44 Pedicle Screw Insertion—Manual and Power Techniques

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INDICATIONS/CONTRAINDICATIONS

Pedicle screws are a versatile option for posterior instrumentation of the pediatric thoracic and lumbar spine. Screw-based constructs are useful for both fusion and growing spine deformity techniques. Over the past decade, numerous studies have demonstrated that pedicle screws are safe and effective for treating pediatric spine deformities and hold significant biomechanical advantages over hook or hybrid hook-screw constructs (1). Stable fixation can be obtained in most pedicles using screws, even those of small diameter. Contraindications are few but include pedicle erosion by significant dural ectasia in patients with neurofibromatosis or Marfan syndrome; in such cases, pedicle screws are still typically used above and below the areas of dural ectasia, with rods spanning the most affected levels. In addition, some surgeons may not be comfortable placing pedicle screws into tiny type D (slitlike) pedicles, and this relative contraindication should be respected to keep the overall use of pedicle screws as safe as possible during pediatric spinal surgery (2).

PREOPERATIVE PREPARATION

On physical examination, standing coronal and sagittal spinal balance should be noted. Shoulder balance, rib prominence, truncal shift, and pelvic obliquity also must be assessed. Having the patient lie prone on the examination table is useful to determine scoliosis flexibility; a push-prone maneuver can also be done to further examine flexibility. For kyphotic patients, having the patient lie supine or prone is very useful to visualize how much passive correction can be achieved. A thorough neurologic exam to detect motor and sensory deficits as well as signs of myelopathy must be performed prior to deformity correction. The skin of the back should also be inspected for acne or previous incisions.

The patient's preoperative radiographs should be reviewed in detail prior to beginning surgery. Pedicle morphology should be assessed on a full-length anterior-posterior (AP) spine radiograph—there is significant variability in pedicle diameter between patients, and the surgeon should have an excellent understanding of the vertebral morphology prior to starting the surgery. In scoliotic patients, pedicle diameter is affected by whether the pedicle is located on the concavity or convexity

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of a curve. Studying the preoperative supine coronal radiograph is very helpful, as the pedicles are always more visible due to having less curvature, rotation, and movement when the radiograph is taken without gravity. In addition, the severity of vertebral rotation can be ascertained from the AP radiograph. The lateral radiograph is useful to estimate desired pedicle screw length.

For pediatric patients with complex deformities, such as severe scoliosis, previous fusions, or a congenital osseous abnormality, a preoperative thoracolumbar computed tomography (CT) scan is typically obtained. While recognizing the need to minimize radiation in children, CT imaging is extremely useful for studying pedicle diameter and morphology, plotting screw length, and creating three-dimensional reconstructions of the spine to fully understand the orientation of each segment of the deformity.

Magnetic resonance imaging is obtained in patients with significant kyphosis, a sharp angular or rapidly progressing scoliosis, an atypical curve pattern such as a left-sided scoliosis, or a known history of Chiari malformation or spinal dysraphism. Knowing whether a patient is at higher risk for neurologic deficit is a critical step in preoperative planning regarding implant selection and correction strategy.

Pedicle screws can be placed using a freehand technique based on posterior spinal anatomic landmarks; alternatively, screw placement can be guided using intraoperative fluoroscopy or CT-based navigation. One advantage of the freehand technique is minimization of radiation exposure. For surgeons who do not place a high volume of pedicle screws or are accumulating experience, using fluoroscopy or navigation might be helpful to minimize complications, as studies have noted a high learning curve for the freehand technique (3). Surgeons should use the technique they feel is safest and most efficacious for the patient. However, understanding the local osseous and neural anatomy necessary for placing screws without any image guidance will help all surgeons during whatever technique they choose. The remainder of this chapter will present the freehand technique.

SURGICAL PROCEDURE

The patient is first positioned prone on an OSI table with a Jackson frame (Mizuho OSI, Union City, CA). Placement of the padded bolsters can influence sagittal spinal alignment, and thus, consideration is taken to make sure that the patient is ideally positioned prior to draping. Moving the distal bolsters under the pelvis, leaving the abdomen free, will increase lumbar lordosis. The back is shaved, and a wide surgical field is sterilized to allow for visualization of the pelvis, ribs, and scapulae throughout the surgery.

1. Exposure and Facetectomies

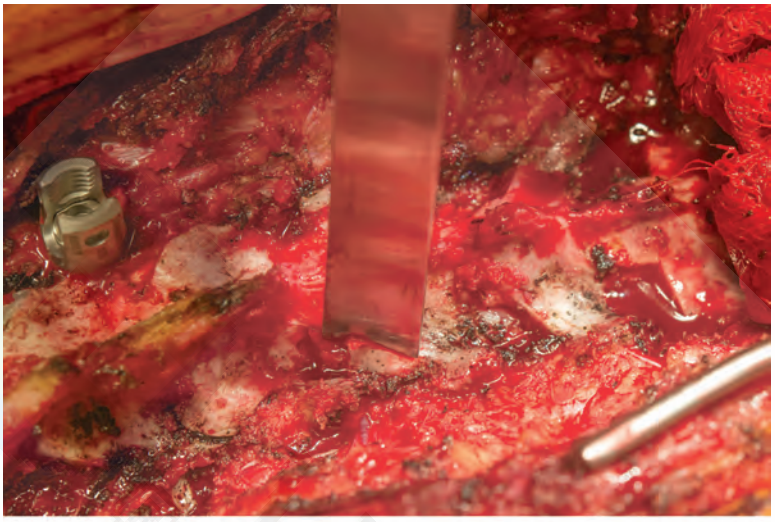
   A subperiosteal exposure of the posterior thoracic/lumbar spine is performed. It is essential to remain subperiosteal to minimize bleeding, a critical consideration in pediatric patients. Maintaining tension on the soft tissues with multiple retractors as dissection progresses will help minimize bleeding as well. Furthermore, during exposure, the anesthesiologist should be asked to maintain mean arterial pressures between 60 and 70 mm Hg.

   Once the skin incision is made, a pointed clamp or pedicle probe is used to mark a vertebra, and intraoperative posteroanterior (PA) and lateral radiographs are obtained. These radiographs serve to confirm that the proper spinal levels are being exposed and also allow the surgeon to visualize the patient's spinal alignment on the operating table. Next, the transverse processes of the thoracic and lumbar spine are fully exposed. The interspinous ligament is left intact on the proximal two spinous processes to minimize risk of proximal junctional kyphosis. Facet joints are thoroughly cleaned of all capsular tissue using monopolar electrocautery. The thoracic joints should be cleaned in a medial-to-lateral direction so that the electrocautery does not inadvertently enter the spinal canal.

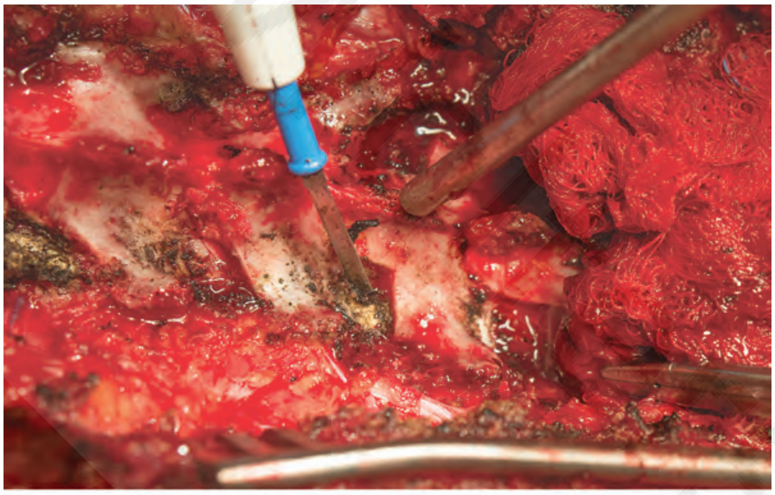
   In the thoracic spine, a ½-inch straight osteotome is then used to remove the inferior 5 mm of the inferior articular facet by making two cuts (Fig. 44-1A). The superior facet cartilage is curetted away. It is *essential* to adequately expose the superior articular facet to visualize the critical landmarks for freehand thoracic pedicle screw placement. In the lumbar spine, a ½-inch osteotome is again used to remove the inferior articular facet by making an oblique cut in the plane of the joint (Fig. 44-1B). These facet preparations also improve the surface area for fusion.

2. Starting Point Identification

   Steps 2 to 6 are completed for each pedicle before moving to the next. Once exposure and facetectomies are complete, the starting point for the first pedicle screw is identified. In the lumbar spine, the starting point is at the junction of the lateral border of the pars interarticularis and the inferior border of the transverse process, at the base of the superior articular process (Fig. 44-2A). To better identify this point, the superior articular facet can be removed using a rongeur; there is sometimes a mamillary process at this junction that should also be rongeured. Once the superior facet is removed, there is often a blush of blood from the cancellous pedicle tube, most often seen in type A (large cancellous channel) and type B (small cancellous channel) pedicles (2). An oval-tipped 4-mm bur is then used to puncture the corticocancellous bone overlying the pedicle.



A



B

FIGURE 44-1
A. Thoracic inferior facetectomy being performed with ½-inch straight osteotome. **B.** Cartilage of superior facet removed using electrocautery.

In the thoracic spine, the starting points vary depending on cephalad-caudad vertebral level (4). Figure 44-2B demonstrates a mnemonic device for remembering the screw start points. Several general rules apply at all thoracic levels. First, no starting point should ever be medial to the midpoint of the superior facet in the medial-lateral direction. Second, no starting point should be distal to the midpoint of the transverse process in the superior-inferior direction. These two guidelines define a "safe zone" for starting thoracic pedicle screws. Typically, the starting points in the proximal and distal portions of the thoracic spine are slightly more lateral than in the midthoracic spine. Also, starting points at the concave apex of larger scoliotic curves tend to be slightly more lateral.

The dorsal transverse process of the thoracic vertebrae can be removed with a rongeur to obtain local autogenous bone graft. Some surgeons will also use a rongeur to remove the dorsal cortical bone at the inflection point of the transverse process as it meets the lamina in order to allow the screw head to rest more ventrally, minimizing implant prominence and facilitating pedicle cannulation. However, biomechanical studies have suggested that removing the dorsal lamina reduces screw pullout strength (5). The overall bone quality of the patient should be taken into consideration before rongeuring the dorsal lamina.

3. Pedicle Cannulation

   Once the starting point has been identified and burred, a pedicle probe is used to cannulate a cancellous track through the pedicle into the vertebral body. Either a straight or a slightly curved pedicle probe can be used (Fig. 44-3). For the curved probe, the point is first oriented laterally in order to avoid medial breach and possible neural tissue penetration (Fig. 44-4A). Care is taken to hold the probe with two hands at all times. The tip is placed into the burred starting hole and used to palpate the softer cancellous bone at the entry to the pedicle tube and then carefully advanced using small, controlled oscillations. In the thoracic spine, the probe is advanced to a depth of 20 to 25 mm, and in the lumbar spine, it is advanced to 30 mm. The probe is then withdrawn from the bone, the tip turned medially, and the probe reinserted to the previously achieved depth. This maneuver helps

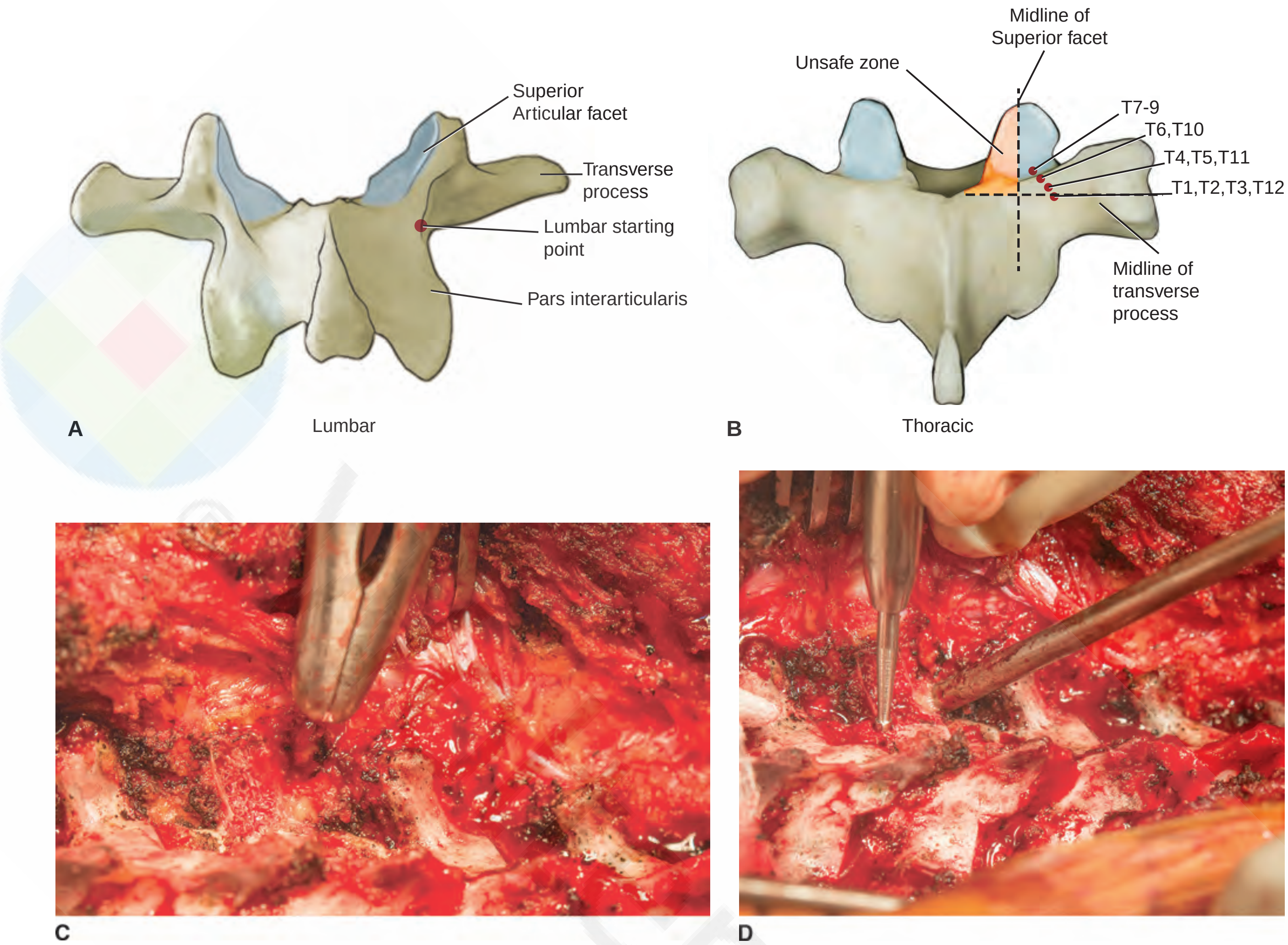


FIGURE 44-2

A. Diagram of standard lumbar starting point. **B.** Diagram of standard thoracic starting points. **C.** Dorsal transverse process removed with rongeur to expose starting point. **D.** Bur used to puncture bone at T9 screw starting point.

FIGURE 44-3

Pedicle probe options: 3-mm straight tip (*top*), 2-mm curved tip (*middle*), and 1-mm curved tip (*bottom*).

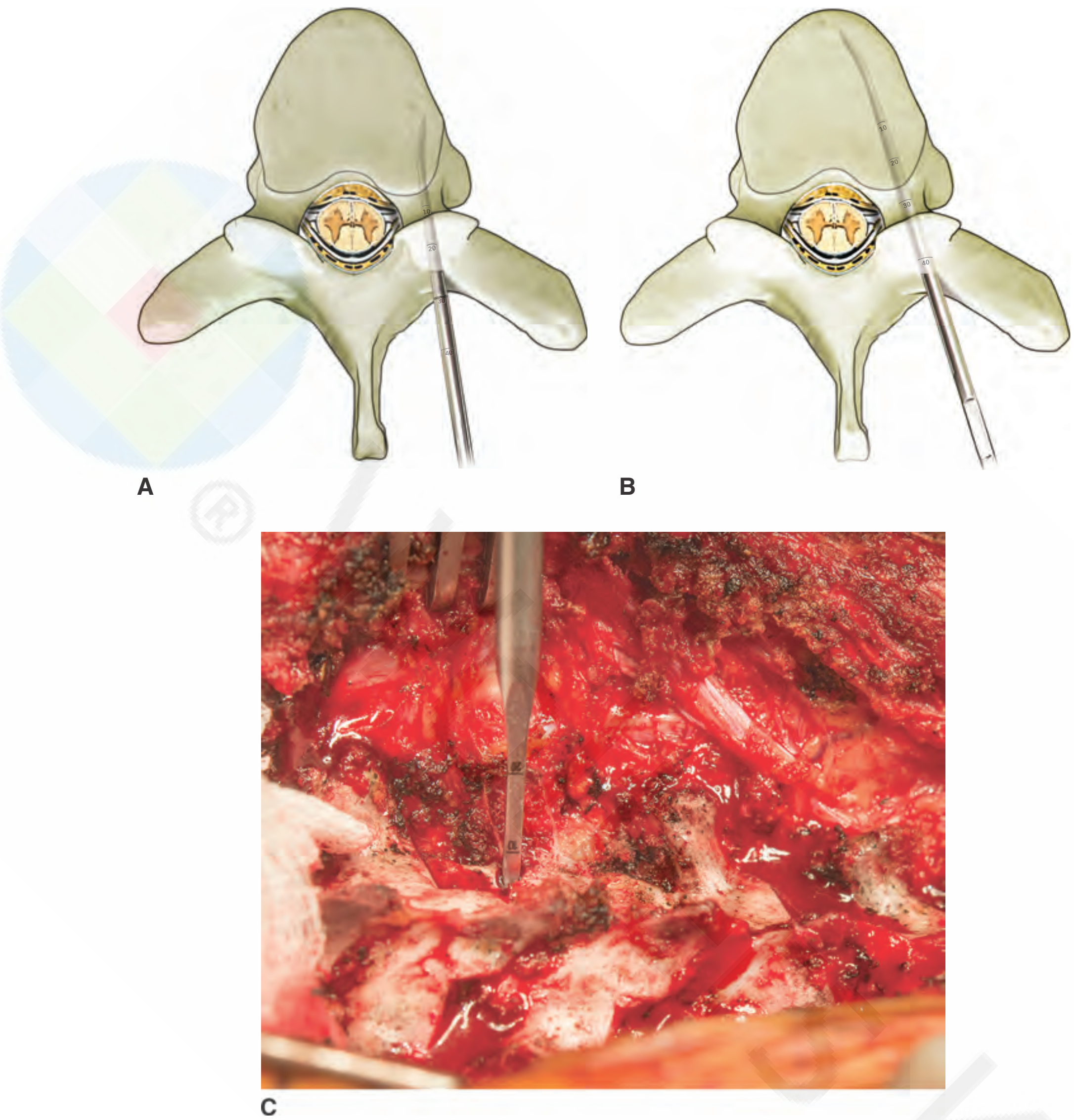


FIGURE 44-4

A. The curved pedicle probe is first inserted to a depth of 25 to 30 mm with the tip facing laterally. **B.** The probe is withdrawn and then reinserted with the tip facing medially as the probe is advanced to the planned length of the screw. **C.** The small 1-mm pedicle probe can be very useful in small, dysmorphic pedicles.

to ensure that the tip of the probe is *ventral* to the spinal canal before it is medialized (Fig. 44-4B). The probe is now advanced to its final depth, and in doing so, the hand is gently moved laterally to cause the tip to progress medially toward the midline of the vertebral body. Once the desired depth is reached, the probe is oscillated a quarter turn in each direction to dilate the bottom of the track.

Preoperative planning and careful attention during surgery to vertebral anatomy are essential to determine the orientation and length of pedicle screws. A general rule is that the handle of the pedicle probe should align with a plane drawn between the transverse processes of the vertebra being cannulated to achieve a straight-ahead screw trajectory, which is more biomechanically favorable than is an anatomic trajectory (6). In other words, the tip of the pedicle probe should be advanced toward the contralateral transverse process, and this will guide cephalad-caudad screw orientation. Vertebral rotation must also be accounted for during freehand cannulation. The cadence of screw angulation in the axial plane should mirror the scoliosis curvature; cues can be taken from adjacent screws, adding or subtracting rotation appropriately as each subsequent screw is placed. Typically, the anterior cortex is not violated to avoid potential great vessel injury; however, on occasion, a bicortical track is cannulated. It is important to recognize the change in resistance against the probe tip when this occurs.

Any sudden advancement of the probe suggests possible breach, and the probe should not be advanced further until integrity of the track has been verified with a ball-tipped pedicle probe.

A sudden rush of venous blood from the pedicle track often indicates rupture of epidural veins by a medial breach. Bone wax is an effective method to achieve hemostasis of a bleeding pedicle track. Be cautious with use of injectable hemostatic agents, as these can enter the spinal canal via a medial breach causing spinal cord compression and loss of neuromonitoring data (7).

Watanabe et al. have published a useful classification of scoliotic thoracic pedicle types (Fig. 44-5) (2). In short, type A pedicles have large cancellous channels that can be easily cannulated. Type B pedicles are small cancellous channels that require more force to cannulate. Type C pedicles have no cancellous channel, just cortical bone. Type D pedicles are "slit pedicles" and cannot be cannulated.

For type B pedicles, a smaller curved-tip pedicle probe (Fig. 44-3) can be extremely useful to safely cannulate a pedicle track. Once this "baby gearshift" has been used to cannulate a track, a small ball-tipped probe (see step 4) is utilized to verify the integrity of the initial pedicle track. Then, the regular-sized pedicle probe can be inserted to further dilate the pedicle track. In order to more easily find the entrance to type B pedicles, the probe tip can be used to gently palpate the cortical bone of the ventral lamina, moving laterally in very small increments until the probe tip falls into the softer cancellous bone at the entrance to the pedicle (Fig. 44-6). This "ventral lamina" technique allows the surgeon to accurately identify the pedicle entrance regardless of vertebral rotation or dorsal anatomic anomalies.

For type C pedicles, there are two techniques that can be used for cannulation. First is to gently mallet the small-tipped pedicle probe down the cortical pedicle tube. Prior to malleting, care must be taken to make sure that the probe is positioned appropriately to travel down the pedicle and not through the ventral lamina. The hard bone of the ventral lamina lies more dorsal and medial than does the hard bone of the entrance into a type C pedicle. Thus, the probe can "feel" the ventral laminar bone and then fall into the base of the type C pedicle starting point sitting lateral and ventral. Second is to use the bur to cannulate the pedicle by advancing the bur in very small increments— think "quick on, quick off." A 3-mm side-cutting bur, such as an AM-8, is preferred. The bur tip is used to palpate the floor and medial wall of the channel as it is advanced. One is typically able to feel when the bur tip reaches the cancellous vertebral body, at which point the pedicle probe can be inserted to finish cannulation.

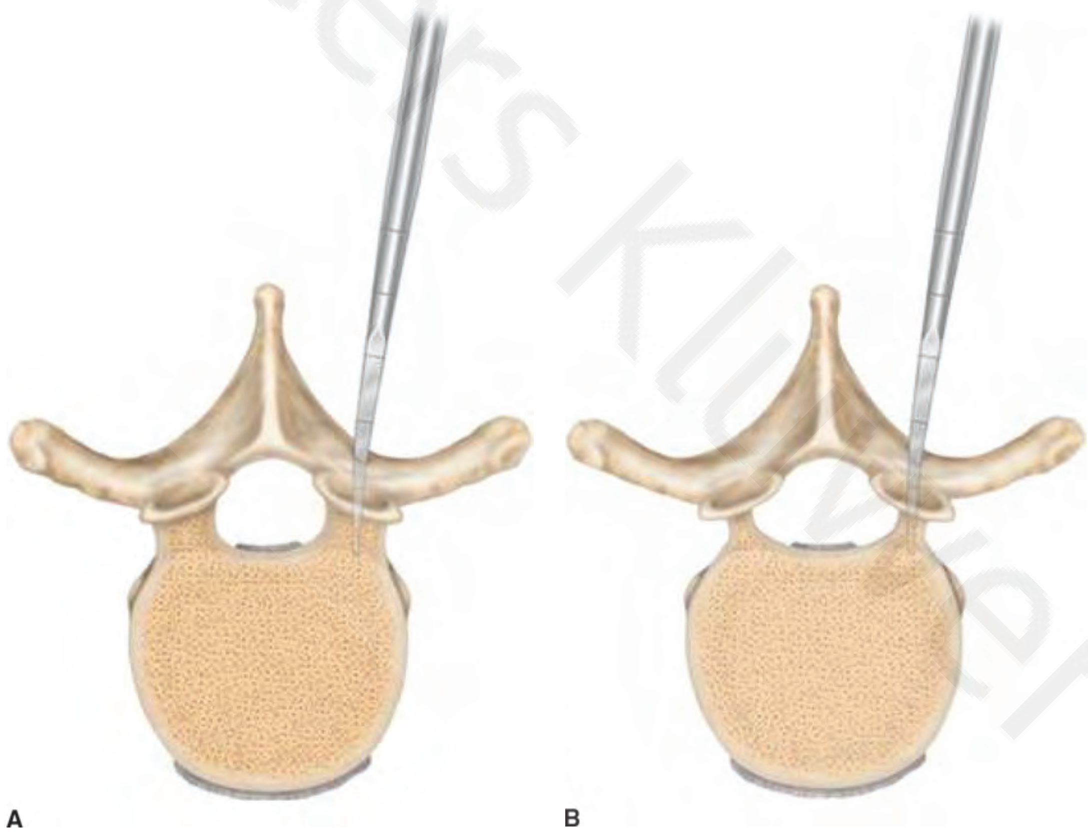
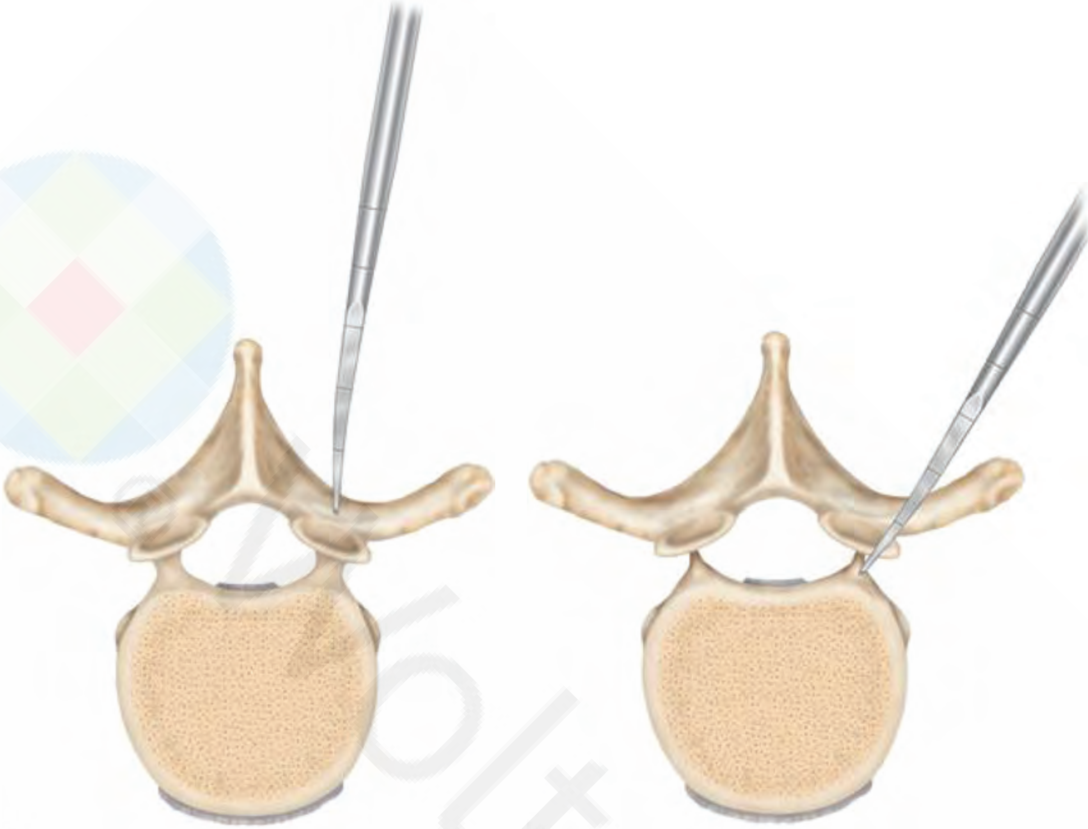


FIGURE 44-5

Diagram of Watanabe pedicle classification. **A.** A-type pedicle: large cancellous channel. **B.** B-type pedicle: small cancellous channel.



C D

FIGURE 44-5 (*Continued*)

C. C-type pedicle: no cancellous channel; pedicle is entirely cortical bone. **D.** D-type pedicle: slit pedicle.

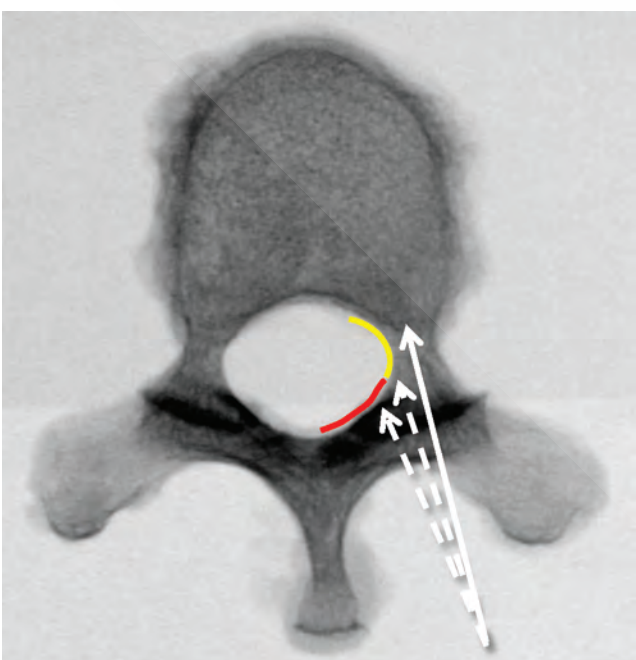


FIGURE 44-6

The ventral lamina (*red line*) has thick cortical bone and can serve as a palpable landmark to guide pedicle cannulation. Note that the medial pedicle wall (*yellow line*) is confluent with the ventral lamina. The *arrows* demonstrate how a pedicle probe can be started in a medial position against the ventral lamina and worked laterally in small increments (*dashed arrows*) until the correct track through the pedicle is found (*solid arrow*).

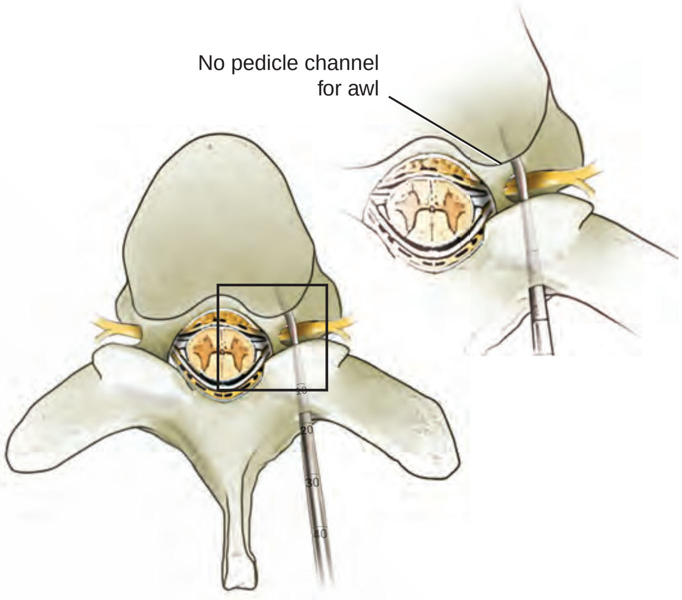


FIGURE 44-7

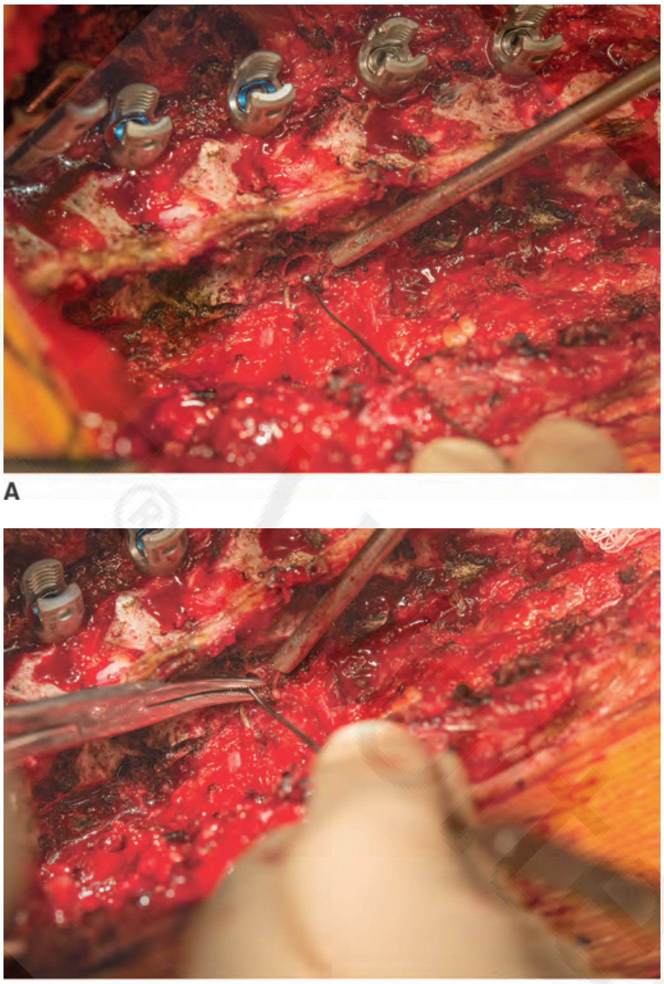
For "slitlike" type D pedicles, an extrapedicular technique can be used to create a screw track that has safe purchase in the vertebral body.

In type D pedicles, which have no viable pedicle tube, an extrapedicular/juxtapedicular screw placement technique can be used (Fig. 44-7). The pedicle probe is carefully advanced through the ventral transverse process just lateral to the lateral pedicle wall to a depth of 20 to 25 mm. Then, the probe tip is angled medially to a more extreme degree than the intrapedicular technique in order to enter the vertebral body just ventral to the spinal canal. This is a safe technique as long as the pedicle probe hugs the lateral outer wall of the pedicle, because typically this places the probe in the costovertebral articulation.

4. Palpation and Measurement
   Once the pedicle has been cannulated, a ball-tipped sounder is then used to palpate first the floor of the pedicle track and then all four walls (medial, lateral, superior, and inferior) (Fig. 44-8). To check each wall, the probe is carefully withdrawn while dragging the ball against the wall to feel for a catch or soft spot suggestive of a breach into the spinal canal or soft tissue. Once the integrity of the pedicle track has been verified, the sounder is reinserted to the floor of the hole and the track depth is obtained using a curved-tip surgical clamp placed on the sounder at the cortical surface. The clipped length of the sounder is then measured on a ruler. If the anterior vertebral cortex is breached, it is important to accurately palpate the ventral edge of the screw track to measure and place a screw of safe length.

   If a breach is present, a new starting point should be burred just adjacent to the previous track, making the appropriate correction. If the breach is medial, an extrapedicular technique can serve as a bailout to still achieve safe screw fixation in the vertebra. Of note, when the extrapedicular technique is used, the more superficial portion of the lateral wall will indeed be breached, but at the bottom of the track (within the vertebral body), all four walls should be intact. A track with a breach should be sealed using bone wax; this is typically effective even if a cerebrospinal fluid (CSF) leak has been caused by the pedicle probe.
5. Tapping and Repalpation
   Type A pedicles in minimally rotated vertebrae do not generally require tapping unless a breach was caused during attempts at cannulation. Tapping these pedicles has been shown to reduce pullout strength, particularly in osteopenic bone (8). However, many type B to D pedicles will be encountered in the deformed pediatric spine, and these should be tapped to ensure that the screws travel along the cannulated tracks. Tapping can be done using either manually or with a powered tap. Biomechanical studies have shown that a tap size 1 mm less than the planned screw thread diameter maximizes pullout strength (9). Once the tap has been withdrawn, the ball-tipped sounder is used once again to palpate and measure the screw track. The clipped sounder is matched directly with the screw to be inserted to verify that the screw is indeed an appropriate and safe length. Sometimes, during tapping, small pieces of bone are driven to the bottom of the hole, causing the depth of the hole to be less than initially measured. If necessary, the pedicle probe is reinserted to regain these last few millimeters of length.

   In pedicle tracks that were repositioned due to an initial breach, or those that were cannulated using an extrapedicular technique, a nonpointed smooth Kirschner wire is first placed into the track, making sure the tip of the wire rests against the ventral floor of the track and advanced to



A

B

FIGURE 44-8

A. A ball-tipped sounder is used to palpate the pedicle track floor and all four walls. **B.** Once the track has been palpated, the sounder is placed against the floor and is clipped with a surgical clamp to determine depth.

the ventral cortex. A cannulated tap is then advanced over the wire. This helps to ensure that the correct path is tapped. If a Kirschner wire is used, a manual tap should always be used rather than with a powered tap. Of note, if the track does not have a floor due to a bicortical cannulation, then a Kirschner wire should *not* be used, as it can easily advance into anterior vascular structures.

6. Screw Insertion

After tapping, repalpating, and remeasuring, the screw can then be inserted (Fig. 44-9). For pedicles that were easily cannulated, a powered screwdriver with good variable speed control can be used. Sometimes, it is necessary to switch to a manual handle during the final few revolutions in order to obtain a better feel of screw grip. In pedicles that required multiple cannulation attempts, a manual screwdriver should be used to maximize feel of screw grip and control of trajectory. If a lateral breach was inadvertently created during cannulation attempts, the surgical assistant can hook a right-angled hemostat clamp around the screw and provide medial force as the surgeon inserts the screw, helping to ensure that the screw travels down the correct intrapedicular trajectory.

Regardless of the method of screw insertion, the screw should be inserted slowly, particularly in small-diameter pedicles, to maximize viscoelastic dilation of the bone. This is especially true in patients with neuromuscular or connective tissue disorders, in whom the bone is often weak and the pedicles easily fractured.

7. Confirmation of Safe Placement

Correct and safe placement of pedicle screws is verified using two methods in pediatric patients. First, intraoperative imaging is performed once all screws have been placed and before any rods are inserted. Full-length PA and lateral radiographs are useful, but fluoroscopy can also be used. On the PA radiograph, screw tips should be oriented medially but should not cross the vertebral midline (Fig. 44-10A) (10). In patients with scoliosis, a symmetry mirroring the spinal curvature should be seen in the screw alignment; screws that appear more medial or lateral than the others should be carefully assessed and possibly removed to repalpate the pedicle track. The lateral radiograph should be reviewed to ensure that no screw extends beyond the

FIGURE 44-9

Screw insertion can be done with either powered or manual screwdrivers; similar to tapping, if a pedicle is small or dysmorphic, then a manual technique should be employed.

FIGURE 44-10

A. Intraoperative PA radiograph demonstrating screws in good alignment and without concern for medial or lateral placement error after freehand placement. **B.** Intraoperative lateral radiograph demonstrating safe screw lengths and straight-ahead trajectories.

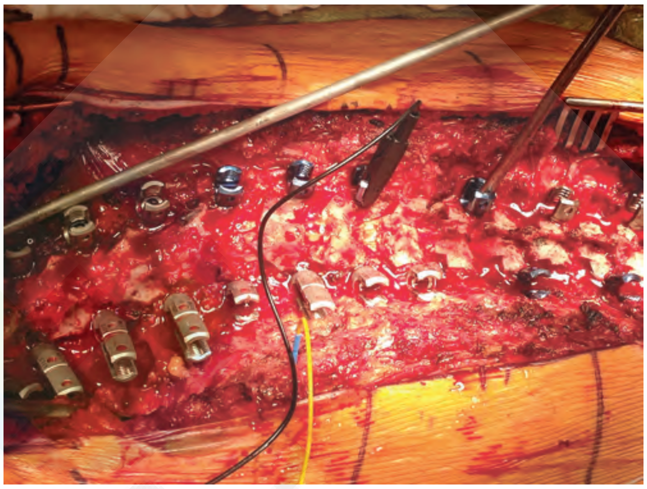


FIGURE 44-11
Triggered EMG setup demonstrating a ground wire in the paraspinal muscles and an alligator clip carrying current to the pedicle screw being tested.

anterior vertebral margins and that screws are parallel to and contained within the pedicles (Fig. 44-10B).

Second, triggered electromyography (EMG) is used to test all lumbar screws and T6–T12 thoracic screws (Fig. 44-11). Each screw is directly stimulated and EMG recordings taken from corresponding muscle groups. The rectus abdominis is recorded for T6–T12. The adductors are recorded for L2, quadriceps for L3 and L4, tibialis anterior for L5, and gastrocnemius-soleus for S1. An EMG threshold less than 8.0 mA is a warning that a pedicle breach may have occurred; a threshold less than 4.0 mA is greater than 95% predictive of a breach. In such cases, the screw in question should be removed and the pedicle carefully re-sounded.

POSTOPERATIVE MANAGEMENT

Patients with posterior-only pedicle screw constructs can typically ambulate without a brace immediately after surgery. Idiopathic scoliosis patients can be out of bed to a chair beginning on the day of surgery. Patients with more complex fusions, particularly those including the sacrum and pelvis, are typically mobilized on the first postoperative day. Bracing is generally not necessary after pedicle screw spine fixation. Rarely, skeletally immature pediatric patients with a deformity remaining above or below an instrumented segment of the spine receive a thoracolumbar orthosis. Spine fusion precautions are maintained for 6 months, after which patients are allowed to resume most normal activities.

COMPLICATIONS TO AVOID

Complications from pedicle screws arise when the pedicle is violated during cannulation or screw placement. The freehand technique has been shown to be a safe method of screw placement. Kim et al. reported no neurologic, vascular, or visceral injuries with placement of over 3,200 consecutive freehand thoracic pedicle screws in pediatric and adult patients; they found only a 1.7% incidence of medial screws on postoperative CT (11). Lehman et al. (3) studied more than 1,000 pedicle screws placed freehand into pediatric deformity patients and found a 10.5% incidence of medial or lateral breach on CT imaging—none of the screws caused complications. This study also demonstrated increasing surgeon accuracy with time, indicating that there is a learning curve for the freehand technique. Systematic review of the literature reveals wide variations between studies in the accuracy of pedicle screw placement using a freehand technique, fluoroscopy, or CT navigation (12). The method that each surgeon feels is most safe for him/her to use, based on training and experience, should be selected.

1. Neurologic Complications
   Direct trauma to the spinal cord and/or nerve roots during pedicle screw placement can occur if the medial pedicle wall is breached. Regardless of the method of pedicle cannulation, whether freehand or with use of fluoroscopy or navigation, careful attention must be paid to sudden changes in resistance during probe or screw advancement that might indicate a breach. Typically, a medial breach results from a starting point that is too medial. If a medial breach is suspected, the ball-tipped sounder should be carefully inserted and removed so as to not impale the spinal cord with the sounder through a perforation in the pedicle.

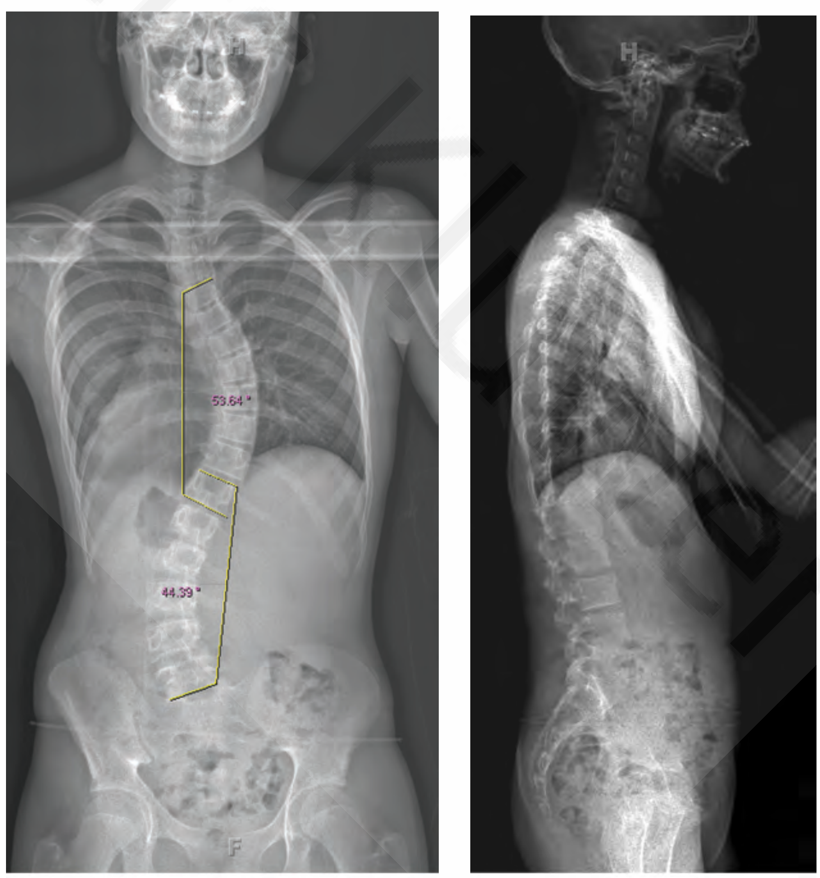
   Nerve root complications can also occur if the pedicle is violated. Sometimes, a pedicle will crack during screw insertion, and the nerve root will be resting against a screw thread or a piece of medially displaced pedicle bone. In such cases, the screw must be removed and safely repositioned if possible and the medial pedicle and nerve root inspected to ensure no bony fragments remain. Triggered EMG can be helpful in detecting these types of breaches.

Dede et al. (13) reviewed 559 pediatric idiopathic scoliosis patients treated with freehand pedicle screw placement over a 12-year period and found that only six patients had neurologic symptoms from malpositioned pedicle screws. Five had radicular symptoms, and one had orthostatic headaches from a CSF leak. Overall, the percentage of symptomatic screws was 0.14%.

2. Vascular Injury
   Vascular injury, particularly aortic perforation, is a potentially catastrophic complication of a pedicle screw that is advanced too anteriorly. In a systematic review of papers reporting complications from pedicle screws, Hicks et al. (14) identified 10 case reports of iatrogenic aortic injury from pedicle screw placement. However, in none of the 21 series they reviewed, which included more than 1,600 patients with pedicle screw constructs, were major vascular complications reported, indicating that this is a very rare complication. Notably, in several of these case reports, the aortic injuries occurred in a delayed fashion as the screw tip eroded into the aorta over several months. Successful endovascular repair of aortic injuries from pedicle screws has been reported with good results and is seemingly the best technique to use for treating these injuries (15).
3. Visceral Injury
   Rarely, thoracic pedicle screws have been reported to cause visceral injury. In their review, Hicks et al. (14) cite one occurrence of a pedicle screw being removed due to persistent pleural effusion after pleural perforation and three other asymptomatic patients in whom intrathoracic screws were removed as a precaution. Both esophageal injury and tracheal injury can be caused by pedicle screw perforation of the anterior vertebral cortex; these complications sometimes occur in a delayed fashion after the screw tip erodes into the lumen.

ILLUSTRATIVE CASE

A 15-year-old male presented with a progressing Lenke 3C double-major idiopathic scoliosis. After discussion with the patient and his family, the decision was made to proceed with selective thoracic fusion from T2 to L1. An all-posterior pedicle screw construct was placed using freehand technique, and posterior column osteotomies were performed from T6 to T11 to facilitate correction. No intraoperative complications occurred. Preoperative and immediate upright postoperative radiographs are shown in Figure 44-12A–D.



A B

FIGURE 44-12

Preoperative upright AP **(A)** and lateral **(B)** radiographs of a 15-year-old male with idiopathic scoliosis in a Lenke 3C pattern. Immediate postoperative upright AP **(C)** and lateral **(D)** radiographs after T2–L1 posterior spinal fusion.

C

D

FIGURE 44-12 (*Continued*)

PEARLS AND PITFALLS

- Pedicle screws can be placed using a freehand technique, intraoperative fluoroscopy, or CT-based navigation. Surgeons should utilize the technique that produces the highest level of accuracy and safety in their hands.
- Preoperative planning based on thoracolumbar radiographs and physical exam is essential for successful freehand pedicle screw placement. CT imaging is very useful in complex deformities or with pathologies that create atypical vertebral and/or pedicle anatomy.
- Thorough exposure of the posterior spine and careful attention to hemostasis allow for identification and constant visualization of the anatomic landmarks necessary to identify the starting points and trajectories for freehand pedicle screws.
- Recognition of pedicle channel type (cancellous A and B, cortical C, or absent D) is crucial to select the best method for screw track cannulation.
- Three techniques are used to confirm screw track safety intraoperatively: direct palpation using a ball-tipped sounder, intraoperative plain film radiographs, and triggered EMG.

EDITOR'S NOTE

An Alternative Technique of Power-Assisted Pedicle Tract Preparation and Screw Placement

It is my (DLS) opinion that using power in spine surgery has the benefits of using less force in a more controlled manner than does using manual force. A survey of the membership of the Scoliosis Research Society found that overuse injuries of the arm and neck of spinal deformity surgeons are much greater than is that of the general population.[1] Use of power may provide some protection for the surgeon against overuse injuries. A review of 4,542 screws placed with this technique reported shorter fluoroscopy times,

[1]Auerbach, JD, Weidner ZD, Milby AH, et al. Musculoskeletal disorders among spine surgeons: results of a survey of the Scoliosis Research Society membership. *Spine.* 2011;36(26):E1715–E1721.

(*Continued*)

EDITOR'S NOTE (*CONTINUED*)

a lower revision rate, and faster operating times in idiopathic patients compared with using manual tools.[2] There was one complication (hemothorax) attributed to a pedicle screw.

Facetectomies—Proper exposure of the superior facet in the thoracic spine is important to allow identification of landmarks to identify the starting point of a pedicle screw, among other benefits. My technique is to use an ultrasonic bone cutting device with a trademark name of "BoneScalpel" (Misonix, Farmingdale, NY) to perform thoracic and lumbar facetectomies. Benefits include less blood loss and less force when compared to using an osteotome. In the lumbar region a single straight cut parallel to the joint removes the majority of the inferior facet. In the thoracic region two straight cuts removes the inferior facet: a vertical one along the medial edge of the underlying superior facet and a transverse one at the top of the underlying superior facet (Video 44-1).

Power-Assisted Pedicle Tract Preparation and Screw Placement

1. Prepare the entry site using standard anatomic markings with a power bur that is 3 mm or so in width such as the M-8 bur for the Midas set. This will create an entry through the cortex approximately 3 mm wide and 2 mm deep.
2. Then using a standard battery operated, variable speed drill, a 1.7-mm drill bit is used. This drill bit is spun very slowly, about 1 to 3 rotations per second. By spinning the drill slowly, the sharpened ends give a different feel when they are against cortical versus cancellous bone. The objective is to avoid the cortical bone on the outside of the pedicle and seek the softer cancellous bone on the inside of the pedicle. By aiming the drill bit in slightly different directions, one can feel the best direction with the softest bone and allow the drill to continue along that tract. Very little force is used. One may imagine the weight of the drill is more than enough force for most pedicles. If one encounters hard cortical bone, such as along the medial portion of the pedicle, more resistance is felt as well as chatter with the sharp drill bits against the cortical bone, signaling the surgeon to change the direction of the drill. This first 1.7-mm drill is used for about 20 mm of depth, just to go past the length of most thoracic pedicles.
3. A ball tip probe is then used to make certain that the pedicle has not been violated in any of the walls and that the depth is intact bone.
4. A 3.2-mm drill is then used. At this point, the direction of the tract is already set, and the drill is merely widening the tract. This drill tends to center within the pedicle itself and rarely goes outside of the pedicle at this point. I will use this drill to go down 5 mm past the intended screw length, that is, for a 35 mm screw I will place this drill 40 mm deep. A pedicle probe is then be used to ensure that there is bone at the end of the tract as well as no cortical violations circumferentially. This technique prepares a tract for a screw 5 mm longer than is actually used to give a margin of safety. While the last 5 mm of screw would add little pull out strength to the screw, long screws can cause problems and require a return to the O.R.
5. For a 5.5-mm screw, which is the most common screw I use in scoliosis surgery, the screw is now placed.
6. I recommend against routine use of a tap. While studies show that undertapping is associated with higher pullout strength than is tapping the full diameter of the screw, the same studies also show that not using a tap at all is associated with an even higher pull out strength than using a tap. If a tap were to be used and inadvertently go past the vertebra, catastrophic injury to vascular structures could occur. I also consider the possibility of tap tearing dura or nerve roots to be an unnecessary risk. In very rare instances with an initial incorrect screw trajectory a tap will be used to help define the correct trajectory.
7. If I am placing a 6.5-mm-diameter screw or bigger in normally hard bone such as in AIS, I will use a pedicle probe to further widen the channel. This is really only needed for the first 20 mm of screw length as the cancellous bone of the vertebra does not need to be widened.
8. I prefer to use a "stab and grab" connection from the drill to the screwdriver. This allows the screw to be quickly disengaged from the drill if an assistant is placing a screw in a manner that I would like to stop. It is also very quick and easy and does not place an overly large amount of force or torque on the screw when it is being disengaged.

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[2]Seehausen DA, Skaggs DL, Andras LM, et al. Safety and efficacy of power assisted pedicle tract preparation and screw placement. *Spine Deform.* 2015;3(2):159–165.

EDITOR'S NOTE (*CONTINUED*)

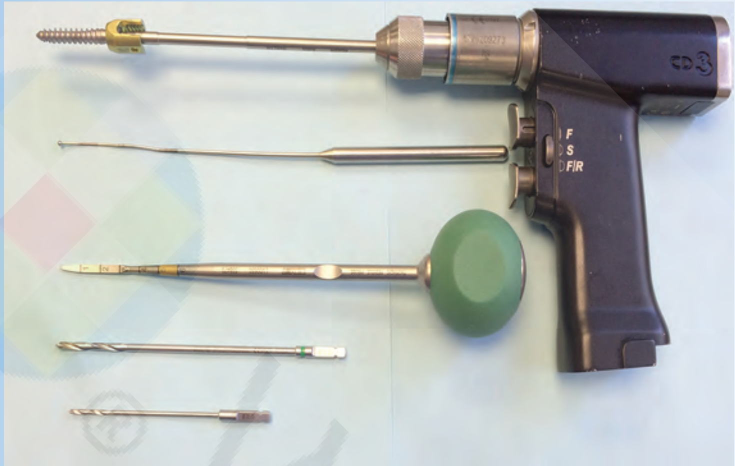

FIGURE 44-13 A 2.0-mm drill bit, a 3.2-mm drill bit, Lenke pedicle probe, ball tip probe, and a pedicle screw on a "stab and grab" connector. (Photograph used with permission of Children's Orthopaedic Center, Los Angeles, CA.)

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