2 Normal MRI Anatomy of the Musculoskeletal System
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To evaluate effectively an MRI examination of a particular joint or region in the musculoskeletal system, it is essential to have at least a basic understanding of the normal MRI anatomy of that region. Many excellent texts and atlases have been written to serve this need for clinicians and radiologists. This chapter provides a brief overview of the most clinically important anatomy for each major region of the musculoskeletal system. The figures and line drawings in this chapter serve to highlight the structures with which the musculoskeletal medicine provider should be familiar before interpreting an imaging examination of the region. Reviewing the normal anatomy images pertinent to a specific anatomic region before reading the corresponding region-specific chapter will enhance the clinician’s understanding of the relevant pathologic conditions and facilitate recognition and differentiation of the subtle regional anatomic alternations that represent various pathologic conditions.

Shoulder

Axial Images
Axial images are obtained from the superior aspect of the AC joint through the inferior glenoid margin. Axial plane images are best used for evaluating the glenoid labrum (anterior and posterior portions) and capsular structures as well as the long head of the biceps tendon in the bicipital groove. In addition, these images provide good visualization of the subscapularis muscle and tendon, the humeral head, and the glenoid (Fig. 2.2). On superior axial images, the normal oblique course of the supraspinatus muscle is displayed with intermediate signal intensity, and the supraspinatus tendon is low in signal intensity. In cross-section, the tendon of the long head of the biceps is seen as a low signal intensity structure within the bicipital groove. Glenoid articular cartilage follows the concave shape of the glenoid cavity and shows intermediate signal intensity on T1-weighted and T2-weighted images. Articular cartilage of the glenohumeral joint is best evaluated on gradient-echo or fat-suppressed T2-weighted sequences.

Coronal Oblique Images
Coronal oblique images are obtained in a plane that is parallel to the course of the supraspinatus tendon; they tend to show shoulder anatomy and pathology in a plane that is familiar to most. The osseous structures of the shoulder are easily recognized (Fig. 2.3A) as they would be seen on an AP shoulder radiograph. Similarly, the sagittal oblique images show the osseous structures as they would be seen from a lateral view (Fig. 2.3B). The coronal oblique images should include the subscapularis muscle anteriorly and the infraspinatus and teres minor muscles posteriorly. Coronal oblique images are best used to evaluate the supraspinatus muscle and tendon (Fig. 2.4), the subacromial and subdeltoid bursa, and the AC joint. The long head of the biceps tendon and biceps attachment, the infraspinatus muscle and tendon, the glenoid labrum (superior and inferior portions), and the glenohumeral joint space can also be visualized in the coronal oblique plane. Each coronal oblique image should be evaluated systematically from anterior to posterior. On anterior coronal oblique images, the subscapularis muscle and tendon can be identified as the tendon courses from its origin in the subscapularis fossa to its insertion on the lesser tuberosity. However, the subscapularis muscle and tendon can be seen more clearly on axial images (Fig. 2.2). The long head of the biceps tendon is best seen in its intraarticular location on coronal oblique images. On anterior and midcoronal oblique images, the supraspinatus muscle and tendon are seen in continuity (Fig. 2.5). The supraspinatus originates in the supraspinatus fossa of the scapula and inserts on the superior facet of the greater tuberosity of the humerus. On coronal oblique images, the anatomy of the AC joint is best displayed at the level of the supraspinatus tendon. The AC joint should be evaluated for the shape of the acromion (Fig. 2.4) and the various ligaments around the shoulder (Fig. 2.6). The superior and inferior portions of the glenoid labrum, as well as the axillary pouch, are also clearly shown on coronal oblique images.
Fig. 2.1 An axial T2-weighted image (A) and artist’s sketch (B) of the right shoulder at the level of the glenoid labrum showing the long head of the biceps tendon as it courses along the bicipital groove.

Fig. 2.2 An axial illustration of the left shoulder showing the anterior position of the subscapularis muscle and the articular cartilage of the glenoid and humeral head.
Fig. 2.4 A coronal proton-density fat-suppressed image (A) and artist’s sketch (B) of the right shoulder at the level of the supraspinatus muscle and the insertion of the conjoined tendon, a site that is very prone to rotator cuff injury. The normal, flat acromion is also seen at this level, without evidence of supraspinatus impingement.
images. The superior and inferior glenoid labrum are seen as low signal intensity structures, in contrast to high signal intensity fluid on T2-weighted images. The axillary pouch usually is collapsed or has a small amount of fluid in the recess (Fig. 2.5). Humeral head articular cartilage, intermediate in signal intensity on T1-weighted and T2-weighted images, is interposed between the low signal intensity supraspinatus tendon superiorly and the cortex inferiorly.

The subclavian artery courses laterally between the anterior scalene and middle scalene muscles. The axillary artery continues from the subclavian artery at the lateral border of the first rib. Branches of the axillary artery are the supreme thoracic artery, thoracoacromial artery, lateral thoracic artery, subscapular artery, and anterior and posterior humeral circumflex arteries. The brachial artery continues from the axillary artery at the lateral border of the teres major muscle (Fig. 2.7). The brachial artery passes posterior to the bicipital aponeurosis, and its branches provide arterial flow to the forearm and hand.

**Sagittal Oblique Images**

Sagittal oblique images, obtained in a plane that is perpendicular to the supraspinatus tendon, should extend from the most lateral aspect of the humeral head to the midscapula (to evaluate rotator cuff muscle atrophy). The osseous structures (Fig. 2.3B) can be used to orient oneself to the location of the rotator cuff muscles, tendons, and other nonosseous structures (Fig. 2.8). These oblique images are well suited for evaluating the rotator cuff muscles and tendons (Fig. 2.9), coracoacromial arch, rotator interval, and acromial morphology. The glenoid labrum and the long head of the biceps can also be evaluated on the sagittal oblique images. However, both structures are better visualized on axial and coronal oblique images. Sagittal oblique images should be
Fig. 2.7 A 3D coronal illustration of the neurovascular structures of the right shoulder and arm showing the subclavian, axillary, and brachial arteries, as well as smaller branch vessels such as the anterior humeral circumflex artery, a tributary of the axillary artery, which is seen coursing anterior to the surgical neck of the humerus.
reviewed systematically from medial to lateral. Medial sagittal sections display the clavicle and AC joint in profile. On midsagittal and lateral sagittal images, the supraspinatus, the infraspinatus, and the confluence of the cuff tendons are visualized between the acromion and the superior articular surface of the humeral head. The supraspinatus originates from the supraspinatus fossa of the scapula, and the infraspinatus originates from the infraspinatus fossa of the scapula. The teres minor originates from the posterolateral aspect of the scapula. All three of these rotator cuff structures (the supraspinatus, infraspinatus, and teres minor) insert at the greater tuberosity of the humerus: the supraspinatus, along the most superior aspect of the greater tuberosity; the infraspinatus, along the middle facet of the greater tuberosity; and the teres minor, along the inferior facet of the greater tuberosity. The subscapularis is the most anterior rotator cuff muscle, and it originates from the subscapularis fossa of the scapula. It is unique in that it is the only rotator cuff structure to insert along the lesser tuberosity of the humerus rather than the greater tuberosity (Fig. 2.6). The biceps tendon can be followed from medial to lateral as it courses from its intraarticular origin within the synovial sheath to its more lateral extracapsular location in the bicipital groove. The long head of the biceps originates from the supraglenoid tubercle, and the short head of the biceps originates from the coracoid (Fig. 2.3).

## Elbow

### Axial Images

Axial images of the elbow should extend from above the humeral epicondyles (Fig. 2.10) to a level distal to the radial tuberosity. The tendons related to the elbow are best evaluated in the axial plane. The major muscles in the anterior compartment of the arm are the biceps brachii and the brachialis; the major muscle in the posterior compartment is the triceps brachii. Ventrally, the biceps tendon is seen as a low signal intensity structure, which courses from its musculotendinous junction, beneath the lacertus fibrosis, to its insertion on the radial tuberosity (Fig. 2.11). Some fibers of...
the distal biceps brachii also contribute to the bicipital aponeurosis. The aponeurosis extends from the myotendinous junction of the biceps to the fascia overlying the anteromedial muscles (flexors and pronators) and is identified as a thin, black, low signal intensity line on an axial image. The biceps brachii spans the shoulder and elbow joints and has a short and long head. The brachialis originates from the anterior aspect of the distal humerus, and its tendon courses immediately deep and slightly medial to the biceps and inserts on the ventral surface of the coronoid process of the ulna. The brachialis muscle is intermediate in signal intensity. Posteriorly, the triceps brachii has three heads with three separate origins; the distal triceps tendon attaches to the olecranon process of the ulna (Figs. 2.12 and 2.13).

Axial images also show the muscle architecture well. Because of the relative complexity of the forearm musculature compared with the arm musculature, forearm muscles are often grouped by location (superficial or deep) or by compartment (anterior, lateral, or posterior). Both classification schemes are acceptable, although individual radiologists or clinicians may have a preference; it may be helpful to review both classification schemes.

**Muscle Classification by Location**

There are seven superficial muscles within the dorsal aspect of the proximal forearm:

- Extensor carpi radialis brevis
- Extensor carpi radialis longus
- Brachioradialis
- Extensor digitorum
- Extensor digiti minimi
- ECU
- Anconeus (not always present)

Five superficial muscles are found within the volar aspect of the proximal forearm:
• Pronator teres
• Flexor carpi radialis
• Flexor carpi ulnaris
• Flexor digitorum superficialis
• Palmaris longus (absent in approximately 15% of the population)

In the proximal forearm, there is only one superficial muscle within the dorsal aspect, the supinator, and one deep muscle within the volar aspect, the flexor digitorum profundus (for the superficial and deep muscles within the distal forearm, see Wrist, below).

Muscle Classification by Compartment
The anterior compartment of the forearm contains the following five muscles:
• Pronator teres
• Flexor carpi radialis

Fig. 2.10 An axial proton-density image (A) and artist’s sketch (B) of the left elbow at the level of the humeral epicondyles illustrating the muscle architecture of the distal arm. The biceps brachii tendon, the common flexor tendon, and the common extensor tendon show normal thickness and low signal intensity.
• Flexor digitorum superficialis
• Flexor carpi ulnaris
• Flexor digitorum profundus

There are four muscles in the lateral compartment of the forearm:
• Brachioradialis
• Extensor carpi radialis longus

• Extensor carpi radialis brevis
• Extensor digitorum

Two muscles are found in the posterior compartment of the forearm:
• Anconeus
• ECU

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**Fig. 2.11** Lateral (ulnar side) (A) and posterior (B) 3D illustrations of the left elbow showing the ligamentous structures that stabilize the elbow joint and a tear of the UCL (**arrow** on B).

**Fig. 2.12** A posterior 3D illustration of the right elbow showing the insertion of the triceps tendon (cut) onto the olecranon process of the ulna. Also seen are other neural and ligamentous structures.
Specialized Pulse Sequences and Protocols

Although imaging protocols of the cervical spine for specific indications can vary among institutions, standard MRI of the cervical spine for degenerative pathologies usually includes the following pulse sequences:

- Sagittal T1-weighted SE
- Sagittal T2-weighted FSE
- Axial gradient-echo
- Axial T2-weighted FSE

A detailed discussion of all the imaging sequences used in the cervical spine is beyond the scope of this chapter; however, salient features of commonly used sequences are discussed below.

T1-weighted images are useful in identifying fracture lines. Because they are sensitive to the presence of gadolinium contrast, they are also used for contrast-enhanced imaging, which is helpful in assessing neoplasms, infections, and the postoperative spine. Typically, fat-suppressed postgadolinium T1-weighted images are used to make lesions more conspicuous. T2-weighted images are sensitive to water (and thus edema) and are useful in identifying areas of potential pathology. However, care must be taken with regard to interpreting bone marrow edema because it may be seen with a variety of conditions, including infection, inflammation, trauma, and degeneration. Although edema may focus attention toward an abnormality, many of these conditions can coexist, so additional analysis is required before finalizing a conclusion. FSE is now routinely used to acquire T2-weighted images at speeds up to 64 times faster than conventional SE T2-weighted images. Sometimes the differentiation of fat, water, and lesions can be difficult, especially on T2-weighted FSE images, and therefore fat suppression is used to make these areas more conspicuous. This sequence can be obtained by applying a fat-suppression pulse to produce fat-suppressed T2-weighted images or by obtaining a STIR sequence. Visualizing edema is helpful in identifying ligamentous injuries, and such visualization is best achieved with STIR or fat-suppressed T2-weighted images. T2-weighted images are also most sensitive for evaluating the cord parenchyma for lesions and edema, which are seen as abnormally bright signal, although the sagittal orientation is subject to linear bright artifact within the cord (Gibbs phenomenon). For this reason, axial T2-weighted images serve as a useful tool for detecting cord abnormalities and confirming lesions suspected on sagittal T2-weighted images.

Gradient-echo images are very susceptible to magnetic artifacts; this important characteristic makes them useful for detecting small areas of hemorrhage, such as with cervical spine trauma and vascular malformations. However, these images can also overestimate the degree of canal and foraminal stenosis secondary to artifact from the adjacent bone. Because of the rapidity with which gradient-echo images are acquired, studies can be obtained with higher resolution than that required for other pulse sequences and even as a 3D volume set, which allows for isotropic voxels and reformations in multiple planes. This volume set can then allow one to characterize the cervical foramina in the appropriate oblique plane.

For evaluation of vascular structures in the neck, MR angiography can be obtained without contrast, using 2D or 3D time-of-flight or phase-contrast imaging. These sequences create contrast between flowing and stationary structures. Phase-contrast imaging may also provide flow-velocity information. As a result of the technique, time-of-flight imaging shows fat or subacute thrombus as bright signal and may be useful in detecting small, subtle thrombi. The 3D techniques require more time and are slightly less sensitive to slow flow states. Gadolinium-enhanced MR angiography may also be obtained and is extremely accurate.

Traumatic Conditions

Although the cervical spine is injured in only 2% to 3% of blunt trauma accidents,1 the potential for instability and critical neurologic injury makes prompt identification and management of cervical spine injuries important. Patients with suspected cervical spine injury should be evaluated initially with conventional radiographs (AP, lateral, and open-mouth odontoid views). CT imaging offers greater osseous detail than does conventional radiography and may reveal fractures or details that are not detected with radiography. CT is especially helpful in assessing fractures of the occipital condyles and cervicothoracic junction, where osseous overlap on conventional radiographs makes fracture detection dif-
MRI provides soft-tissue visualization superior to that of conventional radiography or CT and is useful for the assessment of spinal cord injury, ligamentous injury, degree of spinal stenosis, and additional fracture evaluation. Occult fractures not visible on conventional radiographs or CT images may be detected by the presence of vertebral body edema on MR images. Although MRI is extremely sensitive in identifying cervical spine fractures, their characteristics and the exact appearance of the osseous components can be challenging; CT may be a better choice for assessing such details. In addition, MRI is useful for the evaluation of obtunded patients or those with cervical spine injury, neurologic deficits, or an unreliable physical examination.

MRI is indicated specifically when neurologic deficit, vascular injury, or soft-tissue injury is suspected in the setting of trauma. It is also useful in assessing posttraumatic sequelae. Imaging spinal gunshot injuries is controversial. Theoretically, a ferrous gunshot fragment may become mobile, but most bullets are nonferrous, and therefore such patients can usually be imaged without consequences. Unfortunately, the exact composition of a gunshot fragment is seldom known, and therefore MRI remains controversial and dependent on the clinical need.

It should be noted that there are obstacles to obtaining MRI studies in the trauma setting, especially with regard to cervical spine trauma, because patients may have clinically significant neurologic deficits. These obstacles include the following:

- Lack of availability of MRI capabilities on an urgent basis
- MR-incompatibility of some ventilators, traction devices, and other equipment
- Lack of clinical access to patients during the imaging study

MRI protocols vary by institution, but commonly used sequences in trauma evaluation include the following:

- Sagittal T1-weighted images to assess the alignment of the cervical spine, vertebral body integrity, fractures, and spinal cord caliber
- Sagittal T2-weighted images to assess for the presence of cord edema, compression, and spondylotic changes
- Sagittal STIR images to assess for the presence of paraspinal ligamentous injury and bone marrow edema
- Axial T1-weighted and T2-weighted images to assess for the presence of posterior element fractures, to evaluate for spinal stenosis, to better define disc pathology, and to confirm the precise location of abnormalities detected on sagittal images
- Sagittal T2-weighted gradient-echo images (in some institutions) to assess for the presence of acute spinal cord hemorrhage and disc herniation (high signal in the disc even with severe osseous degeneration, which enables the distinction between bone fragments and a disc herniation)

Regardless of the specific institutional MRI protocol, a systematic approach (see Chapter 3) for the evaluation of cervical spine MRI should be used to avoid missing pathologic conditions (see Table 10.1 for important cervical spine structures to evaluate). In addition, it is essential that the interpretation of the MRI findings be performed in conjunction with that of the other available imaging modalities, including conventional radiographs (with flexion and extension views if clinically indicated) and CT (see Chapter 17).

### Classification of Cervical Spine Trauma

Cervical spine injuries can be classified based on the mechanism of injury. Although six categories have been described (vertical compression, compressive flexion, distracting flexion, lateral flexion, compressive extension, and distracting extension) (Fig. 10.1), the classification scheme is simplified here into three broad categories:

- Hyperflexion
- Hyperextension
- Axial loading

In many instances, the mechanism of injury can be difficult to determine from an analysis of the clinical situation (in the absence of imaging findings), and therefore clinicians may choose to broadly classify cervical spine injuries as follows:

- Secondary to blunt trauma
- Secondary to penetrating trauma

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<th>Anatomy</th>
<th>Evaluation</th>
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<td>Spinal column/</td>
<td>Alignment</td>
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<td>vertebral bodies</td>
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<td>Interspinous and supraspinous</td>
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<td>Evaluation for edema/rupture</td>
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<tr>
<td>Spinal cord</td>
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<td>Osseous fragment</td>
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<td>Vascular</td>
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In addition, cervical spine injuries can be subdivided based on the region of injury within the occipitocervical spine:

- Occipitocervical junction
- Suboccipital cervical spine (C1-C2)
- Subaxial cervical spine (C3-C7)

More recently, the subaxial cervical spine injury classification system has been described as an approach that recognizes the importance of fracture morphology, neurologic injury, and integrity of the discoligamentous complex. A systematic evaluation of these three components can be used to guide the treatment of patients with cervical spine fractures.

**Hyperflexion Injuries**

Flexion-compression injuries range from the minor anterior compression of the anterosuperior end plate (Fig. 10.2) to a severe teardrop or quadrangular fracture. These injuries are associated with retrolisthesis, kyphosis, and circumferential soft-tissue disruption. The radiographic evaluation of flexion-compression injuries includes inspection for the following:

- Anterior and middle column compromise
- Vertebral body-height loss
- Translation
- Angulation
- Posterior element competence

Although conventional radiographs and CT scans can evaluate fracture pattern, alignment, angulation, and translation, MRI provides additional diagnostic value and can assist with the determination of treatment options for such patients because it facilitates the assessment of spinal cord compression and posterior element compromise.

Flexion-distraction forces can lead to facet subluxations, dislocations, or fracture-dislocations. These injuries represent a spectrum of osteoligamentous pathology, ranging from the purely ligamentous dislocation to fracture of the facet and lateral mass. MRI helps assess the compromise of posterior musculature, interspinous ligaments, ligamentum flavum, and facet capsules that is often seen with flexion-distraction injuries. The role of MRI in the treatment algo-

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*Fig. 10.2* C7 vertebral compression fracture. Sagittal T2-weighted (A) and T1-weighted (B) images showing the fracture (*arrow on each*) with minimal loss of height.
rithm of patients who present with bilateral cervical facet dislocations (Fig. 10.3) without neurologic compromise is the subject of substantial debate in the literature and among spine surgeons.\textsuperscript{14–16} The treatment options include MRI before attempting closed reduction or surgical intervention; closed reduction with traction while monitoring the patient’s neurologic examination; and surgical intervention via anterior, posterior, or combined approaches.\textsuperscript{14–16} One of the purposes of obtaining an MRI study before the reduction of bilateral facet dislocations is to rule out the possibility of an extruded disc fragment that may displace into the spinal canal during a closed reduction (Fig. 10.4).

Most flexion injuries are well visualized on MRI, and MRI is particularly effective for the assessment of the following\textsuperscript{11}:

- Alignment
- Fractures
- Ligamentous injury
- Cord abnormalities
- Acute disc herniations
- The cause of anterior subluxation, either chronic degenerative changes or hyperflexion sprain

Facet joint injuries may be seen on parasagittal or axial images, which show increased signal on T2-weighted images secondary to edema from facet capsule tears.\textsuperscript{11,17–19} Injury to posterior ligaments may be seen as areas of hyperintensity on T2-weighted images, especially fat-suppressed T2-weighted or STIR images (Fig. 10.5).

**Hyperextension Injuries**

Cervical spine extension injury results in the posterior translation or rotation of a vertebral body in the sagittal plane.\textsuperscript{6,11,20} Hyperextension injuries often are produced by rear-impact motor-vehicle collisions or direct facial trauma.
Fig. 10.4 Bilateral cervical facet dislocation. (A) A sagittal T2-weighted image showing anterior translation of C7 over T1 with an associated disc extrusion (arrow) and cord compression. Parasagittal T2-weighted (B) and gradient-echo (C) images showing the inferior articular process of C7 (arrow on each) displaced anterior to the superior articular process of T1 (arrowhead on each).
In cervical spine hyperextension injuries, potential findings include the following:

- Tear(s) of the anterior longitudinal ligament
- Avulsion of the intervertebral disc from an adjacent vertebral body
- Horizontal intervertebral disc rupture (Fig. 10.6)

More severe and potentially unstable hyperextension injuries may be associated with the following:

- Prevertebral hematoma
- Widening of the disc space
- Posterior ligament complex edema
- Herniated disc

Elderly patients with spondylosis and kyphosis of the cervical spine may suffer spinal cord injury without fracture or ligamentous injury because of posterior infolding of the ligamentum flavum upon a spinal canal already narrowed by posterior vertebral osteophytes.

Whiplash injuries often have no associated osseous injury on standard radiographs or CT images, and flexion-extension radiographs may be nondiagnostic because of poor excursion secondary to pain. However, MRI is of limited value for the assessment of whiplash; several studies have failed to show positive MRI findings in the absence of neurologic symptoms. In contrast, patients with a fused cervical spine secondary to ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis may benefit from an MRI examination to assess for acute fracture, instability, or neurologic compromise. In such patients, the fused cervical spine acts like a long-bone fracture, and even minimally displaced fractures may be unstable (Fig. 10.7).

Finally, MRI can assess intervertebral disc injury and subtle fractures caused by any of the above-mentioned mechanisms. Intervertebral disc injury may range from tear(s) of the outer annulus fibrosis (seen as increased T2-weighted signal in the outer annular fibers) to frank intervertebral disc herniation. The identification of an annular tear on MRI does not indicate acute traumatic injury and can be seen in asymptomatic individuals. Intervertebral disc separation from the adjacent vertebral body may be seen as a horizontal hyperintense T2-weighted signal. Subtle fractures, such as vertebral end-plate fractures, may be best visualized with MRI because it can detect osseous edema and hemorrhage not seen on conventional radiographs or CT images.
Axial Load Injuries

Axial load injuries are caused by the axial transmission of force through the skull, through the occipital condyles, and into the spine. This force transmission can cause a Jefferson burst fracture or burst fractures of the subaxial cervical spine. MRI is useful for the assessment of C1 compression fractures and associated pathologies such as lateral mass displacement on coronal images, atlantodental interval increase on sagittal images, and transverse ligament disruption on axial images. For burst fractures, MRI is useful for diagnosing associated spinal cord injury caused by an acute herniated disc or retropulsion of osseous fragments (Fig. 10.8). Because a purely axial force subjects the posterior capsuloligamentous structures to compression only, these posterior structures should remain intact. However, there often is some degree of spine flexion during the traumatic event that may cause injury to the posterior spinal elements, which can be detected by MRI. It is important to carefully scrutinize the fat-suppressed T2-weighted and other images for evidence of injury to the posterior ligamentous and osseous structures because such injury will lead to consideration of posterior fusion in addition to the anterior decompression and fusion that is often performed for patients with cervical burst fractures.

Occipitocervical Junction Injuries

Although injury to the occipitocervical junction occurs in a small percentage of blunt trauma victims (0.8% in one study), recognition of such injuries is crucial because of their devastating effects. A detailed discussion of occipitocervical craniotomy and the various measurement techniques for evaluation of occipitocervical pathology is beyond the scope of this chapter, but presented here is an overview of the major types of occipitocervical traumatic findings as seen on MRI. It is important to keep in mind that MRI studies of the occipitocervical junction should be reviewed in conjunction with conventional radiographic and CT imaging.

Atlantoaxial Dissociation

Atlantoaxial dissociation is any separation of the atlantoaxial articulation. The skull may displace anteriorly, posteriorly, or superiorly, and may be complete (disloca-
Atlantooccipital dissociation can be a devastating injury. The primary injury is to the ligaments that provide structural support to the cervicocranial junction. In addition, even without frank dislocation, the occiput–C1 junction may be injured, as indicated by postmortem studies. Although this injury may be fatal, improvement in resuscitative and medical treatment has increased survival rates. CT imaging may be used to assess associated fractures or relationships among the basion, dens, occipital condyles, and atlas in conjunction with atlantooccipital dissociation, whereas MRI is better at detecting injury to the cervicocranial ligaments (e.g., transverse, apical, cruciate, atlantooccipital membrane and capsular ligaments, tectorial membrane), brainstem, or spinal cord.

### Trauma to the Atlas

Axial load to the occipitocervical junction at the atlas may result in a burst fracture of the atlas. The injury is visualized on open-mouth odontoid radiographs or coronal CT images.