CAMPBELL'S OPERATIVE ORTHOPAEDICS

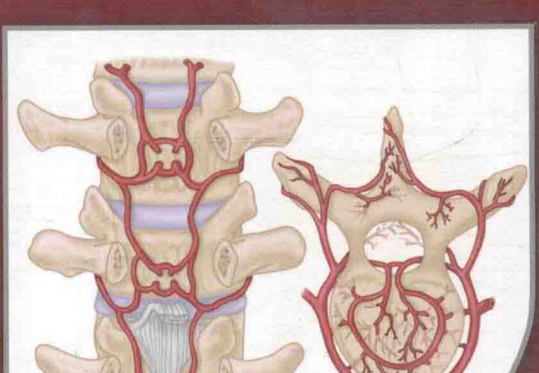
TWELFTH EDITION

英文影印版

坎贝尔骨科手术学

第 12 版

脊柱分册



S. Terry Canale • James H. Beaty

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影印版序

《坎贝尔骨科手术学》由世界级专家联袂编撰，自1939年问世以来，这部巨著伴随了一代又一代骨科医生的成长，成为全球骨科医生不可或缺的参考书，是骨科学领域最权威的著作，同样也被我国广大骨科医生奉为经典。

2013年初，Elsevier 出版公司出版了这部骨科学“圣经”的最新版本——第12版，作为一名旧版的老读者，再次切身感受到该书的严谨、科学。新版分4卷，19部分，89章。介绍了骨科手术的基本原理，详细讲述了髋、膝、踝、肩肘关节置换术，以及截肢与感染、骨肿瘤、先天性异常和发育异常、脊柱损伤、运动损伤、成人骨折与脱位、周围神经损伤、手和足踝部损伤的各种手术技术、儿童神经系统疾病及骨折与脱位。此外，还介绍了关节镜及显微外科的先进手术技术和经验。本书的特点是详细地叙述了各种手术的细节，包括手术指征、手术前后处理和并发症防治的原则、各种技巧和注意事项，还配备详细的手术图解，编排合理，非常符合临床骨科医生的学习需要。

新版《坎贝尔骨科手术学》达到了“去粗存精”、“去伪存真”之目的，删除了第11版中一些陈旧的观点和方法，吸取了近年来的最新成果，除保留作为“金标准”的经典技术之外，还介绍了大量新技术、新装备，并强调了微创骨科技术，对当前及今后一段时间的骨科临床和科研具有非常重要的指导作用。新版配图7000余幅，其中很多图片为重新绘制，直观展现骨科手术技术要点。

随着我国骨科界对外交流的日益增加，以及骨科医生英语水平的整体提高，越来越多的骨科医生希望能够尽快读到原汁原味的国外经典之作，恰逢此时，天津科技翻译出版有限公司在第12版《坎贝尔骨科手术学》刚刚推出之际，便立即引进了这部巨著的影印版本，几乎与原版同步出版，让国内读者在第一时间即能零距离地领略到这部经典原著的风采，更直接地分享这些国际骨科权威专家们对骨科手术学的真知灼见！考虑到读者的需求，出版社将影印版设计为两种形式出版。一种是如原版书，做成精装四卷的形式，另一种则按照骨科学的分支，将这套专著做成平装版，分为14个分册，可以让读者各取所需。此外，影印版均采用优质铜版纸印刷，保持了原版书的风貌，其性价比之高在近些年的影印版书中亦不多见。

最后，借此书出版之际，愿全体骨科同仁不断更新知识、锻炼技能，更好地为广大患者解除病痛，为我国的骨科事业的快速、健康发展做出更大的贡献！

中国工程院院士

PREFACE

As with every edition of this text, we have been amazed by the multitude of new techniques, new equipment, and new information generated by our orthopaedic colleagues worldwide. The emphasis on less-invasive surgical techniques for everything from hallux valgus correction to spine surgery to total joint arthroplasty has produced a variety of new approaches and new devices. The use of arthroscopy and endoscopy continues to expand its boundaries. We have attempted to include the latest orthopaedic procedures, while retaining many of the classic techniques that remain the "gold standards."

Some of the changes in this edition that we believe will make it easier to use include the complete redrawing of the thousands of illustrations, the combining of some chapters and rearrangement of others to achieve a more logical flow of information, the addition of several new chapters, and the placement of references published before 2000 on the website only. Full access to the text and to an increased number of surgical videos is available on ExpertConsult.com, which is included with the purchase of the text. This combination of traditional and electronic formats, we believe, will make this edition of *Campbell's Operative Orthopaedics* easily accessible and useable in any situation, making it easier for orthopaedists to ensure the highest quality of patient care.

The true "heroes" of this work are our dedicated authors, who are willing to endure time away from their families and their practices to make sure that their contributions are as up-to-date and informational as possible. The revision process is lengthy and arduous, and we are truly appreciative of the time and effort expended by all of our contributors. As always, the personnel of the Campbell Foundation—Kay Daugherty, Barry Burns, Linda Jones, and Joan Crowson—were essential in getting the ideas and information from 40 authors into a workable form. The progress of the book was marked by the proliferation of paper-stuffed file folders spread across their offices. Managing to transform all of that raw material into readable text and illustrative images is always an amazing accomplishment. Our thanks, too, to the individuals at Elsevier publishing who provided much guidance, encouragement, and assistance: Taylor Ball, Content Development Editor; Dolores Meloni, Executive Content Strategist; Mary Gatsch, Publishing Director; and John Casey, Project Manager.

We are most grateful to our families, especially our wives, Sissie Canale and Terry Beaty, who patiently endured our total immersion in the publication process.

The individuals who often are overlooked, or at least not recognized often enough, are the community of orthopaedic surgeons to whom we are indebted for their expertise and innovation that make a textbook such as ours necessary. As Dr. Campbell noted in the preface to the first edition of this text, "In some of the chapters we have drawn heavily from authoritative articles on special subjects; the author gratefully acknowledges his indebtedness for this material." We are indeed grateful, and honored and humbled, to be the conduit of such remarkable skill and knowledge that help us to make the most current information available to our readers. We hope that this latest edition of *Campbell's Operative Orthopaedics* will prove to be a valuable tool in providing the best of care to orthopaedic patients.

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CONTENTS

PART XII

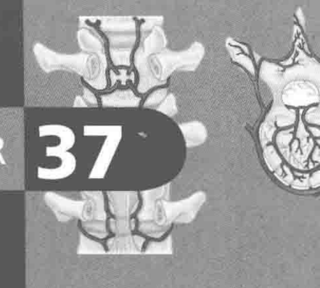
THE SPINE

List of Techniques

SPINAL ANATOMY AND SURGICAL APPROACHES

George W. Wood II

CHAPTER 37



ANATOMY OF VERTEBRAL COLUMN

The vertebral column comprises 33 vertebrae divided into five sections (seven cervical, 12 thoracic, five lumbar, five sacral, and four coccygeal) (Fig. 37-1). The sacral and coccygeal vertebrae are fused, which typically allows for 24 mobile segments. Congenital anomalies and variations in segmentation are common. The cervical and lumbar segments develop lordosis as an erect posture is acquired. The thoracic and sacral segments maintain kyphotic postures, which are found in utero, and serve as attachment points for the rib cage and pelvic girdle. In general, each mobile vertebral body increases in size when moving from cranial to caudal. A typical vertebra comprises an anterior body and a posterior arch that enclose the vertebral canal. The neural arch is composed of two pedicles laterally and two laminae posteriorly that are united to form the spinous process. To either side of the arch of the vertebral body is a transverse process and superior and inferior articular processes. The articular processes articulate with adjacent vertebrae to form synovial joints. The relative orientation of the articular processes accounts for the degree of flexion, extension, or rotation possible in each segment of the vertebral column. The spinous and transverse processes serve as levers for the numerous muscles attached to them. The length of the vertebral column averages 72 cm in men and 7 to 10 cm less in women. The vertebral canal extends throughout the length of the column and provides protection for the spinal cord, conus medullaris, and cauda equina.

ANATOMY OF SPINAL JOINTS

The individual vertebrae are connected by joints between the neural arches and between the bodies. The joints between the neural arches are the zygapophyseal joints or facet joints. They exist between the inferior articular process of one vertebra and the superior articular process of the vertebra immediately caudal. These are synovial joints with surfaces covered by articular cartilage, a synovial membrane bridging the margins of the articular cartilage, and a joint capsule enclosing them. The branches of the posterior primary rami innervate these joints.

The interbody joints contain specialized structures called *intervertebral discs*. These discs are found throughout the vertebral column except between the first and second cervical vertebrae. The discs are designed to accommodate movement, weight bearing, and shock by being strong but deformable. Each disc contains a pair of vertebral end plates with a central nucleus pulposus and a peripheral ring of anulus fibrosus sandwiched between them. They form a secondary cartilaginous joint or symphysis at each vertebral level.

The vertebral end plates are 1-mm-thick sheets of cartilage-fibrocartilage and hyaline cartilage with an increased ratio of fibrocartilage with increasing age. The nucleus pulposus is a semifluid mass of mucoid material, 70% to 90% water, with proteoglycan constituting 65% and collagen constituting 15% to 20% of the dry weight. The anulus fibrosus consists of 12 concentric lamellae, with alternating

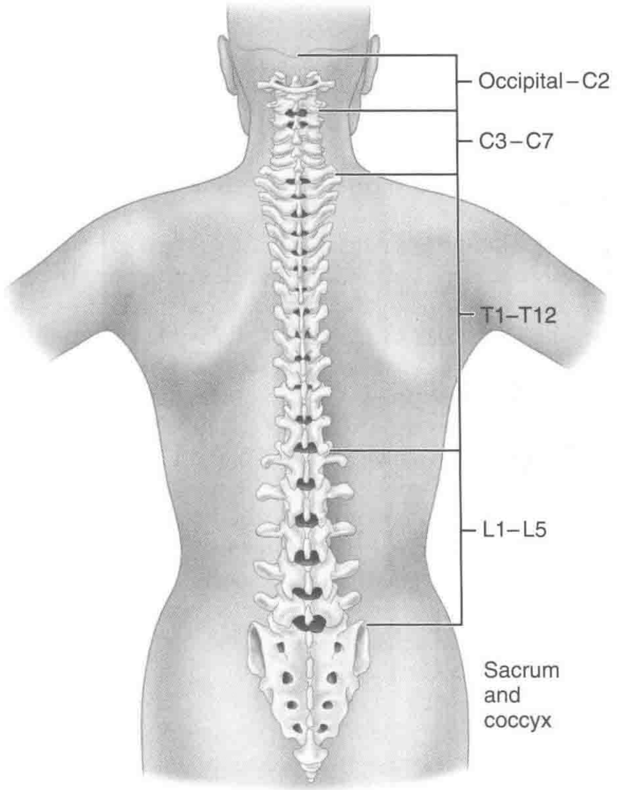


FIGURE 37-1 Vertebral column: upper cervical vertebrae (occiput to C2), lower cervical vertebrae (C3-7), thoracic vertebrae (T1-12), lumbar vertebrae (L1-5), sacrum, and coccyx.

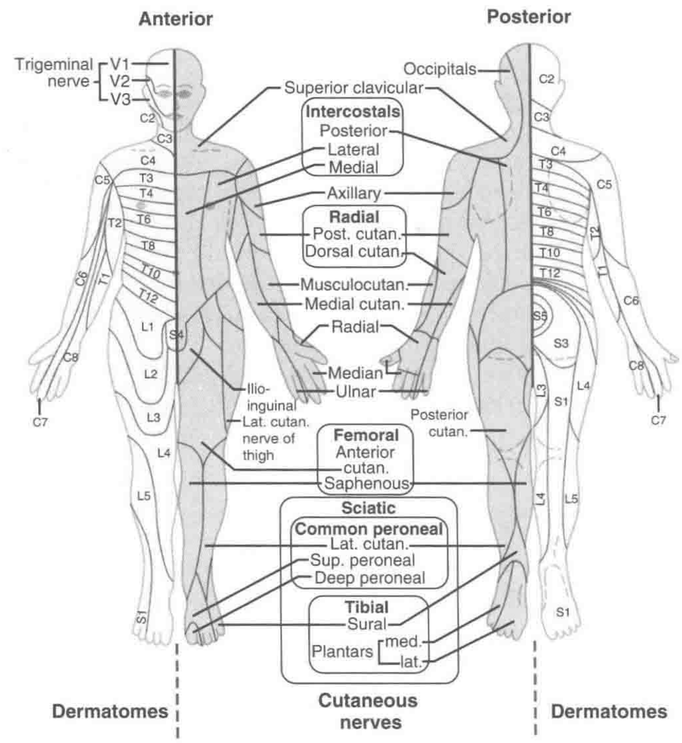


FIGURE 37-2 Dermatomal and sensory distribution. (Redrawn from Patton HD, Sundsten JW, Crill WE, et al, editors: *Introduction to basic neurology*, Philadelphia, 1976, WB Saunders.)

orientation of collagen fibers in successive lamellae to withstand multidirectional strain. The anulus is 60% to 70% water, with collagen constituting 50% to 60% and proteoglycan about 20% of the dry weight. With age, the proportions of proteoglycan and water decrease. The anulus and nucleus merge in a junctional zone without a strict demarcation. The discs are the largest avascular structures in the body and depend on diffusion from a specialized network of end plate blood vessels for nutrition.

ANATOMY OF SPINAL CORD AND NERVES

The spinal cord is shorter than the vertebral column and terminates as the conus medullaris at the second lumbar vertebra in adults and the third lumbar vertebra in neonates. From the conus, a fibrous cord called the *filum terminale* extends to the dorsum of the first coccygeal segment. The spinal cord is enclosed in three protective membranes—the pia, arachnoid, and dura mater. The pia and arachnoid membranes are separated by the subarachnoid space, which contains the cerebrospinal fluid. The spinal cord has enlargements in the cervical and lumbar regions that correlate with the brachial plexus and lumbar plexus. Within the spinal cord are tracts of ascending (sensory) and descending (motor) nerve fibers. These pathways typically are arranged with cervical tracts located centrally and thoracic, lumbar, and sacral tracts located progressively peripheral. This accounts for the clinical findings of central cord syndrome and syrinx. Understanding the location of these tracts aids in understanding different spinal cord syndromes (Figs. 37-2 and 37-3; Table 37-1).

Spinal nerves exit the canal at each level. Spinal nerves C2-7 exit above the pedicle for which they are named (the C6 nerve root exits the foramen between the C5 and C6 pedicles). The C8 nerve root exits the foramen between the C7 and T1 pedicles. All spinal nerves caudal to C8 exit the foramen below the pedicle for which they are named (the L4 nerve root exits the foramen between the L4 and L5 pedicles). The final dermatomal and sensory nerve distributions are shown in Figure 37-2. Because the spinal cord is shorter than the vertebral column, the spinal nerves course more vertically as one moves caudally. Each level gives off a dorsal (sensory) root and a ventral (mostly motor) root, which combine to form the mixed spinal nerve. The dorsal root of each spinal nerve has a ganglion located near the exit zone of each foramen. This dorsal root ganglion is the synapse point for the ascending sensory cell bodies. This structure is sensitive to pressure and heat and can cause a dysesthetic pain response if manipulated.

ANATOMY OF CERVICAL, THORACIC, AND LUMBAR PEDICLES

Numerous studies have documented the anatomical morphology of the cervical, thoracic, and lumbar vertebrae. Advanced internal fixation techniques, including pedicle screws, have been developed and used extensively in spine surgery, not only for traumatic injuries but also for degenerative conditions. As the role for anterior and posterior spinal instrumentation continues to evolve, understanding the morphological characteristics of the human vertebrae is crucial in avoiding complications during fixation.

Placement of screws in the cervical pedicles is controversial and carries more risk than anterior plate or lateral mass fixation. Although cervical pedicles can be suitable for screw fixation, uniformly sized cervical pedicle screws cannot be used at every level. Screw placement in the pedicles at C3, C4, and C5 requires smaller screws (<4.5 mm) and more care in placement than those of the other cervical vertebrae. CT measurements of cervical pedicle morphology found that C2 and C7 pedicles had larger mean interdiameters than all other cervical vertebrae, and that C3 had the smallest mean interdiameter. The outer pedicle width-to-height ratio increased from C2 to C7, indicating that pedicles in the upper cervical spine (C2-4) are elongated, whereas pedicles in the lower cervical spine (C6-7) are rounded. It also is crucial to know that cervical pedicles angle medially at all levels, with the most medial angulation at C5 and the least at C2 and C7. The pedicles slope upward at C2 and C3, are parallel at C4 and C5, and are angled downward at C6 and C7.

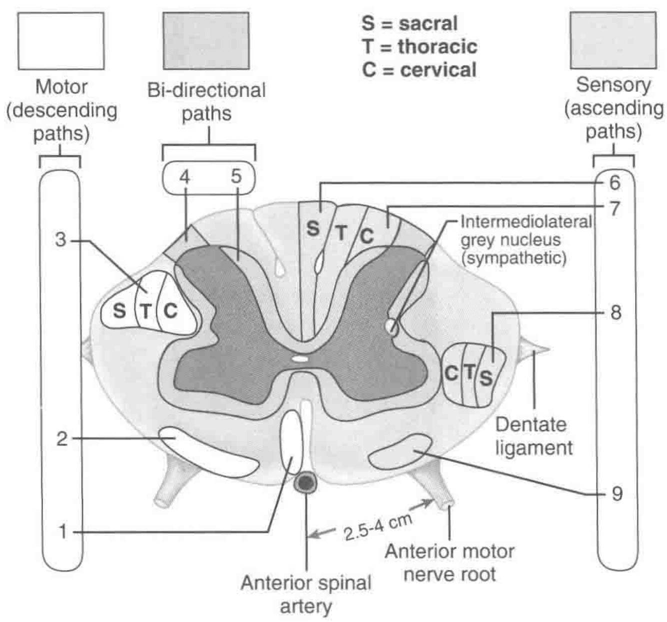


FIGURE 37-3 Schematic cross section of cervical spinal cord. (Redrawn from Patton HD, Sundsten JW, Crill WE, et al, editors: *Introduction to basic neurology,* Philadelphia, 1976, WB Saunders.)

The vertebral artery from C3 to C6 is at significant risk for iatrogenic injury during pedicle screw placement. The pedicle cortex is not uniformly thick. The thinnest portion of the cortex (the lateral cortex) protects the vertebral artery, and the medial cortex toward the spinal cord is almost twice as thick as the lateral cortex. Variations in the course of the vertebral artery also place it at risk during placement of pedicle screws. At the C2 and C7-T1 levels, the vertebral artery is less at risk during pedicle screw fixation. The vertebral artery follows a more posterior and lateral course at C2, whereas at C7-T1 it is outside the transverse foramen.

Pedicle dimensions and angles change progressively from the upper thoracic spine distally. A thorough knowledge of these relationships is important when considering the use of the pedicle as a screw purchase site. A study of 2905 pedicle measurements made from T1 to L5 found that pedicles were widest at L5 and narrowest at T5 in the horizontal plane (Fig. 37-4). The widest pedicles in the sagittal plane were at T11, and the narrowest were at T1. Because of the oval shape of the pedicle, the sagittal plane width was generally larger than the horizontal plane width. The largest pedicle angle in the horizontal plane was at L5. In the sagittal plane, the pedicles angle caudad at L5 and cephalad at L3-T1. The depth to the anterior cortex was significantly longer along the pedicle axis than along a line parallel to the midline of the vertebral body at all levels except T12 and L1.

TABLE 37-1 Ascending and Descending (Motor) Tracts

NUMBER (See Fig. 37-3)	PATH	FUNCTION	SIDE OF BODY
1	Anterior corticospinal tract	Skilled movement	Opposite
2	Vestibulospinal tract	Facilitates extensor muscle tone	Same
3	Lateral corticospinal (pyramidal tract)	Skilled movement	Same
4	Dorsolateral fasciculus	Pain and temperature	Bidirectional
5	Fasciculus proprius	Short spinal connections	Bidirectional
6	Fasciculus gracilis	Position/fine touch	Same
7	Fasciculus cuneatus	Position/fine touch	Same
8	Lateral spinothalamic tract	Pain and temperature	Opposite
9	Anterior spinothalamic tract	Light touch	Opposite

Modified from Patton HD, Sundsten JW, Crill WE, Swanson PD, editors: *Introduction to basic neurology,* Philadelphia, 1976, WB Saunders.

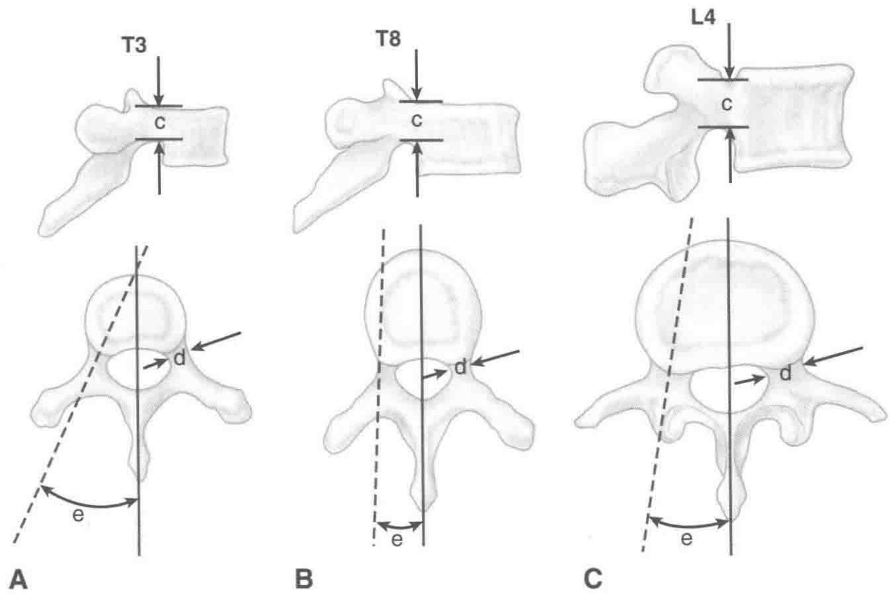


FIGURE 37-4 Pedicle dimensions of T3 **(A)**, T8 **(B)**, and L4 **(C)** vertebrae. Vertical diameter (c) increases from 0.7 to 1.5 cm, horizontal diameter (d) increases from 0.7 to 1.6 cm with minimum of 0.5 cm in T5. Direction is almost sagittal from T4 to L4. Angle (e) seldom extends beyond 10 degrees. More proximally, direction is more oblique: T1 = 36 degrees, T2 = 34 degrees, T3 = 23 degrees. L5 is oblique (30 degrees) but is large and easy to drill. (Redrawn from Roy-Camille R, Saillant G, Mazel CH: Plating of thoracic, thoracolumbar, and lumbar injuries with pedicle screw plates, *Orthop Clin North Am* 17:147, 1986.)

The thoracic pedicle is a convoluted, three-dimensional structure that is filled mostly with cancellous bone (62% to 79%). Panjabi et al. showed that the cortical shell is of variable density throughout its perimeter and that the lateral wall is significantly thinner than the medial wall. This seemed to be true for all levels of thoracic vertebrae.

The locations for screw insertion have been identified and described in several studies. The respective facet joint space and the middle of the transverse process are the most important reference points. An opening is made in the pedicle with a drill or hand-held curet, after which a self-tapping screw is passed through the pedicle into the vertebral body. The pedicles of the thoracic and lumbar vertebrae are tubelike bony structures that connect the anterior and posterior columns of the spine. Medial to the medial wall of the pedicle lies the dural sac. Inferior to the medial wall of the pedicle is the nerve root in the neural foramen. The lumbar roots usually are situated in the upper third of the foramen; it is more dangerous to penetrate the pedicle medially or inferiorly as opposed to laterally or superiorly.

We use three techniques for localization of the pedicle: (1) the intersection technique, (2) the pars interarticularis technique, and (3) the mammillary process technique. It is important in preoperative planning to assess individual spinal anatomy with the use of high-quality anteroposterior and lateral radiographs of the lumbar and thoracic spine and axial CT at the level of the pedicle. In the lumbar spine, coaxial fluoroscopy images are a reliable guide to the true bony cortex of the pedicle. The intersection technique is perhaps the most commonly used method of localizing the pedicle. It involves dropping a line from the lateral aspect of the facet joint, which intersects a line that bisects the transverse process at a spot overlying the pedicle (Figs. 37-5 and 37-6). The pars interarticularis is the area of bone where the pedicle connects to the lamina. Because the laminae and the pars interarticularis can be identified easily at surgery, they provide landmarks by which a pedicular drill starting point can be made. The mammillary process technique is based on a small prominence of bone at the base of the transverse process. This mammillary process can be used as a starting point for transpedicular drilling. Usually the mammillary process is more lateral than the intersection technique starting point, which also is more lateral than the pars interarticularis starting point. With this in mind, different angles must be used when drilling from these sites. With the help of preoperative CT scanning at the level of the pedicle and intraoperative

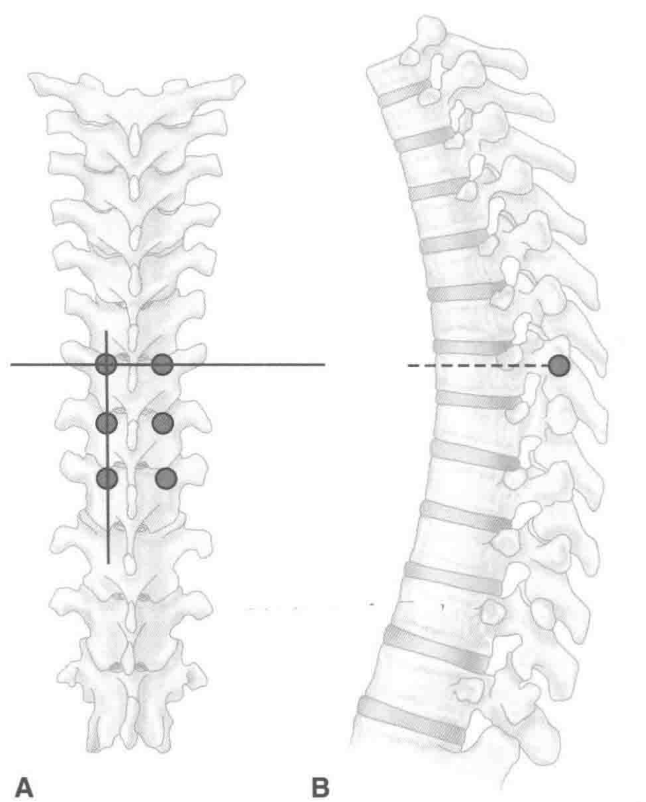


FIGURE 37-5 Pedicle entrance point in thoracic spine at intersection of lines drawn through middle of inferior articular facets and middle of insertion of transverse processes (1 mm below facet joint). **A,** Anteroposterior view. **B,** Lateral view. (Redrawn from Roy-Camille R, Saillant G, Mazel CH: Plating of thoracic, thoracolumbar, and lumbar injuries with pedicle screw plates, *Orthop Clin North Am* 17:147, 1986.)

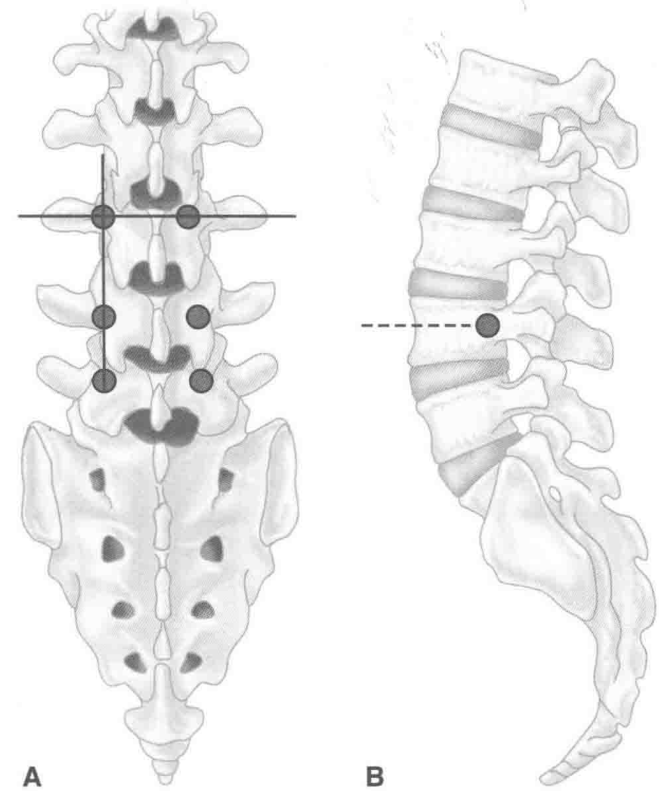


FIGURE 37-6 Pedicle entrance point in lumbar spine at intersection of two lines. On typical bony crest, it is 1 mm below articular joint. **A,** Anteroposterior view. **B,** Lateral view. (Redrawn from Roy-Camille R, Saillant G, Mazel CH: Plating of thoracic, thoracolumbar, and lumbar injuries with pedicle screw plates, *Orthop Clin North Am* 17:147, 1986.)

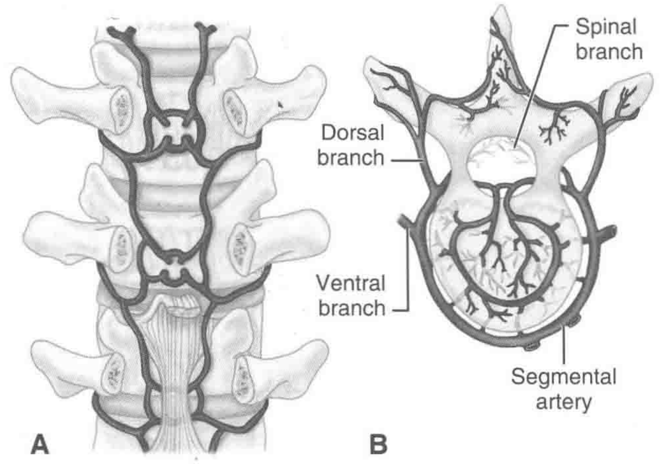


FIGURE 37-7 Vertebral blood supply. **A,** Posterior view; laminae removed to show anastomosing spinal branches of segmental arteries. **B,** Cross-sectional view; anastomosing arterial supply of vertebral body, spinal canal, and posterior elements. (Redrawn from Bullough PG, Oheneba BA: *Atlas of spinal diseases,* Philadelphia, 1988, JB Lippincott.)

radiographs, the angle of the pedicle to the sagittal and horizontal planes can be determined.

CIRCULATION OF SPINAL CORD

The arterial supply to the spinal cord has been determined from gross anatomical dissection, latex arterial injections, and intercostal arteriography. Dommisse contributed significantly to knowledge of the blood supply, stating that the principles that govern the blood supply of the cord are constant, whereas the patterns vary with the individual. He emphasized the following factors:

1. *Dependence on three vessels.* These are the anterior median longitudinal arterial trunk and a pair of posterolateral trunks near the posterior nerve rootlets.
2. *Relative demands of gray matter and white matter.* The longitudinal arterial trunks are largest in the cervical and lumbar regions near the ganglionic enlargements and are much smaller in the thoracic region. This is because the metabolic demands of the gray matter are greater than those of the white matter, which contains fewer capillary networks.
3. *Medullary feeder (radicular) arteries of the cord.* These arteries reinforce the longitudinal arterial channels. There are two to 17 anteriorly and six to 25 posteriorly. The vertebral arteries supply 80% of the radicular arteries in the neck; arteries in the thoracic and lumbar areas arise from the aorta. The lateral sacral, the fifth lumbar, the iliolumbar, and the middle sacral arteries are important in the sacral region.
4. *Supplementary source of blood supply to the spinal cord.* The vertebral and posterior inferior cerebellar arteries are important sources of arterial supply. Sacral medullary feeders arise from the lateral sacral arteries and accompany the distal roots of the cauda equina. The flow in these vessels seems reversible and the volume adjustable in response to the metabolic demands.
5. *Segmental arteries of the spine.* At every vertebral level, a pair of segmental arteries supplies the extraspinal and intraspinal structures. The thoracic and lumbar segmental arteries arise from the aorta; the cervical segmental arteries arise from the vertebral arteries and the costocervical and thyrocervical trunks. In 60% of individuals, an additional source arises from the ascending pharyngeal branch of the external carotid artery. The lateral sacral arteries and, to a lesser extent, the fifth lumbar, iliolumbar, and middle sacral arteries supply segmental vessels in the sacral region.
6. *"Distribution point" of the segmental arteries.* The segmental arteries divide into numerous branches at the intervertebral foramen, which has been termed the *distribution point* (Fig. 37-7). A second anastomotic network lies within the spinal canal in the loose connective tissue of the extradural space. This occurs at all levels, with the greatest concentration in the cervical and lumbar regions. The presence of the rich anastomotic channels offers alternative pathways for arterial flow, preserving spinal cord circulation after the ligation of segmental arteries.
7. *Artery of Adamkiewicz.* The artery of Adamkiewicz is the largest of the feeders of the lumbar cord; it is located on

the left side, usually at the level of T9-11 (in 80% of individuals). The anterior longitudinal arterial channel of the cord rather than any single medullary feeder is crucial. The preservation of this large feeder does not ensure continued satisfactory circulation for the spinal cord. In principle, it would seem of practical value to protect and preserve each contributing artery as far as is surgically possible.

8. *Variability of patterns of supply of the spinal cord.* The variability of blood supply is a striking feature, yet there is absolute conformity with a principle of a rich supply for the cervical and lumbar cord enlargements. The supply for the thoracic cord from approximately T4 to T9 is much poorer.
9. *Direction of flow in the blood vessels of the spinal cord.* The three longitudinal arterial channels of the spinal cord can be compared with the circle of Willis at the base of the brain, but it is more extensive and more complicated, although it functions with identical principles. These channels permit reversal of flow and alterations in the volume of blood flow in response to metabolic demands. This internal arterial circle of the cord is surrounded by at least two outer arterial circles, the first of which is situated in the extradural space and the second in the extravertebral tissue planes. By virtue of the latter, the spinal cord enjoys reserve sources of blood supply through a degree of anastomosis lacking in the inner circle. The "outlet points" are limited, however, to the perforating sulcal arteries and the pial arteries of the cord.

The blood supply to the spinal cord is rich, but the spinal canal is narrowest and the blood supply is poorest at T4-9. T4-9 should be considered the critical vascular zone of the spinal cord, a zone in which interference with the circulation is most likely to result in paraplegia.

The dominance of the anterior spinal artery system has been challenged by the fact that many anterior spinal surgeries have been performed in recent years with no increase in the incidence of paralysis. This would seem to indicate that a rich anastomotic supply does exist, and that it protects the spinal cord. The evidence suggests that the posterior spinal arteries may be as important as the anterior system but are as yet poorly understood. Venous drainage of the spinal cord is more difficult to define clearly than is the arterial supply (Fig. 37-8). It is well known that the venous system is highly variable. Dommisse pointed out that there are two sets of veins: veins of the spinal cord and veins that fall within the plexiform network of Batson. The veins of the spinal cord are a small component of the entire system and drain into the plexus of Batson. The Batson plexus is a large and complex venous channel extending from the base of the skull to the coccyx. It communicates directly with the superior and inferior vena cava system and the azygos system. The longitudinal venous trunks of the spinal cord are the anterior and posterior venous channels, which are the counterparts of the arterial trunks. The three components of the Batson plexus are the extradural vertebral venous plexus; the extravertebral venous plexus, which includes the segmental veins of the neck, the intercostal veins, the azygos communications in the thorax and pelvis, the lumbar veins, and the communications with the inferior vena caval system; and the veins of the bony structures of the spinal column. The venous system plays no specific role in the metabolism of the spinal cord; it communicates directly with the venous system draining the head, chest, and abdomen. This interconnection allows metastatic spread of neoplastic or infectious disease from the pelvis to the vertebral column.

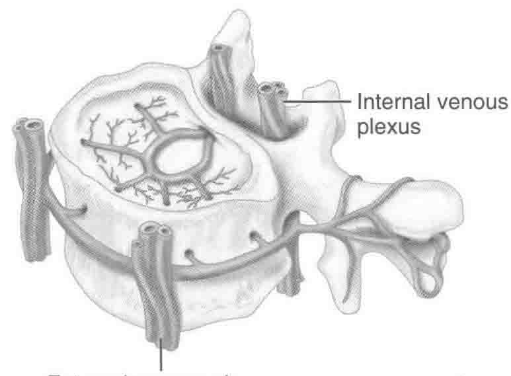


FIGURE 37-8 Venous drainage of vertebral bodies and formation of internal and external vertebral venous plexuses. (Redrawn from Bullough PG, Oheneba BA: *Atlas of spinal diseases,* Philadelphia, 1988, JB Lippincott.)

During anterior spinal surgery, we empirically follow these principles: (1) ligate segmental spinal arteries only as necessary to gain exposure; (2) ligate segmental spinal arteries near the aorta rather than near the vertebral foramina; (3) ligate segmental spinal arteries on one side only when possible, leaving the circulation intact on the opposite side; and (4) limit dissection in the vertebral foramina to a single level when possible so that collateral circulation is disturbed as little as possible.

SURGICAL APPROACHES

ANTERIOR APPROACHES

With the posterior approach for correction of spinal deformities well established, more attention has been placed on the anterior approach to the spinal column. Many pioneers in the field of anterior spinal surgery recognized that anterior spinal cord decompression was necessary in spinal tuberculosis and that laminectomy not only failed to relieve anterior pressure but also removed important posterior stability and produced worsening of kyphosis. Advances in major surgical procedures, including anesthesia and intensive care, have made it possible to perform spinal surgery with acceptable safety.

In general, anterior approaches to the spine are indicated for decompression of the neural elements (spinal cord, conus medullaris, cauda equina, or nerve roots) when anterior neural compression has been documented by myelography, postmyelogram CT, or MRI. Many pathological entities can cause significant compression of the neural elements, including traumatic, neoplastic, inflammatory, degenerative, and congenital lesions. In the lumbar spine, this indication has been expanded to include anterior interbody fusions for discogenic pain and instability.

BOX 37-1 Relative Indications for Anterior Spinal Approaches

1. Traumatic
   a. Fractures with documented neurocompression secondary to bone or disc fragments anterior to dura
   b. Incomplete spinal cord injury (for cord recovery) with anterior extradural compression
   c. Complete spinal cord injury (for root recovery) with anterior extradural compression
   d. Late pain or paralysis after remote injuries with anterior extradural compression
   e. Herniated intervertebral disc
2. Infectious
   a. Open biopsy for diagnosis
   b. Débridement and anterior strut grafting
3. Degenerative
   a. Cervical spondylitic radiculopathy
   b. Cervical spondylitic myelopathy
   c. Thoracic disc herniation
   d. Cervical, thoracic, and lumbar interbody fusions
4. Neoplastic
   a. Extradural metastatic disease
   b. Primary vertebral body tumor
5. Deformity
   a. Kyphosis—congenital or acquired
   b. Scoliosis—congenital, acquired, or idiopathic

Anterior approaches to the spine generally are made by an experienced spine surgeon, and, as a rule, it is inappropriate for surgeons who only occasionally perform spinal techniques to perform this type of surgery. In many centers, a team approach is preferred to employ the skills of an orthopaedic surgeon, neurosurgeon, thoracic surgeon, or head and neck surgeon. The orthopaedic surgeon still must have a working knowledge of the underlying viscera, fluid balance, physiology, and other elements of intensive care. Complications of anterior spine surgery are rare; however, there is a high risk of significant morbidity, and these approaches should be used with care and only in appropriate circumstances. Potential dangers include iatrogenic injury to vascular, visceral, or neurological structures.

The exact incidence of serious complications from anterior spinal surgery is unknown. A thorough understanding of anatomical tissue planes and meticulous surgical technique are necessary to prevent serious complications. The choice of approach depends on the preference and experience of the surgeon, the patient's age and medical condition, the segment of the spine involved, the underlying pathological process, and the presence or absence of signs of neural compression. Commonly accepted indications for anterior approaches are listed in Box 37-1.

ANTERIOR APPROACH, OCCIPUT TO C3

The anterior approach to the upper cervical spine (occiput to C3) can be transoral or retropharyngeal, depending on the pathological process present and the experience of the surgeon.

ANTERIOR TRANSORAL APPROACH

TECHNIQUE 37-1 *Figure 37-9*

(SPETZLER)

- Position the patient supine using a Mayfield head-holding device or with skeletal traction through Gardner-Wells tongs. Monitoring of the spinal cord through somatosensory evoked potentials is recommended. The surgeon may sit directly over the patient's head.
- Pass a red rubber catheter down each nostril, and suture it to the uvula. Apply traction to the catheters to pull the uvula and soft palate out of the operative field, taking care not to cause necrosis of the septal cartilage by excessive pressure.
- Insert a McGarver retractor into the open mouth and use it to retract and hold the endotracheal tube out of the way. The operating microscope is useful to improve the limited exposure.
- Prepare the oropharynx with hexachlorophene (pHisoHex) and povidone-iodine (Betadine).
- Palpate the anterior ring of C1 beneath the posterior pharynx, and make an incision in the wall of the posterior pharynx from the superior aspect of C1 to the top of C3.
- Obtain hemostasis with bipolar electrocautery, taking care not to overcauterize, producing thermal necrosis of tissue and increased risk of infection.
- With a periosteal elevator, subperiosteally dissect the edges of the pharyngeal incision from the anterior ring of C1 and the anterior aspect of C2. Use traction stitches to maintain the flaps out of the way.
- Under direct vision, with the operating microscope or with magnification loupes and headlights, perform a meticulous débridement of C1 and C2 with a high-speed air drill, rongeur, or curet. When approaching the posterior longitudinal ligament, a diamond burr is safer to use in removing the last remnant of bone.
- When adequate débridement of infected bone and necrotic tissue has been accomplished, decompress the upper cervical spinal cord.
- If the cervical spine is to be fused anteriorly, harvest a corticocancellous graft from the patient's iliac crest, fashion it to fit, and insert it.
- Irrigate the operative site with antibiotic solution, and close the posterior pharynx in layers.

POSTOPERATIVE CARE An endotracheal tube is left in place overnight to maintain an adequate airway. A halo vest can be applied, or skeletal traction may be maintained before mobilization.

ANTERIOR RETROPHARYNGEAL APPROACH

The anterior retropharyngeal approach to the upper cervical spine, as described by McAfee et al., is excellent for anterior débridement of the upper cervical spine and allows

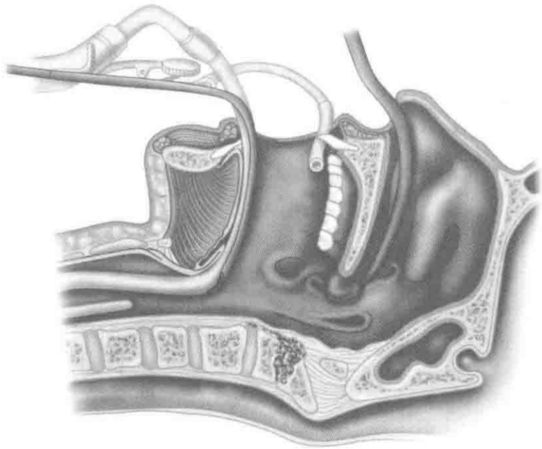


FIGURE 37-9 Anterior transoral approach (see text). (Redrawn from Spetzler RF: Transoral approach to the upper cervical spine. In Evarts CM, editor: *Surgery of the musculoskeletal system*, New York, 1983, Churchill Livingstone.) **SEE TECHNIQUE 37-1.**

placement of bone grafts for stabilization if necessary. In contrast to the transoral approach, it is entirely extramucosal and is reported to have fewer complications of wound infection and neurological deficit.

TECHNIQUE 37-2

(MCAFEE ET AL.)

- Position the patient supine, preferably on a turning frame with skeletal traction through tongs or a halo ring. Somatosensory evoked potential monitoring of cord function is suggested during the procedure.
- Perform fiberoptic nasotracheal intubation to prevent excessive motion of the neck and to keep the oropharynx free of tubes that could depress the mandible and interfere with subsequent exposure.
- Make a right-sided transverse skin incision in the submandibular region with a vertical extension as long as required to provide adequate exposure (Fig. 37-10A). If the approach does not have to be extended below the level of the fifth cervical vertebra, there is no increased risk of damage to the recurrent laryngeal nerve.
- Carry the dissection through the platysma muscle with the enveloping superficial fascia of the neck and mobilize flaps from this area.
- Identify the marginal mandibular branch of the seventh nerve with the help of a nerve stimulator, and ligate the retromandibular veins superiorly.
- Keep the dissection deep to the retromandibular vein to prevent injury to the superficial branches of the facial nerve.
- Ligate the retromandibular vein as it joins the internal jugular vein.
- Mobilize the anterior border of the sternocleidomastoid muscle by longitudinally dividing the superficial layer of the deep cervical fascia. Feel for the pulsations of the carotid artery, and protect the contents of the carotid sheath.
- Resect the submandibular gland (Fig. 37-10B), and ligate the duct to prevent formation of a salivary fistula.
- Identify the digastric and stylohyoid muscles, and tag and divide the tendon of the former. The facial nerve can be injured by superior retraction on the stylohyoid muscle; however, by dividing the digastric and stylohyoid muscles, the hyoid bone and hypopharynx can be mobilized medially, preventing exposure of the esophagus, hypopharynx, and nasopharynx.
- Identify the hypoglossal nerve, and retract it superiorly.
- Continue dissection to the retropharyngeal space between the carotid sheath laterally and the larynx and pharynx medially. Increase exposure by ligating branches of the carotid artery and internal jugular vein, which prevent retraction of the carotid sheath laterally (Fig. 37-10C and D).
- Identify and mobilize the superior laryngeal nerve.
- Following adequate retraction of the carotid sheath laterally, divide the alar and prevertebral fascial layers longitudinally to expose the longus colli muscles. Take care to maintain the head in a neutral position and identify the midline accurately.
- Remove the longus colli muscles subperiosteally from the anterior aspect of the arch of C1 and the body of C2, avoiding injury to the vertebral arteries.
- Meticulously débride the involved osseous structures (Fig. 37-10E); if needed, perform bone grafting with autogenous iliac or fibular bone.
- Close the wound over suction drains, and repair the digastric tendon. Close the platysma and skin flaps in layers.

POSTOPERATIVE CARE The patient is maintained in skeletal traction with the head of the bed elevated to reduce swelling. Intubation is continued until pharyngeal edema has resolved, usually by 48 hours. The patient can be extubated and mobilized in a halo vest, or, if indicated, a posterior stabilization procedure can be done before mobilization.

EXTENDED MAXILLOTOMY AND SUBTOTAL MAXILLECTOMY

Cocke et al. described an extended maxillotomy and subtotal maxillectomy as an alternative to the transoral approach for exposure and removal of tumor or bone anteriorly at the base of the skull and cervical spine to C5. This procedure is technically demanding and requires a thorough knowledge of head and neck anatomy. It should be performed by a team of surgeons, including an otolaryngologist, a neurosurgeon, and an orthopaedist.

Before surgery, the size, position, and extent of the tumor or bone to be removed should be determined, using the appropriate imaging techniques. Three to 5 days before the surgery, nasal, oral, and pharyngeal secretions are cultured to determine the proper antibiotics needed. Cephalosporin and aminoglycoside antibiotics are given before and after surgery if the floral cultures are normal and are adjusted if the flora is abnormal or resistant to these drugs.