in location and occur in the midthoracic region. Angiolipomas can cause bone erosion, pathologic fractures, and cord compression. The other consideration should be extradural lipomatosis, although with this disease process the abnormal soft tissue should be readily identifiable as fat (by inspection of both T1- and T2-weighted scans).

**Extramedullary Hematopoiesis**

Extramedullary hematopoiesis is a compensatory response to insufficient red blood cell production by bone marrow. It is seen in thalassemia, hereditary spherocytosis, and myelosclerosis. Favored sites of involvement include the spleen, liver, and lymph nodes. Thoracic involvement is rare and usually asymptomatic. Thoracic involvement is seen on imaging as a paraspinal mass resulting from extrusion of proliferating marrow from vertebral bodies into a subperiosteal location. Intraspinal lesions can occur as a result of extrusion of bone marrow or development of marrow from embryonic hematopoietic rests. Intraspinal involvement can cause cord compression. The appearance on MRI of thoracic extramedullary hematopoiesis is that of multiple, smoothly margined, paraspinal masses without bone erosion (Fig. 7–17). The masses have the signal intensity of marrow on all pulse sequences. The differential diagnosis should include lymphoma and metastatic disease.

**TRAUMA**

Burst fractures are the most common traumatic bone injury encountered in the thoracic spine. Burst fractures are caused by an axial loading injury. Vertical compression forces the nucleus pulposus into the vertebral body, with radial displacement of fragments. Burst fractures are most common from T9 to L5. The injury is typically limited to one vertebral body, but associated injuries are common. Neurologic deficits occur as a result of the retropulsed fragments. CT is often used for initial evaluation. MRI detects associated cord (edema and hemorrhage) and ligamentous injuries, which are not clearly seen by CT.

**DEGENERATIVE DISK AND BONY DISEASE**

In the thoracic spine, disk herniations are most common at the lower four interspaces, where the spine is more mobile. Thoracic disk herniations are less common than either cervical or lumbar herniations. The clinical presentation is often not clear-cut. Symptoms include back pain, paresthesias, and motor weakness. On high-quality MRI images, small thoracic disk herniations are clearly seen (Fig. 7–18). MRI also clearly demonstrates mass effect on the cord, when present, and contour deformities of the cord. As with cervical disk herniations, part of the abnormality may actually represent dilated epidural venous plexus. On contrast-enhanced images, the dilated, engorged epidural venous plexus above and below the herniated disk (Fig. 7–19) is readily identified.

In addition to dedicated thoracic spine images, a high-quality large field of view localizer should be acquired, on which the dens can be identified, to define the level of disk herniation correctly. The use of MRI markers can assist in correct level identification. Commonly used markers include vitamin E capsules (an oily vitamin that has high signal intensity on T1-weighted scans) or oil (such as Johnson’s baby oil) in a strip of intravenous tubing.

**ABNORMAL ALIGNMENT**

Scoliosis is defined as a lateral curvature of the spine. Ninety percent of cases are idiopathic with no underlying cause. Idiopathic thoracic scoliosis is more common in females, and the thoracic curvature is typically convex to right (with an S-shaped curve). Progression beyond 50 degrees necessitates surgery.
Extremedullary hematopoiesis with severe cord compression. The patient is 32 years of age with thalassemia and presents clinically with progressive paraplegia. A, The T1-weighted coronal image demonstrates large bilateral lobulated paraspinal masses in the upper and midthoracic regions. B, On the T1-weighted midline sagittal view, large intraspinal masses with resultant severe cord compression are identified at the T6 to T8 levels. The soft tissue masses lie within the same space as the thoracic epidural fat. Also noted is a generalized decrease in signal intensity of the thoracic vertebral bodies. C, The corresponding fast spin echo T2-weighted sagittal image confirms the abnormal intraspinal soft tissue masses. The lesions remain relatively low in signal intensity on the T2-weighted scan. Abnormally increased signal intensity compatible with edema or gliosis is identified within the compressed thoracic spinal cord. On postcontrast scans (not shown), there was mild, homogeneous enhancement of the paraspinal and the intraspinal lesions.
FIGURE 7–18. Thoracic disk herniation. A, The midline sagittal fast T2-weighted scan reveals mild anterior indentation of the thecal sac (arrow) at a midthoracic level. B and C, Axial gradient echo T2-weighted scans reveal small left paracentral disk herniations at this level and two levels below. It cannot be determined, however, whether these lesions are acute or chronic in nature. Attention to detail and high-quality images are necessary to diagnose thoracic disk herniations because these are often very small in size (despite being clinically symptomatic).
Thoracic disk herniation demonstrating utility of contrast administration. The patient is a 31-year-old woman with bandlike paresthesias in the midthorax after an automobile accident. A, The $T_2$-weighted scan reveals anterior compression of the thecal sac at T7–8. Abnormal soft tissue can be noted on both the $T_2$-weighted and the precontrast $T_1$-weighted (B) scans. C, Contrast use permits identification of dilated epidural venous plexus and granulation tissue surrounding the disk herniation (arrow). In comparing the pre- (D) and postcontrast (E) axial scans, enhancement aids, in particular, identification of the interface between the disk (arrow) and the thecal sac.
Ten percent of thoracic scoliosis can be attributed to congenital, neuromuscular, or posttraumatic causes. In the congenital category are both vertebral anomalies (butterfly vertebral body and hemivertebra) and abnormalities of the cord. The latter include Chiari malformations, hydrocephaly, diastematomyelia, and spinal cord neoplasm. Cerebral palsy is the primary neuromuscular cause and leads to a C-shaped curve. Posttraumatic causes include fractures, old osteomyelitis, surgery, and radiation therapy. MRI is the imaging modality of choice for study of atypical or progressive scoliosis. In a patient with scoliosis, coronal images are particularly useful in conjunction with sagittal images. Plain x-ray films are used for quantitation of the curvature (degree) and monitoring of progression.

MULTIPLE SCLEROSIS

MS lesions of the thoracic cord are clearly seen on high-quality MRI images, with no difference in appearance than that described for the cervical spine. In acute disease, there can be focal cord swelling, edema (limited to a focal region in both cross-section and craniocaudal extent and best seen on T2-weighted images), and abnormal contrast enhancement (as a result of blood-spinal cord barrier disruption seen on contrast enhanced T1-weighted images). Chronic lesions can be identified on T2-weighted scans because of focal cord atrophy and gliosis (Fig. 7–20).

**Figure 7–20.** Multiple sclerosis (inactive disease). Three short-segment high-signal-intensity lesions (asterisks) are noted within the thoracic cord on a fast spin echo T2-weighted scan. Cord atrophy is noticeable at the level of the highest lesion, determining it to be chronic in nature (with the abnormal signal equating to gliosis). Neither of the lower lesions causes cord expansion, making it unlikely that either represents active disease. The lack of contrast enhancement (images not shown) confirmed the chronic nature of disease in this patient.