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Magnetic Resonance Imaging of Spine Tumors: Classification, Differential Diagnosis, and Spectrum of Disease

By Gregory P. Gebauer, MD, MS, Payam Farjooodi, MD, Daniel M. Scuibba, MD, Ziya L. Gokaslan, MD, Lee H. Riley III, MD, Bruce A. Wasserman, MD, and A. Jay Khanna, MD

Introduction

Magnetic resonance imaging is an excellent modality for imaging pathologic processes involving the spine. It permits high-resolution imaging of not only the osseous structures but also the soft-tissue structures in multiple orthogonal planes through the use of varying pulse sequences that allow for characterization of the different tissues in and around the spine. The purposes of this report are to (1) describe the specialized pulse sequences and imaging techniques available for evaluation of the spine, (2) describe the defining characteristics of the three compartments into which spinal tumors can be classified, (3) define the differential diagnoses for tumors identified in each of these three compartments, and (4) provide a basic knowledge of the tumors that are commonly encountered in the spine.

Essentials of Magnetic Resonance Imaging

Process of Image Production

First, the patient is placed in the scanner. The magnetic field of the scanner (most frequently 1.5 T) aligns all protons within the patient along the longitudinal axis of the scanner. An electromagnetic pulse is sent into the scanner and causes reorientation of the protons (usually 90° to the external field).

Fig. 1-A through 1-D Magnetic resonance images of a normal lumbar spine: sagittal T1-weighted (Fig. 1-A), axial T1-weighted (Fig. 1-B), sagittal T2-weighted (Fig. 1-C), and axial T2-weighted (Fig. 1-D).

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The pulse is turned off, and the protons are allowed to relax. As the protons relax, they emit a radiofrequency signal that is then detected by an antenna in the scanner. The signal is processed with use of an algorithm (Fourier Transformation), and software programs are used to create the images in multiple orthogonal planes.

**Definitions**

T1 indicates the amount of time required for 63% of the protons to return to their preexcited state and is a measure of the longitudinal relaxation of the protons. T2 indicates the amount of time that is needed for 63% of the protons to “dephase,” that is, to start precessing at frequencies different from the applied electromagnetic pulse. This decay rate is a characteristic of the tissue.

**Types of Pulse Sequences**

By manipulating the strength of a radiofrequency pulse, how frequently it is applied, and how long after the pulse the energy emitted by relaxation is measured, the images can be weighted to emphasize the T1, T2, or gradient-echo characteristics of a tissue. T1-weighted images have conventionally been considered to be the best choice for evaluating anatomy, fracture lines, and other osseous detail (Figs. 1-A and 1-B). T2-weighted images are sensitive to pathologic changes in tissue, including any process in which cells and the extracellular matrix have an increased water content (Figs. 1-C and 1-D). These images provide a good myelographic effect but are more susceptible to motion artifact than T1-weighted images.

**TABLE I Basic Pulse Sequences for Magnetic Resonance Imaging of the Spine**

<table>
<thead>
<tr>
<th>Image Type</th>
<th>Repetition Time</th>
<th>Echo Time</th>
<th>Signal Intensity</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1-weighted</td>
<td>Short</td>
<td>Short</td>
<td>Bright</td>
<td>Best anatomic detail; rapid acquisition</td>
<td>Poor demonstration of pathology or edema</td>
</tr>
<tr>
<td>T2-weighted†</td>
<td>Long</td>
<td>Long</td>
<td>Bright</td>
<td>Moderately sensitive for abnormality or edema; nice myelographic effect</td>
<td>Decreased soft-tissue detail; time-consuming</td>
</tr>
<tr>
<td>Fat-suppressed T2-weighted or</td>
<td>Long</td>
<td>Short</td>
<td>Very dark</td>
<td>Most sensitive for abnormality or edema; nice myelographic effect</td>
<td>Decreased soft-tissue detail; time-consuming</td>
</tr>
<tr>
<td>short tau inversion recovery (STIR)†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gradient echo</td>
<td>Short</td>
<td>Short</td>
<td>Variable</td>
<td>Evaluation of articular cartilage, degenerative changes, and ligaments; excellent for evaluation of blood</td>
<td>Very susceptible to metallic artifacts (prostheses); exaggerates effect and/or appearance of osteophytes</td>
</tr>
<tr>
<td>Diffusion-weighted images</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Dark</td>
<td>Can distinguish arachnoid cysts from epidemoid cysts and benign from pathologic compression fracture; can detect spinal infarct</td>
</tr>
</tbody>
</table>

are. Fat-suppressed T2-weighted and short tau inversion recovery images are acquired with use of a pulse sequence to suppress fat and accentuate fluid and edema. These pulse sequences are the most sensitive to pathologic change and edema in the osseous and paraspinal tissues and provide an excellent myelographic effect. Gradient-echo images are most useful for the evaluation of degenerative changes, including osteophytes and neural foraminal narrowing. This modality is also excellent for evaluating hemorrhage, which produces a signal dropout secondary to the high levels of hemosiderin. Diffusion-weighted imaging is an advanced form of magnetic resonance imaging that involves measuring the apparent diffusion coefficient of water molecules. It has a role in distinguishing arachnoid cysts from epidermoid cysts and in distinguishing pathologic from benign compression fractures. It can also be used to diagnose spinal infarcts.

**TABLE II Tissue Characteristics on Magnetic Resonance Imaging***

<table>
<thead>
<tr>
<th>Tissue Type</th>
<th>Signal Intensity</th>
<th>Gradient-Echo Image</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1-Weighted Image</td>
<td>T2-Weighted Image†</td>
</tr>
<tr>
<td>Cortical bone</td>
<td>Very low</td>
<td>Very low</td>
</tr>
<tr>
<td>Red marrow</td>
<td>Intermediate</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Yellow marrow</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Spinal cord</td>
<td>Intermediate</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Cerebrospinal fluid</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Intervertebral disc</td>
<td>Intermediate</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Fat</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Muscle</td>
<td>Intermediate</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Ligaments</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Physeal scar</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>


**Figs. 2-A and 2-B** The effect of gadolinium contrast enhancement. Note the intense enhancement of a schwannoma at the thoracolumbar junction on these sagittal T1-weighted images before (Fig. 2-A) and after (Fig. 2-B) the administration of gadolinium. (Images courtesy of Iain H. Kalfas, MD, Cleveland, OH.)
Basic Steps in Image Interpretation

As previously described, the basic steps in the interpretation of images include the following:

1. Determine the pulse sequence for all images (Tables I and II).

2. Locate the T2-weighted midsagittal image. Then, serially evaluate all parasagittal images in each direction toward the facet joints and neural foramina. Use the coronal localizer image to confirm right or left orientation.

3. Repeat Step 2 for other pulse sequences (usually T1-weighted and occasionally gadolinium-enhanced T1-weighted sequences).

4. Locate the most superior slice on the T2-weighted axial images. Serially evaluate all images from superior to inferior. Use the intervertebral discs and the sagittal localizer image to confirm levels. Repeat this process (step 4) for other pulse sequences.

5. Correlate the magnetic resonance imaging findings with the clinical history and additional imaging modalities (including computed tomography, conventional radiographs, and bone scans) to develop a differential diagnosis.

Gadolinium Enhancement

Gadolinium contrast enhancement increases the conspicuity of most intradural-extramedullary and intramedullary tumors. Normally, the meninges overlying the cord do not enhance, so contrast can be used for detecting intradural-extramedullary processes (such as drop metastases) that are not detectable by other means. For the detection of osseous lesions, contrast enhancement must be accompanied by fat suppression to avoid the blending of lesions with the surrounding bright signal from fatty marrow. The administration of gadolinium can also improve biopsy localization because areas of
greater enhancement correlate with areas of higher cellular activity. Other important applications of gadolinium contrast enhancement are the differentiation of epidural fibrosis from recurrent disc herniation in patients after decompressive surgery and the evaluation of infectious processes.

The presence of contrast enhancement is evaluated by comparing identical levels on precontrast (Fig. 2-A) and postcontrast (Fig. 2-B) sagittal T1-weighted images. Contrast enhancement is seen as an increase in signal on the postcontrast T1-weighted images.

Compartmental Classification

Tumors in the spine can be localized into one of three compartments: extradural, intradural-extramedullary, and intramedullary. Lesions in each of these compartments have common characteristic appearances that help to identify the compartment in which the tumor is located. Once the lesion is localized, a differential diagnosis can be developed based on the tumors that commonly occur in that compartment. Some lesions have characteristic magnetic resonance imaging or radiographic features that may allow for a definitive diagnosis based on imaging studies alone.

Extradural tumors (Fig. 3-A), both benign and malignant, primarily arise from the osseous structures of the spine; however, they may also arise from the dura, nerve roots external to the dura, connective tissue, fat, blood vessels, or lymphatic tissues. Approximately 30% of primary spine tumors originate in the extradural space. The characteristic magnetic resonance imaging finding for tumors in this space is compression of the thecal sac away from the lesion. Unlike intramedullary lesions, the cord is flattened and the tumor origin is eccentric. Extradural tumors can be subclassified as primary spinal tumors (benign and malignant) and secondary spinal tumors or metastatic disease.

Intradural-extramedullary tumors are the most common primary neoplasm in the spine, accounting for approximately 55% of primary spinal tumors. These lesions occur from within the dura but outside of the spinal cord (Fig. 3-B). The magnetic resonance imaging findings of intradural-extramedullary tumors include displacement of the cord to the contralateral side of the thecal sac, widening of the space available for the cerebrospinal fluid above and below the tumor, and a sharp demarcation between the tumor and the cerebrospinal fluid. With larger tumors, the spinal cord is often flattened against the dura on the contralateral side. To avoid confusing the appearance of intradural-extramedullary
tumors with intramedullary tumors, it is important to evaluate orthogonal magnetic resonance images.

Intramedullary tumors arise from the parenchyma of the spinal cord or nerve root (Fig. 3-C). These tumors account for 16% to 25% of primary spinal neoplasms.11,13 The characteristic magnetic resonance imaging finding is widening of the spinal cord in all planes (sagittal, axial, and coronal), with narrowing of the cerebrospinal fluid column on T2-weighted images at the level of the lesion. If the widening of the cord is the result of a tumor, the extent of the widening is usually limited to several levels. Administration of gadolinium is particularly helpful for the evaluation of intramedullary tumors. Many lesions may be associated with syringomyelia or cyst-like lesions within the cord.14

Because extradural tumors primarily involve the osseous structures, they are the tumors most commonly seen and treated by an orthopaedic surgeon. Intramedullary and intradural-extramedullary tumors are more commonly seen and treated by neurosurgeons.

**Extradural Tumors**

Extradural tumors commonly arise from the bone but can also develop in the soft tissues near the spine but outside of the spinal cord. Both benign and malignant lesions can occur in this space (Table III). The most common extradural.
tumor is metastatic disease. Given the degree of osseous involvement, conventional radiographs and computed tomography scans are often necessary for the full evaluation of these lesions. Magnetic resonance imaging is useful to assess the soft-tissue and cartilaginous components of these tumors and the extent of their impingement on the neural elements. Extradural tumors can be divided into primary lesions and metastatic disease. Primary lesions can be subdivided further into benign and malignant tumors.

**Metastatic Disease**

Metastatic disease is second only to intervertebral disc herniation as the most common type of extradural defect in the lumbar spine, and the spine (in particular, the thoracic region) is the most common location of osseous metastasis. Metastatic disease can occur in any compartment, but the extradural space is the most common site. The most common primary neoplasms that lead to metastatic disease are breast, lung, and prostate cancers, followed by renal cell carcinoma, lymphoma, melanoma, and myeloma. At autopsy, up to 40% of patients with systemic cancer have been found to have metastatic disease of the spine. Metastatic lesions often develop first in the posterior vertebral body.

Magnetic resonance imaging can be particularly useful in distinguishing compression fractures from pathologic fractures associated with metastatic disease. Magnetic resonance imaging is also useful for detecting metastatic disease not seen on computed tomography or bone-scan imaging. Additionally, magnetic resonance imaging of metastatic disease can show soft-tissue involvement. Spinal metastatic disease develops in approximately 5% of children with solid tumor malignant neoplasms (most commonly, Ewing sarcoma, neuroblastoma, or osteosarcoma) (Figs. 4-A through 7-B).

**Primary Tumors**

Primary extradural lesions include benign and malignant tu-
mors arising in the bone and soft tissues around the spine. As mentioned previously, conventional radiographs and computed tomography are often useful adjuncts in evaluating these lesions. Several lesions have characteristic appearances that are diagnostic.

Benign Lesions

Hemangiomas: Hemangiomas are relatively common benign lesions located in the vertebral body. They have a characteristic appearance on conventional radiographs, computed tomography, and magnetic resonance imaging. These lesions have “jailhouse” striations on conventional radiographs and sagittal computed tomography images and a “polka-dot” appearance on axial computed tomography. On magnetic resonance imaging, hemangiomas commonly have increased signal on T1-weighted and T2-weighted images, as opposed to most other lesions, which show low T1 signal and high T2 signal. Hemangiomas are commonly found incidentally, but they can be associated with pathologic compression fracture and (rarely) with epidural extension and cord compression (Figs. 8-A, 8-B, and 8-C).

Osteoid osteoma: These small (<1.5 cm) round benign lesions usually are located in the neural arch and are often surrounded by sclerotic bone. The most common location for these lesions is the lumbar spine, followed by the cervical and thoracic spine. Patients often present with severe pain that improves with nonsteroidal anti-inflammatory drugs. Scoliosis may be present in up to 70% of patients, and the lesion usually occurs on the concavity of the curve. Computed tomography images show a small nidus with a rim of sclerotic bone. Magnetic resonance images typically show normal to decreased T1 signal in the nidus and normal to increased T2 signal in the surrounding bone because of the local inflammatory response. It is important to note that computed tomography, given that it provides better spatial resolution and ability to evaluate osseous detail compared with magnetic resonance imaging, is often useful in evaluating these lesions.

Figs. 10-A and 10-B Extravascular lipoma. T1-weighted (Fig. 10-A) and fat-suppressed (Fig. 10-B) magnetic resonance images of a lipoma in the retropharyngeal space. Note the homogeneous appearance of the lesion on the T1-weighted images and the similarity of its appearance to that of the subcutaneous fat. Also observe the complete loss of signal on the fat-suppressed image.

Figs. 11-A and 11-B Sagittal T1-weighted (Fig. 11-A) and T2-weighted (Fig. 11-B) magnetic resonance images of a lumbar plasmacytoma involving the L5 vertebral body. Such lesions contain monoclonal plasma cells.
resonance imaging, is the imaging modality of choice for osteoid osteoma.

Osteoblastoma: Osteoblastomas are similar in nature to osteoid osteomas except that they are larger (>1.5 cm). Also, patients who have an osteoblastoma often have a dull ache that is unresponsive to nonsteroidal anti-inflammatory drugs rather than the sharp severe pain that is more commonly associated with an osteoid osteoma. Osteoblastomas usually originate in the neural arch but can expand into the pedicle, lamina, transverse process, and even the vertebral body. In the presence of scoliosis, the lesion is usually located on the convexity of the curve. These lesions often show normal to decreased T1 signal and normal to increased T2 signal. Fluid-fluid levels may be present.

Aneurysmal bone cyst: Aneurysmal bone cysts are expansile lytic lesions that commonly occur in the neural arch, and they may spread to include the vertebral body, ribs, and adjacent structures. They usually occur in young patients (less than twenty years old) and may occur in conjunction with other bone lesions, such as giant cell tumors and osteoblastoma. Computed tomography may show a thin-walled expansile lytic lesion. Magnetic resonance imaging may show fluid-fluid levels from the breakdown of blood and blood products within intratumoral cysts.

Giant cell tumor: These locally aggressive lytic lesions are located along the midline of the body in the vertebrae or sacrum. Histologic examination shows abundant giant cells, hence, the name of the lesion. Magnetic resonance imaging shows decreased T1 signal and increased T2 signal. The image may be heterogeneous in nature, showing areas of necrosis and fluid-fluid levels from the breakdown of blood products. Although it is rare, such lesions may undergo sarcomatous change; therefore, patients should be followed serially even after surgical excision to monitor for any signs of recurrence.

Lipoma: Lipomas may occur in the extradural and intradural-extradural compartments and may be related to generalized lipomatosis (such as that seen with chronic corticosteroid use) or to lipomyelomeningocele. Large lipomas may have a mass effect on the neural elements or may contribute to a tethered cord syndrome in children. On magnetic resonance imaging, there is a homogeneous T1-weighted signal that is similar to the signal seen in the subcutaneous fat; on fat-suppressed images, the signal should drop out completely. Therefore, the signal of the lesion is identical to that of subcu-
Osteochondroma: Osteochondromas are benign cartilage and bone growths that are sometimes associated with genetic disorders, such as multiple hereditary exostosis. They rarely occur in the spine (5% of all osteochondromas), but when they do, they are most commonly located in the cervical region, particularly at C2. Magnetic resonance imaging is particularly useful for imaging the cartilaginous cap that covers these lesions. There may be some peripheral enhancement surrounding the cartilaginous cap on T2-weighted images. Rarely, these lesions may undergo malignant transformation to chondrosarcoma, which should be suspected if the thickness of the cartilaginous cap is >1 cm.

Eosinophilic granuloma: These lytic osseous lesions usually occur in persons who are younger than twenty years of age. The majority of lesions are located in the cervical spine (56%), with 9% in the thoracic spine and 25% in the lumbar region. The lesions often have a foreign body giant cell reaction, which may be mistaken for a neoplasm. The most common location for eosinophilic granulomas is the vertebral body, but they can also involve the posterior elements, pedicles, and intervertebral disc spaces. Magnetic resonance imaging is particularly useful for identifying the cartilaginous cap that covers these lesions. There may be some peripheral enhancement surrounding the cartilaginous cap on T2-weighted images. Rarely, these lesions may undergo malignant transformation to chondrosarcoma, which should be suspected if the thickness of the cartilaginous cap is >1 cm.

Figs. 14-A and 14-B Ewing sarcoma. Axial (Fig. 14-A) and coronal (Fig. 14-B) T1-weighted gadolinium-enhanced, fat-suppressed magnetic resonance images of a left sacrum-based Ewing sarcoma. These tumors usually occur in young patients and are associated with permeative bone destruction.

Figs. 15-A and 15-B Primitive neural ectodermal tumor. Coronal (Fig. 15-A) and axial (Fig. 15-B) T1-weighted magnetic resonance images showing a right paraspinal neuroblastoma. Such tumors, which occur almost exclusively in children who are younger than ten years of age, arise from embryonic neural crest cells. They commonly originate in the abdominal or thoracic cavities and extend through the neural foramen. (Reprinted, with permission, from: Khanna AJ, Shindle MK, Wasserman BA, Gokaslan ZL, Gonzales RA, Buchowski JM, Riley LH III. Use of magnetic resonance imaging in differentiating compartmental location of spinal tumors. Am J Orthop. 2005;34:475.)
age. They commonly present with vertebra plana (collapse of a single vertebral level). Magnetic resonance imaging may show increased T2 signal. There should not be an associated soft-tissue mass. If a soft-tissue mass is present, additional workup is indicated because the lesion is probably not an eosinophilic granuloma.

Malignant Tumors

Multiple myeloma and plasmacytoma: Multiple myeloma is the most common primary osseous malignant process. It commonly presents with multiple lytic lesions affecting the spine, cranium, and long bones. In the spine, these lesions may present as compression fractures or vertebra plana. Biopsy shows monoclonal plasma cells, and urine and serum studies commonly reveal a gammaglobulinopathy. Plasmacytoma is a variant of the disease, with only a single, biopsy-proven lesion and the absence of systemic signs of the disease (i.e., serum calcium levels and blood-cell counts are normal). On magnetic resonance imaging, these lesions usually are centered at the vertebral body and have a low T1 and a high T2 signal. Multiple myeloma often shows multiple foci within the spine. A complete skeletal survey is useful in detecting other lesions and in differentiating multiple myeloma from plasmacytoma. Bone scans often are not helpful because the lesions frequently do not show increased uptake of technetium. Most patients with a plasmacytoma develop multiple myeloma (Figs. 11-A through 12-B).

Lymphoma: Lymphoma of the spine can be a primary lesion, although metastatic disease is more common. B-cell lymphomas are the most common form (more than 80%), and non-Hodgkin lymphoma is more common than Hodgkin disease. Lymphomas can occur in any compartment but are found most commonly in the extradural space. These lesions show low signal intensity on T1-weighted images, high signal intensity on T2-weighted images, and diffuse and uniform enhancement with contrast.

Chordoma: These malignant tumors arise from the embryonic notochord. They are midline lesions that occur most commonly in the sacrum and, next most commonly, at the sphenoid-occipital junction. Chordomas are often quite large at the time of diagnosis, and pathologic examination shows sheets of physaliphorous cells. These lesions show low signal on T1-weighted images and high signal on T2-weighted images (Figs. 13-A and 13-B).

Schwannoma. Sagittal T1-weighted (Fig. 17-A) and fat-suppressed T2-weighted (Fig. 17-B) magnetic resonance images of an intradural-extradural lesion subsequently proven to be a schwannoma at the L2-L3 level. Note how the neural elements are displaced away from the lesion. (Images courtesy of Edward C. Benzel, MD, Cleveland, Ohio.)
Ewing sarcoma: Ewing tumor of the spine is usually the result of metastatic spread from another location in the body. These lesions typically have a permeative “moth-eaten” pattern of bone destruction. Ewing tumor is often associated with extensive soft-tissue involvement, which is best visualized with use of magnetic resonance imaging. These lesions show increased signal on T2-weighted images and decreased signal on T1-weighted images (Figs. 14-A and 14-B).

Neuroectodermal tumor: These lesions represent a range of tumors originating from embryonic neural crest cells. They usually present as abdominal or thoracic masses with intraspinal extension in children who are younger than ten years of age. These dumbbell-shaped tumors often widen the neural foramen. Magnetic resonance imaging often shows low signal on T1-weighted images, but the T2-weighted images have a variable appearance. Contrast enhancement may show areas of intrallesional necrosis (Figs. 15-A and 15-B).

Chondrosarcoma: Chondrosarcomas are malignant cartilaginous tumors that can occur anywhere that cartilage exists. Approximately 5% of these tumors occur in the spine.
They may be associated with malignant degeneration of osteochondromas. Areas of hyaline cartilage have increased signal on T2-weighted magnetic resonance images, and areas of mineralized matrix have low T2 signal. Contrast may help reveal the typical “rings and stipples” pattern that is also commonly seen on computed tomography and conventional radiographic imaging (Figs. 16-A and 16-B).

**Osteosarcoma:** Osteosarcomas are malignant tumors of osteoblasts that form an immature osteoid matrix. Approximately 4% of these lesions occur in the spine, most commonly in the posterior elements. They can occur primarily or secondarily to irradiation or to degeneration of other lesions, such as Paget disease or bone infarcts. They typically show low signal on T1-weighted and T2-weighted images.

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**Figs. 21-A, 21-B, and 21-C** Meningioma. **Fig. 21-A** Sagittal T2-weighted magnetic resonance image of an intradural-extramedullary mass (arrow) in the thoracic spine. **Fig. 21-B** Axial T1-weighted image at the level of the meningioma (short arrow). Note that the spinal cord (long arrow) is displaced away from the tumor. **Fig. 21-C** Axial T1-weighted gadolinium-enhanced image of the meningioma. Note the intense enhancement of the lesion (arrow).

They may be associated with malignant degeneration of osteochondromas. Areas of hyaline cartilage have increased signal on T2-weighted magnetic resonance images, and areas of mineralized matrix have low T2 signal. Contrast may help reveal the typical “rings and stipples” pattern that is also commonly seen on computed tomography and conventional radiographic imaging (Figs. 16-A and 16-B).

**Astrocytoma.** Sagittal T1-weighted (Fig. 22-A), sagittal T2-weighted (Fig. 22-B), and axial T2-weighted (Fig. 22-C) magnetic resonance images of a lesion at the C3 level that was subsequently found to be an astrocytoma.
The most common intradural-extramedullary tumors are nerve sheath tumors (neurofibromas and schwannomas) and meningiomas. Together, these three lesions account for 55% of primary spinal neoplasms and 80% of the neoplasms occurring in this compartment. There is a wide variety of differential diagnoses for lesions occurring in this compartment (Table III).

**Nerve Sheath Tumors (Schwannoma, Neurofibroma)**

Schwannomas are benign lesions and the most common intradural-extramedullary tumor. They are most often located in the intradural-extramedullary compartment, but they may also be completely extramedullary or may extend from the intradural-extramedullary space to the extradural compartment. The latter dumbbell-shaped lesion may cause widening of the neural foramen. Both of these lesions show...
increased signal on T2-weighted images. Gadolinium-enhanced images may show homogeneous enhancement or areas of cystic degeneration46 (Figs. 17-A through 19).

Neurofibromas commonly occur in patients with neurofibromatosis type 1. Such patients often have other signs of the disease, including café au lait spots, axillary freckling, dural ectasia, scoliosis or kyphosis (or both), and vertebral abnormalities. On magnetic resonance imaging, these lesions have an appearance similar to that of schwannomas; however, neurofibromatosis may have multiple lesions, whereas schwannomas are usually single lesions. Neurofibromas are also less likely to undergo cystic degeneration and often show peripheral enhancement on T2-weighted images47. Additionally, these lesions may undergo malignant transformation, signs of which include increased size (>5 cm) and the presence of an infiltrative soft-tissue mass48 (Figs. 20-A and 20-B).

Meningioma
Meningiomas are slow-growing and commonly benign (>95%) lesions originating from the dura48. They usually occur in the thoracic spine (80%) and are most commonly located dorsal to the spinal cord49,50. These lesions have a signal similar to that of the spinal cord on T1-weighted images and similar to increased signal compared with that of the spinal cord on T2-weighted images. Gadolinium-enhanced T1-weighted images may show “dural tails,” indicating a broad-based attachment to the dura51 (Figs. 21-A, 21-B, and 21-C).

Epidermoid and Dermoid Cysts
These rare (<1% of spinal tumors) and usually cystic lesions are composed of epithelial cells52. They are usually benign but can undergo malignant transformation into squamous-cell carcinoma. These lesions may be congenital (hamartoma) or iatrogenic in nature. Iatrogenic cysts may be caused by the inclusion of some dermal or epidermal tissue during the closure of a myelomeningocele or by the introduction of epithelium during epidural spinal injections52. These lesions have low T1 and high T2 signal. Diffusion-weighted images may help to distinguish epidermoid cysts from arachnoid cysts.

Intradural Tumors
Intradural tumors arise from the parenchyma of the spinal cord or nerve root and account for approximately 16% to 25% of spinal neoplasms11,13. Gliomas are the most common tumor occurring in this compartment, accounting for approximately 90% of tumors in this space (Table III). In adults, ependymomas are more common than astrocytomas, but in children this order is reversed and astrocytomas are more common13,53. Many lesions may be associated with syringomyelia or cyst-like cavities within the spinal cord.

Glioma (Ependymoma, Astrocytoma)
These types of lesions are nearly identical in appearance on magnetic resonance imaging. Typically, these lesions have high T2-weighted signal, and the T1-weighted signal is similar or slightly decreased compared with that of the spinal cord. T2-weighted images are also helpful for identifying perilesional cysts and syrinxes. Gliomas typically show robust enhancement after the administration of gadolinium, which helps to distinguish them from the spinal cord. They are usually located centrally within the spinal cord in the cervical or thoracic spine (Figs. 22-A through 24-B).

Unlike the more common cellular or mixed ependymomas, myxopapillary ependymomas occur in the conus med-
ullaris or filum terminale. These slow-growing lesions may expand to fill the entire thecal sac and extend into the neural foramen. T2-weighted images may show a meniscus-like layer of cerebrospinal fluid around the lesion.

**Hemangioblastoma**

These highly vascular lesions often cause diffuse enlargement of the spinal cord. They are located below the pia mater and therefore occur on the periphery of the spinal cord. On magnetic resonance imaging, they have robust enhancement with contrast and often show flow voids (loss of signal secondary to high-velocity flow). The entire neural axis should be imaged to identify the presence of multiple lesions, which may be associated with von Hippel-Lindau syndrome (Figs. 25 and 26).

**Paraglioma**

Paragliomas, rare tumors that occur in the cauda equina, are highly vascular and appear as well-defined areas of intense enhancement on contrast-enhanced magnetic resonance images. Flow voids may be present.

**Implications in Spinal Surgery**

An understanding of the magnetic resonance imaging characteristics of spinal tumors is an essential component of the evaluation of the patient with spinal abnormalities. Determining the compartmental location of the lesion and taking into account additional information from other imaging modalities and patient-specific factors (age and medical history), the surgeon can develop a differential diagnosis for the tumor type. Additional evaluation of the magnetic resonance imaging characteristics, including tissue composition and contrast enhancement, may provide the definitive diagnosis for some tumors and therefore allow for the determination of patient prognosis and the need for adjuvant therapy.

In addition, by defining the compartment in which the tumor resides and its relation to neighboring anatomic structures, the spine surgeon can select the appropriate operative approach for biopsy or resection, or both, of the tumor. By visualizing and understanding the anatomic limits of the tumor before proceeding to the operating room, a more specific and effective operation can be planned.

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**References**


