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CHAPTER 1.3

Spinal Neurosurgery

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Anterior Fusion/Fixation of the Upper Cervical (C1-C2) Spine

Surgical Considerations

Description: Transoral odontoid excision: The **transoral approach** is indicated primarily to relieve ventral irreducible compression of the cervicomedullary junction due to extradural lesions involving the lower part of the clivus, C1 and C2 vertebral bodies. This approach provides direct access to the C1 anterior arch and odontoid process of C2. The anesthetized patient is positioned supine usually with cervical traction. A Dingman or similar retractor is used to facilitate surgical access. The soft palate is retracted upwards with stay sutures. Through a posterior midline incision over the pharyngeal wall, the C1 anterior arch and C2 vertebra are exposed (Fig 1.3-1). Using fluoroscopic guidance, bony decompression of the clivus, C1 anterior arch, odontoid process, and C2 vertebral body is performed. Instrumentation of C1-C2 may be performed with plate and screws. The wound is closed in two layers after securing hemostasis. As the procedure often results in significant instability at the craniovertebral junction, posterior occipitocervical fusion often is required.

Variants of the transoral procedure: Transpalatal exposure with removal of hard palate or a **tongue-splitting transmandibular approach** may be required for adequate exposure of the clivus or upper C-spine, respectively. A **high cervical anterior retropharyngeal approach** is rarely used to approach C1-C3 without traversing the oral cavity and with less destabilization. A transcervical approach to the C2 body can be performed using an endoscope and a highly beveled tubular retractor.

Transodontoid screw fixation: Fractures of the odontoid process of C2 account for 10–20% of all C-spine fractures and are classified (**Anderson and D'Alonzo**) into three types, based on anatomical location. **Type I fractures**, which occur at the tip of dens, are treated conservatively. **Type II fractures**, which occur through the waist of the odontoid process, are the most common and are often inherently unstable, requiring surgical treatment. **Type III fractures** occur through the body of C2 and can be treated surgically or with external immobilization. Internal instrumented fixation is the ideal treatment for Type II fractures, because it provides immediate stability while preserving C1-C2 rotation.

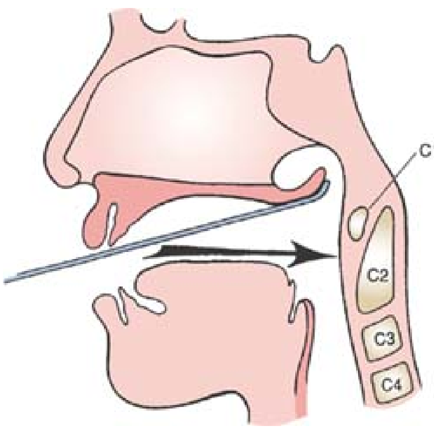

Figure 1.3-1. 1. The transoral approach. (Reproduced with permission from An HS, Cotler JM: *Spinal Instrumentation*. Williams & Wilkins, Philadelphia: 1992.)

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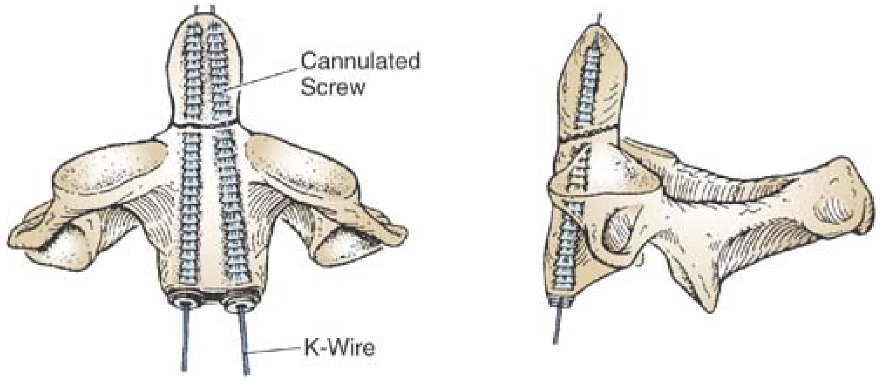

Figure 1.3-2. 2. Screw fixation technique, using cannulated screws. K-wire provides provisional stabilization and allows guided tapping and screw placement. (Reproduced with permission from An HS, Cotler JM: *Spinal Instrumentation*. Williams & Wilkins, Philadelphia: 1992.)

The anesthetized patient is placed in a supine position with traction of 5–10 lb. The mouth may be kept open using a radiolucent jaw distractor. A horizontal skin incision is made at approximately C5 level, and the platysma is cut along the skin incision. The anterior C-spine is exposed by opening the natural plane between the trachea and esophagus medially and carotid sheath laterally. Using a guide tube, a hole is drilled under fluoroscopy through the body of C2, the odontoid process, and its apex, through the fracture. The drilled hole is tapped, and an appropriately sized screw is placed (Fig 1.3-2). At this point, fluoroscopy of the patient's neck in flexion and extension is done to exclude C1-C2 instability.

Usual Preop diagnosis: Basilar impression (telescoping of C-spine into posterior fossa); odontoid fracture; rheumatoid arthritis with atlantoaxial instability; traumatic irreducible atlantoaxial instability; Type II odontoid fractures (recent or remote)

Summary of Procedures

	Transoral	Transodontoid Screw Fixation
Position	Supine, head in mild extension with traction	Supine; head in mild extension with traction
Incision	Posterior oropharynx	Transverse skin incision in the anterolateral neck at C5 level
Special instrumentation	Operating microscope, I.I., Dingman retractor	K-wire, drill, odontoid screw instrumentation
Unique considerations	Requires ≤ 3 cm mouth opening; armored ETT must be taped securely away from surgical field. Tracheostomy is needed occasionally. Fiber optic intubation may be required.	Fiber optic intubation in patients with C1-C2 instability; biplanar fluoroscopy is mandatory.
Surgical time	2–4 h	2–3 h
Closing considerations	Extubation may be delayed due to lingual swelling.	Routine wound closure
EBL	25–200 mL	25–200 mL
Postop care	ICU or close observation unit. Monitor airway for respiratory obstruction. ± Postop immobilization. Will require leaving NG tube in postop.	PACU → room; cervical collar
Mortality	0–3%	1%
Morbidity	All < 20%: CSF leak/dural tear Infection Neural injury Pharyngeal wound dehiscence	All: < 15% Hardware failure (screw pullout, screw fracture): 10% Nonunion: 5–10% Superficial wound infection: 2%
Pain score	3–5	3–5

Patient Population Characteristics

Age range	18–85 yr (usually 20–60 yr)	15–90 yr (usually 20–60 yr)
Male:Female	1:2	1.5:1
Incidence	Rare	Common (10–20% of C-spine fractures)
Etiology	Neoplastic; traumatic; congenital; degenerative	Traumatic
Associated conditions	Rheumatoid arthritis	-

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Anesthetic Considerations

See Anesthetic Considerations for Cervical Neurosurgical Procedures, p. 106.

Suggested Readings

1. Apelbaum RI, Lonser RR, Veres R, et al: Direct anterior screw fixation for recent and remote odontoid fractures. *J Neurosurgery (Spine 2)* 2000; 93:227–36.

2. Crockard AH: Transoral approach to intra/extradural tumors. In *Surgery of Cranial Base Tumors*. Sekhar LN, Janecka ID, eds. Raven Press, New York: 1993, 225–34.

3. Fountas KN, Kapsalaki EZ Nikolakakos LG, et al: Anterior cervical discectomy and fusion associated complications. *Spine* 2007; 32(21):2310–7.

4. Menezes AH: Transoral approach to the clivus and upper cervical spine. In *Neurosurgery*. Wilkins RH, Rengachary SS, eds. McGraw-Hill, New York: 1995, 306–13.

5. Vender JR, Harrison SJ, McDonnell DE: Fusion and instrumentation at C1–3 via the high anterior cervical approach. *J Neurosurgery (Spine 1)* 2000; 92:24–9.

Posterior Fusion/Fixation of the Upper Cervical Spine

Surgical Considerations

Description: Craniocervical (occipitocervical, craniovertebral) fusion/fixation or instrumentation involves stabilization of the occiput and upper three or four cervical vertebrae, while **atlantoaxial fusion/fixation** involves stabilization of the atlas (C1) and axis (C2). Instability may be caused by congenital, traumatic, degenerative, neoplastic, or infectious conditions resulting in compression of the lower brain stem or cervical spinal cord. Symptoms may include paresthesias and/or weakness of the upper and lower extremities.

Atlantoaxial techniques: Atlantoaxial (C1-C2) fusion is performed in the prone position, with or without traction. Through a posterior midline incision, the occiput and upper C-spine are exposed. A posterior iliac or rib graft may be harvested and fashioned appropriately. The bone graft can be secured with wires to the decorticated segments to be fused. Traditionally, the fixation has been performed with sublaminar wires alone; however, other fixation techniques—such as **C1-C2 transarticular screw fixation** and more recently the **C1-C2 lateral mass fusion** *(Print pagebreak 95)* techniques are being used more often because they are biomechanically stronger and permit early ambulation with minimal orthotic support.

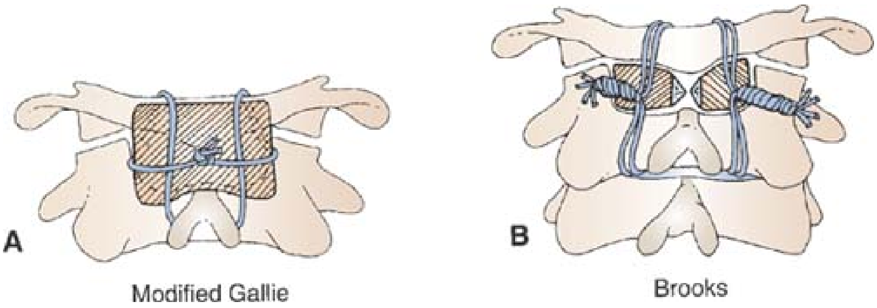

Figure 1.3-3. 3. Posterior wiring techniques. **A.** Modified Gallie using an H-shaped bone graft from the iliac crest, contoured to fit over the posterior arches of C1 and C2. A double U-shaped 18- or 20-ga wire is passed under the arch of C1 from inferior to superior. **B.** Brooks-type fusion with doubled-twisted 24-ga wires passed under the arch of C1 and then under the lamina of C2. Rectangular iliac crest bone grafts are fitted in the intervals between the arch of C1 and each lamina of the axis. (Reproduced with permission from An HS, Cotler JM: *Spinal Instrumentation.* Williams & Wilkins, Philadelphia: 1992.)

In **C1-C2 posterior wiring techniques**, the posterior arches of C1 and C2 laminae are exposed through a midline incision. Of the various wiring techniques used, **Gallie's** and **Brooks'** are the most widely accepted. In **Gallie's fusion** (Fig 1.3-3A), a wire loop or cable is passed underneath the C1 arch and brought over a bone graft wedged between C1 and C2 and then tightened over the C2 spinous process. In **Brooks' technique** (Fig 1.3-3B), wires are passed beneath the C2 lamina and C1 posterior arch on each side and tightened over a bone graft placed between C1 and C2. The posterior aspects of C1 and C2 are decorticated to facilitate the bony fusion. Wiring techniques are simpler, but carry the risk of cord injury during wire placement.

C1-C2 transarticular screw fixation was initially popular because of its greater biomechanical stability, higher fusion rates (87–100%), and superior fixation of atlantoaxial rotation. The occiput and C1-C3 vertebrae are exposed *(Print pagebreak 96)* by a conventional posterior approach. Screws are placed from each lateral mass toward the anterior tubercle of C1 under fluoroscopic guidance. The major risks of this technique include injury to the vertebral artery (4.1%), malposition of screws, or instrumentation failure. Twenty percent of patients will have an anomalous vertebral artery, demonstrated by radiographic studies, precluding use of this technique.

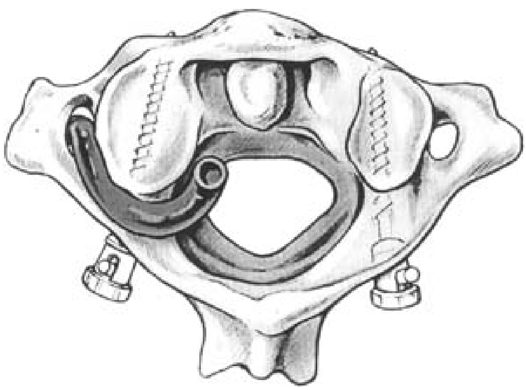

Figure 1.3-4. 4. Axial view of C1 lateral mass screws. (Reproduced with permission from Harms J, Melcher RP: Posterior C1-C2 fusion with polyaxial screw and rod fixation. *Spine* 2001; 26(22):2467–71.)

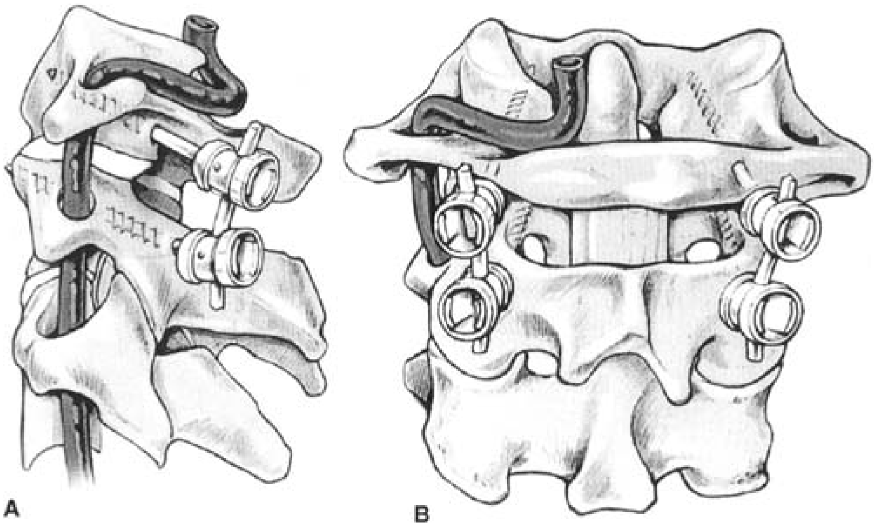

Figure 1.3-5. 5. Lateral **(A)** and AP view **(B)** of C1-C2 fusion. (Reproduced with permission from Harms J, Melcher RP: Posterior C1-C2 fusion with polyaxial screw and rod fixation. *Spine* 2001; 26(22):2467–71.)

In **C1-C2 lateral mass fusion**, the C-spine is exposed subperiosteally from occiput to C3-4 vertebrae by a conventional posterior approach. In this technique, polyaxial screws are passed into the lateral mass of C1 (Fig 1.3-4). Additionally, C2 pedicle screws are also placed and then attached to the C1 screws by connecting rods (Fig 1.3-5). If required, a reduction maneuver is carried out by repositioning the head or by direct manipulation of the C1 and C2 vertebrae. C1-C2 interfacetal fusion or posterior interlaminar fusion may be performed with wiring. The C1-C2 construct can be combined with cervical decompression. Because of the superior and medial placement of C2 pedicle screws, the risk of injuring the vertebral artery is less than with a transarticular fusion.

Craniocervical techniques: Occipitocervical fusion involves a surgical exposure similar to that of atlantoaxial fusion, except that a more extensive exposure of the occipital bone is required. In the past, fixation was performed with a **Luque rectangle/contoured rod and wiring** or plate and screws. An appropriately fashioned rib or iliac crest graft was then secured in place.

In **occipitocervical contoured rod fixation**, the occiput and posterior C-spine are exposed through a posterior incision, and trephines are made 2.5 cm to either side of the midline and about 2 cm above the foramen magnum. Wires or cables are passed from these occipital holes through the foramen magnum on both sides. Sublaminar wires are passed beneath laminae of the atlas, axis, and C3 vertebrae on each side, and are tightened over a rod. Other cervical vertebrae may be included in the fixation as required. A tricorticate iliac or rib graft is fixed with wires over the occipitocervical region. Decortication of occipital bone and laminae of the atlas, axis, or C3 vertebrae is essential for bony fusion.

Occipitocervical plate fixation can be performed by using a T- or Y-shaped plate fixed by screws to the occiput and lateral masses of the cervical vertebrae. C1-C2 transarticular screws, lateral mass screws, or wiring techniques can be added for additional stability. Occipitocervical plating techniques are biomechanically stable, often obviating the need for postop halo immobilization; however, they can be technically challenging. The major concerns include possible dural penetration by occipital screws and obtaining adequate contouring of the construct.

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Usual preop diagnosis: Transoral odontoid resection; occipitoatlantal instability; atlantoaxial instability; odontoid fractures; spinal fractures; cervical instability; previous failed fusions

Summary of Procedures

	Atlantoaxial (C1-C2) Fusion/Fixation	Occipitocervical Fusion/Fixation
Position	Prone, head in tong traction or pins	
Incision	Posterior midline incision	
Special instrumentation	Fluoroscopy; drills; wires/cables; lateral mass plate and/or screws; transarticular screws	Fluoroscopy; drills; rods, wires/cables; plates and screws
	Iliac/rib autograft ± posterior ilium for	

Unique considerations	graft. Fiber optic intubation and SSEPs	
Surgical time	2–3 h	3–4 h
Closing considerations	Routine wound closure	Halo vest may be needed in selected cases.
EBL	100–500 mL	
Postop care	PACU, then → room	
Mortality	< 1%	
Morbidity	Vertebral artery injury: 4.1%CSF leak Instrumentation failure Nonunion	Neural injury
Pain score	5–9	5–10

Patient Population Characteristics

Age range	18–85 yr (usually 20–60 yr)
Male:Female	1:2
Incidence	Rare
Etiology	Neoplastic; traumatic; congenital; degenerative; infections; rheumatoid arthritis

Anesthetic Considerations

See Anesthetic Considerations for Cervical Neurosurgical Procedures, p. 106.

Suggested Readings

1. Harms J, Melcher R: Posterior C1-C2 fusion with polyaxial screw and rod fixation. *Spine* 2001;26:2467–71.

2. Menendez JA, Wright NM: Techniques of posterior C1-C2 stabilization. *Neurosurgery* 2007; 60(suppl 1):S103–11.

3. Vangilder JC, Menezes AH: Craniovertebral abnormalities and their neurosurgical management. In: *Operative Neurosurgical Techniques.* Schmidek HH, Sweet WH, eds. WB Saunders, Philadelphia: 2000, 1934–45.

4. Wright N, Lauryssen C: Vertebral artery injury in C1–2 transarticular screw fixation: results of a survey of the AANS/CNS section on disorders of the spine and peripheral nerves. *J Neurosurg* 1998; 88:634–40.

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Anterior Fusion/Fixation of The Mid and Lower Cervical Spine

Surgical Considerations

Description: The first description of the anterior approach for excision of a cervical disc was made by Smith and Robinson in 1958. This approach permits easy and safe access to the entire C-spine below C2. **Anterior cervical discectomy** is commonly indicated for the removal of herniated discs or osteophytes compressing the spinal cord or nerve roots. Multisegmental cervical spondylosis (narrowing of spinal canal) may require single- or multi-level corpectomy (removal of a vertebral body). During anterior cervical discectomy, an approach from the left side of the neck is often preferred because it minimizes the chances of injury to the recurrent laryngeal nerve. The dissection is carried along the avascular plane between the trachea and esophagus medially, and the carotid sheath laterally (Figs 1.3-6 and 1.3-7). The fascia is incised to expose the longus colli muscles and anterior C-spine. The disc level is confirmed using fluoroscopy. The annulus is incised, and the disc is removed in piecemeal fashion with the use of an operating microscope. **Fusion and instrumentation** are often performed after discectomy to maintain disc space height, restore normal cervical lordosis, prevent graft extrusion, facilitate early ambulation, and possibly prevent delayed deformity and pain due to collapse of the disc space. After the discectomy, osteophytes are removed from the vertebral bodies, and an appropriately sized bone graft or prosthesis is placed in the intervertebral space. PEEK and carbon-fiber cages are radiolucent and allow good assessment of bony fusion. Fusion with instrumentation is often essential for immediate stability and early ambulation.

Anterior screw-plate fixation (with MRI-compatible titanium) is the preferred method of fixation for C2-C7. It provides stable fixation after discectomy or corpectomy, prevents bone graft migration, improves fusion rate, corrects spinal deformities, and may restore anterior and middle column function following cervical trauma. Plates and screws are placed under fluoroscopic guidance to prevent dural penetration or malposition. Hemodynamic changes should be monitored closely during the procedure, because ↓ HR or ↓ BP during the instrumentation may suggest cord compression.

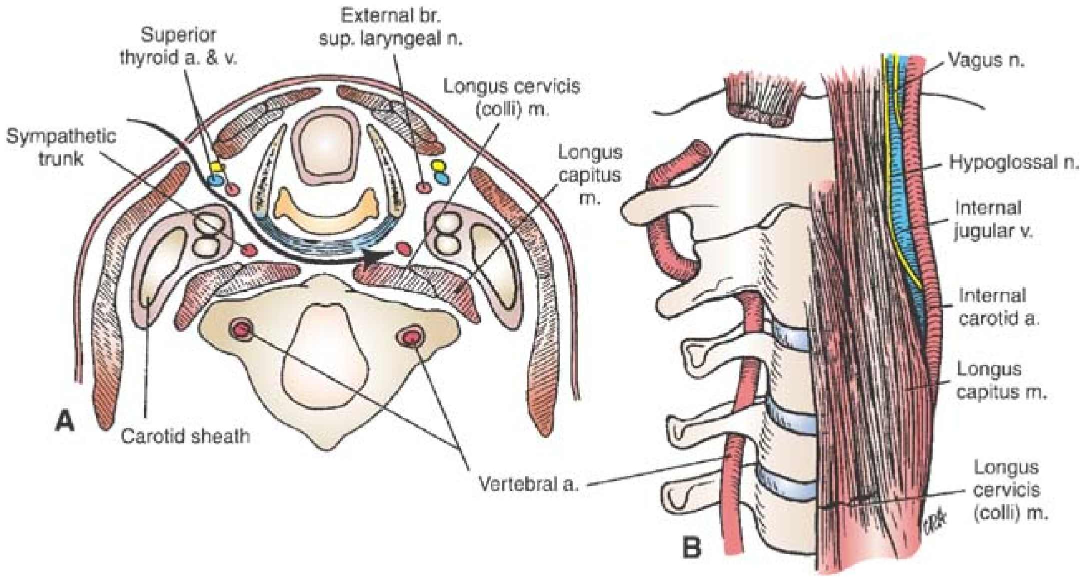

Figure 1.3-6. 6. Upper C-spine. **A.** Cross-section showing the anteromedial approach. **B.** Anterior aspect, after stripping the longus collis muscle. (Reproduced with permission from An HS, Cotler JM: *Spinal Instrumentation*. Williams & Wilkins, Philadelphia: 1992.)

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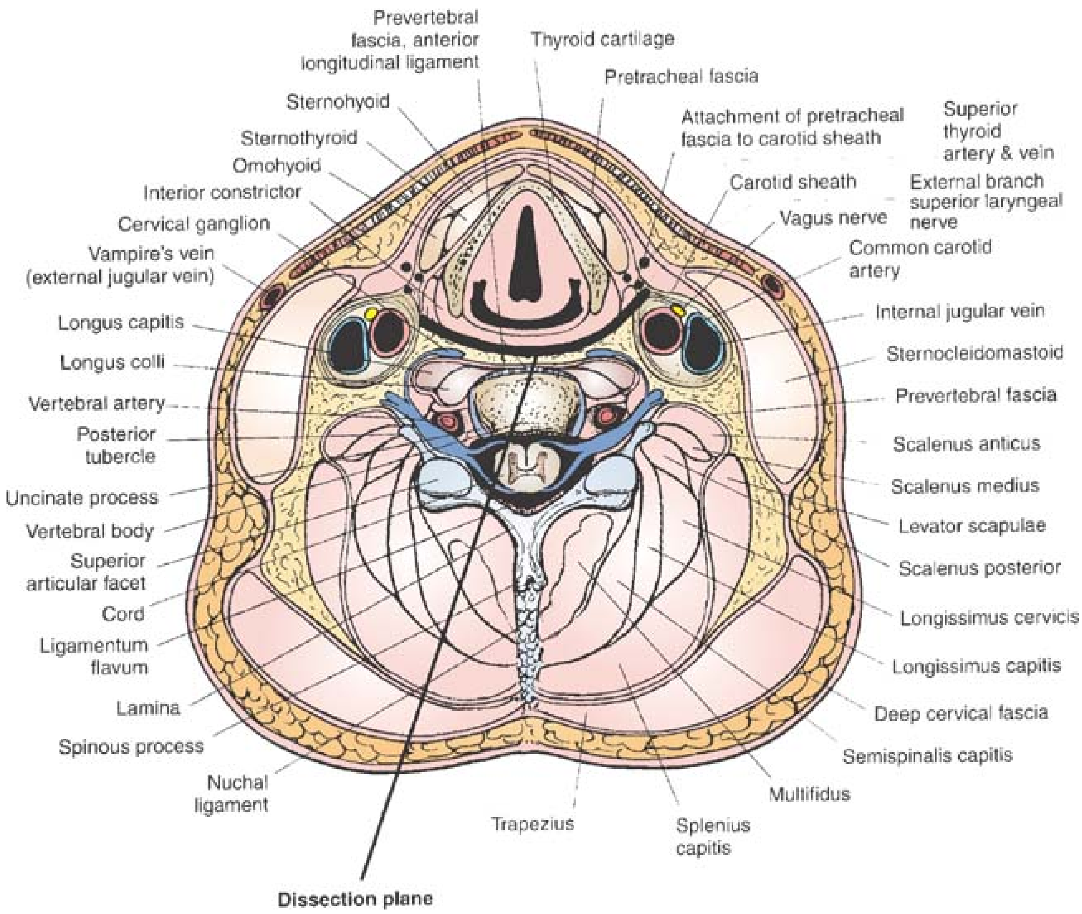

Figure 1.3-7. 7. Cross-section of the C-spine at C5 level. Note the deep cervical fascia, the pretracheal fascia, and the prevertebral fascia. Note the relationship of the pretracheal fascia to the carotid sheath. Dissection plane is shown. (Modified with permission from Hoppenfeld S, deBoer P: *Surgical Exposures in Orthopaedics: The Anatomic Approach*, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 1994.)

Usual preop diagnosis: Cervical radiculopathy (nerve-root compression due to disc herniation or osteophytic compression); cervical myelopathy (spinal-cord compression by disc/osteophytes); cervical instability (ligamentous laxity or disruption)

Variant procedure: Cervical (vertebral) corpectomy and fusion are used to treat conditions in which there is anterior impingement of the spinal cord or narrowing of the spinal canal at the level of the vertebral body, including multisegmental cervical spondylitic compression, ossification of the posterior longitudinal ligament (OPLL), tumors, infections (e.g., TB, osteomyelitis), or C-spine injury. The surgical exposure is similar to that for anterior cervical discectomy. A transverse neck incision is preferred for corpectomy involving two or three vertebrae; however, a vertical skin incision along the anterior border of the sternomastoid may be used if more than three vertebrae are involved. Before the removal of a vertebral body, adjacent discs are resected. The posterior part of the vertebra and osteophytes at the posterior margins are excised. Reconstruction is accomplished with an autograft, allograft, or cages (metal or carbon fiber spaces filled with bone fragments). Some of the newer cages are expandable, facilitating a good fit. Supplemental fixation with plates and screws is essential to prevent graft extrusion, to facilitate fusion, and to permit early ambulation.

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Usual preop diagnosis: Cervical myelopathy (spinal cord compression) 2° fracture of the C-spine (traumatic or pathologic); narrowing of the spinal canal due to congenital conditions; degenerative conditions, such as severe disc disease with osteophyte formation; OPLL; cervical instability (ligamentous laxity or disruption or destruction of bone due to tumor or infection); failed previous spinal fusion

ISBN: 0-7817-6670-2 | 4th_Edition
Golianu, Brenda | Schmiesing, Clifford | Samuels, Stanley | Jaffe, Richard

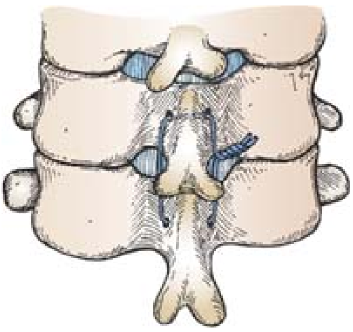

Figure 1.3-8. 8. Intraspinous wiring. Wires passed through drilled holes in base of adjacent spinous processes and tightened. (Reproduced with permission from An HS, Cotler JM: *Spinal Instrumentation*, 2nd edition. Lippincott Williams & Wilkins, Philadelphia: 1999.)

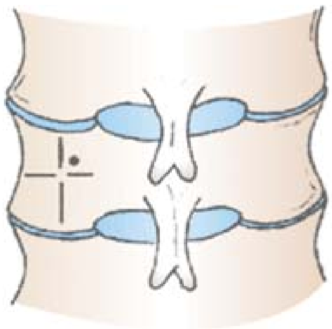

Figure 1.3-9. 9. Magerl technique lateral mass screw entry point. (Reproduced with permission from Barrey C, Mertens P, et al: Quantitative anatomic evaluation of cervical lateral mass fixation with a comparison of the Roy-Camille and the Magerl Screw techniques. *Spine* 2005; 30(6):E140–7.)

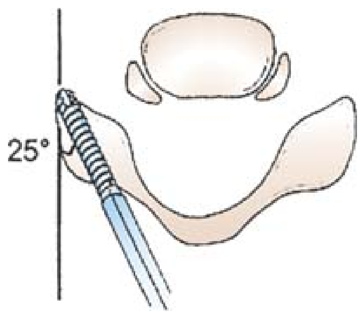

Figure 1.3-10. 10. Magerl technique lateral mass screw axial trajectory angulation. (Reproduced with permission from Barrey C, Mertens P, et al: Quantitative anatomic evaluation of cervical lateral mass fixation with a comparison of the Roy-Camille and the Magerl Screw techniques. *Spine* 2005; 30(6):E140–7.)

Summary of Procedures

	Cervical Discectomy 6 Fusion and Plating	**Cervical Corpectomy 6 Fusion and Plating**
Position	Supine, head extended on headrest	
Incision	Transverse anterolateral	or vertical anterolateral
Special instrumentation	Operating microscope; anterior cervical plates	
Unique considerations	Fiber optic intubation may be necessary; ± cervical traction	
Antibiotics	Cefazolin 1 g	
Surgical time	1–2 h (+ 1h for fusion/plating)	1.5–3 h for single level; add 20–30 min for each additional level.
Closing considerations	Cervical collar (soft/hard)	Cervical collar (soft/hard)

EBL	25–250 mL	50–1000 mL
Postop care	PACU → room	
Mortality	1%	0–5%
Morbidity	Esophageal perforation: < 1% Infection: < 1% Massive blood loss–carotid or jugular injury, : < 1% Myelopathy: < 1% Nerve injury: Recurrent laryngeal nerve: 5% Root: < 1% Sympathetic chain: < 1% Postop instability: < 1% Instrument failure: < 1% Slipped graft: < 1%	1–15%
Pain score	3–5	3–5

Patient Population Characteristics

Age range	18–85 yr (usually 20–60 yr)
Male:Female	1:2
Incidence	Rare
Etiology	Neoplastic; traumatic; congenital; degenerative; OPLL

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Anesthetic Considerations

See Anesthetic Considerations for Cervical Neurosurgical Procedures, p. 106.

Suggested Readings

1. Brislin BT, Hilibrand AS: Avoidance of complications in anterior cervical spine revision surgery. *Curr Opin Orthop* 2001; 12 (3):257–64.

2. Dickman CA, Marciano FF: Principles and techniques of screw fixation of the cervical spine. In *Principles of Spinal Surgery.* Menezes AH, Sonntag VKH, eds. McGraw-Hill, New York: 1995; 123–39.

Posterior Fusion/Fixation of the Mid and Lower Cervical Spine

Surgical Considerations

Description: Posterior cervical laminectomy (removal of lamina), **foraminotomy** (opening of the neural foramina), and **laminotomy** (removal of a portion of the lamina) are posterior procedures for decompression of the neural elements in the C-spine. These procedures are used to treat cervical radiculopathy 2° degenerative disc disease (e.g., herniated discs, osteophytes). The major advantage of **foraminotomy** over an anterior approach is that it does not require fusion and, thus, preserves the motion of the involved vertebral segments and obviates the need for immobilization for fusion. It also permits decompression of multiple levels, if required. Disadvantages of foraminotomy include an increased incidence of neck pain and the fact that it is not an effective approach to midline disc herniation. **Decompressive laminectomy** can be used to treat cervical canal stenosis (congenital or degenerative) and for removal of intraspinal masses (tumors, AVMs, infective granulomas), which may be extradural, intradural, extramedullary, or intramedullary. Depending on the location of the tumor, the surgeon may need to open the dura and/or spinal cord. Obviously, the intradural intramedullary tumors involve more risk and are more delicate to remove. Many laminae may be removed to expose and excise the tumor. Surgical adjunctive tools (e.g., CUSA, laser, surgical microscope, etc.) may be used to aid in removal of the tumor. Intraop evoked potential monitoring may be used during these procedures to test the integrity of the dorsal columns. After the tumor has been removed, the wound is closed in layers, as in a simple laminectomy.

Surgery is performed in the prone or sitting position through a posterior midline incision over the involved vertebrae. The paraspinal muscles are dissected off the spinous processes, and lamina and bone are removed piecemeal. The extent of the procedure depends on the indications for treatment. Hemostasis is achieved with bipolar cautery, and raw bone surfaces are sealed with bone wax. Topical hemostatic agents are used to aid in hemostasis in the epidural gutters. If the patient has an intradural tumor or process, such as syringomyelia, the dura is opened and the operating microscope is used for this portion of the procedure. After the intradural procedure is complete, the dura is closed, and the surgeon may wish to test the integrity of the closure with a Valsalva-like maneuver (sustained inspiration to 30–40 cmH_2O). The wound is closed in layers, and a drain may be left in the epidural space. Multilevel laminectomies with foraminotomies (involving partial removal of cervical facet joints) can result in late-onset cervical kyphosis, an extremely difficult condition to treat. These patients are usually considered for concomitant posterior fusion and instrumentation, especially in the presence of cervical segmental instability.

Newer less traumatic techniques can be used to perform foraminotomies and discectomies in the cervical spine in a **minimally invasive (MIS)** fashion. These use one of many tubular retractor systems [e.g., **METRx** (Medtronic, Memphis, TN, USA)]. These afford similar exposure but minimize blood loss, scar, and pain by spreading the muscles. The disadvantage is unfamiliar exposure, difficulty with retractor placement, and potential of neurological injury by inadvertent penetration of the interlaminar space.

Posterior cervical wiring techniques include: (a) **interspinous wiring** (Fig 1.3-8) (wires are passed through drilled holes in the base of adjacent spinous processes and then tightened); (b) **sublaminar wiring** with Luque rods or rectangles (sublaminar wires are passed at each level on both sides and are tightened over the rods or rectangles); and (c) **a triple-wire technique** with the first wire being passed through drill holes at the base of each spinous process, and the second and third wires passed through the same holes and then through drill holes in the previously placed *(Print pagebreak 102)* bone grafts. This latter technique is biomechanically sound, because it places the bone grafts in compression. Wiring techniques, while stable in flexion, however, are less stable in extension and rotation, and they cannot be performed in patients with prior laminectomy or requiring laminectomy.

In the **posterior cervical lateral mass screw fixation** technique, the C-spine is exposed through a midline incision over the involved vertebral segments. The lateral mass (bony column between facet joints) is identified, drilled, and tapped. Cortical screws are passed into the lateral mass and fixed with plates or rods. The trajectory of the screws in the lateral mass is to the upper outer corner in the classic Magerl technique. The entry point should be approximately 1 mm medial to the midpoint of the lateral mass (Fig 1.3-9). The axial trajectory angulation should be 25°, and the *(Print pagebreak 103)* sagittal angulation should be 45°, which is inline with the facet joints (Figs 1.3-10 and 1.3-11). Adjacent facet joints are decorticated and bone grafts are placed. Lateral mass plating provides a rigid multisegmental fixation and can be performed in patients with prior laminectomy. The major risks involved with this procedure are nerve-root and vertebral artery injuries.

Cervical pedicle screw plate fixation is an effective alternative to lateral mass fixation. In this technique, screws are passed under fluoroscopic guidance into the cervical pedicles and secured to plates or rods. This procedure is technically demanding, as the cervical pedicles are narrow and in close proximity to nerve roots, vertebral artery, and spinal cord and their trajectories are typically unfamiliar. This technique is biomechanically stable and permits the *(Print pagebreak 104)* correction of deformity by application of compression or distraction forces. It is most commonly performed at C2 where the pedicles are relatively larger.

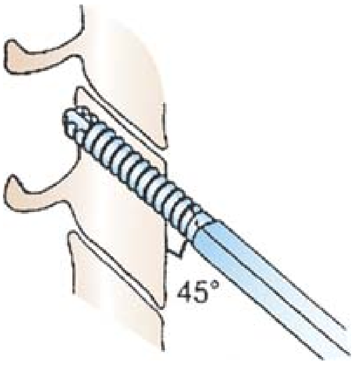

Figure 1.3-11. 11. Magerl technique lateral mass screw sagittal trajectory angulation. (Reproduced with permission from Barrey C, Mertens P, et al: Quantitative anatomic evaluation of cervical lateral mass fixation with a comparison of the Roy-Camille and the Magerl Screw techniques. *Spine* 2005; 30(6):E140–7.)

Usual preop diagnosis: Cervical radiculopathy (nerve-root compression); cervical myelopathy (spinal-cord compression); cervical disc disease (herniation or degeneration of one or more cervical discs); C-spine injury

Variant procedures: Patients with panvertebral disease (involving anterior and posterior elements of the spine) and three-column spinal instability often require **combined anterior and posterior decompression, reconstruction, and instrumentation**. Anterior screw plates provide a strong tension band to resist vertical/horizontal translation and neck extension; however, they are less able to resist flexion or rotation. By contrast, posterior cervical plates strongly resist flexion or rotation, but are less able to resist extension. Thus, in the presence of three-column spinal instability, combined anterior and posterior instrumentation often is required. This technique provides rigid fixation of spinal segments and avoids the need for rigid external orthotic devices.

Combined instrumentation techniques are challenging and require several special considerations. Patients with any unstable C-spine may require fiber optic intubation, intraop cervical traction, and electrophysiological monitoring. **Anterior and posterior cervical instrumentation** is usually carried out in a single surgical session although may be staged. The transition between the anterior and posterior approaches requires a specialized operating table (e.g., Jackson spinal table or Stryker frame) and careful coordination among the entire OR team. The long duration of surgery may be associated with increased incidence of respiratory complications, blood loss, and prolonged ICU stays. In rare instances, an additional anterior or posterior approach may be performed ("540-degree procedure").

Usual preop diagnosis: C-spine injury causing three-column (severe, unstable) injuries; cervicothoracic junctional pathologies; correction of kyphotic deformities; panvertebral disorders involving C-spine (neoplasms, infection, spondylitic myelopathy); failed symptomatic anterior cervical fusions

Summary of Procedures

	Cervical Laminotomy/Foraminotomy	Cervical Laminectomy with Instrumentation	Combined Anterior/Posterior Cervical Instrumentation
Position	Prone or sitting; pin fixation or horseshoe headrest	Prone; pin fixation or horseshoe headrest	+ supine
Incision	Posterior midline neck		+ transverse or longitudinal anterolateral
Special instrumentation	Operating microscope for intradural procedures	+ implants, pedicle screws with plates	Implants; anterior and posterior plates with screws
Unique considerations	Fiber optic intubation; I.I. to assess correct level	I.I. for screw placement	Implants; anterior and posterior plates with screws
Antibiotics	Cefazolin 1 g		
Surgical time	1.5–2 h	Add 30–45 min/level of instrumentation	4–5 h
EBL	25–500 mL		250–600 mL
Postop care	PACU → room		; sometimes needs short ICU stay
Mortality	0–3%		
Morbidity	All < 5%: Neurological deterioration Myelopathy Nerve-root injury CSF leak Postop instability Infection	additionally: Instrumentation failure Vascular injury Nerve-root injury 2° screws	5–10% additionally: Bone graft dislodgement Respiratory problems
Pain score	2–6	5–10	7–10

(Print pagebreak 105)

Patient Population Characteristics

Age range	18–85 yr (usually 20–60 yr)
Male: Female	1:2
Incidence	Rare
Etiology	Neoplastic; traumatic; congenital; degenerative; infections; rheumatoid arthritis

Anesthetic Considerations

See Anesthetic Considerations for Cervical Neurosurgical Procedures, p. 106.

Suggested Reading

1. Collias JC, Roberts MP: Posterior surgical approaches for cervical disk herniation and spondylitic myelopathy. In *Operative Neurosurgical Techniques.* Schmidek HH, ed. WB Saunders, Philadelphia: 2000, 2016–28.

Anterior Cervicothoracic Spine Surgery

Surgical Considerations

Description: The **anterior approach** to the **cervicothoracic junction** (CTJ-C7-T3) is performed for discectomy, stabilization of spinal fractures, tumor resection, spinal reconstruction, and instrumentation. Anterior approaches to the CTJ often are challenging, as this area represents a rapid transition from cervical lordosis to thoracic kyphosis, resulting in abrupt increase in the depth of the wound. The confluence of great vessels, and visceral (trachea, esophagus) and neural structures at the thoracic inlet makes them susceptible to injury. The modified anterior approach utilizes a "hockey stick" incision to allow greater access to the lower cervical and upper thoracic spine. This technique does not require any additional bone resection during the approach. The **transsternal** approach involves a longitudinal incision along the anterior border of the sternomastoid, extended over the midline of the sternum to the xiphisternum. The sternum is divided using an oscillating saw and retracted to expose the anterior aspect of the CTJ. The wide exposure available with this approach permits vertebral resection, reconstruction, and instrumentation. The **transclavicular** approach involves a T-shaped incision over the clavicles, with a vertical limb extending down the midline of the sternum. Subplatysmal flaps are elevated; and the sternal and clavicular heads of the sternomastoid are detached from their origin and retracted superolaterally. The medial third of the clavicle and manubrium are resected to provide an excellent direct anterior approach to the CTJ for vertebral decompression, reconstruction, and stabilization.

Variant procedure and approaches: Axillary thoracotomy and high transthoracic thoracotomy approaches permit an anterolateral exposure to CTJ. As these procedures involve entering the thoracic cavity, they typically require OLV during the procedure.

Usual preop diagnosis: C7-T3 disc disease, fracture, tumor, and deformity

Summary of Procedures

	Transsternal Approach	Transclavicular Approach	Axillary/High Thoracotomy
Position	Supine		Lateral
Incision	Longitudinal incision along anterior border of sternomastoid	T-shaped incision over clavicles with a vertical limb down the midline of sternum	Lateral chest wall
Special instrumentation	Anterior cervical plates Special oscillating saw for sternal opening	Special blades for clavicular resection	
Unique considerations	OLV not necessary		OLV necessary
Antibiotics	Cefazolin 1 g iv		

Surgical time	3–4 h		
Closing considerations	Soft cervical collar		
EBL	200–500 mL		
Postop care	PACU → room		
Mortality	1–2%		
Morbidity	Wound infection/breakdown Injury to great vessels at thoracic inlet	Cosmetic deformity	Respiratory problems
Pain score	7–10	7–10	7–10

(Print pagebreak 106)

Patient Population Characteristics

Age range	30–50 yr
Male:Female	1:1
Incidence	Uncommon
Etiology	Disc herniations; trauma; tumor; infections

Suggested Reading

1. Kim DH, Beck CE, Dietz DD, et al: Surgical approaches to the cervicothoracic junction. In: *Operative Neurosurgical Techniques.* Schmidek HH, ed. WB Saunders, Philadelphia: 2000, 2107–21.

Anesthetic Considerations for Cervical Neurosurgical Procedures

(Procedures covered: anterior/posterior fusion/fixation of upper and mid/lower C-spine; anterior cervicothoracic spine surgery)

Preoperative

Surgery of the C-spine is common, primarily because of the frequency of herniation of a cervical intervertebral disc causing compression of the adjacent spinal nerve roots. Other, less frequent indications for cervical surgery include: acute or chronic instability of the neck requiring fusion; removal of a tumor of the spinal cord; or craniocervical decompression for Arnold-Chiari malformation.

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Respiratory	Acute fractures of the C-spine may be associated with sufficient trauma to the spinal cord to cause acute respiratory insufficiency and inability to handle oropharyngeal secretions. If this occurs, immediate tracheal intubation is necessary. Before initiating intubation, the neck must be stabilized, preferably in Gardner-Wells tongs or a body jacket; lacking those, a tight neck collar with sandbags on each side of the head will suffice. The objective is to **not flex or extend the head or move it laterally** during the course of tracheal intubation. Fiberoptic intubation techniques that secure the airway with minimal or no manipulation of the cervical spine should be used. **Tests**: Consider ABG to substantiate degree of respiratory impairment, if present. Acute fractures of the C-spine and associated spinal cord trauma

Cardiovascular	may → loss of sympathetic tone, which, in turn, may cause peripheral vasodilation and bradycardia. Generally, this condition can be treated effectively with crystalloid and/or colloid infusion, and atropine to ↑ HR. Rarely is it necessary to use vasopressors to maintain BP or HR. If spinal cord injury is suspected an A-line must be placed and MAP should be maintained above 80 at all times to avoid vascular insufficiency of the spinal cord.**Tests:** As indicated from H&P.
Neurological	Patients with herniation of a cervical disc generally complain first of pain in the neck, particularly with lateral rotation of the head. The pain may radiate down one or, rarely, both arms. As nerve compression continues, patients begin to develop weakness and atrophy of specific muscle groups in the arm. These Sx, however, are not specific to herniation of a disc and may be caused by a spinal cord tumor or cyst. Patients with acute fractures of the neck and attendant spinal cord trauma at the T1 level may be paraplegic to some degree, whereas fractures above C5 may result in quadriplegia and loss of phrenic nerve function. Injuries between these two levels result in variable loss of motor and sensory functions in the upper extremities. A careful documentation of preop sensory and motor deficits is important. **Tests:** MRI has replaced myelography as the primary diagnostic test because it distinguishes disc from tumor from cyst. Emergency CT is invaluable in the assessment of patients with acute neck injuries and suspected cervical fracture; if not available, A-P and lateral x-rays of the neck generally will reveal the site and extent of bony injury.
Hematologic	Antiplatelet agents should be stopped 10 d before elective surgery. At least 2 units of PRBCs should be ready along with a type and screen if large amounts of blood loss are anticipated, as can occur in some posterior cervical surgeries.**Tests**: Hct; T&C, others as indicated from H&P.
Laboratory	Other tests as indicated from H&P.
Premedication	Premedication is very useful in this patient population. Midazolam 2–4 mg iv and meperidine 20–40 mg iv in divided doses prior to entering the OR makes patients amnestic and tractable. Also, antibiotics (usually 1 g of cefazolin if not PCN allergic) should be given at least **30 min** prior to skin incision for them to be effective against infection.

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Intraoperative

Anesthetic technique:	GETA
Induction	For patients with a stable neck, orotracheal intubation using standard laryngoscopy is acceptable. If the operation is to be performed transorally or at C1–2; if the patient's neck is unstable; if the head is in tongs, a halo device, or a body jacket; or if the findings on the H&P suggest that tracheal intubation may be difficult, the ETT should be placed using FOL. FOL can be performed under local anesthesia before induction of GA, but this requires topicalization of the airway, which will cause coughing and potential injury to the spinal cord. A much better method is to perform a Plan C under general anesthesia. (For details of fiberoptic intubation and Plan C, see p. B-5.) Consider using a wire-reinforced tube as it allows for maximal bending of the tube to remove it from the surgical field, and it will not be compressed by the Dingman retractor. A wire-reinforced tube is also desirable when the surgical procedure is to be done in the prone position. Most importantly, it is vital to discuss the severity of the surgical lesion and the planned intubation with the surgeon before proceeding.

Nasotracheal intubation is rarely needed for this type of surgery. After the ETT is in place, anesthesia is induced with propofol 0.5–2.5 mg/kg or STP 3–5 mg/kg.
FOI should be performed when there is any question that the neck is unstable or if positioning could potentially cause injury to the spine. The patient remains awake during positioning and FOI, then a post-intubation neuro exam is performed, and only then is the patient anesthetized. This applies even for cases where the patient is in a Mayfield head-holder.

Maintenance

Standard maintenance (see p. B-2). Neuromuscular blockade with rocuronium 0.6 mg/kg or vecuronium 0.1 mg/kg is helpful for positioning the patient and insertion of the Dingman retractor. After the retractor is in place and the operation is under way, further use of relaxants is usually not necessary.

Emergence

If a cervical fusion has been performed and the patient has been returned to a halo device or body jacket, it is desirable to leave ETT in place until the patient is fully awake, responding to commands, and able to manage his/her own airway. **NB:** Immediate airway obstruction 2° soft-tissue occlusion or superior laryngeal nerve damage may occur on extubation. A useful way to test for airway patency is to deflate the cuff of the tracheal tube and determine that the patient is able to breathe around the tube as well as through it. If there is any question about adequacy of the airway, it is prudent to leave the ETT in place and spray lidocaine 4% 4 mL down the trachea using a laryngotracheal anesthesia device (LTA) before emergence. This technique will usually prevent or minimize coughing or bucking on the ETT for about 15–30 min. One also should consider inserting an airway exchange catheter (AEC) through the ETT tube before its removal. AECs are well tolerated, and can be left in place until one is confident that no further airway compromise will occur. So long as the AEC is not touching the carina, it will not induce coughing or bucking, and the patient can talk without difficulty. This catheter will provide a conduit for immediate reinsertion of an ETT if airway obstruction from early or delayed swelling, bleeding, or hematoma formation should occur.

Blood and fluid requirements

iv: 16–18 ga × 1
NS/LR @ 4–6 mL/kg/h

Blood transfusion is rarely needed for operations on the C-spine.

Monitoring

Standard monitors (see p. B-1).
± Arterial line
± CVP line
± Doppler
± Urinary catheter

If a standard BP cuff is to be used, consider placing it on a leg at the ankle. If placed on an arm without rigid protection (e.g., sleds), the surgeons tend to lean on the cuff, making it difficult to take consistent, reliable measurements. If the patient has a CV, respiratory, or metabolic disorder (e.g., insulin-dependent diabetes) consider inserting an arterial catheter. During cases of spinal cord injury or severe stenosis, it is important to keep in mind that an arterial line should be placed prior to induction when hypotension is most likely. If a posterior surgical approach with patient in seated position is planned, an arterial catheter is useful for monitoring BP, and a CVP catheter is necessary for monitoring CVP and aspiration of air, if VAE occurs. If patient is seated, an ultrasonic Doppler flow probe also should be placed on the anterior chest wall, with confirmation of its performance by injecting 1 mL of agitated NS into CVP line and listening for the characteristic change in Doppler sound.

SSEP

If SSEP monitoring is planned, the combination of sevoflurane (1 MAC or less), O_2 opiates (fentanyl or meperidine), and neuromuscular blockade (rocuronium) is an appropriate anesthetic regimen for

Positioning

Supine:
and pad pressure points.
eyes.
Shoulder roll
Cervical traction

Prone:
and pad pressure points.
eyes.
genitalia.

Sitting:
and pad pressure points.
eyes.
VAE monitoring:
ETT position.

VAE

optimizing the potentials. More than 50% N_2O and 0.5 MAC isoflurane make SSEP monitoring less satisfactory.

For **anterior cervical discectomy** and/or fusion, patient is positioned supine with a roll under the shoulders or neck, and the head is moderately extended. A cervical strap may be placed below the chin and behind the occiput, and attached to a weight of 5–10 lb hung over the head of the bed. If patient is in a halo or tongs, 5–10 lb of weight are attached to the device. Alternatively, the surgeon may request traction intermittently during insertion of bone plugs for fusion. The surgical incision can be made on either side of the neck at the discretion of the surgeon.

A **posterior approach** is used if the operation is for spinal stenosis or craniocervical decompression. With this approach, patient is usually positioned prone (on a Wilson frame or on bolsters), or more rarely sitting, with the head in 3-point fixation.

Although seldom used today, there are advantages to the neurosurgeon, the anesthesiologist, and, thus, the patient as well, in using a seated position. Advantages for the neurosurgeon: (a) easier access to the lesion; (b) less blood loss, since both arterial and venous pressures are lower than if patient were prone; (c) less interference from CSF, since it readily drains away from the operative site; and (d) lower incidence of postop neurological injury. Advantages to the anesthesiologist are: (a) less chance that ETT and other arterial and venous catheters will become dislodged than with patient prone; (b) less chance for inadvertent pressure injury; (c) easier assessment and management of ventilation; and (d) easier access to patient for insertion of additional catheters, if necessary.

The major disadvantage of the sitting position is the risk of VAE, particularly paradoxical air embolism to the left side of the heart through a PFO (or, rarely, through the pulmonary circulation) → CNS or coronary emboli. Incidence of VAE is 25–45% in patients operated on in the seated position. VAE is easily detected using a combination of Doppler, $ETCO_2$ and ETN_2 analysis; and complications are rare. If VAE is suspected (Sx =↓$ETCO_2$ ↑ ETN_2 ↓BP, dysrhythmias), notify the surgeon and aspirate the right atrial catheter using a 10-mL syringe. This generally will confirm the Dx as well as provide treatment. If VAE continues, and the

		surgeon has difficulty identifying the site of air entrainment, consider using PEEP ≤ 10 cm H_2O or bilateral jugular compression to increase CVP and cerebral venous pressure. Low levels of PEEP applied and released gradually will not promote paradoxical air embolism.
Complications	Esophagus perforation	A possible complication of anterior cervical surgery is esophageal perforation. One way to assess for this type of injury is to flood the operative field with water and then force air though the oropharynx and look for any signs of bubbling. These can be occult and manifest post-op as fistulas as well.
	Retraction nerve injury	Another potential complication of anterior surgery is retraction injury to various nerves including the recurrent laryngeal. Pressure can be taken off of the nerve by reducing the cuff pressure once the retractors are in place to mitigate any compression due to the nerve being trapped between the retractor and the ET cuff.
	Hypotension	↓ BP caused by venous pooling, inadequate venous return to the heart, and ↓ CO can be treated by wrapping lower extremities while patient is supine, infusing adequate fluid volume to maintain right heart filling pressure, and avoiding excessive depth of anesthesia. Any **acute** drop in MAP may be due to a vascular injury, either obvious (vertebral artery injury) or occult (deep great vessel injury) until proven otherwise. The source of bleeding should be identified.

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Postoperative

	Airway obstruction, edema Hematoma Neurologic deficit	The cause of airway obstruction is usually from soft tissue falling back against the posterior pharyngeal wall, which cannot be corrected by forward displacement of the mandible because of the neck fusion or postop traction/stabilization device. May require oral or nasal airway. Consider inserting an airway exchange catheter (AEC) before removing the ET tube. Delayed respiratory insufficiency usually is caused by either development of a tension pneumothorax from entrainment of air via the surgical wound or an unsuspected oropharyngeal laceration during tracheal intubation, or from bleeding into the neck at the surgical site, with progressive compression and occlusion of the airway. If a tension pneumothorax is suspected and circulatory signs are stable, immediate

Complications	Tension pneumothorax	CXR should confirm the Dx. If circulation is failing, an 18- or 20-ga needle catheter should be inserted immediately anteriorly at the 2nd intercostal space on the suspected side to relieve the pneumothorax. If the Dx is airway obstruction from bleeding into the neck, the wound should be opened immediately and clots and blood removed. This should be done before any attempts at intubation, because direct laryngoscopy may not be possible if tracheal deviation distorts the view. Emergent tracheostomy or cricothyrotomy can be lifesaving in patients with significant soft tissue swelling. If the Dx is soft tissue swelling, then exploration usually results in very little blood being found. These patients are given high-dose short-course steroid and have a good prognosis. It is sometimes difficult to distinguish airway obstruction from tension pneumothorax by physical signs. One useful way is to check for the "puff sign." With airway obstruction from any cause, what gas moves in and out of the airway does so very slowly because of an obstruction. In contrast, with tension pneumothorax, gas moves out of airway with great speed because of high intrapleural pressure. By applying positive pressure to the airway and listening at the patient's mouth for the sound of gas escaping as airway pressure is released, one hears either a puff or jet of air escaping (tension pneumothorax) or slow, gradual exit of air (airway obstruction).
Pain management	PCA	(see p. C-3).
Tests	CXR Hct	Repeat neurological exam prior to discharge from PACU.

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Suggested Readings

1. Black S, Cucchiara RF, Nishimura RA, et al: Parameters affecting occurrence of paradoxical air embolism. *Anesthesiology* 1989; 71(2):235–41.

2. Black S, Ockert DB, Oliver WC Jr, et al: Outcome following posterior fossa craniectomy in patients in the sitting or horizontal positions. *Anesthesiology* 1988; 69(1):49–56.

3. Cucchiara RF, Nugent M, Seward JB, et al: Air embolism in upright neurosurgical patients: detection and localization by two-dimensional transesophageal echocardiography. *Anesthesiology* 1984; 60(4):353–5.

4. Larson CP: A safe, effective, reliable modification of the ASA difficult airway algorithm for adult patients. *Curr Rev Clin Anesth* 2002, 23:1–12.

5. Pearl RG, Larson CP Jr: Hemodynamic effects of positive end-expiratory pressure during continuous venous air embolism in the

dog. *Anesthesiology* 1986; 64(6):724–9.

6. Sonntag VKH, Hadley MN: Management of upper cervical spinal instability. In *Neurosurgery Update*, Vol II. Wilkins RH, Rengachary SS, eds. McGraw-Hill, New York: 1991, 222–33.

7. Zasslow MA, Pearl RG, Larson CP Jr, et al: PEEP does not affect left atrial-right atrial pressure difference in neurosurgical patients. *Anesthesiology* 1988; 68(5):760–3.

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Anterior Thoracic Spine Surgery

Surgical Considerations

Description: The **anterior approach** to the mid and lower thoracic spine (T4-T12/L1) is performed for spinal fracture, scoliosis/kyphosis, tumor, and infection. The **anterior transthoracic approach** provides a wide and easy exposure of the thoracic spine from T4-T10. The patient is placed in a lateral decubitus position (right or left, based on spinal pathology). An incision is made over the involved vertebrae and extended rostrally one or two intercostal spaces. The muscles and ribs are retracted, the pleura are opened, and lungs retracted to expose the vertebral bodies. Discectomy, corpectomy, bony reconstruction, and stabilization can be performed as required under radiographic guidance. The risk of spinal cord injury depends on the extent of surgery and reconstruction. The complex vasculature can be challenging. Hemostasis is vital to prevent hemothorax. Chylothorax and lymphatic injury are rare.

The **transition zone** at the thoracolumbar (TL) spine (T11-L1) is somewhat difficult to expose and requires a combined transthoracic and retroperitoneal approach through the diaphragm **(thoracolumbar transdiaphragmatic approach)**. A left-sided approach is preferred, since it is easier to retract the spleen and stomach than the liver. The skin incision is made over the 10^{th} rib, down to thoracic muscles, and the rib is resected subperiosteally to provide wide exposure. Blunt dissection separates the peritoneum from the undersurface of the diaphragm and lateral and posterior abdominal walls. With gentle retraction of the lung and abdominal contents, the diaphragm is well visualized and is sectioned circumferentially from the chest wall. This provides an excellent exposure of the anterior aspect of the TL junction. Most procedures can be performed with minimal retraction of lung tissue at this level; thus, OLV is not typically required. Vertebral resection, reconstruction, and stabilization are performed with radiographic guidance. Reconstruction of the diaphragm is important to prevent hernation. This is rare with pure retroperitoneal approaches.

Variant procedure or approach: An 11th rib extrapleural-retroperitoneal approach offers an alternative approach to the TL junction. It provides excellent exposure without the need to incise the diaphragm, resulting in less morbidity and reduced risk of pulmonary complications. Since the pleural cavity is not entered, chest drains and OLV are not needed.

Thoracoscopic spine surgery: This technically challenging procedure is performed in the lateral position with GA, using OLV. Four or more 10–15 mm portals are made, with the working portal centered over the target vertebra. The optical (scope) portal is placed two or three intercostal spaces cranial to the target vertebra. Separate portals anterior to the working channel allow suction/irrigation and retraction. When using **thoracoscopic instrumentation**, hardware is placed through the portals in the chest wall under fluoroscopic guidance. Blood loss must be minimized as hemostasis is difficult with this approach. Since instrumentation requires a wide exposure of the spine, OLV is essential. The major advantages of thoracoscopic surgery include minimal rib retraction; minimal blood loss, with consequent early removal of chest drain; reduced wound pain; early ambulation; and low morbidity. These factors combine to reduce hospital stay.

Usual preop diagnosis: Fractures (usually at the TL junction); scoliosis; primary and metastatic tumors of the spine; pyogenic and tuberculous osteomyelitis; Scheuermann's kyphosis

Summary of Procedures

	Transthoracic (T4-T10)	Transdiaphragmatic (T11-L1),10th Rib	Thoracoscopic
Position	Lateral decubitus + axillary roll		
Incision	Over involved vertebrae	Along 10th rib	3–4 portals (10–15 mm)
Special instrumentation	Anterior thoracic instrumentation/cages		Thoracoscopic spinal instrumentation
Unique considerations	DLT ± OLV		DLT; OLV mandatory
Antibiotics	Cefazolin 1 g iv		
Surgical time	2–6 h		
Closing considerations	Transfer to bed before emer gence. **NB:** sudden move ment may dislodge grafts or implants.		+ May need closure of diaphragm.
EBL	200–5,000 mL; nontumor cases: 200–400 mL		50–200 mL
Postop care	Chest tube to water seal Chest physiotherapy/incen tive spirometer Short ICU stay is usual. Bleeding > 200 mL/h → re-exploration		Shorter period of chest drain/ ICU stay
Mortality	3–5%		
Morbidity	Overall: 5–15% DVT Neurological: 1–2% Infection Vascular injury Sepsis Atelectasis Pneumonia		+ Problems with OLV Conversion to open surgery: 4% – – –
Pain score	7–10	7–10	5–8

Patient Population Characteristics

Age range	12–30 yr (scoliosis surgery); > 40 yr (tumor and infection surgery)
Male:Female	1:1; except for > scoliosis surgery in females
Incidence	20,000/yr
Etiology	Scoliosis, idiopathic (50%); trauma (20%); scoliosis, neuromuscular (15%); infections, tumors (10%); scoliosis, congenital (5%)
Associated conditions	See Etiology

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Anesthetic Considerations

See Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures, p. 124.

Suggested Readings

1. Francaviglia N, Maiello M: Anterolateral techniques for stabilization in the thoracic spine. In: *Operative Neurosurgical Techniques.* Schmidek HH, Sweet WH, eds. WB Saunders, Philadelphia: 2000, 2141–5.

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Posterior Thoracic Spine Surgery

Surgical Considerations

Description: Thoracic laminectomy (midline removal of the lamina) and **costotransversectomy** (off midline removal of the rib head and transverse process) are procedures for decompressing the neural elements of the thoracic spine via a posterior approach. (Commonly used approaches are shown in Fig 1.3-12.)

Thoracic laminectomy is used to treat spinal cord compression due to disc herniation, neoplasm, or trauma. It also is used to gain access to the spinal canal or spinal cord for various intradural mass lesions, including syringomyelia. Thoracic laminectomy is done through a posterior midline incision centered over the involved vertebrae. The paraspinal muscles are retracted subperiosteally from *(Print pagebreak 115)* the spinous processes and laminae on both sides. Laminae are removed piecemeal with rongeurs or drills. Extensive laminectomy involving several segments or requiring removal of facet joints may require stabilization with transpedicular screws or hooks. Intradural procedures are performed with an operating microscope and microneurosurgical instruments. After completion of the intradural procedure, watertight closure of the dura is obtained and tested with Valsalva maneuver (sustained inspiration at 30–40 cmH_2O).

A **transpedicular approach** may be indicated for removal of herniated discs, excision or decompression of tumors, and the treatment of infection involving vertebral bodies. This procedure is performed in the prone position through a posterior midline incision centered over the affected vertebrae. The paraspinal muscles are retracted subperiosteally on both sides to expose laminae and facet joints. Facet joints and the superior half of the involved pedicle are drilled out to expose the lateral limits of the thecal sac and the nerve roots. A laterally herniated disc can be removed in a piecemeal fashion. If required, total removal of the pedicle is done to facilitate adequate bony decompression. Posterior instrumentation by pedicle screws, sublaminar wiring with rods, or a hook-rod construct may be performed.

The **lateral extracavitary approach** is a modification of a **costotransversectomy** and provides access to the anterior and posterior elements of the spine, thereby avoiding the need for a thoracotomy. This approach is performed with the patient in the prone position. A midline skin incision is made three levels above and below the involved vertebrae. The lower part of the incision may be curved over the involved side, if needed. A myocutaneous flap is developed by dissecting the scapular muscles (trapezius, rhomboids, etc.) laterally. Paraspinal muscles are freed from the spinous processes and dorsal spinal elements to enable retraction, which exposes the entire rib cage and dorsal vertebral elements. Subperiosteal resection, from its costovertebral tip to the posterior bend of the appropriate rib is done. The parietal pleura are gently separated from the ribs and the vertebrae to expose the posterolateral aspect of the vertebral bodies. The transverse process, pedicle, and laminae are removed, as required, to permit direct visualization of the cord during decompression of the vertebral body. Discectomy/corpectomy, vertebral reconstruction, and instrumentation are performed as required. Complete spondylectomy and anterior reconstruction is possible with this approach with minimal retraction to the cord. Combined anterior-posterior instrumentation can be used to leverage off each other for deformity correction. At the end of the procedure, the operative field is filled with saline to check for any evidence of air leak. A small chest tube can be placed if an air leak is present. A layered wound closure with drain is performed.

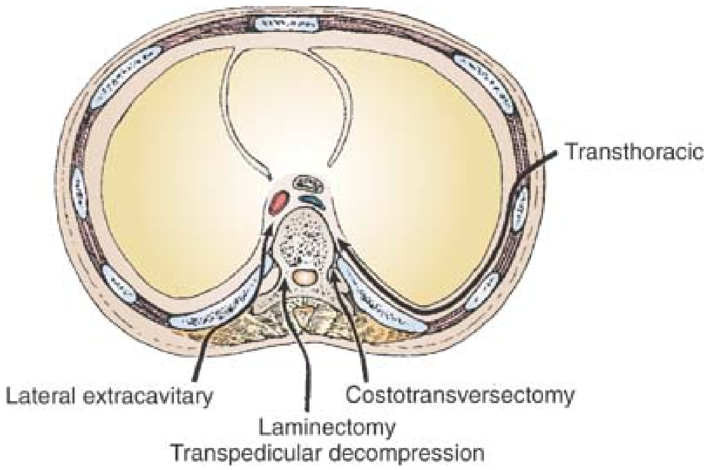

Figure 1.3-12. 12. Surgical approaches to the thoracic spine. (Reproduced with permission from Tindall GT, Cooper PR, Barrow DL: *The Practice of Neurosurgery*, Vol. II. Williams & Wilkins, Philadelphia: 1996.)

Thoracic pedicle screws have largely replaced the older hook-rod construct and **Harrington** rods as the fixation of choice. These can be technically challenging because the thoracic pedicles tend to be rather narrow and variable. Potential complications include injury to surrounding nerves, spinal cord, blood vessels (both local and great vessel), and lung parenchyma.

Usual preop diagnosis: Thoracic radiculopathy (nerve-root compression); thoracic disc disease (herniation or degeneration of thoracic disc); thoracic myelopathy (spinal cord compression); thoracic canal stenosis (degenerative); infections (TB, pyogenic osteomyelitis) and tumors to spine (primary bone tumors or metastatic); intraspinal tumors; syringomyelia

Summary of Procedures

	Thoracic Laminectomy	Transpedicular Approach	Lateral Extracavitary Approach
Position	Prone		
Incision	Posterior midline		; with/without hockey-stick extension
Special instrumentation	Operating microscope± EP monitoring± Pedicle screws/hooks		± anterior and posterior spinal instrumentation
Unique considerations	I.I. localization		
Surgical time	2–3 h	Add 30–45 min for bony/tumor decompression	3–7 h, based on need for anterior bony resection/reconstruction
Closing considerations	Often no cast	TL support/orthosis	
EBL	100–1000 mL	200–1000 mL	300–3000 mL
Postop care	PACU → room		± ICU
Mortality	0–5%		
Morbidity	All < 5% Neurological: Myelopathy Nerve-root injury Massive blood loss CSF leak		
Pain score	6–10	6–10	8–10

Patient Population Characteristics

Age range	18–85 yr (usually 20–60 yr)
Male:Female	1:2
Incidence	Rare
Etiology	Neoplastic; traumatic; congenital; degenerative

(Print pagebreak 116)

Anesthetic Considerations

See Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures, p. 124.

Suggested Readings

1. Fessler RG: Lateral extracavitary and extrapleural approaches to the thoracic and lumbar spine. In: *The Principles of Spine Surgery.* Menezes AH, Sonntag VKH, eds. McGraw-Hill, New York: 1995, 1279–91.

2. Kim DH, Beck CE, Dietz DD, et al: Surgical approaches to the cervicothoracic junction. In: *Operative Neurosurgical Techniques.* Schmidek HH, Sweet WH, eds. WB Saunders, Philadelphia: 2000, 2107–21.

3. Kumar R, Dunsler SB: Surgical management of thoracic disc herniation. In: *Operative Neurosurgical Techniques.* Schmidek HH, Sweet WH, eds. WB Saunders, Philadelphia: 2000, 2122–31.

Anterior Lumbar/Lumbosacral Spine Surgery

Surgical Considerations

Description: The use of anterior procedures is steadily increasing among spine surgeons. Most procedures permit short-segment instrumentation of the spine, which often obviates the need for subsequent posterior fixation. The most significant disadvantage of these procedures involves the risk of injury to the great vessels; thus, these procedures are commonly done in association with a vascular or general surgeon. There is also risk of injury to the peritoneal contents and the neural plexus around the lumbosacral spine. Anterior instrumentation systems generally fall *(Print pagebreak 117)* into three categories: (a) **plating systems** (e.g., Z plating, anterior locking plates, and MACS-TL); (b) **rod systems** (e.g., Kostuik-Harrington, Kaneda, and Moss-Miami); and (c) **interbody devices** (e.g., cages and allografts).

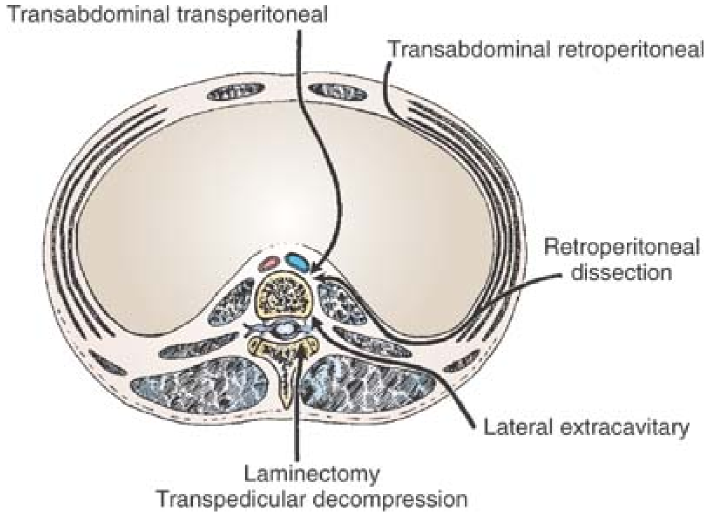

Figure 1.3-13. 13. Surgical approaches to the lumbar spine. (Reproduced with permission from Tindall GT, Cooper PR, Barrow DL: *The Practice of Neurosurgery*, Vol. II. Williams & Wilkins, Philadelphia: 1996.)

An **anterior lumbar interbody fusion** (ALIF) can be done with artificial cages or bone. After exposure of the disc space, the exact midline of the space is marked and verified with fluoroscopy. A spacing guide determines the exact position for pilot holes; and a partial discectomy is performed through these pilot holes, which are distracted and later reamed. Bone or cage is then attached to a specialized implant driver for insertion under fluoroscopic guidance. Harvested bone chips and other fusion enhancers are placed into the cages or around the bone dowel. Anterior lumbar interbody fusion provides immediate mechanical stability and long-term load support, with the ability to heal through the disc space. Its primary disadvantages include bleeding and possible major vessel injury.

A **lumbar artificial disc** can be placed via this approach. The approach is similar to that of the ALIF but instead of placing a bone graft or cage, a mobile prosthetic disc is placed according to manufacturer's instruction. No additional stabilization or bone grafting is required. Accurate placement of this disc is absolutely critical to the success of this procedure. Fluoroscopy is used extensively to ensure this. There is immediate stability and because motion is preserved, early mobilization is recommended.

Anterior instrumentation after ALIF can be done with a variety of screws and/or plates. These include a screw and screw/plate combination to buttress the graft from falling out. Other devices provide plate stabilization across interspaces. These can be used alone or with a posterior stabilization surgery. These add time to the anterior case and run the risk of hardware failure, but have the advantage of potentially improving the overall fusion rate and decreasing the graft related complications.

A **transperitoneal approach** involves laparotomy through a Pfannenstiel's or subumbilical vertical midline incision. After opening the peritoneum, intestines are retracted to expose the anterior aspect of lower lumbar and lumbosacral spine, an exposure that is often difficult to achieve with the retroperitoneal approach. Exposure of L4-L5 disc spaces requires mobilization of the aorta and inferior vena cava, along with its bifurcations.

Variants of the transperitoneal approach: A laparoscopic transperitoneal approach often is used at the L5-S1 level. With the patient supine, Trendelenburg position is used to move the small intestine away from the operative field. The procedure is performed through one 10 mm portal for a 30° endoscope, two 5 mm portals for retraction, and one 20 mm working portal for instruments. For access to the L5-S1 level, the posterior peritoneum is incised at the base of the sigmoid mesocolon with endoscopic scissors. Laparoscopic interbody fusion and instrumentation is performed as required, using specially designed long-alignment tubes, distraction plugs, and a reamer, as in the open procedure. The peritoneum is closed with endoscopic sutures or clips. The major advantages of this technique are related to the minimal manipulation of abdominal viscera required and minimal trauma to the abdominal wall. Additionally, postop pain, recovery time, and length of hospitalization are often less, permitting an early return to the patient's normal activities.

Variants of the retroperitoneal approach: A lateral retroperitoneal approach provides an excellent exposure of the lumbar spine from L1-S1 through a flank incision. The procedure is performed in the lateral decubitus position. The skin incision is made from the lateral border of the paravertebral muscles at the midlumbar level to the lateral border of the rectus abdominis. The incision is angulated below the umbilicus for exposure of the lower lumbar and lumbosacral junction, and is carried down to the peritoneum.

The **supine retroperitoneal approach** is accomplished through a left paramedian incision, and the peritoneum and abdominal contents are retracted. This is one of the most common approaches. Ligation of lumbar intersegmental arteries and tributaries of the iliac vein may be required to allow a direct anterior exposure from L3-S1. An approach surgeon trained in vascular or general surgery can often expose even more. With blunt dissection, the peritoneum is peeled off the lateral and posterior abdominal walls, diaphragm, and iliopsoas, exposing the anterior aspect of the lumbar spine. Vertebral resection and reconstruction are carried out in the routine manner. During this procedure, the great vessels, ureter, and sympathetic trunk need to be protected. Monopolar cautery is avoided, because it can cause injury to the presacral plexus, which can result in retrograde ejaculation.

A **laparoscopic retroperitoneal approach** can be used for performing an anterior lumbar interbody fusion following discectomy in patients with lumbar segmental instability. This procedure is performed in the right lateral decubitus position. A 10–12 mm port is made in the posterior axillary line midway between the 12th rib and iliac crest, and a trochar is advanced into the peritoneum. Retroperitoneal dissection is accomplished by balloon inflation, with 1,000 mL of air or saline, through a trochar. This procedure is carried out under direct vision through the laparoscope. Discectomy, fusion, or instrumentation requires two additional working portals. Retroperitoneal insufflation with CO_2 may be required during the procedure.

(Print pagebreak 118)

Usual preop diagnosis: Degenerative disc disease; segmental instability; vertebral fractures; benign and neoplastic diseases of lumbar spine; vertebral osteomyelitis; TB

Summary of Procedures

	Transperitoneal Instrumentation	Retroperitoneal Instrumentation	Endoscopic Approach
Position	Supine	Supine/lateral decubitus	Right lateral decubitus
Incision	Pfannenstiel's/vertical subumbilical	Flank incision	3–4 ports
Special instrumentation	Z plates, Kaneda instrumentation, MACS-TL, femoral rings, cages; intervertebral disc replacements		Endoscopic instrumentation; balloon dissector
Unique considerations	NG tube, preop bowel prep		
Antibiotics	Cefazolin 1 g iv		
Surgical time	3–4 hrs		
Closing considerations	Transfer to bed while anesthetized. Smooth emergence necessary to avoid graft/implant disruption.		Rapid closure of ports
EBL	200–600 mL	200–5000 mL; nontumor cases: 200–400 mL	100–500 mL
Postop care	PACU → ward; patients with infections/tumors → ICU. Postop ileus common.		
Mortality	Malignancy and sepsis: 1–2% Elective: 1%		–
Morbidity	Neurological injury: 2–6% Vascular injury: 2–15% Retrograde ejaculation: 5–35%	< 5%	–
Pain score	6–7	6–7	4–6

Patient Population Characteristics

Age range	Variable, infant-adult (usually 20–60 yr)
Male:Female	1:1 (usually)
Incidence	Uncommon
Etiology	Degenerative; lumbar segmental instability; neoplastic; traumatic; infectious

(Print pagebreak 119)

Anesthetic Considerations

See Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures, p. 124.

Suggested Readings

1. Harrington FJ, Friehs G, Epstein MH: Surgical management of segmental spinal instability. In: *Operative Neurosurgical Techniques.* Schmidek HH, Sweet WH, eds. WB Saunders, Philadelphia: 2000, 2280–2302.

2. Kostuik JP, Carl A, Ferron S: Anterior Zielke instrumentation for spinal deformity in adults. *J Bone Joint Surg* 1989; 71 (6):898–906.

3. Kozak JA, O'Brien JP: Simultaneous combined anterior and posterior fusion. An independent analysis of a treatment for the disabled low-back pain patient. *Spine* 1990; 15(4):322–8.

4. Leong JCY: Anterior interbody fusion. In: *Lumbar Interbody Fusion.* Lin PM, Gill K, eds. Raven Press, New York: 1989,133–47.

Posterior Lumbar Spine Surgery

Surgical Considerations

Description: Lumbar laminotomy (partial removal of lamina) and **laminectomy** (complete removal of lamina) are procedures for decompressing the neural elements of the lumbar spine via a posterior approach. They can be used to treat lumbar radiculopathy 2° degenerative disc disease (e.g., herniated discs or osteophytes). **Decompressive laminectomy** can be used to treat compression of the cauda equina, usually 2° degenerative disease, congenital stenosis, neoplasm, and, occasionally, trauma. Lumbar laminectomy is also used to gain access to the spinal canal for dealing with intradural tumors, arteriovenous malformations (AVMs), and other spinal cord lesions.

Through a vertical midline incision, the lumbodorsal fascia is exposed, and then the paraspinal muscles are dissected off the spinous process and lamina of the segments intended for decompression. The level may need to be checked by intraop x-ray or fluoroscopy if the surgeon is not able to identify location based on visual confirmation of anatomic level. The bone landmarks are identified and ligamentous attachments are cut. The bone is removed piecemeal with rongeurs, gouges, or power drills. Care is taken not to injure the underlying dura. If a dural tear is found, it usually must be repaired. The surgeon may want a **Valsalva-like maneuver** (sustained inspiration at 30–40 cmH_2O) performed to test the integrity of the repair. If disc is to be removed, the dura is retracted and the annulus incised. The disc is removed piecemeal with a series of curettes and disc-biting rongeurs. There is a risk of damage to retroperitoneal structures (e.g., great vessels or intestines) during this portion of the procedure. More commonly, there may be troublesome epidural bleeding, which may be difficult to control and will necessitate transfusion. Hemostasis is obtained prior to closure. The wound is closed in layers and a drain may be left in the epidural space. The patient is rolled supine onto a bed at the completion of the procedure.

Minimally invasive surgery (MIS) lumbar surgery is performed through a short paramedian incision at the level of the affected disc. Under radiographic guidance, a series of soft tissue dilators are inserted over a previously placed guide wire to create an operative corridor through the paraspinous musculature. A tubular retractor is inserted over the dilators and connected to a flexible support arm assembly. Endoscope or microscope is used to perform laminotomy and discectomy and/or decompressive laminectomy. As the retractor is withdrawn at the end of the procedure, the paraspinal muscles resume their normal anatomic position, obliterating the dead space. Skin margins are closed with subcuticular sutures. Although all the major risks of surgery are still present, the blood loss, postoperative pain, and hospital stay are reduced. In theory, less trauma to the paraspinous muscles compromises less the post-operative function of the spine.

Usual preop diagnosis: Lumbar radiculopathy (nerve-root compression); lumbar disc disease (herniation or degeneration of lumbar discs); lumbar canal stenosis; lateral recess stenosis; neurogenic claudication; herniated disc; metastatic tumor to spine; lumbar spine tumor; lumbar spondylosis (degeneration of lumbar spine); spondylolysis (structural defect in the pars interarticularis of the vertebra); spondylolisthesis (slipping of one vertebra over another)

(Print pagebreak 120)

Summary of Procedures

	Lumber Laminectomy	Lumbar Laminotomy	MIS
Position	Prone		
Incision	Posterior midline		Paramedian port over disc
Special instrumentation	± Operative microscope		Endoscopic instrumentation (optional)

Unique considerations	I.I. localization to assess the correct level		
Antibiotics	Cefazolin 1 g iv		
Surgical time	1–2 h for single level; add 0.5–1 h/additional level	2 h for single level; add 0.5 h/additional level	
EBL	25–500 mL	50–1000 mL	10–50 mL
Postop care	PACU →room		
Mortality	0.5%		
Morbidity	All < 5%: CSF leak Nerve root injury Infection		
	Postop instability		–
	Massive blood loss	–	–
	Injury to retroperitoneal structures	–	–
Pain score	4–7	4–9	3–6

Patient Population Characteristics

Age range	15–85 yr (usually 30–60 yr)
Male:Female	3:2
Incidence	Common
Etiology	Degenerative; traumatic; neoplastic; infectious

Anesthetic Considerations

See Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures, p. 124.

Suggested Readings

1. Finneson BE, Schmidek HH: Lumbar disc excision. In: *Operative Neurosurgical Techniques.* Schmidek HH, Sweet WH, eds. WB Saunders, Philadelphia: 2000, 2219–31.

2. Foley KT, Smith MM, Raja Rampersaud Y: Microendoscopic discectomy. In *Operative Neurosurgical Techniques.* Schmidek HH, Sweet WH, eds. WB Saunders, Philadelphia: 2000, 2246–56.

Posterior Lumbar Fusion and Instrumentation

Surgical Considerations

Description: Posterior lumbar spinal fusion may relieve low-back pain resulting from intervertebral movement. This surgery is often indicated for segmental lumbar instability, spondylolisthesis, or iatrogenic instability due to extensive laminectomy or facetectomy.

The **pedicle screw stabilization** technique provides rigid three-column spinal fixation and is the preferred mode of instrumentation in lumbar spinal surgery (Fig. 1.3-14). Pedicle screws are passed after tapping the entry site, and are fixed with rods or plates on each side of each vertebral segment. The major risks with pedicle screw fixation include screw malposition and nerve-root injury. Pedicle screws may be combined with hooks to provide fixation of the lumbar/thoracolumbar spine, an approach that improves the stability of the construct and minimizes the risk of instrumentation failure. Facet screw stabilization can also be performed to fix levels together. This is usually not used in a stand alone fashion but in combination with anterior fixation. Instrumentation can be placed via percutaneous techniques that decrease blood loss and patient pain; however, complications often go undetected and unseen.

Posterolateral fusion (PLF) is performed through a posterior midline incision, with the paraspinal muscles retracted subperiosteally from the affected lumbar vertebrae. Decompressive laminectomy and discectomy are performed as needed. Posterolateral fusion is performed by decorticating the facet joints and transverse processes. Bone graft is then placed over the decorticated bone. Instrumentation with pedicle screws and plate/rod constructs often is done for stability and to facilitate fusion.

Posterior lumbar interbody fusion (PLIF) consists of a bilateral laminectomy and removal of the inferior facet and the medial portion of the superior facet. The dural sac is retracted, and a total discectomy, together with the removal of cartilaginous end plates, is performed. The anterior disc space is packed with bone graft. Appropriately sized rectangular bone grafts or cages are inserted into the posterior half of the disc space on both sides to provide structural support close to the center of rotation. The nerve roots above and below the disc space should be visualized during the procedure to avoid excessive retraction. Instrumentation with pedicle screws, and a rod/plate construct is often added to facilitate early fusion and ambulation, while preventing the extrusion of the graft. The major advantage of this procedure is that it provides the ability to achieve combined anterior and posterior spinal fusion, while avoiding *(Print pagebreak 122)* the significant morbidity often associated with anterior lumbar surgery. Its major disadvantages include the potential risk of nerve-root injury and compromise of the structural integrity of both facet joints.

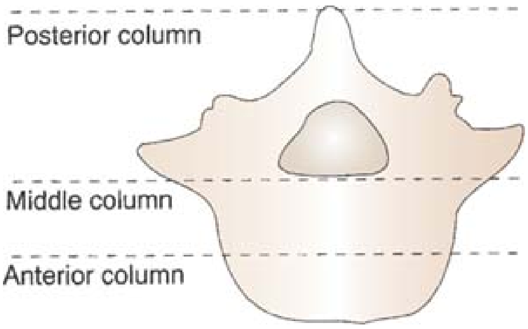

Figure 1.3-14. 14. Spinal three-column model developed by F. Denis. Disruption of elements of two or more columns renders the spine unstable. (Reproduced with permission from Tindall GT, Cooper PR, Barrow DL: *The Practice of Neurosurgery*, Vol. II. Williams & Wilkins, Philadelphia: 1996.)

Tansforaminal lumbar interbody fusion (TLIF) is a modification of the PLIF, using a unilateral posterolateral approach. A **hemilaminectomy and total facetectomy** is performed on one side. A near total discectomy is performed and the first bone graft or cage is inserted across the disc space to the contralateral side. A second bone graft may be inserted into the ipsilateral posterior disc space, and satisfactory placement of the bone grafts is confirmed by fluoroscopy. Supplemental pedicle screw stabilization is indicated as in PLIF. This approach has been adopted to be performed with MIS techniques to afford circumferential lumbar decompression and stabilization via an all posterior approach.

Direct/Extreme Lateral Interbody Fusion (DLIF/XLIF) is an MIS (minimally invasive surgery) procedure performed by having the patient positioned on his/her side where the surgeons approach to the spine will be directly laterally through the retroperitoneal cavity. A specialized retractor is used with multiple long blades that allow for visualization of the spine through the deep layers of tissue. **Neuromonitoring** (EMG nerve root mapping) is essential in the procedure to help avoid nerve injury. Therefore, when this neuromonitoring is being performed, minimal or no paralytic should be used as they may confound monitoring.

Transaxial Lumbo-sacral fusion (Trans1) is an **MIS**
procedure performed by having the patient positioned prone. A complete L5-S1 discectomy and fusion with screw instrumentation is performed. This is done via a 1-cm incision at the base of the sacrum. Specialized tubular dilators and shims protect the visceral contents while a reamer and disc remover tools are used to remove disc. There is minimal blood loss, but occult injury to peritoneal contents including the viscera and blood vessels can occur acutely or present in a delayed fashion.

Usual Preop diagnosis: Lumbar segmental instability; spondylolisthesis; iatrogenic lumbar instability; lumbar disc disease, spondylolysis; mechanical back pain syndrome

Summary of Procedures

	Posterolateral Fusion	PLIF	TLIF (DLIF/XLIF)
Position	Prone		(DLIF/XLIF: Lateral)

Incision	Posterior midline		(DLIF/XLIF: Lateral)
Special instrumentation	Drills, pedicle screws, or hooks	osteotomes, curettes, bone plugs, or cages	angled curettes, angled impactors
Unique considerations	I.I. localization and guidance		(DLIF/XLIF: EMG)
Antibiotics	Cefazolin 1 g iv		
Surgical time	2 h for single level + 0.5 h/additional level	3–4 h for single level + 1 h/additional level	2–3 h for single level + 1 h/additional level
Closing considerations	No brace/lumbosacral corset		
EBL	250–500 mL	250–1000 mL	250–750 mL (less with MIS)
Postop care	PACU → room		
Mortality	0–5%		
Morbidity	Nonunion: 20–30%Nerve-root injuryCSF leakInfectionMassive blood loss	10–20%	
Pain score	6–10	6–10	6–10 (4–7 with MIS)

Patient Population Characteristics

Age range	15–85 yr (usually 30–60 yr)
Male:Female	3:2
Incidence	Common
Etiology	Degenerative; traumatic; neoplastic; infectious

(Print pagebreak 123)

Anesthetic Considerations

See Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures, p. 124.

Combined Anterior and Posterior Instrumentation of the Thoracic and Lumbar Spine

Surgical Considerations

Description: Patients with multilevel vertebral collapse, unstable three-column injuries, severe kyphosis or scoliosis, and/or neoplastic or infective conditions involving multiple spinal levels often require **combined anterior and posterior instrumentation**. This approach provides: (a) complete circumferential neural decompression, which facilitates maximal neuronal recovery; (b) rigid short-segment spinal fixation, which facilitates early ambulation with minimal orthotic support; and (c) maximal correction of deformities with low instrumentation failure and high fusion rates. The combined approach maximizes the possibility of complete resection of the neoplastic or infective process. Patients with major systemic disease or poor marrow reserve may require staged procedures. Combined instrumentation procedures are often lengthy, requiring 5–10 h of surgery. Major related morbidities include infection, wound breakdown, respiratory complications, and significant blood loss. The transition between anterior and posterior procedures should be performed carefully to minimize disruption of the instrumentation.

Usual preop diagnosis: Lumbar segmental instability; spondylolisthesis; iatrogenic lumbar instability; spondylolysis; mechanical back pain syndrome

Summary of Procedures

Position	Prone + supine/lateral

Incision	Posterior midline skin incision + transverse
Special instrumentation	Anterior and posterior spinal implants and instrumentation sets
Unique considerations	OLV for anterior thoracic approaches; radiological localization; intraop EP monitoring (optional)
Antibiotics	Cefazolin 1 g
Surgical time	4–10 h
EBL	500–5000 mL
Postop care	PACU → room; sometimes needs short ICU stay.
Mortality	0–3%
Morbidity	Respiratory problems: atelectasis, pneumonia InfectionBone graft dislodgement
Pain score	7–10

Patient Population Characteristics

Age range	15–85 yr (usually 30–60 yr)
Male:Female	3:2
Incidence	Common
Etiology	Congenital, degenerative; traumatic; neoplastic; infectious >; infectious

(Print pagebreak 124)

Suggested Readings

1. Denis FF: The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine* 1983; 8:817–31.

2. Harrington FJ, Friehs G, Epstein MH: Surgical management of segmental spinal instability In *Operative Neurosurgical Techniques.* Schmidek HH, Sweet WH, eds. WB Saunders, Philadelphia: 2000, 2280–2302.

3. Leong JCY: Anterior interbody fusion. In: *Lumbar Interbody Fusion.* Lin PM, Gill K, eds. Raven Press, New York: 1989, 133–47.

4. Lowe TG, Tahernia D: Unilateral transforaminal posterior lumbar interbody fusion. *Clin Ortho* 2002; 394:227–36.

5. Sundaresan N, Steinberger AA, Moore F, et al: Surgical management of primary and metastatic tumors of the spine. In: *Operative Neurosurgical Techniques.* Schmidek HH, Sweet WH, eds. WB Saunders, Philadelphia: 2000, 2146–70.

Anesthetic Considerations for Thoracolumbar Neurosurgical Procedures

(Procedures covered: anterior/posterior thoracic spine surgery; anterior lumbar/lumbosacral spine surgery; posterior lumbar spine surgery; posterior lumbar fusion and instrumentation; combined anterior/posterior instrumentation of the thoracic and lumbar spine)

Preoperative

Surgery of the lumbar or thoracic spine is common as a result of a variety of spinal disorders, including herniation of lumbar or thoracic intervertebral disks causing compression of the adjacent spinal cord or nerve roots; spinal stenosis from bony overgrowth causing compression of the nerve roots or spinal cord; spondylolisthesis; traumatic injury to the spine; and removal of a spinal tumor or placement of a shunt from a spinal cord cyst into the subarachnoid or peritoneal spaces. Because these diseases span a wide age range, the patients may be healthy, or they may have severe cardiovascular and/or respiratory disorders. Generally, the surgical incision is made in the thoracic or lumbar region, but the surgeon may elect to approach a lumbar disk retroperitoneally using an abdominal or flank incision. Sometimes both anterior and posterior approaches are used sequentially. Finally, some anterior abdominal or thoracic procedures are performed thorascopically.

Neurologic	Patients with a herniated disk or spinal stenosis generally complain of pain, often in the pelvis or radiating down one or both legs. As nerve or spinal cord compression continues, patients develop motor weakness and atrophy of muscle groups in the legs as well as sensory deficits and/or bowel/bladder dysfunction. These changes also may result from a spinal cord tumor or cyst, so an MRI must be obtained to establish the cause. The MRI may be enhanced by the use of gadolinium or other contrast material. **Tests:** MRI
Hematologic	Blood loss may be substantial if the surgeon plans both an anterior and posterior approach in the same patient, or if the operation includes both spinal cord decompression and posterior spinal instrumentation. For these operations, at least 2 U autologous, directed-donor, or bank blood should be available at all times. Consideration should also be given to utilizing a cell saving device. Many of these patient will have been taking aspirin or NSAIDs, which may have been stopped ≤ 1 wk before surgery, and bleeding can be excessive even if coagulation studies are normal.
Laboratory	Preop Hct if autologous donations made and to assess baseline. Other tests as indicated from H&P.
Premedication	Adequate premedication is important. Many of these patients will have had prior back operations and dread having another one. Also, they often come to the preop suite complaining of pain because they were instructed not to take their daily analgesic medication. Midazolam 2–4 mg and sometimes meperidine 20–30 mg will increase their preop comfort level.

(Print pagebreak 125)

Intraoperative

Anesthetic technique: GA is almost invariably used for these operations because it maximizes patient comfort, provides airway control, and permits use of controlled hypotension. Spinal and epidural anesthesia are, in principle, excellent techniques for lumbar surgery, particularly for removal of a lumbar intervertebral disc, but they are seldom used because of the medicolegal concern that the regional anesthetic may be blamed for a new neurological deficit, if one should occur as a result of the surgery. Regional anesthesia is generally not suitable for lumbar fusion or removal of a spinal cord tumor or cyst because the duration of operation is usually unpredictable, and may be prolonged.

Induction	Standard induction (p. B-2). Use of a wire-reinforced tube should be considered if the patient is to be turned prone to avoid tube kinking and occlusion. If the surgeon elects to approach isolated disease of the thoracic spine through the chest, a DLT will be necessary to deflate the lung on the operative side Avoid use of N_2O for thorascopic or anterior intra- or retroperitoneal approaches to prevent hypoxemia and bowel enlargement with impingement on the operative site.
	Standard maintenance (see p. B-2). A combination of N_2O, opiate, sevoflurane or isoflurane, and NMB will provide adequate anesthesia. Once exposure is completed with the posterior approach, muscle relaxation is no longer needed. If an anterior and then a posterior approach are to be used in the same patient, one can either move the patient to a gurney after the anterior portion is completed, and then roll the patient onto the same operating table, or transfer the patient from one OR table to another. Another alternative is to perform the operation on a Jackson table, which allows the patient to be

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Maintenance	turned from supine to prone without having to move them. If this table is used, it is advisable for the anesthesiologist to disconnect all iv lines and electrical wires so they are not inadvertently pulled out during the 180° rotation. For thoracscopic or anterior abdominal approaches, neuromuscular blockade should be maintained until the spine surgery is complete and closure is under way. If both SSEP and motor evoked potentials are to be monitored, which is standard in scoliosis surgery, the anesthetic management must be tailored to avoid the use of nitrous oxide or volatile agents. The usual technique is total intravenous anesthesia (TIVA), generally using continuous infusions of propofol (75–200 mcg/kg/min) and remifentanil (0.1–0.5 mcg/kg/min). The higher doses of both are used at the start of the anesthetic, and gradually tapered over time to the lower doses. Depending upon the duration of the operation, it is advisable to terminate the propofol 30–60 min before its conclusion. The remifentanil will need to be continued in low dose until the closure is complete. Be prepared to administer fentanyl to provide prompt analgesia until a blood level of longer acting opiates (morphine, dihydromorphone) can be established. During induction in these patients, it is prudent to administer midazolam 5 mg or more to prevent recall until the propofol and remifentanil blood levels can be established. Also, it is useful to administer a small dose of rocuronium (20–30 mg) or succinylcholine to facilitate endotracheal intubation. After the baseline SSEP and motor evoked potentials have been established, some surgeons will request NMB during dissection of the muscles from the bones. This can be accomplished safely with rocuronium (20–40 mg).	
Emergence	Standard emergence (p. B-3), after the patient has been returned to the supine position on a bed or gurney. If the intubation was difficult, or the operation was prolonged and airway edema or respiratory depression is possible, it may be advisable to leave the patient's trachea intubated overnight.	
Blood and fluid requirements	iv: 16–18 ga × 1 NS/LR @ 5 mL/kg/h up to a maximum of 40 mL/kg.	To perhaps lessen the chance of postop blindness from ischemic optic neuropathy, do not administer more than 40 mL/kg of crystalloid regardless of the duration of surgery if the operation is performed with the patient in the prone position. If additional fluid is needed, administer hetastarch 6% up to a maximum of 20 mL/kg, albumin 5% or blood. Blood transfusion is usually necessary when there has been extensive bony decompression and fusion. Cell Saver® is used by some if large blood loss is anticipated.
Control of blood loss	Controlled hypotension	In the absence of severe cord compression, modest decreases in BP are helpful to ↓ blood loss when extensive surgery is anticipated. This may be accomplished with combinations of sevoflurane or isoflurane and opiates, or by the use of α and β-blockers (e.g., labetalol, esmolol) and SNP. BP values 20% the patient's lowest recorded pressure when awake are usually satisfactory, but should not be 60 mmHg MAP in young adults or 80 mmHg in elderly patients. After the bony dissection is complete, the benefit of controlled ↓ BP wanes, and a more normal BP is advisable.
	Standard monitors (see p. B-1). ± Arterial line	For simple back surgery, standard monitors are sufficient. If controlled ↓ BP or if an extensive posterior or anterior and posterior approach are planned, an arterial catheter is essential to monitor BP, and a CVP catheter is recommended for infusion of vasoactive drugs and monitoring of CVP.

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Monitoring	± CVP line ± Urinary catheter	A urinary drainage catheter is also desirable if surgery is expected to last several h or substantial fluid shifts are anticipated. Do not administer excessive crystalloid volumes to promote urine output. For reasons not yet determined, urine output is often less than expected when patients are positioned prone. These patients will not develop severe renal insufficiency because of decreased urine output during surgery.
Positioning	and pad pressure points. eyes and ears frequently. breasts and genitals. free abdominal movement. Neutral C-spine	Except for syringoperitoneal shunts, which are performed with the patient in the lateral position, patients are positioned prone on a Wilson frame or on bolsters, or in the knee-chest position on an Andrews table. The head is placed in a neutral position using a foam pillow with cutouts for the eyes, nose, and chin (e.g., Andrews Gentle-Rest pillow). Whenever possible maintain the patient's head at or above the level of the heart to lessen the development of facial and intracranial edema. If the patient also has cervical disk disease, it is advisable to place a cervical collar before turning the patient prone. Other options are to use a horseshoe headrest or place the head in Gardner-Wells tongs or in a Mayfield head clamp. When placed in a headrest, the ET should be strain-relieved near the mouth with a penrose drain tied around the head clamp to prevent gradual extubation due to gravity. Elbows, knees, feet, and any pressure points need padding.
Complications	↓ BP Bowel or ureteral injury Hemorrhage	↓ BP may be 2° abdominal compression and ↓venous return. ↑ blood loss may occur 2° epidural vein engorgement, abdominal compression or vascular injury.

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Postoperative

Complications	↓ BP Hemorrhage Nerve-root injury Blindness	Any acute drop in BP may be due to a vascular injury, either obvious (segmental artery) or occult (deep great vessel injury) until proven otherwise. The source of bleeding should be identified. If ↓BP persists despite vigorous blood and fluid administration, suspect bleeding into the retroperitoneal space or abdomen. Alert the surgeon of this possibility and prepare for immediate exploration.
Pain management	PCA (p. C-3) Epidural opiate (p. C-2)	Some surgeons may place a mixture consisting of Duramorph ± fentanyl, ± steroid, in Avitene® hemostat into the epidural space before closing. This provides excellent postop analgesia. If postop bleeding is suspected, serial Hct

Tests	Hct; document neurological status.	determinations are useful.

Suggested Reading

1. Sonntag VRH, Hadley MN: Surgical approaches to the thoracolumbar spine. In *Clinical Neurosurgery*, Vol 36. Williams & Wilkins, Baltimore: 1990, 168–85.