Cervical Spine Surgery

A Guide to Preoperative and Postoperative Patient Care

AANN Reference Series for Clinical Practice

AANN
American Association
of Neuroscience Nurses

American Association of Neuroscience Nurses
8735 W. Higgins Road, Suite 300
Chicago, IL 60631
888.557.2266
International phone 847.375.4733
Fax 877.734.8677
info@aann.org • www.aann.org

Cervical Spine Surgery Task Force

Chair
Catherine Harris, MBA MSN CNRN CRNP

Content Authors
Jodi Boling, MSN RN CNS CNRN
Shelly Fields-Ryan, MS RN CCRN CNRN FNP-C
Tina S. Georgievski-Resser, MSN RN CNP

Co-Editors
Andrea L. Strayer, MS A/GNP CNRN
Joseph Haymore, MS RN CCRN CNRN ACNP

Content Reviewers
Susan D. Bell, MSN RN CNRN APN
Catherine Harris, MBA MSN CNRN CRNP
Angela R. Starkweather, PhD ACNP RN CNRN CCRN
Michael P. Steinmetz, MD

Acknowledgment
This publication was made possible by a restricted Educational Charitable Contribution by Medtronic's Spinal and Biologics Business.

Publisher's Note
The authors, editors, and publisher of this document neither represent nor guarantee that the practices described herein will, if followed, ensure safe and effective patient care. The authors, editors, and publisher further assume no liability or responsibility in connection with any information or recommendations contained in this document. These recommendations reflect the American Association of Neuroscience Nurses' judgment regarding the state of general knowledge and practice in their field as of the date of publication and are subject to change based on the availability of new scientific information.

Contents

Preface . . . 3
Cervical Spine Functional Anatomy and Physiology . . . 4
Diagnostic Studies . . . 10
Cervical Spine Disorders . . . 11
    Neck Pain Without Radiculopathy . . . 11
    Cervical Radiculopathy . . . 11
    Cervical Myelopathy . . . 11
Degenerative Cervical Spine Disorders . . . 12
    Intervertebral Disc Herniation—Herniated Nucleus Pulposus . . . 12
    Spondylosis . . . 13
    Cervical Spondylotic Myelopathy . . . 13
    Cervical Stenosis . . . 14
Inflammatory Cervical Spine Disease . . . 15
    Rheumatoid Arthritis . . . 15
    Ankylosing Spondylitis . . . 15
Neoplastic Cervical Spine Disease . . . 16
    Metastatic . . . 16
    Primary . . . 16
Deformity of the Cervical Spine . . . 17
    Osteoporosis . . . 17
    Congenital Anomalies . . . 17
Infection . . . 18
    Pyogenic Vertebral Body and Disc Infections . . . 18
    Epidural Spinal Abscess . . . 18
Treatment of Cervical Spine Disorders . . . 19
    Nonsurgical Medical Treatment . . . 19
    Surgical Treatment . . . 20
Nursing Assessment, Intervention, Monitoring, and Documentation . . . 26
Resources . . . 29
Cervical Spine Disorder Case Studies . . . 30
References . . . 38
Bibliography . . . 40

Preface

To meet its members' needs for educational tools, the American Association of Neuroscience Nurses (AANN) has created a series of guides to patient care called the *AANN Reference Series for Clinical Practice.* Each guide has been developed based on current literature and is built upon best practices. The purpose is to help registered nurses, patient care units, and institutions provide safe and effective care to patients who are undergoing cervical spine surgery.

Degenerative cervical spine disease is a common problem associated with aging. It is often asymptomatic or experienced as episodic neck pain. Population-based data (Rochester, MN), 1976–1990, shows a cervical radiculopathy incidence of 107.3 males and 63.5 females (per 100,000 population) with a peak incidence among persons 50–54 years of age (Radhakrishnan, Litchy, O'Fallon, & Kurland, 1994). A study from Sicily, Italy, reported a prevalence of 3.5 cases per 1,000 population (Salemi et al., 1996). The most common etiology of cervical myelopathy is spondylosis (Edwards, Riew, Anderson, Hilibrand, & Vaccaro, 2003). While the exact incidence of cervical spondylotic myelopathy is unknown, it is reported to be the most common cause of spinal cord dysfunction of persons over 55 years of age (McCormick, Steinmetz, & Benzel, 2003). Degenerative cervical spine disease, when associated with nerve root or spinal cord compression, can lead to significant pain and disability for the afflicted patient.

Under most circumstances, the patient with cervical spine disease will undergo 6 weeks of nonoperative treatment before surgery is considered. The decision to perform surgery is based on the patient's spine pathology and clinical symptoms, current medical evidence, and the physician's preference. It is essential for nurses involved in the care of the patient with cervical spine disease to understand the disease processes, various surgical interventions, and nursing considerations.

This reference is a valuable resource for nurses responsible for the care of spine patients. It is not intended to replace formal education but rather to augment the knowledge of clinicians and provide a readily available reference tool.

Neuroscience nursing and AANN are indebted to the volunteers who have devoted their time and expertise to this valuable resource, created for those who are committed to neuroscience patient care.

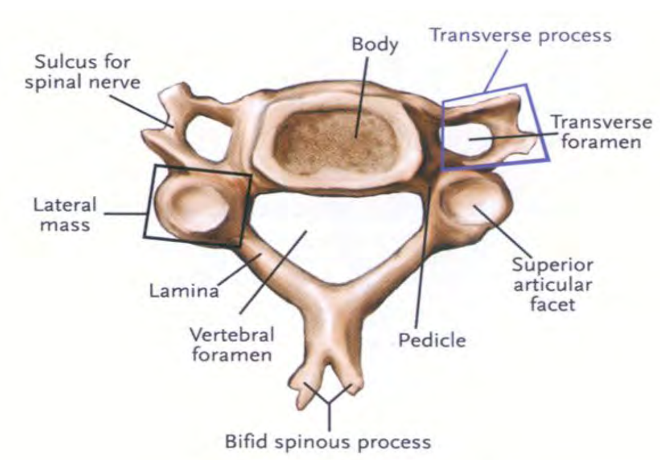
Cervical Spine Functional Anatomy and Physiology

I. Cervical Vertebrae

The cervical spine has seven vertebrae. The body, or centrum, of the vertebra is located anteriorly. To either side of the body lies a small transverse process and transverse foramen that the vertebral artery travels through. The first six vertebrae usually are the only vertebrae to have a transverse foramen through which vertebral vessels (i.e., arteries and veins) pass. Occasionally, the vertebral artery enters at C7 through its transverse foramen.

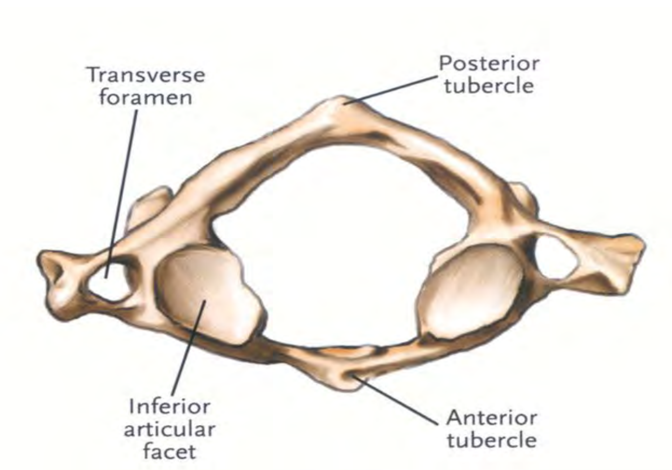
The vertebral foramen, referred to as the spinal canal, is behind the vertebral body. The superior articular processes are lateral to the transverse foramen (**Figure 1**). These processes are connected to the anterior portion of the vertebrae via small foot-like projections called pedicles. The first vertebra (atlas) and second vertebra (axis) are unique. C1 is a ring, formed by an anterior and posterior arch. C2 has a finger-like projection called the odontoid process (dens), which articulates with the posterior surface of the anterior tubercle of C1. The head rests on C1, with C1 pivoting around the dens. The cervical vertebrae are smaller and much more delicate than the lumbar vertebrae (**Figures 2–5**).

Figure 1. Cervical vertebra



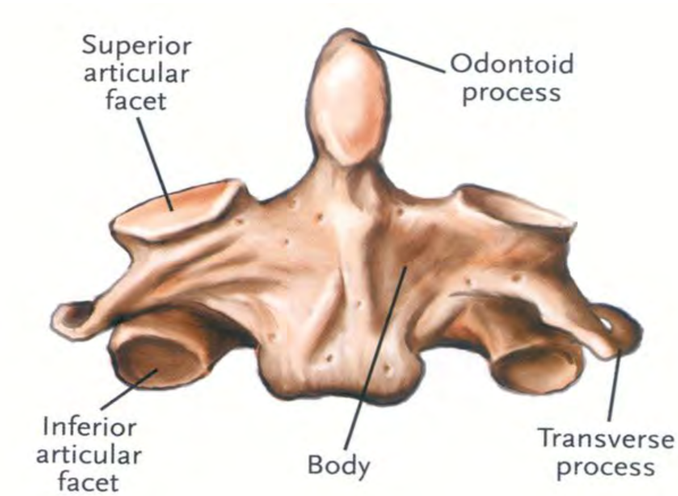
Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 41), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 2. Ring of C1, inferior view. Articulations for C2



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 39), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 3. C2, anterior view



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 40), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

II. Intervertebral Disc

With the exception of C1–C2, an intervertebral disc resides between each of the cervical vertebral bodies. Each intervertebral disc provides support and facilitates movement, while also resisting excessive movement. The disc permits slight anterior flexion, posterior extension, lateral flexion, rotation, and some circumduction (Schnuerer, Gallego, & Manuel, 2003).

The disc is the largest avascular structure in the body (Anderson & Albert, 2003). It is composed of the nucleus pulposus, an inner capsule with tissue the consistency of crabmeat, and the annulus fibrosus, a thick outer ring of tissue much like cartilage. Although the nucleus pulposus is usually soft and spongy in younger people, it tends to dehydrate as people age.

The annulus fibrosus surrounds the nucleus pulposus. It has concentric fibers, somewhat like the layers of a radial tire, which provide resistance and strength for motions such as translation and rotation. Each disc is bonded to the vertebral body below and above it by a thin cartilaginous plate referred to as the end plate (**Figure 6**). The end plate resists herniation of the disc into the vertebral body and gives the disc its shape (Benzel, 2001). Approximately 25% of the cervical spine height is composed of the intervertebral discs. Longitudinal ligaments between the vertebral bodies maintain the discs in proper alignment.

III. Ligaments

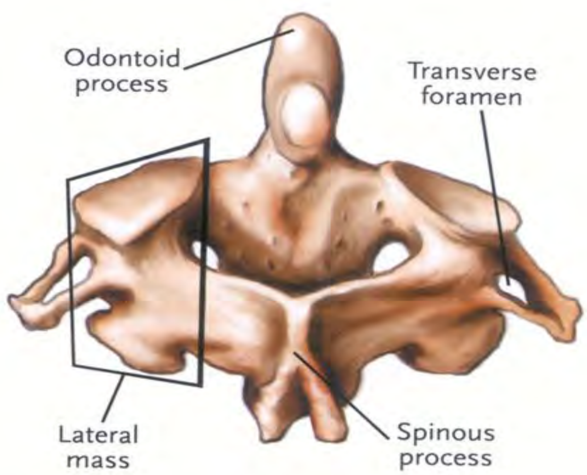
A *ligament* is a band of fibrous tissue connecting bones or cartilage. It is instrumental in maintaining cervical spine alignment. Ligaments help provide stability to intervertebral joints and help absorb physical stress during movement. They also aid in preventing excessive movement between the vertebrae.

Several ligaments help prevent abnormal flexion and extension of the cervical spine. For instance, the ligamenta flava are yellowish membranes that are highly elastic in nature. In fact, they have the highest percentage of elastic fibers in human tissue. They are found between the lamina. Supraspinous and interspinous ligaments play a role in preventing anterior horizontal displacement of the vertebral bodies, and, because of their anatomic location (they connect adjacent spinous processes), these ligaments provide significant flexion resistance (Benzel, 2001).

Primary stability between the occiput, C1, and C2 is maintained through several important ligamentous structures. Connection between C1 and the occiput is maintained through an extension of the anterior longitudinal ligament that extends from the anterior surface of the foramen magnum to the anterior arch of C1. A posterior membrane connects the posterior arch of C1 to the posterior surface of the foramen magnum (**Figures 7–9**).

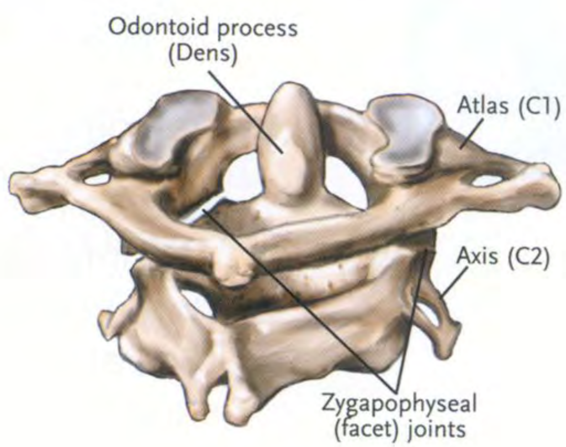
The anterior longitudinal ligament (ALL) spans the entire length of the spinal column. Attached to the occiput, it begins as the anterior occipitoatlantal membrane and ends at the sacrum. A strong ligament, the ALL covers about 25% of the spinal column's anterior surface, adhering

Figure 4. C2, posterior view



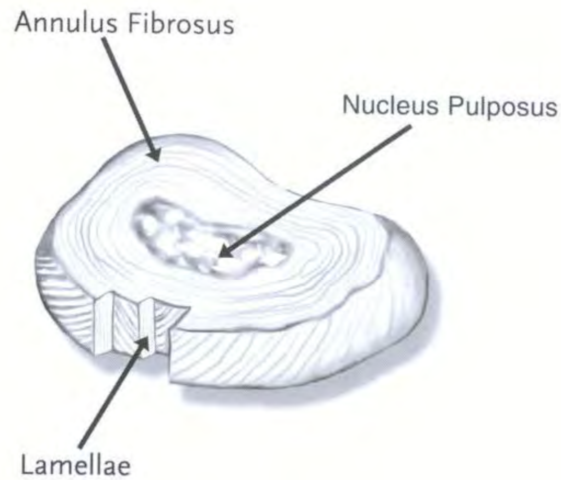
Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 40), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 5. C1 and C2 articulation



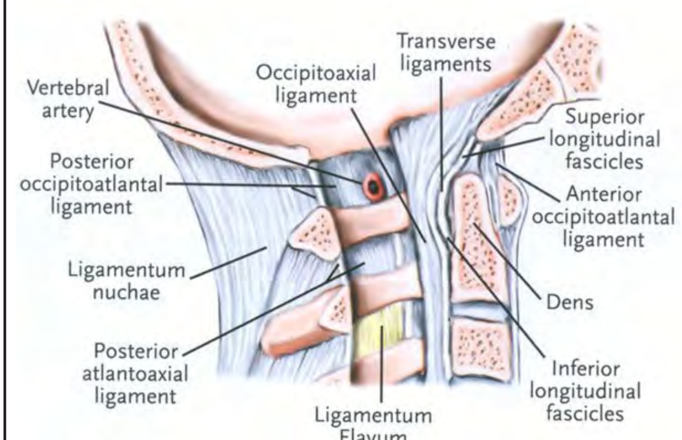
Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 54), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 6. Cervical disc



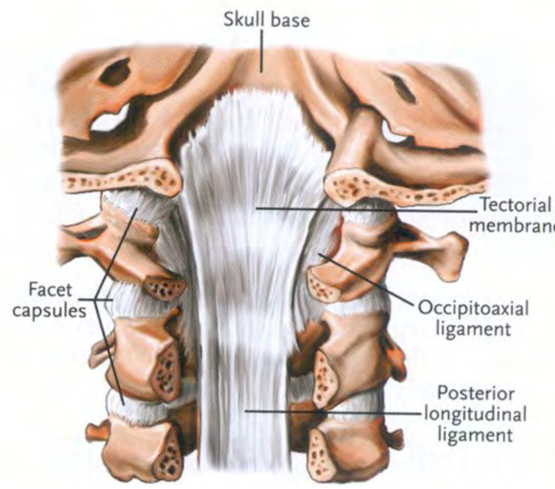
Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 92), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 7. Cervical spine ligaments



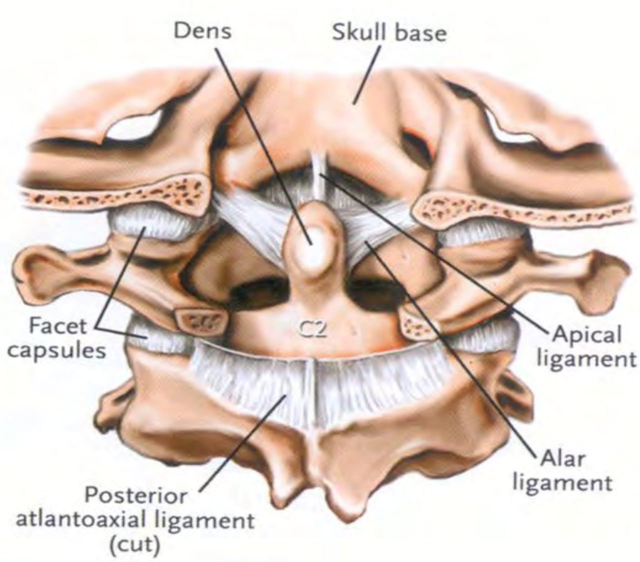
Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 62), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 8. Upper cervical spine ligaments, anterior view



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 60), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 9. Upper cervical spine ligaments, posterior view



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 60), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

closely to the vertebral bodies. The posterior longitudinal ligament (PLL) also extends the entire length of the spinal column. It begins as the tectorial membrane at C2 and ends at the sacrum. Unlike the ALL, the PLL adheres most closely with the annulus fibrosus and narrows at the vertebral body (Benzel, 2001).

The alar ligaments attach from the dens to the occipital condyles, whereas the cruciate ligament attaches the dens to the lateral mass of C1.

IV. Cervical Spine Joints

In general, a *joint* is a junction between two or more articulating surfaces, providing motion and flexibility. There are five main types of joints along the cervical spine: joints of the vertebral bodies (intervertebral), joints of the vertebral arches (zygapophyseal), uncovertebral joints (of Luschka), atlantoaxial joints, and the atlantooccipital joints.

The joints of the vertebral bodies (i.e., intervertebral joints) are secondary cartilaginous joints (symphyses) that are involved in weight bearing and provide strength to the spine. These "joints" are composed of a complex of structures including adjacent vertebral bodies, the disc between the vertebral bodies, and the corresponding ligaments.

The joints of the vertebral arches (e.g., zygapophyseal) are commonly referred to as the facet joints. Cervical spine vertebrae have two superior articular processes and two inferior articular processes. Facet joints are formed when the inferior articular process forms a joint with the superior articular process of the vertebrae below it. For example, the inferior articular processes of C3 form two facet joints with the superior articular processes of C4. These facets are located on the anterior segments of the vertebral arch. These joints are surrounded by a thin, loose articular capsule, which contains the synovial fluid necessary for proper joint function. These zygapophyseal joints are stabilized by the accessory ligaments of the laminae, transverse processes, and spinous processes. These joints permit a gliding motion between the vertebrae and assist in weight bearing.

The uncovertebral joints, also referred to as the joints of Luschka, are so unlike the previously mentioned joints that they have been referred to as "false joints." Located from C3 to T1, the uncinate process, or uncus, is a slightly curved ridge along the edges of the upper surface of the vertebral body. It functions as a rail, providing resistance to lateral shifting in the cervical spine. The region between the uncinate process and the vertebra above it is referred to as the uncovertebral joint—or joint of Luschka (Ahn, Ahn, Amundson, & An, 2004; Krag, 1997; **Figure 10**).

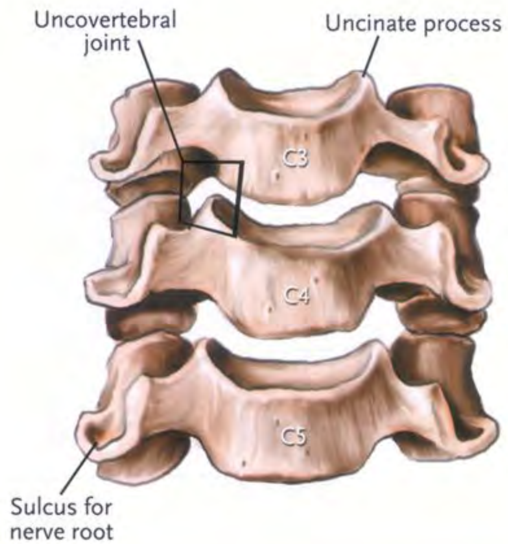
The atlantoaxial joint is formed by the facets between C1 and C2 and comprise the joining of the superior facets of C2 with articular surfaces on the anterior arch of C1. This joint is primarily responsible for rotation of the head.

The atlantooccipital joint connects the top of the cervical spine to the base of the skull. This joint is formed by the superior facets of C1, the anterior and posterior atlantoaxial membranes that span between the anterior and posterior arches of C1, and the skull's foramen magnum. This joint is involved primarily with nodding (i.e., capital flexion) as well as sideways tilting of the head.

V. Spinal Cord and Spinal Nerves

The spinal cord extends from the foramen magnum to the upper lumbar spine (usually L1–L2) and gives rise to 31 pairs of spinal nerves. The eight cervical roots exit through intervertebral foramina, an opening between the vertebrae. The meninges (i.e., dura mater, arachnoid layer, and pia mater)

Figure 10. Anterior view of cervical spine



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 56), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

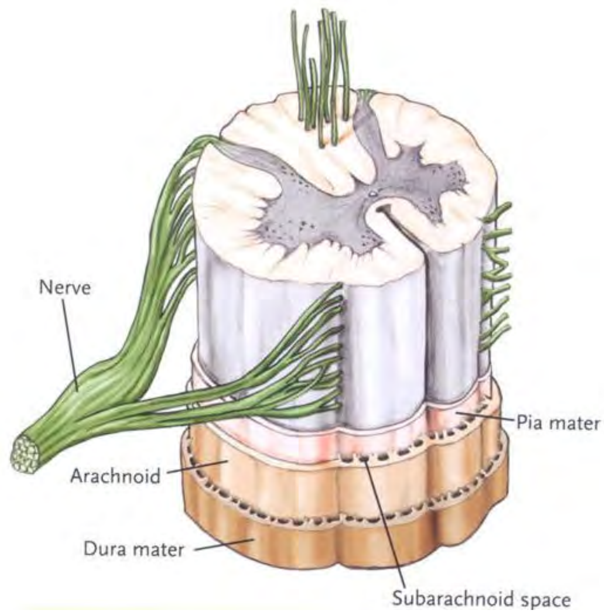
cover the spinal cord. Cerebrospinal fluid bathes the spinal cord and is found in the subarachnoid space (**Figure 11**).

The spinal cord consists of an outer area of white matter surrounding an area of gray matter, which appears in the shape of a butterfly. The butterfly's "wings" are the horns of the spinal cord and are designated into the following three zones:

- **Ventral or anterior gray matter (motor):** Motor neurons are large neurons found in the ventral horns of the gray matter. Their function is to communicate messages to the specified voluntary skeletal muscle.
- **Dorsal or posterior gray matter (sensory):** Sensory input arrives to the dorsal horns via sensory neurons whose cell bodies are located outside of the gray matter in the dorsal root ganglia. In the dorsal horn, input may be integrated through interneurons, into a spinal reflex, or relayed through ascending spinal cord tracts to the brain.
- **The middle zone of the gray matter:** The neurons that comprise this area of association often are called interneurons, or association neurons. They have both excitatory and inhibitory capacity between the motor and sensory neurons on the same or opposite side.

The white matter of the spinal cord is made up of large bundles of nerve fibers called funinculi, which connect the spinal cord to the brain. Like the motor and sensory neurons of the gray matter, the funiculi are separated into ascending pathways, or tracts, that are usually sensory and descending pathways that are motor. Large ascending pathways communicate to the medulla, brainstem, reticular formation, and thalamus. Most major descending pathways communicate with the forebrain and midbrain (**Figures 12a, 12b**).

Figure 11. Spinal cord cross-section



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 70), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 12a. Spinal cord with selected tracts

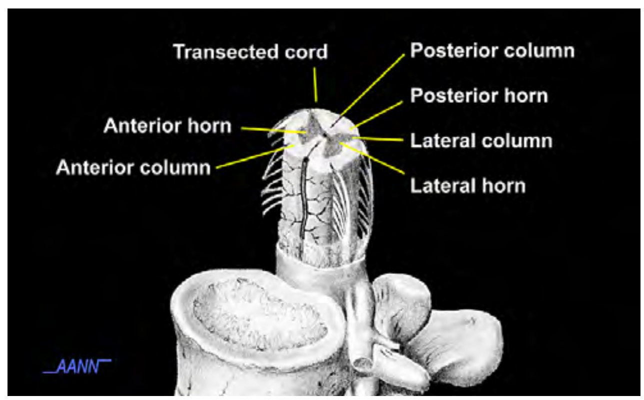


Figure 12b. Spinal cord cross-section with tracts

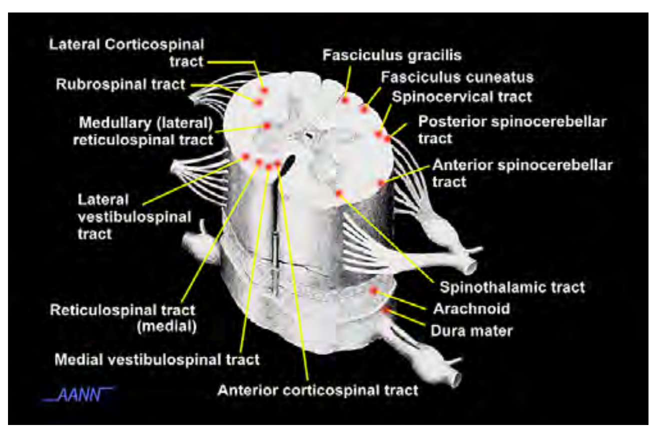


Table 1. Nerve Root Level, Function and Radicular Distribution

Disc Level	Nerve Root	Sensory distribution	Motor distribution	Reflex	Radicular Pain Distribution
C2–3	C3	Posterior upper neck, occiput, ear	none	none	Posterior upper neck, occiput
C3–4	C4	Base of neck, medial shoulder	Some neck extension; elevation of scapula (dorsal scapula–rhomboids)	none	Neck, upper scapula
C4–5	C5	Lateral upper arm	Deltoid–arm abduction; supraspinatous, infraspinatous	Brachioradialus	Scapula border, lateral upper arm
C5–6	C6	Bicep area, lateral forearm, thumb and 1st finger	Biceps, brachioradialis, wrist extensors	Bicep	Lateral forearm, thumb and 1st finger
C6–7	C7	Posterior forearm, middle finger	Triceps–Elbow extension; wrist flexors, finger extension	Triceps	Scapula, posterior arm, dorsum of forearm, 3rd finger
C7–T1	C8	Ulnar forearm and 5th finger	Thumb flexors, abductors, instrinsic hand muscles	none	Shoulder, ulnar forearm, 5th finger

There are eight pairs of cervical spine nerve roots, which are composed of the root sleeve, the dorsal root ganglion, and the postganglionic spinal nerve. The root sleeve is responsible for holding the motor and sensory roots. An interruption along the nerve roots may affect a patient's sensory or motor function. It is important to remember that in the cervical spine, the lower vertebra identifies the nerve root level. For example, the C6 nerve root lies between C5 and C6 (see **Table 1**).

A dermatome is an area of skin innervated by the fibers of an individual dorsal nerve root. As nerve roots leave the spinal column at predictable levels, disruption due to swelling, disc herniation, or other injury can result in sensory changes to the affected dermatome pattern. The dermatomal level is named after the corresponding cervical spine level (**Figures 13, 14**).

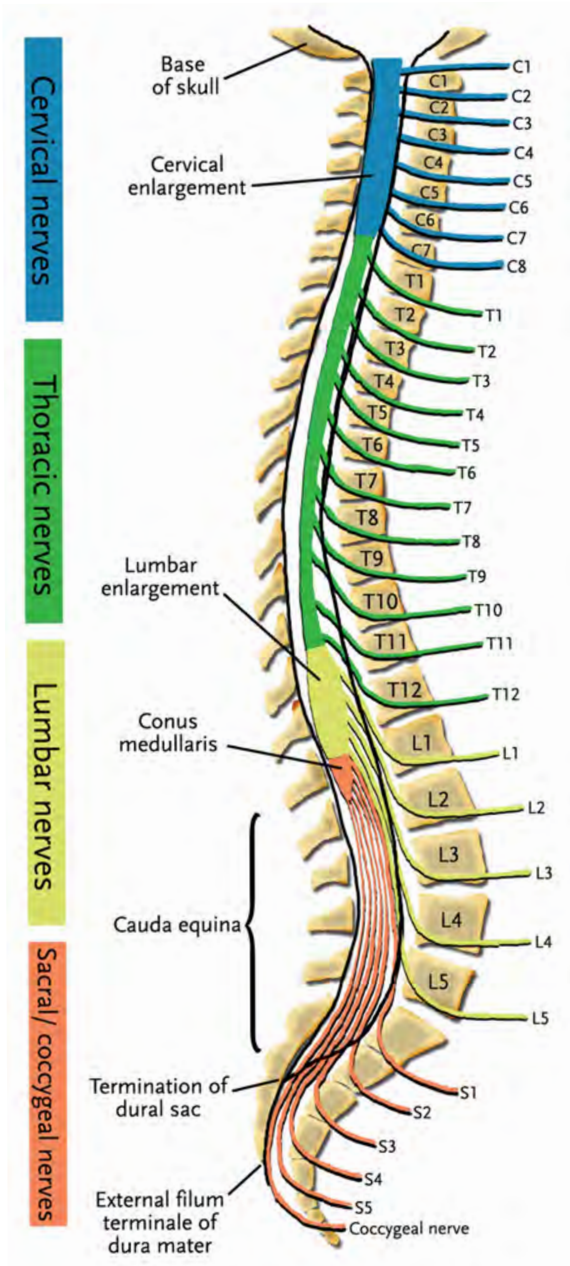
VI. Vasculature

The vertebral and spinal arteries provide the primary vascular supply to the cervical spinal cord. The vertebral arteries arise from the subclavian arteries and ascend via the transverse foramen of the first six cervical vertebrae (and rarely the seventh vertebra, as well) into the foramen magnum (**Figure 15**). They meet at the pons to form the basilar artery. The anterior spinal artery arises from the vertebral artery. It is located in the ventral median sulcus of the spinal cord, terminating approximately 1.5 cm from the end of the conus. The anterior spinal artery supplies the anterior two-thirds of the spinal cord. The posterior spinal artery plexus originates from the vertebral artery and the posterior radicular arteries. The posterior spinal arteries supply the posterior one-third of the spinal cord.

VII. Biomechanics

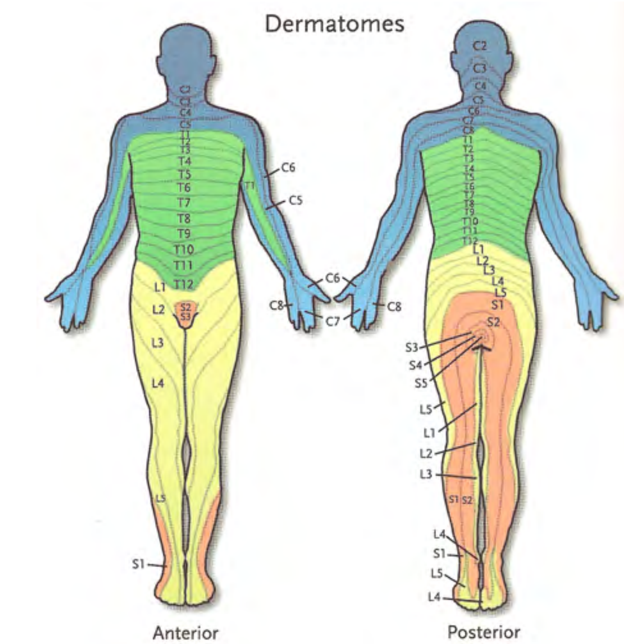
The cervical spine generally can be thought of as a mechanical structure that lists transmitting loads, allowing motion, and protecting the spinal cord as its primary functions. More specifically, the cervical spine supports and allows movement for the cranium. Normally, the cervical spine allows for several types of movement, including rotation, flexion, extension, lateral bending, and gliding between the vertebrae. Vertebral alignment and spinal curvature are taken into consideration when determining the most appropriate surgical intervention for the patient.

Figure 13. Nerve root distribution



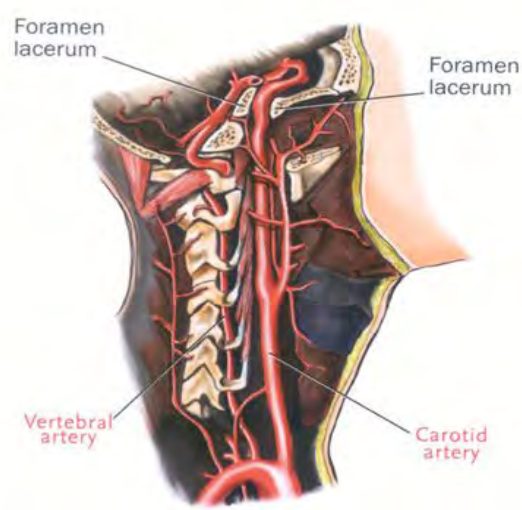
Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 71), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 14. Dermatome diagram



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 134), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 15. Cervical spine vasculature



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 76), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Diagnostic Studies

Common diagnostic studies used to evaluate the non-traumatic cervical spine patient are outlined below. In general, imaging in acute neck pain is not used for the first 4–6 weeks if the following conditions are met:

- no neurologic deficit
- no trauma
- no history of malignant tumor
- no constitutional symptoms
- patient's age is between 18 and 50 (Winters, Kluetz, & Zilberstein, 2006).

I. Plain Radiographs

The plain radiograph is inexpensive and noninvasive and shows general changes of arthritis and bony alignment. X rays show only bony structures, and there is radiation exposure. Serial X rays help clinicians evaluate bone healing and degree of fusion. Moreover, they are often taken with the patient standing, which may reveal instability that might have been missed on a supine computed tomography (CT) scan or magnetic resonance imaging (MRI) study.

II. Computed Tomography

A CT scan may be utilized either as an adjunct to MRI studies or in patients who cannot undergo MRI evaluation. A CT scan shows the bony elements of the spine, as well as the discs, nerves, and ligaments. Although it provides excellent visualization of the bony components, the CT scan is less sensitive to changes in the soft tissues of the spine. One advantage the CT scan has over plain radiographs is that images can be reformatted on axial, coronal, and sagittal planes. In addition, CT scan images are able to show the upper cervical spine and cervical thoracic junction, which often are not well-visualized on plain radiographs. The use of contrast agents may be useful for highlighting masses and abnormal tissue or fluid collections. The CT scan also is occasionally used for intraoperative three-dimensional (3-D) image guidance during posterior cervical fusions.

III. Magnetic Resonance Imaging

Utilizing strong magnetic fields and radio frequencies, MRI can provide useful information on all tissues in the spine (e.g., bones, soft tissues, spinal cord, nerves, ligaments, musculature, discs). MRI is superior to CT for evaluation of soft tissue structures. Contrast agents may be used to highlight masses and abnormal tissue or fluid collections. MRI is contraindicated in patients with many metallic implants and cardiac pacemakers. Titanium and stainless steel implants in the spine are not contraindicated.

IV. Bone Scan

Radioactive tracers are injected into the patient. These tracers then attach themselves to areas of increased bone production or increased vascularity associated with tumor or infection.

V. Myelogram/Postmyelogram CT

A contrast agent is injected under fluoroscopy into the intrathecal space through either lumbar puncture or cisternal puncture. The contrast agent is then visualized with radiographs, or more commonly, with CT. The resulting images are useful for evaluating patients who cannot undergo MRI studies (e.g., people with pacemakers) or as an adjunct to MRI. This test also is useful for evaluating nerve root lesions and any other mass lesion or infection that is within, or impinging upon, the thecal sac.

VI. Electromyography/Nerve Conduction Velocities

Small needles are inserted into specific muscles to assess muscle activity and nerve conduction time, as well as the amplitude of electrical stimulation along specific nerves. Electromyography (EMG) may be indicated for the patient without a clear radiculopathy. It also may be useful in differentiating among cervical radiculopathy, ulnar or radial neuropathy, carpal tunnel syndrome, or other peripheral nerve problems such as brachial plexopathy.

VII. Somatosensory Evoked Potentials

Somatosensory evoked potentials (SSEPs) use small needles to send electrical signals back and forth between the peripheral nerves and the brain. Typically, stimulating electrodes are placed along the median nerve in the wrist and recording electrodes are placed over the scalp, spine, and peripheral nerves. This technique evaluates the function of the afferent sensory fibers. Although SSEPs are commonly used intraoperatively, the test is of limited value in evaluating patients preoperatively.

Cervical Spine Disorders

Neck pain, a common problem, often is episodic and self-limiting. However, neck pain also can be a symptom of degenerative cervical spine disorders, inflammatory cervical spine disease, neoplastic disease, deformity, or a cervical spine infection, all of which will be presented in this section. The most common problem, degenerative disorders, will be discussed in greater detail. A brief overview on the remaining conditions follows. Although a complete and in-depth discussion is beyond the scope of this guide, the significance and impact that these cervical spine diagnoses have on the neuroscience patient warrants their mention.

Neck Pain Without Radiculopathy

Neck pain without radiculopathy is a common, albeit often complicated, problem. Like low back pain, it affects most people at some point in their lives. Neck pain can be classified as mechanical (i.e., associated with the spine) or myofascial (i.e., muscular). Mechanical pain usually is deep and agonizing, aggravated by activity and alleviated by rest. This type of pain often is associated with degenerative cervical spine conditions. Myofascial pain is muscular, often resulting in muscle spasms and posterior occipital headaches. Myofascial pain syndromes respond best to exercise and stress-reducing interventions. These symptoms are generally self-limiting.

Many neck-pain syndromes are attributable to numerous factors. Côté, Cassidy, and Carroll (2003) found that, overall, neck pain resulting from whiplash was a multifaceted problem that included legal and sociodemographic factors. A recent study demonstrated that whiplash injuries are not associated with kyphotic deformity (Johansson, Baann Liane, Bendix, Kasch, & Kongsted, 2011).

Although most neck pain is self-limiting, the following "red flags" warrant further investigation for the possibility of a more serious underlying cause:

- fever
- unexplained weight loss
- previous cancer
- unrelenting night pain
- immunosuppression
- recent history of intravenous drug use (Carette & Fehlings, 2005).

Cervical Radiculopathy

Radiculopathies are the result of nerve root compression. In the cervical spine, the most common cause of radiculopathy is foraminal narrowing and impingement onto the spinal nerve. Radiculopathies result from herniated nucleus pulposus (HNP) in only about 25% of cases; the majority of them are caused by cervical spondylosis (Radhakrishnan et al., 1994). The pain can be insidious, developing over weeks from a dull ache to severe burning, depending on the level of radiculopathy. Symptoms include neck pain and upper-extremity pain in the distribution of the affected nerve. Motor and sensory changes also may be present.

Cervical Myelopathy

Myelopathy is the result of spinal cord compression, which can stem from clinical entities such as long-standing progressive compression from spondylosis or ossification of the posterior longitudinal ligament. It can also be caused by an acute problem such as acute disc herniation.

Myelopathy may be exhibited in a number of ways, including the following:

- upper motor neuron signs of hyperreflexia
- poor coordination or lack of fine motor dexterity
- pathologic reflexes such as a positive Hoffman's sign or Babinski reflex
- bowel or bladder changes
- balance problems
- falling episodes.

The patient may have varying degrees of weakness and sensory changes, depending on the degree and acuity of the spinal cord compression.

Degenerative Cervical Spine Disorders

Intervertebral Disc Herniation—Herniated Nucleus Pulposus

I. Description and Etiology

Intervertebral disc herniation is also known as herniated nucleus pulposus (HNP). The intervertebral discs make up approximately one-fourth of the cervical spine's height. Over time the water content within the nucleus pulposus of the disc decreases from approximately 90% at birth to 70% by age 70 (Naderi, Benzel, & Resnick, 1999). The diminished water content, along with changes due to the effects of proteoglycan, collagen, keratin sulfate, and chondroitin sulfate, results in degeneration. As the degenerative process continues, the nucleus pulposus cannot generate the intradiscal force required to keep the annulus fibrosus expanded. In turn, the annulus is subjected to excessive compressive and shear forces, causing weakening and tears in its layers. The weakness puts the annulus at risk of nucleus pulposus bulging, protrusion, or herniation. A degenerated disc is also referred to as a desiccated disc (**Figures 16, 17**).

An HNP may be asymptomatic despite radiographic evidence of bulging, protrusion, or herniation. Its etiology may be either nonspecific or attributable to a precipitating event. Even when symptomatic, surgical intervention often is not required.

An HNP may be symptomatic due to a combination of direct nerve root compression, the release of inflammatory chemicals (e.g., matrix metalloproteinases, prostaglandin E_2, interleukin-6, nitric oxide), and hypoxia of the nerve root and basal ganglion (Carette & Fehlings, 2005). Conversely, if the disc is sufficient in size and herniates centrally, spinal cord compression to varying degrees also can occur.

Radiculopathy is pain in the anatomic distribution of the affected nerve root. Pain can be accompanied by paresthesias or paresis (i.e., weakness), or both, in the anatomic distribution of the affected nerve root.

Spinal cord compression resulting from a central disc herniation can present in varying degrees of symptomatology. The patient may complain only of neck pain, or may have signs of myelopathy to severe neurologic dysfunction.

II. Definitions

A. **Bulge:** Symmetrical extension of the disc beyond the endplates
B. **Protrusion:** Focal area of bulge/disc extension that is still attached to the disc (annulus fibrosis)
C. **Extruded fragment:** Nucleus pulposus no longer connected to the disc
D. **Sequestered fragment (i.e., free fragment):** Nucleus pulposus in the posterior longitudinal ligament
E. **Radiculopathy:** Pain in the distribution of a nerve root resulting from irritation/compression on that nerve root

Figure 16. MRI scan sagittal, T2 weighted image; C5–C6 HNP

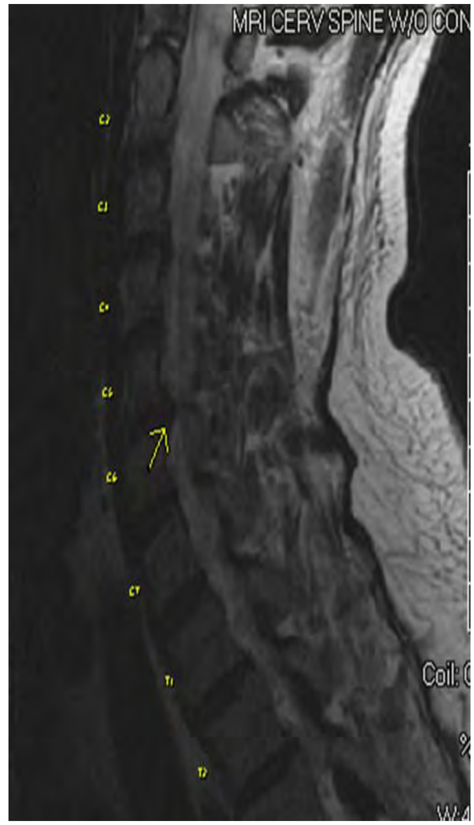
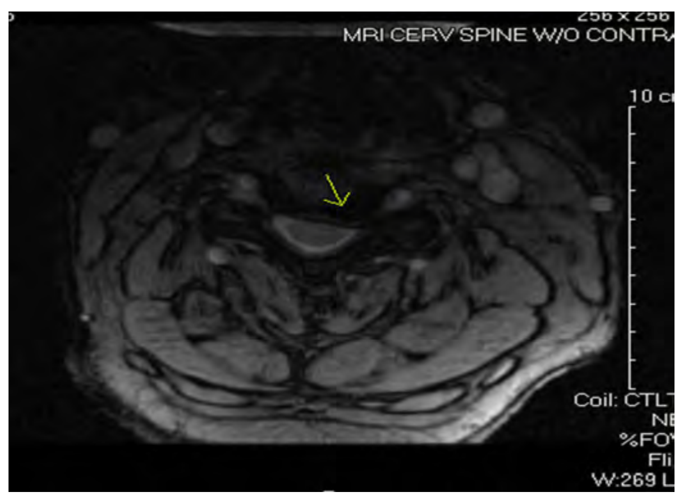


Figure 17. MRI scan, axial, T2 weighted image; C5–C6 HNP



III. Incidence

A. Cervical radiculopathy has an annual incidence of 107.3 per 100,000 (men) and 63.5 per 100,000 (women). Peak onset is 50–54 years of age. Only 15% of cases reported a history of physical exertion or trauma. However, HNPs are responsible for only

20%–25% of radiculopathy cases. Approximately 70%–75% are from spondylosis of the cervical spine (Radhakrishnan et al., 1994).

B. Most cervical HNPs occur at C5–C6, or C6–C7 levels.

IV. Supporting Data

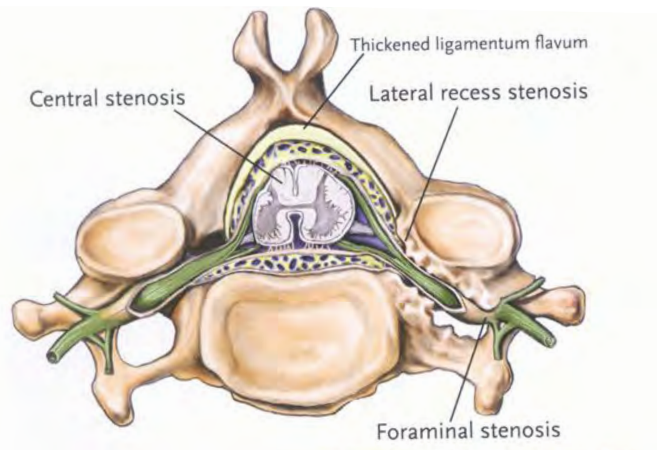
A. MRI studies are the best test to evaluate the spinal structures, HNP, and nerve root compression. A CT scan may be required to further evaluate the bony structures in some patients.

B. Motor weakness, sensory changes, or alteration in deep tendon reflexes (DTRs)—or all three—are noted. Please refer to Table 1 for more information.

C. Cervical root tension may be tested with a Spurling's sign. It is elicited by hyperextending and rotating the neck toward the symptomatic side. A reproduction of the pain is a positive indicator.

D. In addition, preoperative diagnostic studies that are consistent with the patient's clinical history and a neurological examination may be performed.

Figure 18. Depiction of central and lateral recess stenosis



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 106), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Spondylosis

I. Description and Etiology

From the Greek word meaning "vertebra," *spondylosis* is generally defined as age- and use-related degenerative changes of the spine. This diagnosis includes degenerative disc disease and the progressive changes that occur as a result of disc degeneration, such as osteophyte formation, ligamentous hypertrophy, and facet hypertrophy (**Figure 18**). As the degenerative cascade continues, changes in normal spinal curvature occur.

Disc degeneration leads to loss of disc height, more so anteriorly in the cervical spine. The biomechanics of the cervical spine are altered, placing more force on the uncovertebral and facet joints. This asymmetric loss of disc height may promote the formation of cervical kyphosis, an abnormal forward curvature (i.e., lordosis is lost). Reactive bone formation, bone developing because bone is touching bone, may form along the posterior vertebral bodies. Osteophytes form, which can encroach on the foraminal openings. Loss of disc height also causes foraminal narrowing. Collapse of the anterior portions of the discs may lead to ligamentum flavum buckling and bulging of the posterior disc (Jenis, Kim, & An, 2004).

Nerve root compression also can occur with osteophyte formation, degenerated disc, or a bulging or herniated disc, which causes neural foraminal narrowing. Spinal cord compression can occur from central disc herniation, ligamentous hypertrophy, and facet hypertrophy. Persons with a congenitally small cervical canal are predisposed to cervical canal stenosis.

II. Incidence

The most common cause of cervical radiculopathy is encroachment of the spinal nerve due to decreased height and degenerative changes of the uncovertebral joints anteriorly and zygapophyseal joints posteriorly (Carette & Fehlings, 2005) Herniation of the nucleus pulposus and spinal tumors are less frequest causes (Carvette & Fehlings, 2005).

III. Supporting Data

A. The patient often has a history of intermittent neck pain and a gradual decrease in cervical range of motion.

B. See Intervertebral Disc Herniation (page 12) for more details.

Cervical Spondylotic Myelopathy

I. Description and Etiology

Cervical spondylotic myelopathy is defined as "spinal cord dysfunction accompanying typical age-related degeneration of the cervical spine" (Tortolani & Yoon, 2004, p. 701). Spondylosis is the most common etiology, and spondylotic myelopathy is the most common cause of spinal cord dysfunction in persons older than 55 years. However, cervical spondylosis is commonplace in the aging spine, and most patients will not develop myelopathy.

Radiographically, cervical spondylotic myelopathy is considered when the central canal is less than or equal to 13 mm (normal = 17 mm) or when patients have greater than or equal to 30% narrowing of the cross-sectional area of the canal with associated symptoms.

Researchers hypothesize that the clinical signs and symptoms of myelopathy develop because of damage to the central gray matter and demyelination along the corticospinal tracts below the area of compression. Debate exists as to whether the cause is due to direct pressure or injury or to ischemia from spinal cord vascular supply compression (Tortolani & Yoon, 2004).

Symptom development is insidious, with highly variable symptomatology and clinical course, making diagnosis difficult. Often patients experience a gradual neurologic deterioration. The exact rate of deterioration is indeterminable. Surgery is preferred over conservative measures (McCormick et al., 2003); but management must be carefully individualized based on clinical and radiographic factors (Edwards et al., 2003).

II. Incidence

As mentioned above, cervical spondylotic myelopathy is the most common cause of spinal cord dysfunction in people over the age of 55 (Murray & Tay, 2004).

III. Supporting Data

A. Symptoms are highly variable and can include pain, hyperreflexia, impaired fine motor dexterity, paresthesias, weakness, and gait disturbances.

B. Questions to ask the patient include the following:
- Does the patient have problems with handwriting?
- Does the patient have problems with buttoning or zipping?
- Has the patient experienced balance difficulties? Any recent falls?
- Have there been changes in how the patient walks? Any tripping? Does the patient tire more easily?
- Has the patient experienced cramping in the hands or feet?
- Has the patient experienced any weakness? Any paresthesias?
- Would the patient say that one side (right or left) is more bothersome than the other?

C. MRI studies are the best test to evaluate the spinal structures and cord compression. A CT scan may be required to further evaluate the bony structures in some patients.

D. A correlation of clinical examination and radiographic findings is essential.

Cervical Stenosis

I. Description and Etiology

Cervical stenosis, classified as either congenital or acquired, is a result of either being born with a narrow spinal canal or developing a narrow spinal canal as a result of degenerative changes. These degenerative changes have been discussed in previous sections of this guide.

Ossification of the posterior longitudinal ligament (OPLL) is a specific condition that causes cervical spinal stenosis. OPLL is characterized by calcification and thickening of the PLL. This results in narrowing of the spinal canal and potential spinal cord compression as well as increased spine rigidity.

With any cause of stenosis, the degree of spinal canal narrowing determines the significance of the clinical implications. If spinal cord compression is evident, the patient will be counseled on operative management options, alternatives to surgery, and the risks involved with both operative and nonoperative management. Stenosis may exist throughout the cervical spine or may be limited to a few adjacent segments. In severe spinal cord compression, even with no neurologic deficit, there is a potential for catastrophic neurologic impairment.

II. Supporting Data

A. Signs and symptoms are dependent on the degree of spinal cord compression.

B. Cervical stenosis may be asymptomatic and found incidentally, such as during evaluation for radiculopathy.

C. Evaluation for stenosis is the same as for spondylosis or cervical spondylotic myelopathy.

Inflammatory Cervical Spine Disease

Rheumatoid Arthritis

I. Description and Etiology

Definite rheumatoid arthritis (RA) is defined by the American College of Rheumatology/European League as "the presence of synovitis in at least one joint, absence of an alternative diagnosis, and achievement of a total score of 6 or greater (of a possible 10) from the individual scores in 4 domains: number and site of involved joints, serologic abnormality, elevated acute-phase response, and symptom duration" (Aletaha et al., 2010). Synovitis, an acute inflammatory response, is a result of antibody-antigen complex formation. Eventually, this can lead to complete destruction of the joint. The acute process is followed by a chronic granulomatous process of pannus formation. This produces collagenase and other enzymes that destroy surrounding cartilage and bone. The cervical spine is at risk because the atlantooccipital (occiput and C1) and atlantoaxial (C1 and C2) articulations are purely synovial. Common deformities that occur are atlantoaxial instability (i.e., subluxation) or cranial settling.

II. Definitions

A. **Basilar invagination:** Basilar invagination is the superior migration of the odontoid into the foramen magnum, which can lead to compression (constant or intermittent) on the brain stem.

B. **Pannus:** Pannus is a sheet of inflammatory granulation tissue that spreads from the synovial membrane and invades the joint, ultimately leading to fibrous ankylosis.

III. Incidence

A. Cervical spine disease is seen in as many as 88% of people with RA.

B. C1–C2 instability occurs in up to 74% of people with RA (Thomas, Rea, & Weinstein, 2005).

IV. Supporting Data

A. Cervical instability includes atlantoaxial (C1 and C2) instability, cranial settling, basilar invagination, and subaxial subluxations. With atlantoaxial (C1 and C2) instability and subaxial subluxation, the motion between C1 and C2 can cause compression on the brain stem and upper spinal cord.

B. The most common presenting symptoms of RA are neck pain, occipital headaches, and neck stiffness. Less common symptoms are consistent with myelopathy: gait disturbance, weakness, and loss of fine motor dexterity (Grauer et al., 2004; Jeong & Bendo, 2004).

C. Neurological examination results can be highly variable and are dependent on the presence of brain stem or spinal cord compression.

D. Initial radiographic evaluation should be a lateral, flexion/extension cervical spine X ray. An MRI study may help practitioners to further evaluate neural elements and pannus. A CT scan may be indicated for further bony element evaluation.

Ankylosing Spondylitis

I. Description and Etiology

Ankylosing spondylitis, a seronegative spondyloarthropathy associated with the human leukocyte antigen B27 (HLA-B27), causes inflammation in the synovial joints, beginning in the sacroiliac joints (Webb, Hitchon, & Sengupta, 2005). As the disease progresses, ossification and ankylosis occurs in an ascending manner. The patient eventually develops a rigid, brittle, and immobile spine. This leaves the individual very susceptible to deformity (loss of normal spinal curvature) and fractures.

II. Incidence

A. Incidence of ankylosing spondylitis is rare; onset usually occurs at approximately 40 years of age.

B. Ankylosing spondylitis is more common in males (Jeong & Bendo, 2004).

III. Supporting Data

A. Patients are at high risk of suffering vertebral fractures due to impaired spinal mobility.

B. Secondarily, there is a high incidence of osteoporosis among patients with ankylosing spondylitis.

C. Fractures can occur as a result of relatively minor trauma.

D. Because of spinal rigidity, cervical and lumbar range of motion (ROM) are impaired.

E. Severe deformity can leave the patient out of spinal balance or can lead to chin-to-chest deformity. Safety issues can be problematic due to the patient's decreased cervical ROM.

F. Neurological examination and correlation of radiographic studies are warranted.

Neoplastic Cervical Spine Disease

Metastatic

More than 95% of the clinically significant spinal column tumors are metastases, and 60% of those are from cancers of the breast, lung, and prostate; myelomas; or lymphomas (Scott, Pedlow, Hecht, & Hornicek, 2004). Approximately 8%–20% of spine metastases are in the cervical spine. In addition, 11%–17% of breast cancer patients will suffer metastases to the cervical spine; the percentage increases to 40% in patients with advanced disease (Hecht, Scott, Crichlow, Hornicek, & Pedlow, 2004). Cancers of the lung, of the prostate, renal, and thyroid glands, as well as gastrointestinal and gynecologic cancers, and melanoma, in descending order of frequency, commonly metastasize to the cervical spine.

Spinal involvement of metastatic cancer can lead to vertebral collapse and instability, causing pain and potential neurologic compromise. Nerve root or spinal cord compression also can be caused by the infiltration of the tumor mass, resulting in neural element compression.

Although surgical intervention may not cure these patients, it may be indicated to treat tumor-induced neurologic compromise or fracture. Surgical intervention is aimed at stabilizing the spine and optimizing neurologic function (Patchell et al., 2005).

Primary

Primary spine tumors comprise less than 10% of central nervous system tumors and are classified by location (Scott et al., 2004). Spinal tumors may be extradural (i.e., outside of vertebral body or epidural space), intradural (i.e., within the leptomeninges or nerve roots, yet outside of the spinal cord), and intramedullary (i.e., within the spinal cord). Spinal tumors also may be described as primary (i.e., originating from the spinal tract or vertebrae), metastatic, benign, or malignant. Most spinal tumors cause neurologic sequalae by compressing on nerve roots or the spinal cord and not infiltrating into neural elements.

Primary, extradural, benign tumors include hemangioma, aneurysmal bone cyst, chordoma, osteoid osteoma, osteoblastoma, osteochondroma, giant cell tumor, and eosinophilic granuloma. The malignant, primary, extradural tumors include multiple myeloma, osteosarcoma, and chondrosarcoma (Scott et al., 2004). Intradural and extramedullary tumors include ependymomas and astrocytomas (Wolcott, Malik, Shaffrey, Shaffrey, & Jane, 2005).

Deformity of the Cervical Spine

Deformities develop from either anterior or posterior vertebral element disruption. This can be caused by a number of conditions, such as congenital anomalies, surgery, osteoporosis, tumor, or inflammatory or degenerative processes (Grauer et al., 2004). The underlying pathology and biomechanical imbalances it creates will determine the extent and significance of the deformity.

The most common cervical spine deformity is kyphosis. As the deformity forms, the head is shifted forward, which increases compression on the anterior vertebral bodies. The posterior neck muscles become less effective at holding up the head. As the cycle continues, kyphosis, unfortunately, worsens over time. Common signs and symptoms are neck pain, muscle fatigue, radiculopathy, myelopathy, potentially poor posture because of looking down, and poor nutritional status because of the patient's inability to look up.

Brief descriptions follow of possible causes of deformity that have not been previously discussed.

Osteoporosis

I. Description and Etiology

Osteoporosis, the most common metabolic bone disease, is characterized by low bone mass and structural deterioration of bone tissue. These events occur when bone resorption happens too quickly or replacement occurs too slowly. Structural deterioration leads to increased susceptibility to fractures, which are related to increased bone fragility most often seen in the hip, spine, or wrist. The definition of osteoporosis considers the following several factors that lead to bone fragility: advanced age, prior fragility fractures, parental history of proximal femur fractures, low BMI, low bone mass, glucocorticosteroid treatment, rheumatoid arthritis, smoking, and overuse of alcohol (Czerwinski, Baduriski, Macinowski-Suchowierska, & Osienleniec, 2007).

Certain risk factors are linked to or contribute to the likelihood of an individual developing osteoporosis. Some of these factors are genetically determined and others are related to lifestyle. Increasing age plays a significant factor as the resorption of bone surpasses its formation, putting both sexes at increased risk. Persons may not be aware that they have developed osteoporosis because bone loss occurs without symptoms. The first sign may be pain, spinal deformity, loss of height, or fracture.

In addition to aging, other risk factors include long-term calcium deficiency, secondary hyperparathyroidism, withdrawal from estrogen (for women), decreased physical activity, cigarette smoking, and excessive alcohol intake. Secondary osteoporosis may be caused by thyroid disease, parathyroid excess, hypothalamic hypogonadism, diabetes mellitus, steroid exposure, multiple myeloma, leukemia, and prolonged bedrest (Gill & Einhorn, 2004).

II. Incidence

Worldwide, osteoporosis is three times more common in women than in men. Women are more susceptible than men due to the changes in bone tissue and the increased loss of bone that occurs during menopause (World Health Organization, 2003; Kanis et al., 2008). When considering spinal care in older adults, it is important to remember that both men and women are afflicted with osteoporosis (Tis & Kuklo, 2005).

III. Supporting Data

The microarchitectural deterioration that occurs as a consequence of osteoporosis may compromise the effectiveness of internal fixation and, with severe osteoporosis, may eliminate the option for internal fixation. Surgical options for the patient with poor bone quality include the following:

- using multiple fixation points
- using anterior and posterior instrumentation
- augmenting with wires or hooks, or both
- injecting polymethylmethacrylate or calcium phosphate paste
- performing a noninstrumented fusion (Dmitriev & Kuklo, 2005; Rosner & Ondra, 2005).

Congenital Anomalies

Congenital anomalies such as os odontoideum, torticollis, atlantoaxial subluxation, and Klippel-Feil deformities, can lead to cervical deformity because of abnormal formation and development of the spine and its supporting structures. A complete discussion of congenital anomalies is beyond the scope of this text.

Infection

Pyogenic Vertebral Body and Disc Infections

Routes for infection to enter the spinal column include the following:

- hematogenous spread from urinary tract, skin, or cardiac valve infection
- local extension from nearby infection, such as abdominal, pelvic, retroperitoneal, or thoracic empyema
- direct inoculation, such as postsurgical, postinjection, or penetrating trauma (Rhee & Heller, 2004).

The vertebral body tends to be infected first, then the disc space. If untreated, it will spread to the next vertebral body, then the anterior longitudinal ligament, and into the paravertebral soft tissues. The cervical spine is the least common site of pyogenic infection, occurring in only 7% of the total number of incidences. By comparison, the thoracic region is subject to infection in 35% of the incidences and the lumbar spine, 50%. (Rhee & Heller, 2004). A recent retrospective study demonstrated the following items as risks for surgical site infection: body mass index > 35, hypertension, thoracic surgery and lumbar surgery (when compared to cervical surgery), and surgical invasiveness index of > 21 (Cizik et al., 2012).

Epidural Spinal Abscess

The posterior epidural space contains a rich complex of small arteries and a venous plexus, along with fat. Bacteria may be introduced into this space by trauma or surgical intervention. More frequently, this type of infection is due to seeding from a systemic infection. Bacteremia, bacterial endocarditis, intravenous (IV) drug abuse, diabetes mellitus, chronic alcohol abuse, and immunosuppression are major risk factors for epidural spinal infections. Most patients present with pain and signs of spinal cord compression (e.g., motor, reflex, and sensory changes).

Treatment of Cervical Spine Disorders

Nonsurgical Medical Treatment

There are many options for treating neck and radicular pain. As with low back pain, nonsurgical treatment for pain is warranted for 6–12 weeks unless a progressive, functionally important motor deficit is present (Carette & Fehlings, 2005). Nonsurgical treatment includes analgesic agents, immobilization, cervical traction, physical therapy (PT), epidural steroid injections (ESI), manipulation, and short-term bracing. In addition, healthcare providers should promote general well-being, such as smoking cessation, weight management, and adequate physical activity.

I. Medication

Short-term relief from pain symptoms enables patients to participate in an exercise program. There are several effective strategies for symptom management, including muscle relaxants to reduce muscle spasm, nonsteroidal antiinflammatory drugs (NSAIDs) to reduce inflammation of the nerve root, and opioids for short-term acute pain relief. Some clinicians advocate a brief oral steroid boost for patients with acute pain (Wolff & Levine, 2002).

II. Epidural Steroid Injections

ESIs consist of either a translaminar or interlaminar injection of a corticosteroid (e.g., methylprednisolone). The mechanism of action is their ability to inhibit prostaglandin synthesis and decrease immunologic responses. Additional mechanisms are thought to be membrane stabilization, suppression of neuropeptides, and the ability to block phospholipase A2 activity and nociceptive C-fiber conduction (Ngu, DeWal, & Ludwig, 2003). The approach for ESI needs to be individualized to each patient's symptomatology and radiographic findings. Although cervical ESIs have been reported to have significant success rates, complications can be severe. A randomized, double-blind, controlled trial demonstrated no additional benefit for chronic radicular pain relief (Ng, Chaudhary, & Sell, 2005). A systematic review demonstrated moderate evidence that epidural steroids are ineffective for chronic spinal pain (Abdi et al., 2007). One case report found that the transforaminal epidural injection is associated with profound neurological complications (Beckman, Mendez, Paine, & Mazzilli, 2006)

III. Physical Therapy

PT often reduces pain and improves function in patients with cervical spine disease. Cervical traction also has been recommended. Although cervical traction, as well as active range-of-motion (ROM) exercises, aerobic conditioning, and isometric and progressive-resistive exercises, are common practice, none of these methods is supported by evidence from clinical trials (Carette & Fehlings, 2005). In addition, Kay et al. (2012) completed a systematic review of the literature to assess the effectiveness of exercise therapy to relieve pain or to improve function, disability, patient satisfaction, and the overall perceived effect in adults with mechanical neck disorders. The reviewers concluded that, although there is a role for exercise in the treatment of acute and chronic mechanical neck pain and neck pain with headache, there was limited evidence of the benefit for strengthening, stretching and strengthening, or eye-fixation exercises for neck disorder with headache. There was limited evidence of benefit for active ROM exercises or a home exercise program for acute mechanical neck pain (Kay et al., 2012).

IV. Spinal Manipulation (Chiropractic or Osteopathic)

Chiropractic or osteopathic spinal manipulation is used to relieve symptomatology. A systematic review assessed whether manipulation and mobilization, either alone or in combination with other treatments, relieved pain or improved function and disability, patient satisfaction, and overall perceived effect in adults with mechanical neck disorders. Results demonstrated that neither a single session nor multiple sessions of manipulation or mobilization, or both, showed significant benefit. There was, however, strong evidence for the benefit of multimodal care, specifically manipulation and mobilization, plus exercise (Kay et al., 2012).

V. Bracing

Short-term (fewer than 2 weeks) immobilization with either a soft or hard collar may be recommended. There is no evidence, however, for the benefits of such a practice (Carette & Fehlings, 2005).

VI. Acupuncture

In acupuncture, very fine needles are placed into specific trigger points to stimulate anatomic points in the body. Researchers theorize that acupuncture works by influencing the body's electromagnetic field, which can alter the chemical neurotransmitters within the body. Evidence of acupuncture's efficacy for the treatment of neck pain is emerging, but definitive evidence is not currently available (Irnich et al., 2001; White, Lewith, Prescott, & Conway, 2004).

VII. Back School

Back school is a structured, educational mechanism that strives to teach patients active self-management, prevention, and general spine biomechanics and principles. Such programs often are multidisciplinary and, ideally, include a health psychologist.

VIII. Alternative Management Techniques

Alternative pain management techniques include prolotherapy, magnet therapy, Yoga, tai chi, biofeedback, psychotherapy, and massage therapy. There is no scientific evidence about the efficacy of these techniques for neck pain.

Surgical Treatment

Cervical spine surgical treatment options vary. Before making a decision about which option to pursue, the surgeon takes into account the patient's cervical spine pathology, clinical signs, symptoms, and other general medical conditions; biomechanical and technical considerations; the current medical evidence; and his or her own personal training and preferences.

Surgical treatment for the patient with a cervical radiculopathy is indicated for patients with (a) persistent signs and symptoms, despite approximately 6 weeks of appropriate nonsurgical treatment or (b) a progressive motor deficit and in whom there is radiographic correlation. Surgical approaches for cervical radiculopathy for either HNP or spondylosis include anterior cervical discectomy with or without fusion and posterior laminoforaminotomy. For patients with myelopathy that requires spinal cord decompression, anterior cervical discectomy, anterior cervical corpectomy (single or multiple levels) with fusion, laminectomy with or without fusion, and laminoplasty may be indicated. Occasionally, a combination anterior/posterior approach is necessary. Surgical treatment for the other diagnoses noted above is case specific. Currently, a comprehensive, evidenced-based medical resource for cervical spine surgical treatment does not exist.

Many factors are considered by the surgeon prior to offering surgery. When discussing the surgery with the patient, the operation, graft material, and instrumentation, as well as the risks, benefits, potential complications, and alternatives, should be covered in detail.

I. Expected Outcomes

There are few quality studies comparing surgical and nonsurgical treatment of cervical radiculopathy. Persson, Carlsson, and Carlsson (1997) randomized patients to surgical or nonsurgical treatment ($N = 81$) and found that at 3 months the surgical group had a reduction in pain; however, at one year, there was no difference between the groups. Kadanka et al. (2000) evaluated patients ($N = 51$) with mild spondylotic myelopathy (i.e., no functional impairment, no weakness) and randomized study patients to surgical and nonsurgical treatment. At the 2-year follow-up, there were no differences in neurologic outcomes.

Hacker, Cauthen, Gilbert, and Griffith (2000), as well as Casha and Fehlings (2003), found that 75% of patients with preoperative radiculopathy, but without myelopathy, had significant relief of symptoms 2 years after surgery. Following a literature review, Fouyas, Statham, and Sandercock (2002) completed a Cochrane Database Review and concluded that the small, randomized trials did not provide enough evidence on the effects of surgery for patients with cervical spondylotic radiculopathy or myelopathy. The authors could not ascertain to their satisfaction whether the short-term risks of surgery are offset by any long-term benefits.

II. Anterior Approach

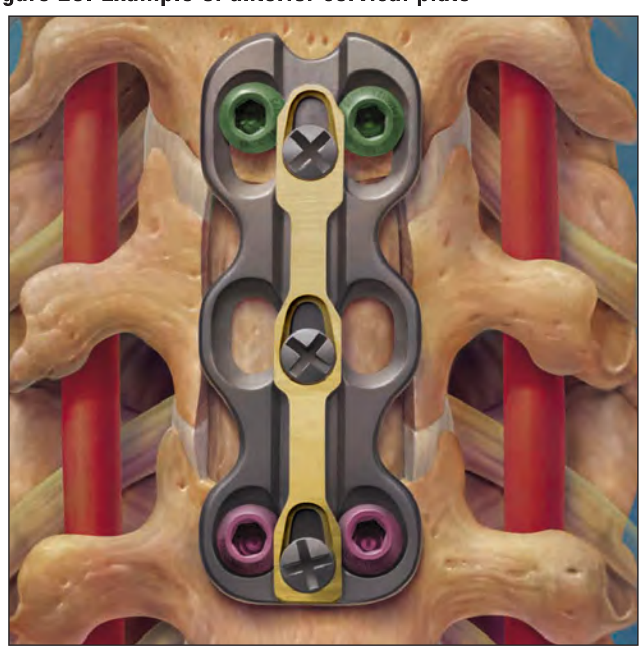
A. Cervical Discectomy With and Without Fusion

Single/multilevel: The purpose of both anterior cervical discectomy with fusion (ACDF) and without fusion (ACD) is to relieve pressure on the neural elements of the spinal cord and nerve roots. More commonly, a fusion is performed utilizing graft

Figure 19. Example of anterior cervical plate

Note. Photo (n.d.), retrieved January 26, 2007, from www.myspinetools.com/products/atlantis/overview.html. Copyright © by Medtronic Sofamor Danek. Reprinted with permission.

Figure 20. Example of anterior cervical plate



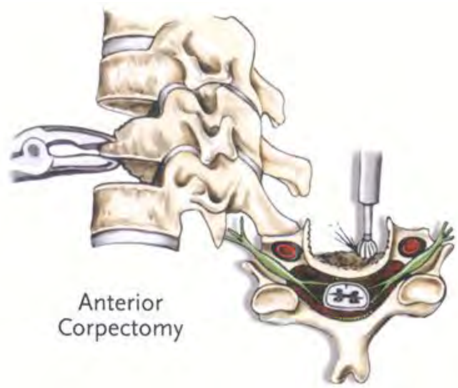
Note. Photo (n.d.), retrieved January 26, 2007, from www.myspinetools.com/products/premier/overview.html. Copyright © by Medtronic Sofamor Danek. Reprinted with permission.

material and anterior plate fixation to prevent disc collapse and subsequent kyphosis (**Figures 19, 20**). Traditionally, an autogenous bone graft is used. This graft typically is harvested from the patient's iliac crest. Many surgeons now favor the use of interbody fusion devices (e.g., allograft, synthetic spacers, cages) with allograft or other fusion materials. The patient's length of stay is usually 23 hours or less. Occasionally, in some centers, patients are discharged the same day.

B. Corpectomy

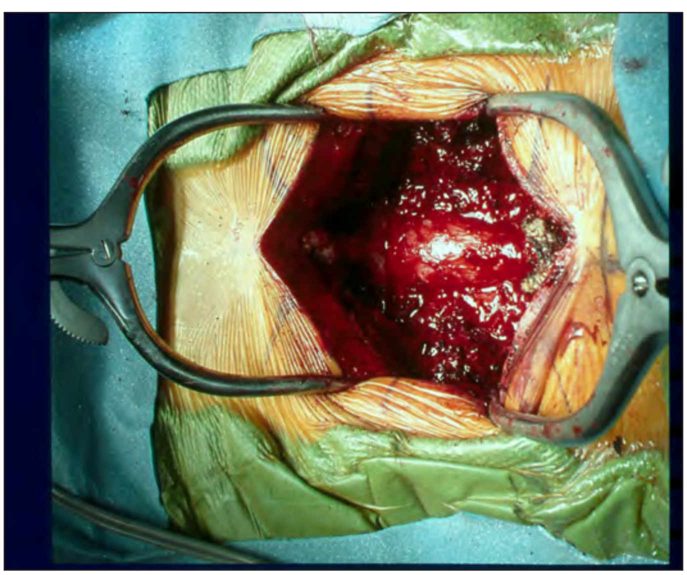
Single/multilevel: Corpectomy is the removal of one or more of the vertebral bodies and the adjacent discs, thereby decompressing the spinal canal (**Figure 21**). More extensive than a discectomy, a corpectomy requires stabilization with an autograft or a strut graft (i.e., a long, thin piece of bone, cage, or other graft material) inserted between the remaining vertebrae, supporting the anterior spinal column. Commonly, anterior plate fixation is also used. Length of stay is commonly one night. Occasionally, two nights are needed for extensive procedures.

Figure 21. Anterior corpectomy



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 115), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

Figure 22. Intraoperative cervical spine decompression after multilevel laminectomy



C. Disc Arthroplasty (Artificial Disc)

The artificial disc is an alternative to the use of bone grafts, plates, and screws in cervical disc surgery. Proponents say cervical disc arthroplasty preserves motion at the disc space, thus simulating normal movement. This procedure begins as an anterior discectomy; following the discectomy an artificial disc is inserted into the disc space. The purpose of the artificial disc is to remove the degenerated disc and replace it with a prosthesis that will preserve the natural cervical ROM.

Intervertebral disc replacements are increasing because several devices have received Investigational Device Exemption from the U.S. Food and Drug Administration (FDA), resulting in clinical trials in the United States. At the time of publication, no artificial disc device has received FDA approval for use except for in a research study. Length of stay is overnight.

D. Transoral Approach

Utilized in a very select patient population, the transoral approach permits the surgeon to gain access to the anterior (ventral) aspects of the lower clivus (i.e., the portion of the skull base from the dorsum sellae to the foramen magnum) and the upper cervical spine through the back of the mouth. The ventral arch of C1 is opened, or removed, giving the surgeon access to the odontoid process (dens). A great deal of planning and preparation are necessary, including potential tracheostomy evaluation, nutritional evaluation and possible enteral feeding alternatives, special oral hygiene, and patient understanding as well as appropriate expectations. Length of stay is variable.

E. Potential Complications–Anterior Cervical Surgery

Complications, although rare, may include nerve root injury (2%–3%), recurrent laryngeal nerve palsy resulting in hoarse voice (2%), spinal cord injury (<1%), esophageal perforation (<1%), or instrumentation failure, including nonunion (<5% for a single level surgery) (Casha & Fehlings, 2003; Edwards, Heller, & Murakami, 2002; Hacker et al., 2000).

III. Posterior Approach

A. Laminectomy

A laminectomy is the removal of the vertebral lamina to decompress the spinal cord (**Figure 22**). A hemilaminectomy involves removal of one lamina, between the pars and the spinous process, whereas a standard laminectomy removes both laminae and the spinous process. Length of stay is commonly 2–3 days, whether the patient has a fusion or not.

B. Laminectomy with Fusion

A laminectomy also may include a fusion if there is concern about the stability of the cervical spine as a result of the laminectomy (**Figures 23, 24**). The fusion may include instrumentation (i.e., screws, hooks, and rods) or a bony fusion without instrumentation.

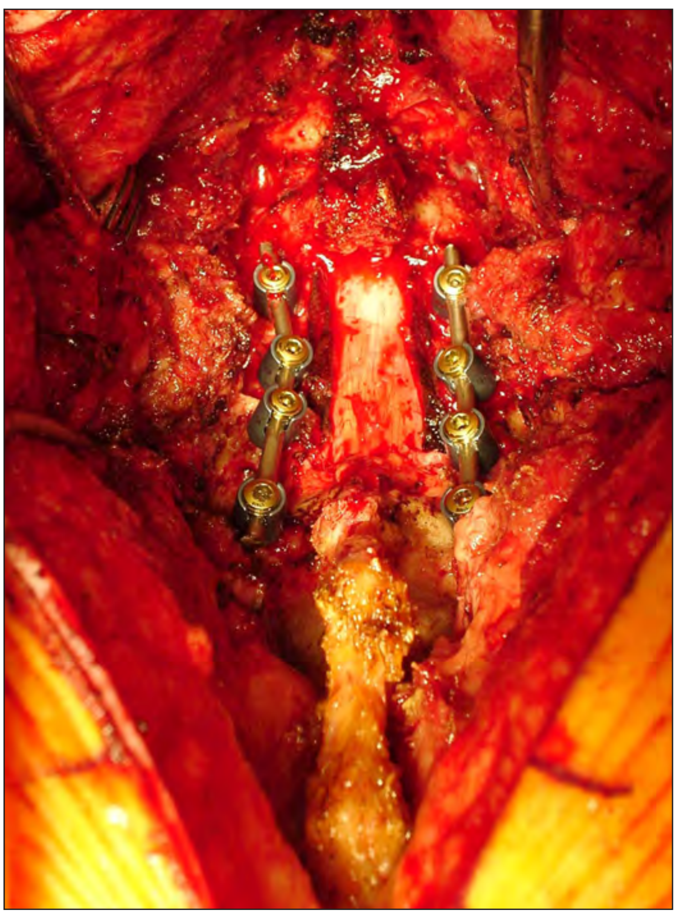
C. Laminoplasty

Cervical laminoplasty is used to relieve spinal compression without removing the lamina or spinous processes. Although there are several variations of laminoplasty, in general, a trough is drilled in one lamina, and a "door" is drilled through the opposite laminae. The posterior arch is distracted away—or the door is opened. This is completed at several cervical levels, for example, C3–C6. Graft material may be placed in the opening in the laminae, and a miniplate is placed for fixation. This procedure enlarges the spinal canal without removing bony structures. Length of stay is commonly 2–3 days.

D. Foraminotomy

Foraminotomy is a posterior surgical procedure used to treat patients with cervical disc herniation. This procedure is effective when one nerve root is compressed and an obvious radicular symptomology is present. With foraminotomy, the intravertebral foramen or canal is enlarged with the goal of removing tension or compression on the nerve root. Only the portions of the disc that are pressing on the nerve root are removed. A spinal fusion is not usually required. Length of stay is usually overnight.

Figure 23. Intraoperative cervical laminectomy and fusion with instrumentation



E. Posterior Discectomy

A posterior discectomy is performed with a laminectomy. Once the lamina is removed, the neural structures are retracted (i.e., moved aside) and any portions of the intervertebral disc that has herniated are removed. The remaining annulus is left in place. The discectomy may be performed with or without a fusion. Length of stay is usually overnight.

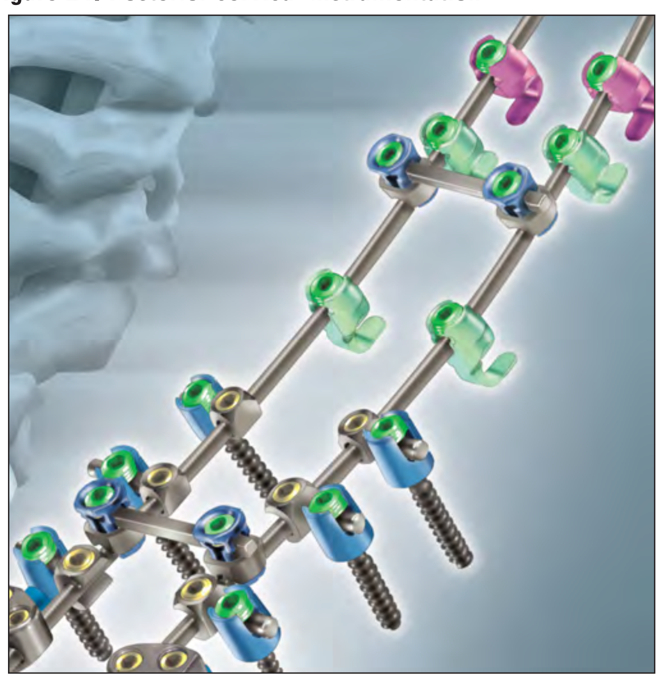
F. Upper Cervical Fusion

Occipital cervical fusion is indicated if the patient has instability of the craniocervical junction—either pathologically or as a result of a surgical procedure. The fixation can be performed with a variety of wires, rods, and plates. Length of stay is variable, but commonly is 2–3 days.

IV. Combined Anterior/Posterior Approach

A patient with extensive pathology involving both the anterior and posterior elements of the cervical spine, or a patient requiring a major procedure that leaves the cervical spine very unstable may require a combined anterior/posterior procedure (**Figures 25, 26**). Typically, the patient will undergo a multilevel ACDF or corpectomy followed by a posterior fusion with or without a laminectomy. Both

Figure 24. Posterior cervical instrumentation



Note. Photo (n.d.), retrieved January 26, 2007, from www.sofamordanek.com/patient-spinal-vertex.html. Copyright © by Medtronic Sofamor Danek. Reprinted with permission.

procedures may be done at the same time or may be staged (i.e., performed at different times).

V. Minimally Invasive/Minimal Access Approach

Minimally invasive techniques in the cervical spine are reported to be endoscopic posterior cervical lamino-foraminotomy and anterior cervical foraminotomy. These techniques are performed through very small incisions, utilizing muscle splitting. Proponents say that the posterior approach offers decreased postoperative pain and muscle spasms while maintaining posterior muscle integrity. The anterior approach preserves the disc, maintaining the motion segment (Perez-Cruet, Fessler, & Perin, 2002). These techniques require specialized equipment and surgical training. Minimal access surgical procedures are designed to reduce perioperative discomfort and shorten surgical healing times. Minimal access surgeries are evolving and gaining popular support.

VI. The Basics of Bone Healing

A solid bony fusion (i.e., arthrodesis) must be achieved in order to provide permanent spinal stability. Spinal instrumentation provides only temporary, internal fixation. If a solid bony fusion is not achieved, fusion failure may result in the fatigue and failure of supporting instrumentation. The patient's symptoms may persist or worsen. Nurses caring for cervical fusion patients are in a pivotal position to explain and reinforce to the patient the importance of providing an ideal environment to promote bony healing (**Figure 27**).

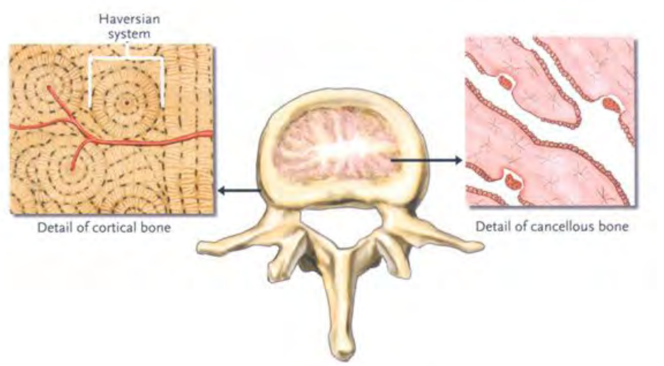
A. Three Primary Bone Types

1. Woven bone: Woven bone occurs in embryonic development, during fracture healing, and in disease states such as hyperparathyroidism and Paget's disease.
2. Cortical bone: This type of bone is composed of osteons; it is compact and cylindrical. Haversian canals are the vascular channels at the center. These are connected to each other by horizontal Volkmann's canals. The cortical bones form internal and external tables of flat bones and external surfaces of long bones. Their mechanical strength depends on the tight packing of the osteons.
3. Cancellous bone: Also referred to as the trabecular bone, it lies between the cortical bone surfaces. Its network of honeycombed interstices contains hematopoietic stem cells and bony trabeculae. The cancellous bone is arrayed in a perpendicular orientation to provide structural support and is continually undergoing remodeling on the internal endosteal surfaces.

Figure 25. Anterior/posterior cervical spine decompression and fusion, A/P X ray

Figure 26. Anterior/posterior cervical spine decompression and fusion, lateral X ray

Figure 27. Cortical and cancellous bone



Note. Illustration from *Core Curriculum for Basic Spinal Training* (2nd ed.; p. 31), by A. Schnuerer, J. Gallego, and C. Manuel, 2003, Nashville: Medtronic Sofamor Danek. Copyright © 2003 by Medtronic Sofamor Danek. Reprinted with permission.

B. Cellular Components of Bone

1. Osteoblasts: Mature, metabolically active bone-forming cells
2. Osteocytes: Mature osteoblasts trapped in the bone matrix
3. Osteoclasts: Multinucleated bone-resorbing cells that are controlled by hormonal and cellular mechanisms
4. Bone metabolism: Under constant regulation by a host of hormonal and local factors

C. Basic Physiology of Bone Repair

1. Osteogenesis
   a. Ability of the graft to produce new bone
   b. Dependent on the presence of live bone cells in the graft; unites the graft with the host bone
2. Osteoconduction
   a. The physical property of the graft to serve as a scaffold for bone healing
   b. Allows for the ingrowth of neovasculature and infiltration of osteogenic precursor cells into the graft in cancellous autograft and allograft
3. Osteoinduction
   a. Osteoinduction is the graft material's ability to induce stem cells to differentiate into mature bone cells.
   b. It is typically associated with the presence of bone growth factors within the graft material or as a supplement to the bone graft.
      (1) Bone morphogenic proteins (BMPs) and demineralized bone matrix are the principal osteoinductive materials.
      (2) Autograft and allograft have some osteoinductive properties, but to a much lesser degree.
4. Autograft is the only material demonstrating all three properties (i.e., osteogenesis, osteoconduction, and osteoinduction).

D. Basic Principles of Bone Remodeling

1. Early inflammatory stage
   a. First 2 weeks postinjury
   b. Initiated after hemorrhage caused by vascular injury
   c. Infiltration of inflammatory cells and fibroblasts occurs
   d. This leads to vascularization and formation of granulation tissue (procallus; Pilitsis, Lucas, & Rengachary, 2002).
   e. No antiinflammatory medications or cytotoxic drugs, especially during the first week. As described above, bone healing is an inflammatory process, and use of antiinflammatory agents would interfere with bone remodeling.
2. Repair stage
   a. With vascular ingrowth progression, a collagen matrix is laid down, and a soft callus forms.
   b. This temporary callus develops in the first 4–6 weeks and has limited strength.
3. Late remodeling stage: Adequate strength is generally achieved by 6 months; however, the process occurs over months to years.
4. Wolff's law: An important concept in spine surgery is Wolff's law, which states that bone placed under compressive stress is remodeled. Bone is formed where stresses require its presence and is resorbed where stresses do not require it (Kalfas, 2001). Thus, when a bone graft is placed, it requires mechanical compressive stress for new bone to form.
5. Limitations to proper bone healing: A number of factors may negatively affect proper bone healing, including antiinflammatory, cytotoxic, and steroid medications during the early inflammatory stage; nicotine use; radiation; and systemic illnesses such as diabetes mellitus, RA, and osteoporosis (Pilitsis et al., 2002). If the graft site is shielded from stress, according to Wolff's law, new bone will not be formed.

E. Graft Materials

1. Autograft
   a. From the recipient's own body
   b. Often harvested from the iliac crest
2. Allograft: Cadaver bone
3. Biologics
   a. Demineralized bone matrices: Demineralized bone is made from bone that has been decalcified under acidic conditions. The matrices are composed of

a mixture of type I collagen and noncollagenous proteins—including a variety of growth factors and cytokines. It is both osteoinductive and osteoconductive.

(1) Variable carrier material dependent on the specific product
(2) Many products and manufactures on the market

b. Recombinant human BMP
   (1) Derived from bone matrix
   (2) Highly osteoinductive
   (3) Osteogenic
   (4) Only FDA-approved product is INFUSE® Bone Graft (rhBMP-2).
      (a) Not FDA-approved for cervical spine surgeries
      (b) Only FDA-approved spinal surgery use is in anterior lumbar spine with LT-CAGE®, INTERFIX™, or INTERFIX™ RP device.
      (c) Indications are skeletal maturity with degenerative disc disease at one level; may also have up to Grade I spondylolisthesis at the involved level; to be implanted via an anterior open or an anterior laparoscopic approach (Medtronic INFUSE fact sheet, 2005).

c. Synthetic osteoconductive materials: Synthetic osteoconductive materials are artificial substrates that are only osteoconductive. They are scaffolds for the ingrowth of new bone (Whang &Wang, 2005). The following materials are used in the osteoconduction process:
   (1) Ceramics
   (2) Coralline matrices
   (3) Mineralized collagen
   (4) Bioactive glasses
   (5) Calcium sulfate
   (6) Acid polymers
   (7) Porous metals

F. Instrumentation

Instrumentation provides internal fixation and stabilization while the bone heals, providing a solid bony arthrodesis. Instrumentation includes plates, cages, rods, screws, and wires, among other things. There is a variety of different types and brands of instrumentation devices available.

Nursing Assessment, Intervention, Monitoring, and Documentation

I. Preoperative Teaching

A. Surgical procedure
B. Preoperative history and physical
C. Informed consent
D. Anticipation of perioperative and postoperative care needs
   1. Initially, the patient will not be able to be alone and must make arrangements for a care provider.
   2. Patient should arrange for help with household chores, yard work, pet care, and other activities of daily living (ADLs).
   3. Patient may not drive while wearing a cervical collar.
   4. An orthotics consultation should be arranged before the surgery in order to fit the patient for a cervical collar or cervical-thoracic orthosis (if ordered).
E. Potential risks and complications: Surgery and patient specific
F. Expected outcomes, both postoperatively and long-term
   1. Realistic patient expectations
   2. Mutual patient and physician expectations
G. Preoperative testing required
   1. For this patient population, special attention needs to be paid to preoperative medical clearance for advanced age or other medical conditions.
   2. If the patient has had anterior cervical surgery before, he or she may need a vocal cord evaluation to ensure that there is no impairment before undergoing another anterior cervical surgery.
   3. An anesthesia evaluation may be required for patients with any instability or decreased cervical ROM; fiberoptic intubation may be necessary.
H. Discontinuation of medications, including herbal products, NSAIDs, anticoagulants, aspirin, warfarin, and clopidogrel bisulfate
I. Instruct patient on how to perform an antibacterial soap prep as per protocol
J. Explain where to arrive, time to arrive, and surgery time
K. Instruct on eating and drinking restrictions
L. Instruct on medications to be taken the morning of surgery with a sip of water; be aware of institution's anesthesia guidelines
M. Remind to wear comfortable clothing and to leave jewelry and valuables at home
N. Remind to remove dentures, partial plates, eyeglasses, contact lenses, nail polish, and sculptured nails
O. Remind to bring collar, if ordered, and fit preoperatively

II. Perioperative

A. Immediately prior to surgery, follow institution-specific procedures for taking preoperative vital signs, conducting a neurologic examination, and reviewing medications and allergies, among other things.
B. If indicated, fingerstick glucose is checked.
C. Check for other laboratory studies, and so on, as ordered.
D. Ensure that antibiotics and other medications are on chart for transfer to the operating room.
E. Prepare for any special anesthesia considerations.
F. Per individual hospital's policies and procedures, take a "time out" to confirm the following: correct patient, correct site, correct operation.

III. Intraoperative

A. Antibiotics are to be administered prior to skin incision.
B. Anterior procedures are usually performed in the supine position.
C. Posterior procedures are usually performed in the prone position.
D. Pressure points and genitalia are checked to avoid positioning injuries.
E. SSEPS may be ordered for patients with myelopathy.
F. Plan for intraoperative equipment needs.
G. Plan for intraoperative blood loss (Chen et al., 2013)

IV. Postoperative

A. Neurological assessment
   1. Postoperative neurological assessment is compared to the patient's preoperative status; focus is on upper-extremity strength and sensation.
   2. Correlate postoperative neurological findings to the operative intervention.
   3. In the event of significant nerve root manipulation intraoperatively or neurological deficits postoperatively, the physician may order steroids for the first 24–48 hours after surgery.

B. General considerations
   1. Antibiotics may be continued for 24 hours after surgery. This is controversial and physician specific.
   2. Monitor for complications, such as the following:
      a. Hematoma or swelling at incision
      b. Cerebrospinal fluid (CSF) leak
      c. Wound infection
      d. Airway protection (Marquez-Lara, Nandyala, Fineberg, & Singh, 2014).

C. Anterior procedures
   1. Assess airway patency.

a. Dysphagia: Assess the patient's ability to safely swallow and speak (Rihn, Kane, Albert, Vaccaro, & Hilibrand, 2011; Ryu et al, 2012).
b. General discomfort: Patient may experience a "lump" feeling when swallowing, excessive phlegm production, or a sore throat.
2. Patient's voice may tire easily, especially initially. He or she may experience a "hoarse" vocal quality, which is usually self-limited, as a result of irritation or damage to the recurrent laryngeal nerve due to intraoperative manipulation.
3. There may be postoperative biomechanical issues related to improper hardware installation, instrumentation failure, and pseudarthosis (uncommon).
4. Assess for gastroesophageal reflux (Rihn, Kane, & Joshi, et al, 2011).

D. Posterior procedures

1. Expect a rather lengthy incision; 5–6 in. (12.70–15.24 cm) is common.
2. The incision initially often has serosanguinous drainage and may require dressing changes three times per day.
3. If extra drainage occurs, the physician may oversew or staple the problematic area.
4. It is important to keep the site very clean and dry.
5. Pain at the incision site, along with posterior cervical muscle spasms, is expected to be problematic in the initial postoperative period. Relief from these symptoms requires appropriate pain management.
6. Patient will need to wear a cervical collar, if ordered.
7. Assess for dysphagia (Radcliff et al., 2013).

E. Mobility

1. The patient's postoperative mobility will vary greatly based on diagnosis, preoperative mobility, and the type of surgery that was performed.
2. The patient who underwent a single-level ACDF for radiculopathy may be ready to mobilize as soon as 2 hours after return to the inpatient unit.
3. The patient who underwent posterior decompression and fusion for long-standing myelopathy will be slower to mobilize and likely will need PT or occupational therapy (OT), or both, assessments.
4. Instruct and help patient to roll to one side.
5. Patient may benefit from a walker if he or she is deconditioned, has a preexisting myelopathy that affects gait, or has difficulty with mobility.
6. Evaluate the patient for ambulatory needs such as a PT referral for gait training or a walker.
7. Instruct patient to take short walks to avoid excessive fatigue; note preoperative walking endurance.

F. Pain control

1. The degree of pain varies considerably.
   a. Patients who underwent an anterior cervical discectomy or corpectomy and fusion should have very little anterior neck pain. It is common, however, for patients to experience pain at the base of the neck and intrascapular from intraoperative disc space distraction.
   b. Patients who underwent posterior laminectomy, with or without fusion, or laminoplasty will experience significant pain and muscle spasms.
2. IV hydromorphone or morphine sulfate may be used as needed until the patient is able to take oral medications.
3. Codeine, hydrocodone, or oxycodone, with or without acetaminophen, may be prescribed as needed when the patient is able to take oral medications.
4. NSAIDs, as needed, can be very beneficial; however, they interfere with bony fusion. Many surgeons advise patients not to take NSAIDs postoperatively. Although the length of time these medications are withheld varies, it can be for up to 3 months after surgery.
5. Neuromodulating drugs may be considered for postoperative pain control.
6. Antispasmodics may be prescribed if muscle spasms are present.
7. Heat may be applied for spasms and muscular tension.
8. Ice may be applied for radicular pain for no more than 20 minutes per hour.
9. Gentle massage may be used away from the incision.
10. Have patient change positions frequently.
11. Note geriatric considerations when administering medications.

G. Constipation prevention

1. Consider initiating techniques preoperatively.
2. Ensure adequate water intake.
3. Diet should include adequate fresh fruits, vegetables, and fiber.
4. A stool softener (e.g., ducosate) may be used 2–3 times per day.
5. Motility agents (e.g., senna) should be used only as needed.
6. Geriatric patients are prone to chronic constipation problems.

H. Urination

1. Urinary hesitancy, especially in the immediate postoperative period, is usually only temporary.
2. Assess urinary output, frequency, and volume.

3. Assess to be sure there is adequate emptying. Bladder scanning or intermittent bladder catheterization may be necessary to assess for retention or incomplete emptying.

I. Incision care

1. Assess incision to be sure it is clean and dry.
2. Care varies widely depending on the type of closure (i.e., staples, sutures, or skin glue).
    a. Lengthy posterior cervical incisions can require twice-per-day dressing changes. During the initial period after surgery, dressings can become saturated quickly. Advise the patient that he or she may need to change the dressing frequently during this period. The dressing is to be kept dry to promote healing.
    b. In general, the incision needs to be monitored daily for redness, drainage, and signs of infection.
    c. Patient and caregiver need to be instructed on specific incision care, evaluating for signs and symptoms of infection, and knowing when and who to call with questions or problems.
3. Anterior procedure: The patient's head may be placed in traction or tongs with 10–15 lb (4.54–6.80 kg) weights used to stabilize the spine during surgery. Postoperatively, the pin site(s) may require care. Assess the patient's scalp for skin tears or bleeding pin site(s), or both, and provide appropriate local care.

J. Postoperative teaching

1. Avoid heaving lifting (anything heavier than a gallon of milk) for the first 4–6 weeks.
2. Avoid overhead work or lifting.
3. Avoid excessive neck flexion, such as reading or desk work. Ensure that computer monitor is at an appropriate height.
4. Outpatient PT and OT will be decided on individual basis.
5. Patient will gradually be weaned from pain medication.

K. Discharge planning

1. Discharge planning should be initiated preoperatively.
2. Talk to patient about how to gradually return to ADLs and lifestyle.
3. Reinforce to patient the importance of not bending or twisting the neck during convalescence.
4. Remind patient not to drive while using opioids or while in cervical collar.
5. Explain to patient that sexual activity may be resumed when it is comfortable to do so.
6. Emphasize to patient the importance of safety while wearing the cervical collar.
7. Ensure that the patient is aware of return-to-work and activity recommendations. Return to work will vary depending on type of work (e.g., sedentary roles sooner than heavy labor). Return to work may be a gradual progression to full time.
8. Reinforce alternative planning and problem solving for practical, everyday activities such as vacuuming, laundry, pet care, household chores, gardening, and lawn care.
9. Incision care: See page 28. Instruct patient on showering or bathing.
10. Ensure that the patient is aware of postoperative follow-up recommendations.
11. Patient comorbidities may affect postoperative recovery.
12. Instruct patient on when to call the doctor
    a. temperature greater than 101.5 °F
    b. increased swelling
    c. excessive or foul-smelling drainage
    d. worsening weakness or numbness in upper extremity, increased pain unrelieved by pain medication

L. Collar maintenance

1. Some patients may be discharged home with a soft or rigid cervical collar to limit neck mobility and enhance bone healing if a fusion procedure was performed.
2. Cervical collars are worn at the discretion of the surgeon.
3. If the surgery is at C7 or the upper thoracic spine, a cervical-thoracic orthosis may be ordered.
4. Patients are to wear the collar at all times, unless instructed otherwise by the doctor. Sometimes they may remove the collar for showering or sleeping. Again, this is at the discretion of the surgeon.
5. Cervical collar preferences are highly variable and surgeon specific.
6. Teach the patient to clean pads and change the collar in front of a mirror while holding the neck still; patient should not move his or her head without the collar in place. Tell the patient to leave one portion of the pad or collar in place at all times.
7. Keep incision and neck area dry.

M. Halo immobilization device

In certain cases, a halo immobilization device will be applied by the surgeon for postoperative external immobilization. For example, it may be used after a posterior occipital-cervical fusion.

1. The halo ring is applied to the skull by four or six stabilizing pins, depending on the device. The pins are threaded though holes in the ring,

screwed into the outer table of the skull, and locked into place.

2. Pin care protocols vary widely. Generally, cleaning with a normal saline swab, initially twice per day then once per day, provides problem-free pin sites. Provide caregivers with written instructions on pin site care.
3. Hair washing can be accomplished by leaning over a kitchen sink or a tub that has a flexible sprayer nozzle or leaning backward over the edge of a bed that has been protected with plastic, and running the water into a tub or water catcher. Minimal amounts of shampoo should be used to aid in rinsing.
4. It is advisable that the sheepskin vest be changed only by a healthcare provider.
5. The caregiver should be instructed on how to monitor the skin under the vest, and to use thin towels, rubbing side to side under the vest to clean. The sheepskin is made to absorb body oils and perspiration.
6. Patient and caregiver should be provided with education and training on walking with the halo, navigating stairs, and getting into and out of a vehicle. They should also be made aware that hitting the halo on something will cause vibrations through the ring and pins and that subjecting the patient wearing a halo to extreme temperatures is not advisable.
7. Caregivers require written instructions on whom to call when questions arise and when to worry (e.g., if the patient experiences sudden onset of increased pain or feels the halo shifting; if there is redness, drainage, pain from a pin site).

Resources

www.spine-health.com
www.back.com
www.spine.org
www.spineuniverse.com
www.ahrq.gov/clinic

Cervical Spine Disorder Case Studies

I. C6 Radiculopathy

RN, a 51-year-old female, had a 4-week history of neck pain, left anterolateral arm pain that radiated to her elbow, and paresthesias down her forearm into her thumb and first finger. Her pain was at worst a 9/10, and at best 3/10. Her pain was aggravated by daily activities and was alleviated by rest and a prednisone boost. She had no therapy, injections, or other conservative management other than the steroid boost.

A. History and Review of Systems

1. Social history: Licensed practical nurse (LPN) in a family physician's office, unable to work because of symptoms, married, nonsmoker
2. Medical history: Thyroid disorder, gastroesophageal reflux disease
3. Surgical history: Thyroidectomy, hysterectomy, cholecystectomy
4. Medications: Levothyroxine, atenolol, estradiol, ibuprofen
5. Allergies: Lansoprazole
6. Review of systems: Unremarkable

B. Focused Neurologic Examination and Diagnostics

The neurological examination indicated a significant limitation in cervical ROM because of neck pain. RN's left upper-extremity strength and sensation were intact. DTR at the left bicep was diminished as compared to the right. Reflexes were otherwise intact. A review of the MRI scan revealed a large C5–C6 extruded disc fragment with concomitant hematoma, both rostrally and caudally, behind the C5 and C6 bodies.

C. Further Conservative Management

RN's symptoms, although altering her usual ADLs, were gradually improving. Her MRI scan had been obtained shortly after the onset of symptoms. She was placed on muscle relaxants and initiated a trial of PT.

D. Operative Intervention

After 4 weeks of nonoperative management without significant improvement, RN elected to undergo a C5–C6 anterior cervical discectomy and fusion with allograft and plate. Upon exposure of the posterior annulus, a disc fragment was visualized penetrating the PLL. The disc fragment was removed and the area carefully inspected to ensure there was no further compression by herniated or loose fragments. After surgery, she experienced complete resolution of her symptoms and was able to resume normal activities **(Figures 28, 29)**.

II. C7 Radiculopathy

DM, a 52-year-old male, had a 2.5-year history of neck pain, intermittent right posterior arm pain to the elbow, and

Figure 28. C5–C6 herniated nucleus pulposus (extruded) causing significant central canal compromise

Figure 29. Postoperative X ray showing C5–C6 anterior cervical discectomy and fusion

numbness in the fourth and fifth digits of his right hand. He described his pain as constant, deep, and burning; aggravated by activity and alleviated by rest and NSAIDs. His most recent PT was 2 years ago.

A. History and Review of Systems

1. Social history: Married, works as a courier, has not missed work on account of pain, smokes half of a pack of cigarettes per day for the past 35 years
2. Medical history: Hypertension
3. Surgical history: Low back surgery, left tibia surgery, remote
4. Medications: Triamterene/hydrochlorothiazide, tramadol, naproxen sodium, multivitamin
5. Allergies: No known drug allergies. Aspirin causes gastrointestinal upset
6. Review of systems: Unremarkable

B. Focused Neurologic Examination and Diagnostics

The neurological examination indicated an absent right tricep DTR, decreased pinprick sensation on the ulnar surface of his right forearm, and normal strength. A review of his MRI scan revealed a C6–C7 disc protrusion eccentric to the right.

C. Further Conservative Treatment

Following a 6-week trial of PT and therapeutic doses of NSAIDs, DM continued to have arm discomfort and wished to proceed with surgery for C7 radiculopathy. He stopped smoking during this time.

D. Operative Intervention

DM underwent a C6–C7 anterior cervical discectomy and fusion with allograft and plate for excision of a large disc osteophyte complex causing a right C7 radiculopathy. Likely because of his long history of neck and arm discomfort preoperatively, DM continued to experience pain for several weeks after the surgery. Initially, his pain symptoms were managed with opioid analgesics, muscle relaxants, and gabapentin. By 6 weeks after the surgery, the opioids and muscle relaxants were tapered, and symptoms were managed with gabapentin and NSAIDs. PT and work hardening (i.e., a reconditioning program simulating a person's particular work environment) were initiated at 3 months after surgery. At 6 months he returned to full-time, full-duty work (**Figures 30, 31, 32, 33**).

Figure 30. T2 weighted, MRI scan, axial view showing C6–C7 HNP

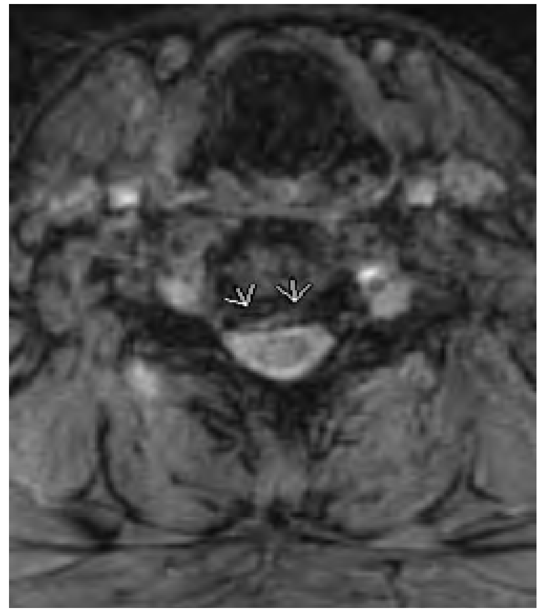


Figure 31. MRI scan, T2 weighted image, sagittal view showing C6–C7 HNP

III. C6–C7 Disc Arthroplasty

AD, a 40-year-old female, had a 2.5-year history of neck pain following a motor vehicle accident. At the time of presentation, she had been experiencing an exacerbation of the neck pain for the past 2 months, as well as pain that radiated from her posterior left upper extremity to her elbow. Activity aggravated her symptoms, and changing positions seemed to help alleviate her symptoms. She had participated in PT, undergone cervical traction and cervical injections, worn a cervical collar, and taken pain medications. She denied any weakness or numbness, stating that the pain had become intolerable.

A. History and Review of Systems

1. Social history: Divorced with six children who live with her, works as a registered nurse (RN) in a family practice clinic, nonsmoker, previously very active
2. Medical history: Hypertension
3. Surgical history: Hysterectomy
4. Medications: Valsartan, ibuprofen, oxycodone ER as needed
5. Allergies: No known drug allergies
6. Review of systems: Unremarkable

B. Focused Neurologic Examination and Diagnostics

The neurological examination indicated weakness in her left tricep, rated at a strength of 4 out of 5 with an absent left tricep reflex. Sensation was intact. A review of the MRI scan revealed C6–C7 disc herniation compressing the left C7 nerve root.

C. Operative Intervention

AD consented to participate in the Prestige artificial disc versus standard discectomy and fusion clinical trial. She was randomized and underwent a C6–C7 disc replacement with the Prestige artificial disc. Two years after surgery, she is participating in all her usual activities and is pain free (**Figures 34, 35, 36**).

IV. Cervical Stenosis

RH, a 46-year-old female, had an approximately 2-year history of progressively worsening upper- and lower-extremity weakness; the arms were worse than her legs. She described numbness in her hands more so than her feet, balance difficulties, and urinary urgency. At the time of presentation, she was using a cane to walk and an electric wheelchair at work. Her symptoms were somewhat aggravated by driving a car and turning her head in certain directions. She had been to PT without relief of symptoms.

A. History and Review of Systems

1. Social history: Divorced, two adult children, works full time/full duty as a manager at a local company, nonsmoker
2. Medical history: Sleep apnea—uses continuous positive airway pressure (CPAP) device
3. Surgical history: Ovarian cyst, appendectomy
4. Medications: Meloxicam, nifedipine XL, rabeprazole, metoprolol XL, ibuprofen, cyclobenzaprine, folic acid, B complex
5. Allergies: Sulfa caused swelling and hives
6. Review of systems: Unremarkable

B. Focused Neurological Examination and Diagnostics

The neurological examination indicated hyperreflexia in her upper extremities and knees as well as a positive Hoffman's sign, bilaterally. Vibratory sense, proprioception, strength, and sensation were intact in the upper and lower extremities. A review of her MRI scan revealed cervical stenosis caused by

Figure 32. A/P X ray showing C6–C7 plate after ACDF

Figure 33. Lateral X ray showing C6–C7 ACDF with plate

Figure 34. Lateral X ray showing disc arthroplasty at C6–C7

Figure 35. Disc arthroplasty at C6–C7, A/P view

Figure 36. Intraoperative disc arthroplasty

a congenitally narrow cervical spine canal and disc protrusion at C4–C5, C5–C6, and C6–C7.

C. Operative Intervention

RH underwent a C3–C6 laminoplasty and rostral C7 laminectomy for cervical canal spinal stenosis with myelopathy. She has done well postoperatively and is able to walk without any assistive devices (**Figures 37, 38, 39, 40**).

V. Cervical Spondylotic Myelopathy

CW, a 64-year-old male, had a several-year history of progressive gait imbalance, ambulation difficulties, and decreased hand dexterity. Subjectively, he noted the right side of his body was more affected than the left. He had difficulty buttoning buttons, writing, picking up small objects, and walking.

A. History and Review of Systems

1. Social history: Married, retired, smokes approximately five cigarettes per day, drinks approximately 6–10 ounces of liquor per day.
2. Medical history: Poorly controlled insulin-dependent diabetes for 34 years, hemoglobin A1c was 9.3, also hypertensive
3. Surgical history: Left carotid endarterectomy, 7 years ago
4. Medications: Aspirin, Lisinopril, amitriptyline, fluvastatin, folic acid, multivitamin, lantus insulin, humalog insulin
5. Allergies: No known drug allergies
6. Review of systems: Denied any chest pain, palpitations, or dyspnea on exertion; however, he is sedentary
7. Family history: Father died at age 70 from a myocardial infarction

Figure 37. MRI scan, sagittal, T2 weighted image showing cervical spinal stenosis

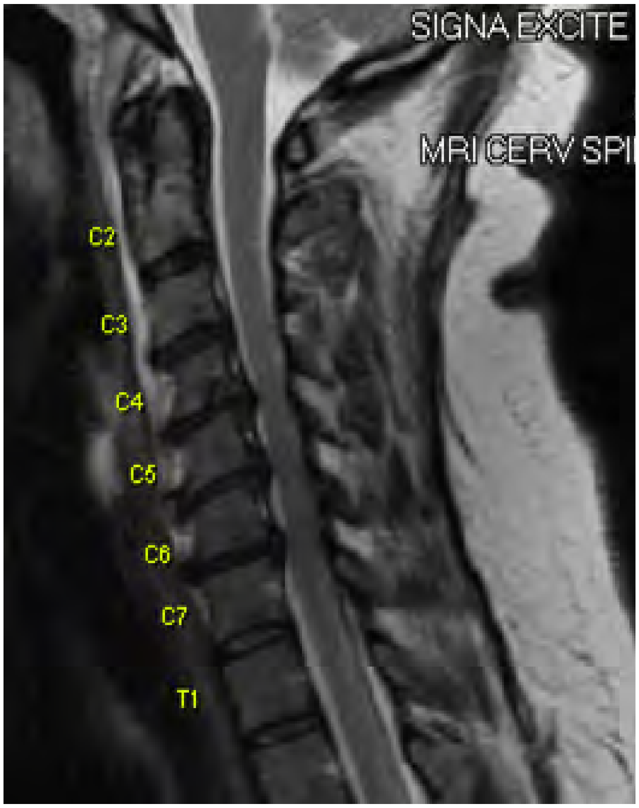


Figure 39. Lateral X ray after laminoplasty

Figure 38. MRI scan, axial, T2 weighted image showing central canal stenosis

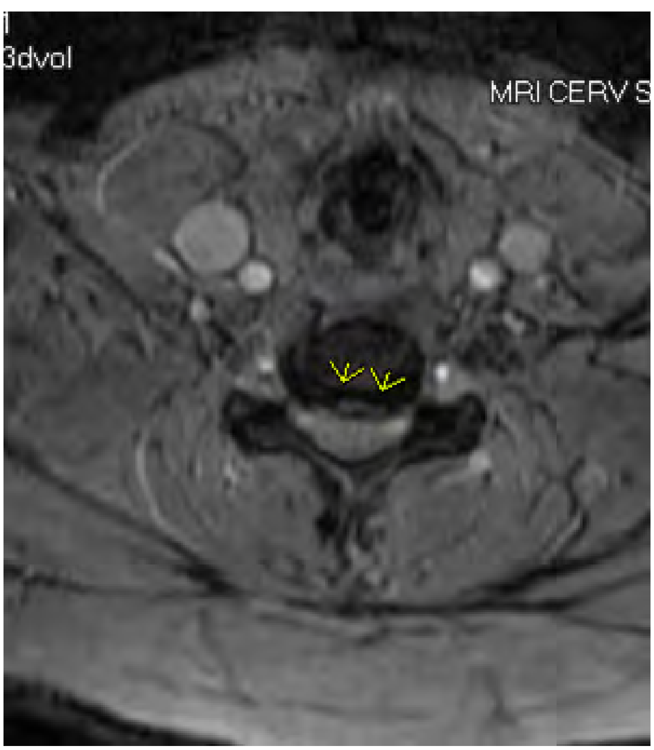


Figure 40. A/P X ray after laminoplasty

B. Focused Neurological Examination and Diagnostics

The neurological examination indicated a positive Hoffman's sign, bilaterally; upgoing toes, bilaterally; and decreased vibratory sense in his left foot and right hand. Ankle DTRs were absent in both ankles, knee DTRs were intact and symmetric, and tricep, bicep, and brachioradialus DTRs were hyperactive, bilaterally. Sensation was decreased in a stocking-glove distribution. His gait was very spastic, and he used a cane for ambulation. Strength was full in all muscle groups. A review of his MRI scan revealed severe cervical canal stenosis from spondylosis at the C3 through C7 levels. Myelomalacia was noted within the cord, predominantly at the C5 to C6 levels.

C. Preoperative Evaluation

CW presented with uncontrolled insulin-dependent diabetes mellitus, hypertension, and a sedentary lifestyle due to his neurologic deterioration. A cardiology consult advised that CW undergo a preoperative evaluation with a pharmacologic stress test and consultation with his endocrinologist to optimize glucose control. Stress testing revealed a reversible ischemic defect; further evaluation was indicated with a cardiac catheterization. Following his cardiac catheterization, CW was cleared for surgery, during which his diabetes would be closely monitored. Operative intervention was needed to prevent further neurologic decline.

D. Operative Intervention

CW underwent a C3–C7 laminectomy and C3–T2 fusion with instrumentation and autograft. He was discharged to inpatient rehabilitation for diabetes management and education, gait retraining, strength and endurance training, and OT for hand function. Two years after surgery, he had improved hand dexterity as well as mobility (**Figures 41, 42, 43, 44, 45**).

Figure 41. MRI scan, sagittal, T2 weighted image showing severe cervical spondylosis

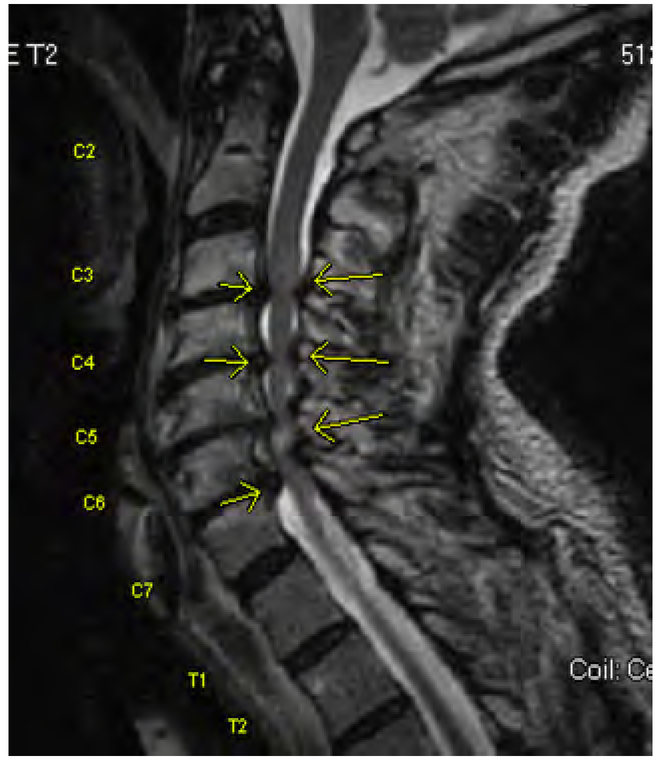
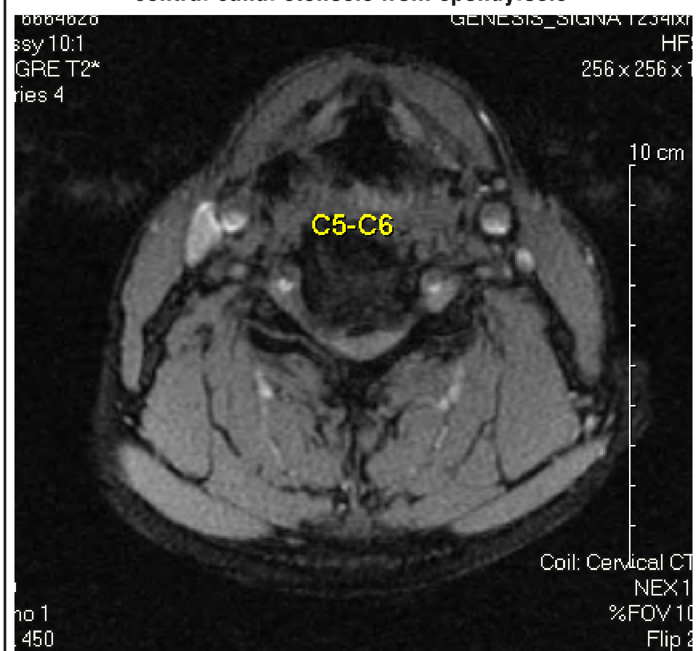


Figure 42. MRI scan, axial, T2 weighted image showing central canal stenosis from spondylosis



VI. C1–C2 Instability

WE, a 67-year-old female, was afflicted with rheumatoid arthritis. While watching television, she experienced sudden onset neck pain associated with electric shock sensations into both arms down to her hands. Subjectively, her symptoms were exacerbated by neck flexion and rotation. She reported that her arms were weak and that her gait was unsteady because of leg weakness. She had presented to a local emergency room two days prior where she was prescribed opioids and muscle relaxants. She was admitted upon presentation to her neurosurgical care provider and placed into cervical traction.

A. History and Review of Systems

1. Social history: Married, retired, nonsmoker
2. Medical history: Rheumatoid arthritis, long standing
3. Surgical history: Bilateral knee replacements, right shoulder aspiration positive for listeria
4. Medications: Alendronate, leflunomide, hydroxychloroquine, Prednisone, tramadol, lansoprazole, aspirin, docusate calcium, acetaminophen, multivitamin
5. Allergies: Methotrexate

Figure 43. MRI scan, axial, T2 weighted image showing central canal stenosis

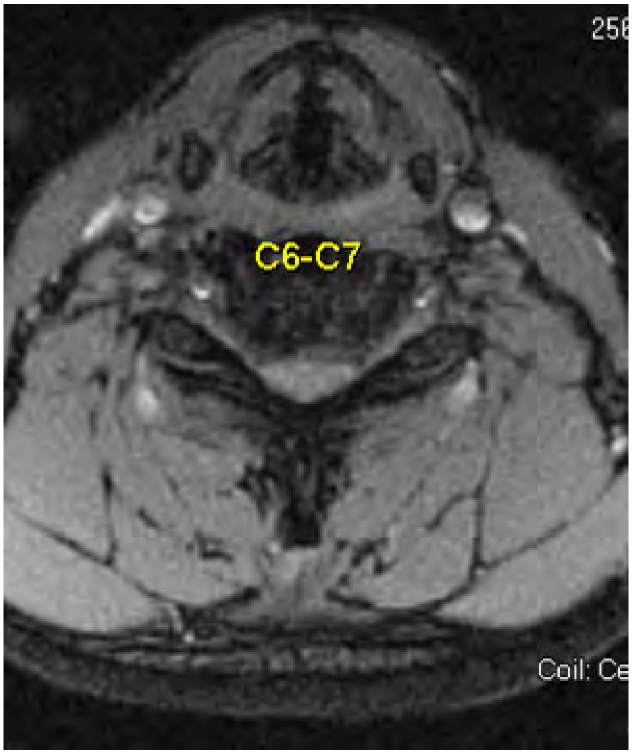


Figure 44. Lateral X ray after multilevel cervical laminectomy and fusion with instrumentation

Figure 45. A/P X ray after multilevel cervical laminectomy and fusion with instrumentation

B. Focused Neurologic Examination and Diagnostics

The neurologic examination indicated weakness in her arms and legs of 4 out of 5; her gait was unsteady. DTRs were hyporeflexic in the upper extremities and absent in the lower extremities; there was no Hoffman's sign, her toes were downgoing, and there was no ankle clonus. Her sensation was intact to light touch and pinprick throughout. Review of her MRI scan revealed anterior subluxation of C1 on C2 with an atlanoodontoid interval of approximately 6–7 mm. A pannus was sitting behind the arch of C1. In addition, there was cranial settling with basilar invagination.

Figure 46. MRI scan, sagittal, T1 weighted image showing basilar invagination, pannus formation

Figure 47. Lateral X ray, posterior occiptocervical fusion with loop and wires

C. Operative Intervention

WE underwent an occiput to C4 fusion with cable, loop, and iliac crest autograft following occipitocervical reduction and alignment by utilizing 2 days of 5 lb (2.27 kg) traction in Gardner-Wells tongs. Halo immobilization was instituted for 3 months following surgery. An external bone growth stimulator was applied for 6 months. She was discharged to a local nursing/rehabilitation facility and was able to return home once the halo was removed. She has done well and experienced resolution of her preoperative symptoms (**Figures 46, 47**).

References

Abdi, S., Datta, S., Trescot, A. M., Schultz, D. M., Adiaka, R., Atluri, S. L...Manchikanti, L. (2007). Epidural steroids in the management of chronic spinal pain: A systematic review. *Pain Physician, 10*(1), 185-212.

Ahn, N. U., Ahn, U. M., Amundson, G. M., & An, H. S. (2004). Cervical disc disease. A. axial-mechanical neck pain and cervical degenerative disease. In J. W. Frymoyer & S. W. Wiesel (Eds.), *The adult and pediatric spine* (3rd ed., pp. 671–688). Philadelphia: Lippincott Williams & Wilkins.

Aletaha, D., Neogi, T., Silman, A. J., Funovits, J., Felson, D. T., Bingham. C. O., ...Hawker, G. (2010). 2010 Rheumatoid arthritis classification criteria: An American College of Rheumatology/European League Against Rheumatism collaborative initiative. *Arthritis and Rheumatism, 62*(9), 2569-2581.

Anderson, D. G., & Albert, T. J. (2003). The molecular basis of intervertebral disk degeneration. *Seminars in Spine Surgery, 15*, 352–360.

Beckman, W. A., Mendez, R. J., Paine, G. F., & Mazzilli, M. A. (2006). Cerebellar herniation after cervical transforaminal epidural injection. *Regional Anesthesia and Pain Medicine, 31*(3), 282-285.

Benzel, E. C. (2001). Biomechanically relevant anatomy and material properties of the spine and associated elements. In *Biomechanics of spine stabilization* (pp. 1–17). Rolling Meadows, IL: American Association of Neurological Surgeons.

Carette, S., & Fehlings, M. G. (2005). Cervical radiculopathy. *New England Journal of Medicine, 353,* 392–399.

Casha, S., & Fehlings, M. (2003). Clinical and radiological evaluation of the Codman semiconstrained load sharing anterior cervical plate: Prospective multicenter trial and independent blinded evaluation to outcome. *Journal of Neurosurgery, 99,* (Suppl. 3), 264–270.

Chen, Y., Tai, S. C., Nayak, D., Kumar, N., Chua, K. H., Lim, J. W.,...Wong, H. K. (2013). Blood loss in spinal tumour surgery and surgery for metastatic spinal disease: A meta-analysis. *The Bone and Joint Journal, 95-B*(5), 683-688.

Cizik, A. M., Lee, M. J., Martin, B. I., Bransford, R. J., Bellabarba, C. , Chapman, J. R., Mirza, S. K. (2012). Using the spine surgery invasvieness index to identify risk of surgical site infection: A multivariate analysis. *The Journal of Bone and Joint Surgery, 94*(4), 335-342.

Côté, P., Cassidy, J. D., & Carroll, L. (2003). The epidemiology of neck pain: What we have learned from our population-based studies. *Journal of the Canadian Chiropractic Association, 47*(4), 284–290.

Czerwinski, E., Badurski, J. E. Macinowska-Suchowierska, E., & Osienleniec, J. (2007). Current understanding of osteoporosis according to the position of the World Health Organziation (WHO) and the International Osteoporosis Foundation. *Orthopedia, Traumatologia, Rehabilitacja, 9*(4), 337-356.

Dmitriev, A.E., & Kuklo, T.R. (2005). Biomechanical considerations of spinal instrumentation in the aging spine. *Seminars in Spine Surgery, 17*(3), 215–222.

Edwards, C., Heller, J., & Murakami, H. (2002). Corpectomy versus laminoplasty for multilevel cervical myelopathy: An independent matched cohort analysis. *Spine, 27*, 1168–1175.

Edwards, C., Riew, D., Anderson, P., Hilibrand, A., & Vaccaro, A. (2003). Cervical myelopathy: Current diagnostic and treatment strategies. *Spine Journal, 3*(1), 68–81.

Fouyas, I. P., Statham, P., & Sandercock, P. (2002). Cochrane review on the role of surgery in cervical spondylotic radiculomyelopathy. *Spine, 27*(7), 736–747.

Gill, S. S., & Einhorn, T. A. (2004). Metabolic bone disease of the adult and pediatric spine. In J. W. Frymoyer & S. W. Wiesel (Eds.), *The adult and pediatric spine* (3rd ed., pp. 121–141). Philadelphia: Lippincott Williams & Wilkins.

Grauer, J. N., Beiner, J. M., & Albert, T. J. (2004). Evaluation and management of cervical instability and kyphosis. In J. W. Frymoyer & S. W. Wiesel (Eds.), *The adult and pediatric spine* (3rd ed., pp. 713–731). Philadelphia: Lippincott Williams & Wilkins.

Hacker, R., Cauthen, J., Gilbert, T., & Griffith, S. (2000). A prospective randomized multicenter clinical evaluation of an anterior cervical fusion cage. *Spine, 25*(20), 2646–2654.

Hecht, A. C., Scott, D. L., Crichlow, R., Hornicek, F. J., & Pedlow, F. X. (2004). Metastatic disease. In J. W. Frymoyer & S. W. Wiesel (Eds.), *The adult and pediatric spine* (3rd ed., pp. 247–289). Philadelphia: Lippincott Williams & Wilkins.

Irnich, D., Behrens, N., Molzen, H., König, A., Gleditsch, J., Krauss, M., et al. (2001). Randomised trial of acupuncture compared with conventional massage and "sham" laser acupuncture for treatment of chronic neck pain. *British Medical Journal, 322*(7302), 1574–1578.

Jenis, L. G., Kim, D. H., & An, H. S. (2004). Cervical radiculopathy. In J. W. Frymoyer & S. W. Wiesel (Eds.), *The adult and pediatric spine* (3rd ed., pp. 689–701). Philadelphia: Lippincott Williams & Wilkins.

Jeong, G. K., & Bendo, J. A. (2004). Spinal disorders in the elderly. *Clinical Orthopaedics and Related Research, 425,* 110–125.

Johansson, M. P., Baann Liane, M. S., Bendix, T., Kasch, H., & Kongted, A. (2011). Does cervical kyphosis relate to symptoms following whiplash injury? *Manual Therapy, 16*(4), 378-383.

Kadanka, Z., Bednarik, J., Vohanka, S., Stejskal, L., Smrcka, V., & Vlach, O. (2000). Spondylotic cervical myelopathy: Three aspects of the problem. *Supplements to Clinical Neurophysiology, 53,* 409–418

Kalfas, I. H. (2001). Principles of bone healing. *Neurosurgery Focus, 10*(4), 1–4.

Kanis, J. A., Burlet, N., Cooper, C., Delmas, P. D., Reginster, J. Y., Borgstom, F., ... European Society for Clinical and Economic Aspects of Osteoporosis and Osteosrthritis (ESCEO). (2008). European guidance for the diagnosis and management of osteoporosis in postmenopausal women. *Osteoporosis International, 19*(4), 399-428.

Kay, T. M., Gross, A., Goldsmith, C. H., Rutherford, S., Voth, S. Hoving, J. L., Bronfort, G, & Santaguida, P. L. (2012). Exercises for mechanical neck disorders. *The Cochrane Database of Systematic Reviews, 15*; 8:CD004250.

Krag, M. H. (1997). Biomechanics of the cervical spine. In J. W. Frymoyer (Ed.), *The adult spine: Principles and practice* (2nd ed., pp. 1075–1119). Philadelphia: Lippincott-Raven.

Marquez-Lara, A., Nandyala, S. V., Fineberg, S. J, & Singh, K. (2014). Incidence, outcomes, and mortality of reintubation after anterior cervical fusion. *Spine, 39*(2), 134-139.

McCormick, W., Steinmetz, M. P., & Benzel, E. (2003). Cervical spondylotic myelopathy: Make the difficult diagnosis, then refer for surgery. *Cleveland Clinic Journal of Medicine, 70*(10), 899–904.

Medtronic (2005). *Medtronic INFUSE® Bone Graft + LT-CAGE® Lumbar Tapered Fusion Device fact sheet.* Retrieved December 14, 2006, from http://wwwp.medtronic.com/Newsroom/LinkedItemDetails.do?itemId=1101769224707&itemType=fact_sheet&lang=en_US.

Murray, M. T., & Tay, B. K. B. (2004). Natural history of cervical myelopathy. *Seminars in Spine Surgery, 16*(4), 222–227.

Naderi, S., Benzel, E. C., & Resnick, D. K. (1999). Spinal lesions of the aged. In W. Selman & E. C. Benzel (Eds.), *Neurosurgical care of the elderly* (pp. 141–157). Rolling Meadows, IL: AANS Publications.

Ng, L., Chaudhary, N., & Sell, P. (2005). The efficacy of corticosteroids in periradicular infiltration of chronic radicular pain: A randomized double-blind, controlled trial. *Spine, 30*(8), 857-862.

Ngu, B. B., DeWal, H. S., & Ludwig, S. C. (2003). Conservative therapies for degenerative lumbar problems. *Seminars in Spine Surgery, 15*(4), 384–392.

Patchell, R. A., Tibbs, P. A., Regine, W. F., Payne, R., Saris, S., Kryscio, R. J.,...Young, B. (2005). Direct decompressive surgical resection in the treatment of spinal cord compression caused by metastatic cancer: A randomized trial. *The Lancet, 366*(9486), 643-648.

Perez-Cruet, M. J., Fessler, R. G., & Perin, N. I. (2002). Review: Complications of minimally invasive spinal surgery. *Neurosurgery, 51*(Suppl. 2), 26–36.

Persson, L., Carlsson, C., & Carlsson, J. (1997). Long-lasting cervical radicular pain managed with surgery, physiotherapy, or a cervical collar: A prospective randomized study. *Spine, 22*(7), 751–758.

Pilitsis, J. G., Lucas, D. R., & Rengachary, S. R. (2002). Bone healing and spinal fusion. *Neurosurgery Focus, 13*(6), 1–6.

Radcliff, K. E., Koyonos, L., Clyde, C., Sidhu, G. S., Fickes, M., Hilibrand, A. S.,...Rihn, J. A. (2013). What is the incidence of dysphagia after posterior cervical surgery? *Spine, 38*(13), 1082-1088.

Radhakrishnan, K., Litchy, W. J., O'Fallon, W. M., & Kurland, L. T. (1994). Epidemiology of cervical radiculopathy: A population-based study from Rochester, Minnesota, 1976 through 1990. *Brain, 117*(2), 325–335.

Rhee, J. M., & Heller, J. G. (2004). Spinal infections. In J. W. Frymoyer & S. W. Wiesel (Eds.), *The adult and pediatric spine* (3rd ed., pp. 165–189). Philadelphia: Lippincott Williams & Wilkins.

Rihn, J. A., Kane, J., Albert, T. J., Vaccaro, M. D., & Hilibrand, A. S. (2011). What is the incidence and severity of dysphagia after anterior cervical surgery? *Clinical Orthopaedics and Related Research, 469*(3), 658-665.

Rihn, J. A., Kane, J., Joshi, A., Albert, T., Vaccaro, A., Harrop, J., ...Hilibrand, A. S. (2011). Gastroesophageal reflux after anterior cervical surgery: A controlled prospective analysis. *Spine, 36*(24), 2039-2044.

Rosner, M. K. & Ondra, S. L. (2005). Surgical management of degenerative scoliosis. *Seminars in Spine Surgery, 17*(3), 205–214.

Ryu, J. S., Lee, J. H., Kang, J. Y., Kim, M. Y., Shin, D. E., & Shin, D. A. (2012). Evaluation of dysphagia after cervical surgery using laryngeal electromyography. *Dysphagia, 27*(3), 381-324.

Salemi, G., Savettieri, G., Meneghini, F., DiBenedetto, M.E., Ragonese, P., Morgante, L., ... Di Perri, R. (1996). Prevalence of cervical spondylotic radiculopathy: A door-to-door survey in a Sicilian municipality. *Acta Neurologica Scandinavia, 93*(2-3), 184-188.

Schnuerer, A., Gallego, J., & Manuel, C. (2003). *Core curriculum for basic spinal training* (2nd ed.). Nashville: Medtronic Sofamor Danek.

Scott, D. L., Pedlow, F. X., Hecht, A. C., & Hornicek, F. J. (2004). Primary benign and malignant extradural spine tumors. In J. W. Frymoyer & S. W. Wiesel (Eds.), *The adult and pediatric spine* (3rd ed., pp. 191–247). Philadelphia: Lippincott Williams & Wilkins.

Thomas, N. M., Rea, G. L, & Weinstein, P. R. (2005). Anatomy and pathophysiology of acquired spinal lesions. In E. C. Benzel (Ed.), *Spine surgery: Techniques, complication avoidance, and management* (2nd ed., pp. 88–100). Philadelphia: Elsevier.

Tis, J. E., & Kuklo, T. R. (2005). Fracture risk, bone densitometry, and the medical management of osteoporosis. *Seminars in Spine Surgery, 17*(3), 137–143.

Tortolani, P. J., & Yoon, S. T. (2004). Cervical spondylotic myelopathy. In J. W. Frymoyer & S. W. Wiesel (Eds.), *The adult and pediatric spine* (3rd ed., pp. 701–713). Philadelphia: Lippincott Williams & Wilkins.

Webb, J. K., Hitchon, P. W., & Sengupta, D. K. (2005). Ankylosing spondilitis and related disorders. In E. C. Benzel (Ed.), *Spine surgery: Techniques, complication avoidance, and management* (2nd ed., pp. 703–728). Philadelphia: Elsevier.

Whang, P. G. & Wang, J. C. (2005). Fusion biology and contemporary graft options. *Seminars in Spine Surgery, 15*(4), 460–472.

White, P., Lewith, G., Prescott, P., & Conway, J. (2004). Acupuncture versus placebo for the treatment of chronic neck pain: A randomized, controlled trial. *Annals of Internal Medicine, 141*(12), 911–919.

Winters, M. E., Kluetz, P., & Zilberstein, J. (2006). Back pain emergencies. *Medical Clinics of North America,* 90, 505–523.

Wolcott, W. P., Malik, J. M., Shaffrey, S. I., Shaffrey, M. E., & Jane, J. A. (2005). Differential diagnosis of surgical disorders of the spine. In E. C. Benzel (Ed.), *Spine surgery: Techniques, complication avoidance, and management* (2nd ed., pp. 33–61). Philadelphia: Elsevier.

Wolff, M. W., & Levine, L. A. (2002). Cervical radiculopathies: Conservative approaches to management. *Physical Medicine and Rehabilitation Clinics of North America, 13*(3), 589–608.

World Health Organization. (2003). *Prevention and management of osteoporosis,* WHO Technical Report Series 921. Retrieved December 20, 2006, from http://whqlibdoc.who.int/trs/WHO_TRS_921.pdf

Bibliography

Benzel, E. (2001). Degenerative and inflammatory diseases of the spine. In *Biomechanics of spine stabilization* (pp. 45–60). Rolling Meadows, IL: American Association of Neurological Surgeons.

Greenberg, M. S. (2010). *Handbook of neurosurgery* (7th ed.). New York: Thieme.

Gross, A., Hoving, J., Haines, T. A., Goldsmith, C., Kay, T. M., Aker, P., et al. (2004). Manipulation and mobilisation for mechanical neck disorders. *The Cochrane Database of Systematic Reviews, 1,* CD004249.

Henwood, A. M., Adams, M. S., Sypert, G. W., & Benzel, E. C. (2005). Nonoperative management of neck and back pain. In E. C. Benzel (Ed.), *Spine surgery: Techniques, complication avoidance, and management* (2nd ed., pp. 1954–1963). Philadelphia: Elsevier.

Prendergast, V., Jones, R., Kenny, K., Henwood, A., Strayer, A., & Sullivan, C. (2004). Spine disorders. In M. K. Bader & L. R. Littlejohns (Eds.), *AANN core curriculum for neuroscience nurses* (4th ed., pp. 403–488). St. Louis: Elsevier Health Sciences.

Rhee, J. M., & Riew, K. D. (2005). Evaluation and management of neck pain, radiculopathy, and myelopathy. *Seminars in spine surgery, 17*(3), 174–185.

Storm, P. B., Chou, D., & Tamargo, R. J. (2002). Surgical management of cervical and lumbosacral radiculopathies: Indications and outcomes. *Physical and Medical Rehabilitation Clinics of North America, 13*(3), 735–759.

Strayer, A., Prendergast, V., & Henwood, A. (2010). Spine disorders. In M. K. Bader & L. R. Littlejohns (Eds.), *AANN core curriculum for neuroscience nurses* (5th ed., pp. 417–484). Chicago: American Association of Neuroscience Nurses.