

Anterior cervical discectomy and fusion

Anatomy & Pathophysiology

OSSEOUS ANATOMY

- The spinal column consists of 33 vertebrae divided into five regions: 7 cervical, 12 thoracic, 5 lumbar, 5 fused sacral, and 4 or 5 fused coccygeal vertebrae [3].
- The vertebral body is a cylindrical mass of bone connected by pedicles to the posterior arch, which consists of the lamina and spinous process [3].
- The spinal canal is formed by the vertebral body anteriorly, the lamina posteriorly, and the pedicles laterally [3].
- Vertebral bodies function primarily to bear weight and transfer forces to the pelvis and hips [3].
- The posterior elements provide protection to neural structures and function as a tension band [3].
- The cervical spine is composed of seven vertebrae and assumes a lordotic curvature [8].
- The thoracic spine is composed of 12 vertebrae and assumes a kyphotic curvature [8].
- The lumbar spine is composed of five vertebrae and assumes a lordotic curvature [8].
- The sacral vertebrae are fused and form a portion of the pelvis [8].
- The coccyx consists of four small, fused vertebrae at the most caudal extent of the spinal column [8].
- Each vertebra is composed of an anterior vertebral body and a posterior arch formed by the pedicle, facet, lamina, and spinous process [8].
- The vertebral body is composed of an inner region of cancellous bone surrounded by a thin shell of cortical bone [8].
- The thoracic spine represents two transitional zones: from the highly mobile cervical spine to the rigid thoracic region, and then to the more mobile lumbar spine [5].
- The thoracic spine forms a bony “cube” with the ribs and sternum, providing protection to the heart and lungs [5].
- Thoracic vertebral bodies are larger than cervical vertebrae but smaller than lumbar vertebrae [5].
- Thoracic pedicles arise more superiorly from the posterior vertebral body than in the cervical or lumbar spine and project obliquely from superodorsal to inferoventral [5].

- The spinal canal is narrowest in the thoracic region [5].
- The spinous processes of the upper four thoracic vertebrae project more horizontally with slight inferior angulation [5].
- In the midthoracic spine, spinous processes project sharply obliquely, overlapping the lamina and spinous processes inferiorly [5].
- From T10 to T12, thoracic spinous processes transition to a more horizontal projection consistent with lumbar vertebrae [5].
- The rib heads articulate with the lateral aspect of the vertebral bodies, with a shared articulation at the disk space referred to as a demifacet [5].
- The first, eleventh, and twelfth vertebral bodies have only a single articulation for the same-numbered rib head [5].
- The transverse processes of the thoracic spine project obliquely superolaterally [5].
- There is no costotransverse articulation at T11 or T12 [5].
- The cervical vertebral body is an oblong structure with a coronal diameter larger than its sagittal diameter [20].
- Cervical endplates have a cup-in-saucer configuration, distinct from the flat endplates of the thoracic and lumbar vertebrae [20].
- The posterior aspect of the cervical transverse process guides the cervical spinal nerves as they exit the spinal canal [20].
- The cervical spinal nerves lie posterior to the vertebral artery within the transverse process [20].

INTERVERTEBRAL DISC ANATOMY

- The intervertebral disc (IVD) separates each successive vertebral body except between C1 and C2 [8].
- The IVD provides a combination of compressive stiffness and flexibility to support normal spine biomechanics [8].
- The IVD is composed of an inner nucleus pulposus (NP) and an outer ring termed the anulus fibrosus (AF) [8].
- The nucleus pulposus serves as an osmotic pump to attract water and generate hydraulic pressure under load [8].
- The anulus fibrosus encapsulates the nucleus pulposus and provides mechanical support to contain NP pressure and constrain intervertebral rotations [8].
- The outer anulus fibrosus is integrated with the vertebral rim via a fibrocartilage enthesis consisting of a thin layer of calcified cartilage, or “tidemark” [8].
- The end plate is a bilayer of cartilage and bone that separates the disc from adjacent vertebrae [8].
- The cartilage end plate integrates with the inner anulus fibrosus to fully encapsulate the nucleus pulposus [8].

- The end plate must be strong and thick to resist loads but also permeable to favor chemical transport and disk cellular vitality [8].

LIGAMENTS AND SOFT TISSUE

- The spinal column is stabilized by the anterior longitudinal ligament, posterior longitudinal ligament, ligamentum flavum, facet joint capsule, interspinous ligament, and supraspinous ligaments [8].
- The erector spinae muscles run longitudinally on the dorsal surface of the spinal column and function to extend the spine [8].
- The psoas muscles run longitudinally on the ventrolateral surface of the spinal column and serve to flex the hip or laterally bend the trunk [8].
- The multifidus muscles connect intersegmentally to stabilize the spine by acting like a bowstring to maintain lordosis [8].

BIOMECHANICS AND ALIGNMENT

- Normal cervical alignment is approximately 15° of lordosis [7].
- The thoracic spine generally ranges from 20° to 40° of kyphosis [7].
- The lumbar spine has approximately 40° to 50° of lordosis [7].
- Kyphotic segments (thoracic, sacral) are considered “primary” curvatures present in utero and at birth [7].
- Lordotic curvatures of the cervical and lumbar spine develop secondarily later in life to allow upright posture [7].
- The center of gravity of the spinal column runs from the odontoid process proximally through the sacral promontory caudally [7].
- Changes in sagittal balance that shift the center of gravity too far ventrally can result in significant pain and disability [7].
- The functional spinal unit consists of two vertebrae, the disk between them, and the facet joints and their capsules [7].
- Vertebral bodies bear 70% to 90% of the static axial load of the spine [7].
- Facet joints support 10% to 20% of axial load in a standing, neutral alignment [7].
- In extension, facet joints may bear up to 30% of the axial load [7].
- In flexion, facet joints may be burdened with up to 50% of the anterior shear load [7].
- The nucleus pulposus deforms under compressive forces, redistributing axial forces radially [7].
- The anulus fibrosus resists radial pressure through the tensile properties of its alternating bands of fibers [7].
- Spinous and transverse processes act as lever arms providing mechanical advantage for inserting muscles [7].

VASCULAR ANATOMY

- The cervical spine derives its circulation primarily from the vertebral arteries [12].
- The vertebral arteries arise from the subclavian arteries and typically enter the transverse foramen at the C6 level [12].
- The vertebral arteries run proximally through the transverse foramina to C1, then course posteriorly over the superior aspect of the C1 ring before entering the foramen magnum [12].
- Segmental branches to each cervical vertebra arise from the vertebral artery and the deep cervical branch of the costocervical trunk [12].
- The vertebral artery anatomy is variable, with one side typically more dominant than the other [12].
- The vertebral artery may enter through the transverse foramen of C7 rather than C6 [12].
- Anomalous courses of the vertebral artery, such as looping through a cervical vertebral body, are not uncommon [12].
- The vascular supply of the spinal cord is primarily from the medullary branches of the segmental spinal arteries [12].
- The anterior spinal artery supplies approximately 80% of the vascular supply to the spinal cord [12].
- The arteria medullaris magna (AMM), also known as the artery of Adamkiewicz, typically arises on the left side between T8 and L1 [12].

NEURAL ANATOMY

- A typical mixed spinal nerve has three distinct components: motor, sensory, and sympathetic [13].
- Motor rootlets leave the anterolateral sulcus of the spinal cord and unite to form each motor root [13].
- Motor fibers arise from anterior horn cells and innervate skeletal muscles [13].
- Sensory fibers arise from pain, thermal, tactile, and stretch receptors with cell bodies located within the dorsal root ganglia [13].
- Axons of sensory fibers enter the posterolateral sulcus of the cord via several rootlets [13].
- The sympathetic component of all 31 mixed spinal nerves leaves the spinal cord along only 14 motor roots [13].
- Sympathetic cells of origin are in the intermediolateral cell column extending throughout the thoracic and upper lumbar cord segments [13].
- White rami pass anteriorly to the corresponding sympathetic ganglion [13].
- Postganglionic fibers pass back to the mixed spinal nerve as a gray ramus [13].
- Mixed spinal nerves branch into anterior and posterior primary rami after leaving the intervertebral foramina [13].
- Posterior primary rami supply the paraspinal musculature and skin along the posterior aspect of the trunk, neck, and head [13].
- The upper three cervical posterior rami are larger than their corresponding anterior rami [13].

CQ HAND + UPPER LIMB

- Anterior primary rami of all cervical, the first thoracic, and all lumbosacral nerves join to form plexuses [13].
- The upper four cervical anterior rami form the cervical plexus [13].
- The lower four cervical and first thoracic anterior rami form the brachial plexus [13].
- The area of skin supplied by the fibers of a single spinal root is called a dermatome [13].
- Segmental dermatomal patterns are well preserved in the thoracic region but not in the limbs [13].

PATHOPHYSIOLOGY OF DEGENERATION AND STENOSIS

- Degeneration of the disc occurs with disc narrowing and subsequent ligamentous redundancy, which compromises the spinal canal area [17].
- Instability resulting from disc degeneration precipitates the formation of facet overgrowth and ligamentous hypertrophy [17].
- The ligamentum flavum may be markedly thickened into the lateral recess where it attaches to the facet capsule, causing nerve root compression [17].
- Central spinal stenosis denotes involvement of the area between the facet joints occupied by the dura and its contents [17].
- Symptomatic central spinal stenosis results in neurogenic claudication with generalized leg pain [17].
- The lateral recess begins at the medial border of the superior articular process and extends to the medial border of the pedicle [17].
- Facet arthritis most frequently causes stenosis in the lateral recess zone [17].
- The foraminal region lies ventral to the pars and is bordered by the lateral recess medially, posterior vertebral body and disc ventrally, pars and intertransverse ligament dorsally, and lateral border of the pedicle laterally [17].
- The dorsal root ganglion and ventral motor root occupy 30% of the foraminal space [17].
- The exit zone is identified as the area lateral to the facet joint [17].
- The most common type of spinal stenosis is caused by degenerative arthritis of the spine [17].
- Degenerative spinal stenosis is most commonly localized to the facet joints and ligamentum flavum [17].
- The L4-5 level is the most commonly involved in degenerative spinal stenosis, followed by L5-S1 and L3-4 [17].
- Hypertrophy and ossification of the posterior longitudinal ligament usually are confined to the cervical spine [17].
- Diffuse idiopathic skeletal hyperostosis (DISH) syndrome may result in an acquired form of spinal stenosis [17].
- Congenital spinal stenosis usually is central and evident on imaging studies [17].
- In achondroplasia, the canal is narrowed in the anteroposterior plane owing to shortened pedicles and in lateral diameter because of diminished interpedicular distance [17].

Investigations

MAGNETIC RESONANCE IMAGING (MRI)

- MRI is the standard for advanced imaging of the spine and is superior to CT in most circumstances, particularly for identifying infections, tumors, and degenerative changes within the discs [23].
- MRI is superior to CT for imaging the intervertebral disc and directly imaging neural structures [23].
- MRI typically shows the entire region of the spine, including cervical, thoracic, or lumbar segments [23].
- MRI provides the ability to image the nerve root in the foramen, which is difficult even with postmyelography CT because the subarachnoid space and contrast agent do not extend fully through the foramen [23].
- MRI evidence of disc degeneration has been reported in the cervical spine in 25% of patients younger than 40 years [23].
- MRI evidence of disc degeneration has been reported in the cervical spine in 60% of patients 60 years and older [23].
- MRI evidence of lumbar disc degeneration was found in 35% of patients aged 20 to 39 years [23].
- MRI evidence of lumbar disc degeneration was found in 100% of patients older than 50 years [23].
- The best way to obtain meaningful clinical information from MRI is to have a specific question derived from the patient's history and physical examination before the study [23].
- Specific questions for MRI evaluation should be posed using the parameters of neural compression, instability, and deformity [23].
- Only abnormalities in one or a combination of the categories of neural compression, instability, and deformity are important for operative treatment [23].
- Failure to interpret MRI in the context of specific clinical questions leads to poor clinical choices and outcomes [23].
- A normal intervertebral disc exhibits signal hyperintensity on T2-weighted images due to its high water content [22].
- The aging process results in gradual desiccation of disc material and loss of T2-weighted signal hyperintensity [22].
- Disc herniations or extrusions appear as convex or polypoid masses extending posteriorly into the ventral epidural space [22].
- Disc herniations or extrusions frequently maintain a signal intensity similar to that of the disc of origin [22].
- Sagittal T2-weighted or gradient-echo images create a “myelographic” effect useful for evaluating compromise of the subarachnoid space [22].
- Sagittal T1-weighted images should be closely examined to identify narrowing of the neuroforamina [22].
- Normal T1-weighted hyperintense perineural fat in the foramina provides excellent contrast to darker displaced disc material [22].

- Far lateral disc herniations are best seen on selected axial images localized through disc levels [22].
- Free disc fragments appear discontinuous with the intervertebral disc and usually have intermediate T1-weighted signal in contrast to hypointense cerebrospinal fluid [22].
- MRI detects significant spinal cord compromise, with edema within the cord demonstrated as hyperintensity on T2-weighted images [22].
- Diffusion tensor imaging has been reported to demonstrate spinal cord impairment in patients with early stage cervical spondylosis before it is visible on plain MRI scans [26].
- Diffusion tensor imaging information can be helpful in early identification of patients in whom operative treatment is indicated [26].

COMPUTED TOMOGRAPHY (CT)

- CT has largely supplanted plain radiographs as the initial screening study of choice for spine injuries due to its combination of high sensitivity and specificity [24].
- CT allows for the identification of subtler fractures that might have remained undiagnosed on plain radiographs [24].
- CT provides additional three-dimensional detail, including the degree of canal compromise and the amount of fracture comminution [24].
- CT is particularly useful in differentiating compression fractures from burst fractures [24].
- CT identifies subtle features of injury such as the presence of facet widening [24].
- The primary disadvantage of CT imaging compared to MRI is that it does not provide as good a visualization of soft tissues [24].
- CT myelography is reserved for patients who have contraindications to MRI or who have equivocal MRI examinations [22].

DIAGNOSTIC PRINCIPLES

- The most common indication for MRI of the spine is evaluation of intervertebral disc disease [22].
- After routine radiography, MRI is the procedure of choice for screening patients with low back or sciatic pain [22].
- In the lumbar and thoracic spine, MRI has supplanted CT myelography because it is noninvasive and less expensive [22].
- The demonstrated findings on MRI must be carefully correlated with the clinical impression [23].
- The specific location of an abnormality should be suspected before MRI and confirmed with the study [23].
- Ideally, an advanced imaging study should be used for confirmation, not reevaluation [26].

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