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Thoracoscopic Spinal Fusion Compared with Posterior Spinal Fusion for the Treatment of Thoracic Adolescent Idiopathic Scoliosis

Surgical Technique

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ABSTRACT

BACKGROUND:

Posterior spinal fusion with segmental instrumentation is the gold standard for the surgical treatment of thoracic adolescent idiopathic scoliosis. More recently, anterior surgery and video-assisted thoracoscopic surgery with spinal instrumentation have become an option. The purpose of the present study was to compare the radiographic and clinical outcomes as well as pulmonary function in patients managed with either anterior thoracoscopic or posterior surgery.

METHODS:

Radiographic data, Scoliosis Research Society patient-based outcome questionnaires, pulmonary function, and operative records were reviewed for fifty-one patients undergoing surgical treatment of scoliosis. Data were collected preoperatively, immediately postoperatively, and at the time of the final follow-up. The radiographic parameters that were analyzed included coronal curve correction, the most caudad instrumented vertebra tilt angle correction, coronal balance, and thoracic kyphosis. The operative parameters that were evaluated included the operative time, the estimated blood loss, the blood transfusion rate, the

continued

INTRODUCTION

Idiopathic scoliosis accounts for approximately 80% of all types of scoliosis in the adolescent population, and >50% of these idiopathic curves in adolescents are thoracic. The standard technique for the operative management of thoracic idiopathic scoliosis has been through a posterior approach. Despite good outcomes with posterior surgery, that approach requires extensive muscle dissection, results in a long midline scar, does not reproducibly correct the thoracic hypokyphosis typically associated with idiopathic scoliosis, and may lead to pain from implant prominence. Anterior surgery with a thoracoscopic technique appears to result in equivalent curve correction with minimal muscle dissection of the chest wall, improved kyphosis correction, more desirable scars, an acceptable complication rate, and a return

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of baseline pulmonary function within several months after the operative procedure[1-5].

SURGICAL TECHNIQUE

Preoperative Planning

Full-length standing posteroanterior and lateral radiographs of the spine as well as supine or fulcrum right and left bending radiographs are made. Secondary structural curves in the cephalad thoracic and thoracolumbar/lumbar regions that might require inclusion in the arthrodesis are ruled out, and the levels to be included in the construct are selected. Typically, the Cobb end vertebrae and the intervening levels are treated. Pulmonary function testing may be performed to rule out substantial restrictive lung disease, particularly in patients with large curves, marked hypokyphosis, or pulmonary symptoms.

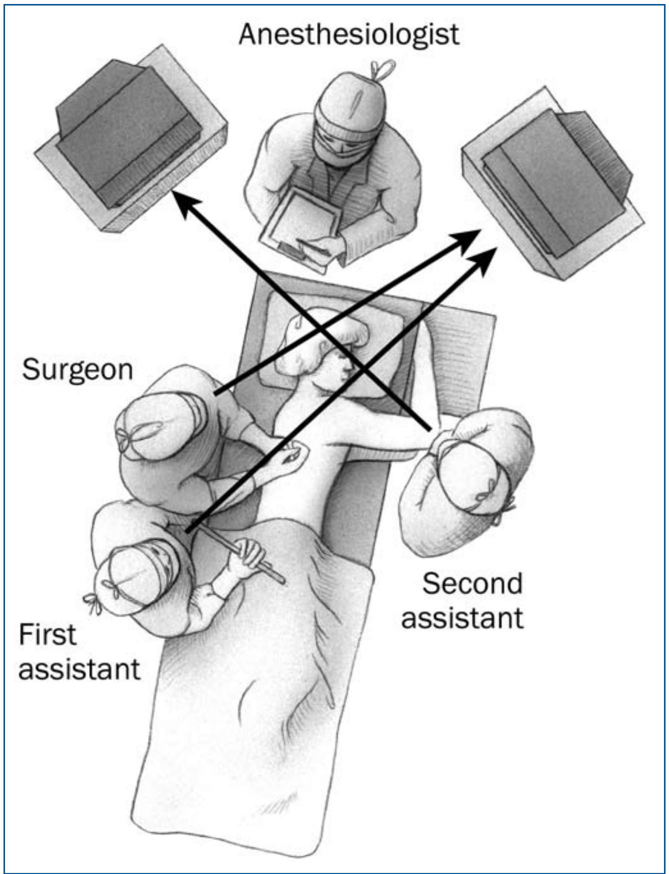

FIG. 1

Operating room setup and patient positioning.

ABSTRACT | continued

number of levels fused, the type of bone graft used, and the number of intraoperative and postoperative complications. The pulmonary function parameters that were analyzed included vital capacity and peak flow.

RESULTS:

The thoracoscopic group included twenty-eight patients with a mean age of 14.6 years, and the posterior fusion group included twenty-three patients with a mean age of 14.3 years. The percent correction was 54.5% for the thoracoscopic group and 55.3% for the posterior group. With the numbers available, there were no significant differences between the two groups in terms of kyphosis ($p = 0.84$), coronal balance ($p = 0.70$), or tilt angle ($p = 0.91$) at the time of the final follow-up. The mean number of levels fused was 5.8 in the thoracoscopic group, compared with 9.3 levels in the posterior group ($p < 0.0001$). The estimated blood loss in the thoracoscopic group was significantly less than that in the posterior fusion group (361 mL compared with 545 mL; $p = 0.03$), and the transfusion rate in the thoracoscopic group was significantly lower than that in the posterior fusion group (14% compared with 43%; $p = 0.01$). Operative time in the thoracoscopic group was significantly greater than that in the posterior group (6.0 compared with 3.3 hours, $p < 0.0001$). There were no intraoperative complications in either group. Vital capacity and peak flow had returned to baseline levels in both groups at the time of the final follow-up. Patients in the thoracoscopic group scored higher than those in the posterior group in terms of the total score ($p < 0.0001$) and all of the domains ($p < 0.01$) of the Scoliosis Research Society questionnaire at the time of the final follow-up.

CONCLUSIONS:

Thoracoscopic spinal instrumentation compares favorably with posterior fusion in terms of coronal plane curve correction and balance, sagittal contour, the rate of complications, pulmonary function, and patient-based outcomes. The advantages of the procedure include the need for fewer levels of spinal fusion, less operative blood loss, lower transfusion requirements, and improved cosmesis as a result of small, well-hidden incisions. However, the operative time for the thoracoscopic procedure was nearly twice that for the posterior approach. Additional study is needed to determine the precise role of thoracoscopic spinal instrumentation in the treatment of thoracic adolescent idiopathic scoliosis.

CRITICAL CONCEPTS

INDICATIONS:

- Structural thoracic adolescent idiopathic scoliosis
- Structural thoracic idiopathic scoliosis in an adult with normal bone density
- A normokyphotic or hypokyphotic thoracic spine (≤40° of kyphosis)
- A curve between 40° and 70°
- Curve flexibility to ≤30°
- Eight or fewer vertebrae to be included in the arthrodesis
- A need for an arthrodesis that extends no more cephalad than T4 and no more caudad than L1
- Normal pulmonary function

CONTRAINDICATIONS:

- Rigid curvature of >70°
- Thoracic kyphosis of >40°
- Previous surgery within the thoracic cavity on the ipsilateral side
- A history of recurrent pneumonia, pulmonary tuberculous infection, or abnormal lung function
- Osteopenia
- A seizure disorder or a suspicion that the patient will not comply with postoperative instructions. These are contraindications because of concerns about implant loosening with a single-rod construct.

Operating Room Setup

Two video monitors (Fig. 1) are placed at the head of the patient to allow easy visualization of the endoscopic operative field by both the primary surgeon and the two assistants. A thoracic surgeon experienced in thoracoscopic technique should be part of the operative team, at least initially until the spine surgical team gains experience with the approach. We prefer to use a 10-mm 45° angled scope, but

FIG. 2-A

Specially adapted spinal instruments.

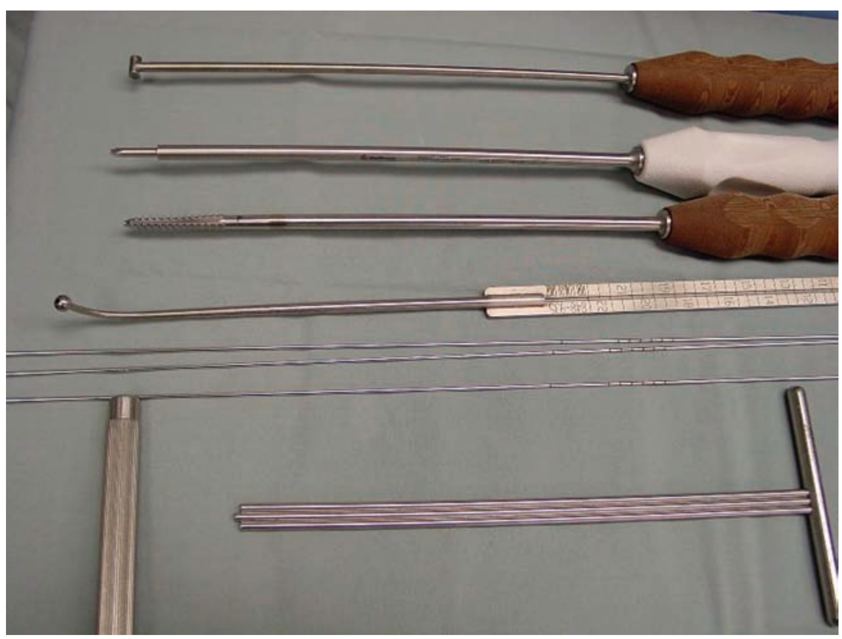

FIG. 2-B

Tools used to perform spinal instrumentation.

other angles can be utilized depending on the surgeon's preference. The angle allows visualization around corners, permitting visual access to the disc space on both sides of the spine. The working instruments are designed to span the distance between the chest wall and the spine, with the working portion small enough to traverse a 15-mm opening or portal and include Cobb elevators, curets, and pituitary and Kerrison rongeurs (Figs. 2-A and 2-B). Additional instruments include a harmonic scalpel for dissection of the pleura and coagulation and incision of the segmental vessels over the operative spinal levels. This tool generates little heat, which could damage vital structures. The harmonic scalpel can also be used to incise the disc, as can a long scalpel; however, we prefer a standard electrocautery with a long shaft. An articulating fan retractor is used as needed to retract the lung and diaphragm. A radiolucent operative table that allows fluoroscopic visualization of the thoracic spine is used. The imaging unit is brought in from the anterior aspect of the patient.

Anesthesia

The patient is placed under general endotracheal anesthesia. A double-lumen endotracheal tube is utilized to allow single-lung ventilation. The right lung is deflated in almost all cases, as most thoracic curves are convex to the right and are approached on that side. Bronchial endoscopy is used to confirm the accuracy of tube placement. A radial arterial line and a urinary catheter are then placed. Intravenous antibiotics are administered. Spinal cord monitoring is employed, and we prefer to utilize both somatosensory and transcranial motor-evoked-potential monitoring. After baseline waveforms are obtained, muscle relaxant is administered to ease the approach through the chest wall musculature. Approximately one-half hour of muscle relaxation is required to allow portal placement and rib graft harvesting.

Patient Positioning

The patient is placed in the lateral decubitus position with care taken to pad all osseous prominences and to avoid pressure on the peroneal nerves. An axillary roll is placed under the downside part of the chest, and the upside arm is placed in an armholder. The upper arm is held loosely to allow manipulation of the scapula for proximal portal placement (Fig. 1). A portable fluoroscopy unit is brought into position to be certain that adequate radiographic visualization is possible. The patient is held in position with a beanbag, and 90° decubitus positioning is confirmed.

Approach

Prior to preparation, the chest wall is marked for portal placement with a fluoroscopy unit in position for guidance. Anteroposterior and lateral views are obtained. Three portals are made in the posterior axillary

CRITICAL CONCEPTS | continued

PITFALLS:

An inexperienced anesthesiologist can find it difficult to achieve single-lung ventilation. A double-lumen endotracheal tube appears to allow better control and easier deflation of the lung than does a bronchial blocker. The position of the tube must be checked once the patient has been positioned for the procedure. If the cuff of the right-sided tube is caudad to the take-off of the upper lobe bronchiole from the right mainstem bronchus, lung deflation and subsequent visualization will be inadequate. The possible need for a formal thoracotomy, if adequate single-lung ventilation cannot be achieved, should be discussed with the family.

Positioning of the patient is crucial. If the patient is not at a 90° orientation to the table or if that position changes during the procedure, the surgeon may be misled about the orientation of the spine and tend to direct the screw toward the spinal canal or in an excessively anterior orientation. The upside arm should be relatively mobile as the scapula tends to lie over the cephalad portal, potentially blocking entrance to the thoracic cavity. The scapula can usually be mobilized easily posteriorly while the portal is placed.

Segmental vessels over the segments to be included in the instrumentation are usually easy to control. However, a large segmental vessel may not be amenable to coagulation with the harmonic scalpel. An endoscopic bipolar cautery or vascular clip applier may be helpful. In cases in which the caudad fusion level is L1, the segmental vessel is

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CRITICAL CONCEPTS | continued

obscured by the diaphragm, and control may be difficult. If bleeding is not readily stopped, a small incision extending through the caudad posterior or anterior portal allows direct visualization of the vessel and easy access to the area. An incision of ≤10 cm is all that is required in that scenario.

Proper portal placement is crucial in order to allow accurate placement of vertebral body screws. One must strive to place the posterior portals at the posterior one-third of the vertebral body. Anterior portal placement will tend to result in screws being directed toward the spinal canal or with inadequate purchase in the anterior aspect of the vertebral body.

Screw orientation in the cephalocaudad direction is essential to avoid inadequate resistance to pull-out during the corrective maneuver or postoperatively. The ideal placement is perpendicular to the vertebral body in the midpart of the body. Occasionally midbody placement is difficult and juxta-end plate positioning is performed. This is satisfactory as long as the end plate has not been overly weakened and the screw is firmly in bone throughout its course. Otherwise, plowing of the screw through the end plate is likely.

The cephalad screw can pull out during the cantilever reduction maneuver. This is avoided by fixing the rod to two or three screws cephalad, performing a gentle compression maneuver, and only then doing the cantilever reduction. Leaving the cephalad screw head protruding slightly by placing a washer on the screw also helps to resist this tendency.

continued

line, and two are placed in the anterior axillary line (Fig. 3-A). The posterior portals are placed in a location that allows screw placement in the posterior aspect of the vertebral bodies. Two or three vertebrae are accessible through each portal. Five to eight vertebrae are included in the arthrodesis in the majority of cases. The anterior portals are placed in a manner to allow access to the discs for discectomy and for the scope as well to assist in the application of the spinal instrumentation. In some cases, complete access to the discs, particularly at the cephalad end of the arthrodesis, is not possible and the disc removal is completed through a posterior portal. The middle posterior portal, usually over the eighth rib, is the first to be made. A 15 to 20-mm incision is made, and dissection to the rib is performed. Handheld retractors are used to access the rib, which is

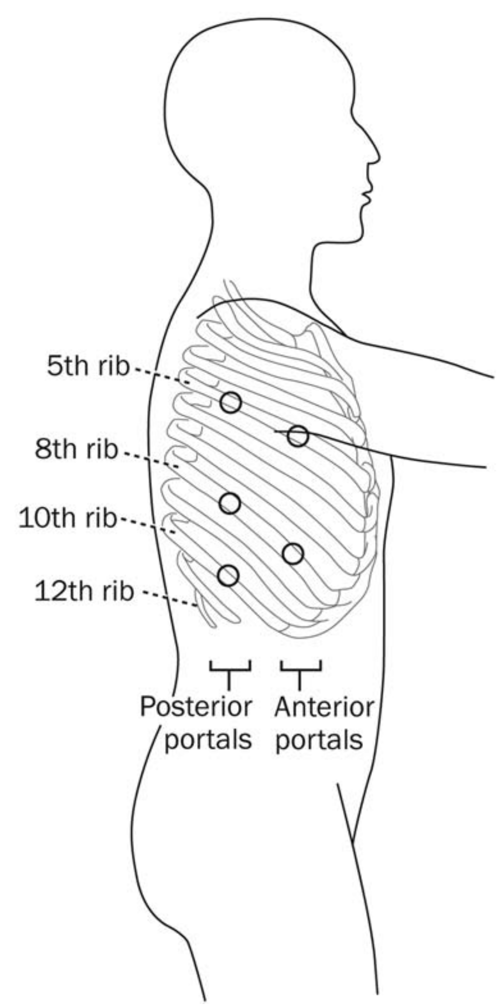


FIG. 3-A

Portal configuration.

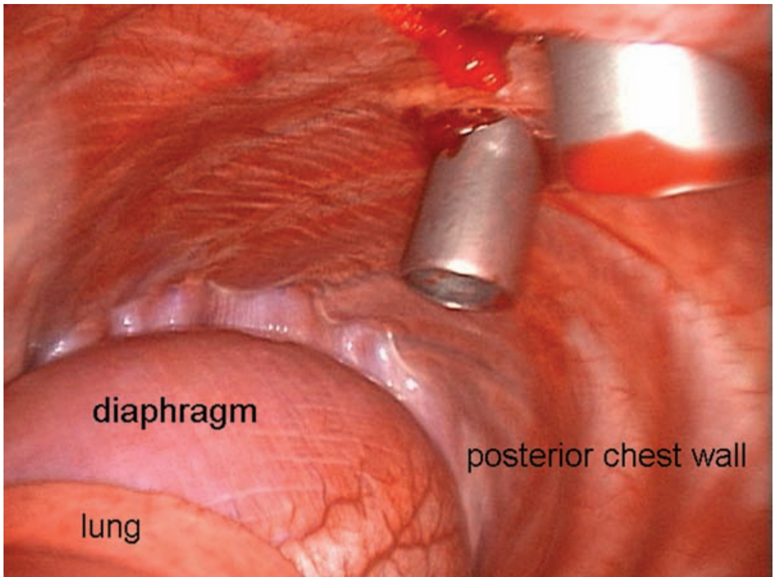


FIG. 3-B

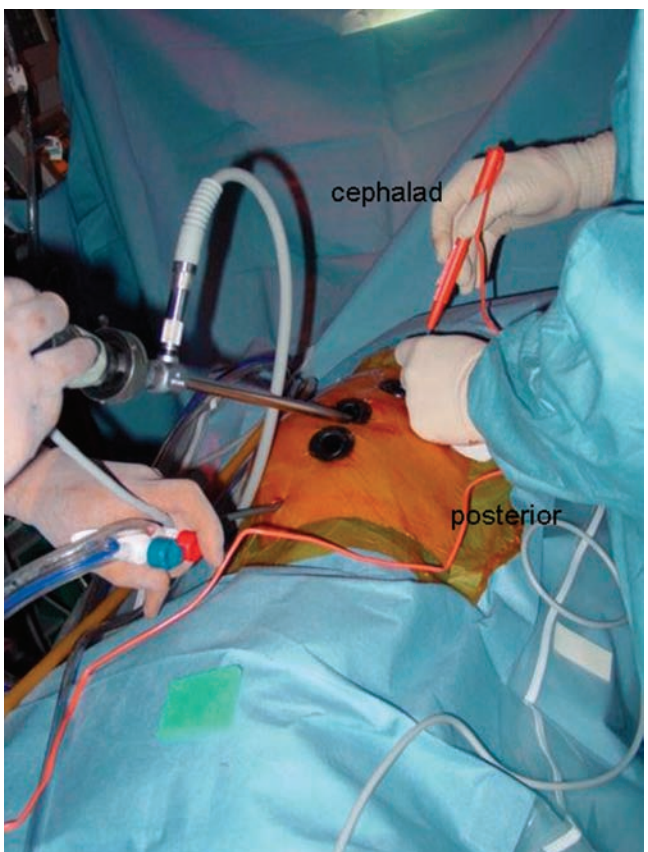


FIG. 3-C

Portals are placed under direct visualization after the first portal has been placed.

CRITICAL CONCEPTS | continued

Seating the rod into the vertebral body screws may be difficult if the screws are not placed in a collinear fashion. Accurate screw placement depends on choosing the starting hole carefully with a position just anterior to the rib head and visualizing the screw alignment with use of the scope in a so-called pipeline view.

Rod breakage was noted in our series. We have found this to be related to difficult seating of a rod due to an imprecise alignment of the vertebral body screws and the requirement for excessive manipulation during rod seating. Breakage of stainless-steel rods has not been noted, to our knowledge. Use of a dual-headed screw that accepts two rods is an alternative to use of a single stainless-steel rod. Another factor that may result in rod breakage or screw loosening is pseudarthrosis. The surgeon must be meticulous when preparing the end plates as well as when grafting the disc spaces in order to allow timely onset of fusion.

Failure to recognize and treat a structural cephalad curve may result in elevation of the left shoulder and patient dissatisfaction. Thoracoscopic instrumentation is not suitable for double structural curves.

AUTHOR UPDATE:

No substantial changes have been made in the technique since publication of the original article.

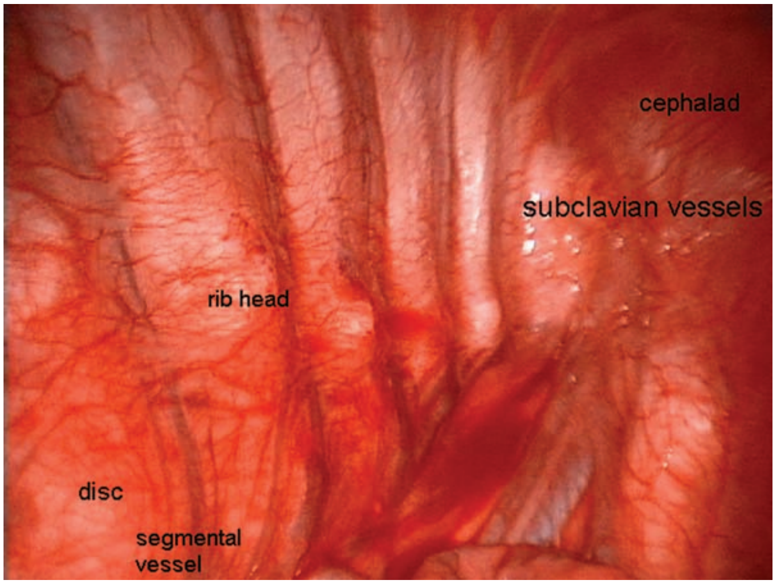


FIG. 3-D

The first rib is identified deep to the subclavian artery.

then dissected subperiosteally. A specially designed rib-cutter allows resection of the rib through the small incision. A 5 to 6-cm portion of the rib is removed and then is morsellized for the purpose of bone-grafting. An additional rib can be harvested as needed through another portal. Each additional portal is then made after the scope is introduced into the chest cavity under direct visualization so as not to injure underlying structures during portal placement (Figs. 3-B and 3-C). These portals are placed on either the cephalad or the caudad aspect of the rib, which is resected only if additional graft is required. To maintain the aperture, a metal cylinder is placed to act as the conduit for work through the portal.

The chest wall, lung, and diaphragm are evaluated for abnormalities other than the scoliosis. Levels are determined by counting down from the first rib, which is partially hidden beneath the pulsating subclavian artery (Fig. 3-D). Pleural dissection at the involved levels and coagulation, incision, and dissection of the segmental vessels over the vertebrae to be included in the instrumentation are performed with use of the harmonic scalpel. Blunt dissection of the pleura to the contralateral side of the spine is done so that approximately 270° of the disc perimeter is exposed. The levels are then confirmed radiographically with

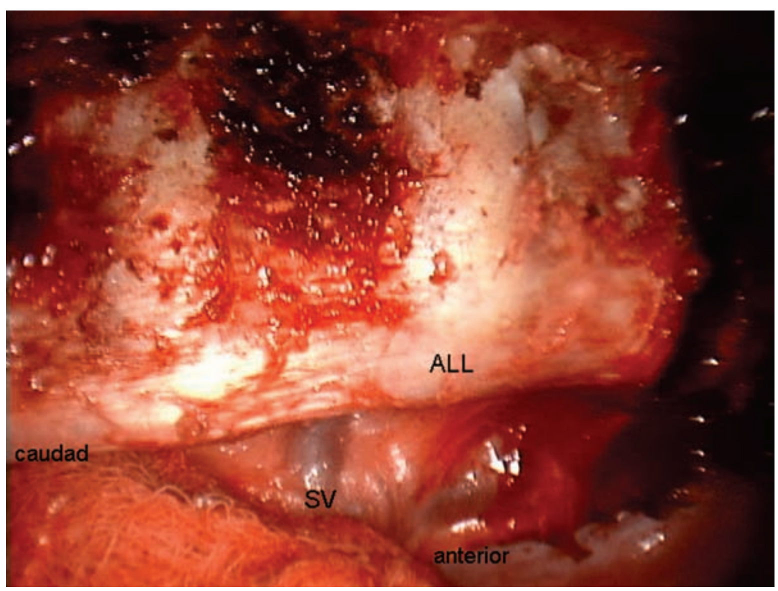


FIG. 4-A

The spine is circumferentially exposed. ALL = anterior longitudinal ligament and SV = segmental vessel.

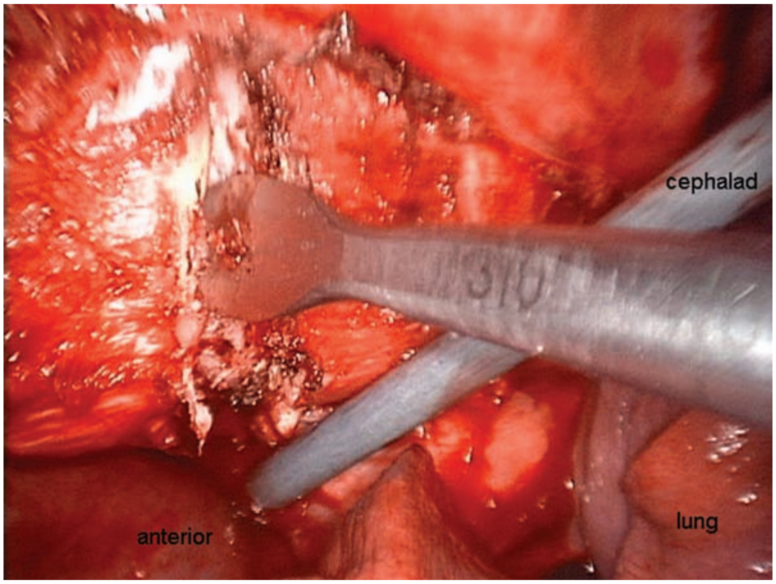


FIG. 4-B

A discectomy is performed.

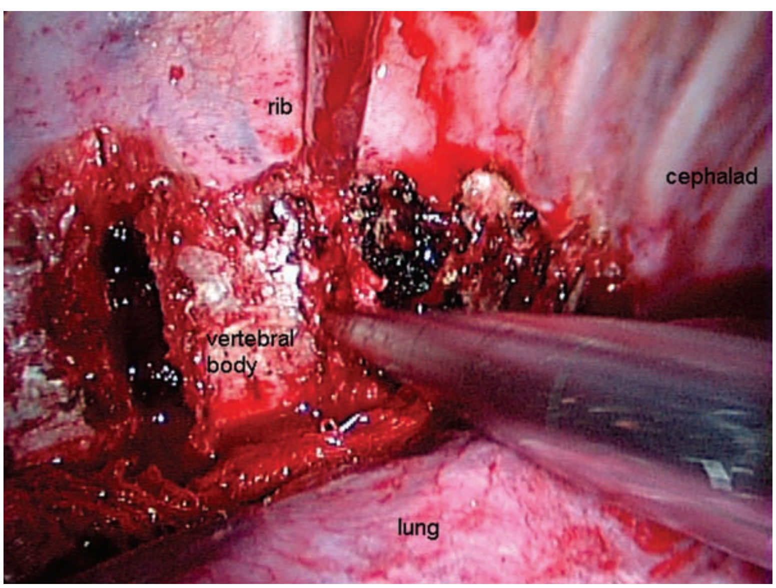


FIG. 4-C

The end plates are carefully denuded of cartilage and disc material, creating a bleeding subchondral surface.

a guidewire placed into one of the caudad discs.

Discectomy and End-Plate Preparation for Arthrodesis

The intervening discs between the Cobb end vertebrae are removed. This is done by first incising the anulus fibrosus with electrocautery. Suction is required to keep the field clear of smoke. Pituitary rongeurs are utilized to remove the anulus fibrosus and to debulk the nucleus pulposus. The cartilaginous end plate is elevated from the underlying subchondral bone with a Cobb elevator and removal is facilitated by the use of a pituitary rongeur. Remaining disc material is removed with curets. Disc material is removed from the underside of the overlying rib head with use of a Kerrison rongeur (Figs. 4-A, 4-B, and 4-C). Following discectomy, each disc space is packed with a hemostatic agent to limit blood loss from the vertebral end plates. We prefer to perform bone-grafting following instrumentation so that graft material is not lost from the disc spaces during screw placement.

Spinal Instrumentation and Curve Correction

The fluoroscopy unit is draped in a sterile fashion and then is brought into position. Screw placement is guided radiographically and endoscopically. A system consisting of a 4.5-mm rod and vertebral screws is used. Initially, we used titanium implants, but we switched to stainless steel because of anecdotal reports of rod breakage in addition to two cases noted in our own series. The cephalad-most screw is placed first, and the length of this screw (typically, 27.5 or 30 mm) is determined by templating the most cephalad vertebra on the preoperative posteroanterior radiograph. The lengths of the subsequently placed screws are estimated on the basis of fluoroscopic imaging. In our early experience, we used a calibrated guidewire technique to determine screw length; however, this was abandoned because of concerns about the guidewire migrating into the contralateral side of the chest[5].

Ideally, the screw is positioned 1 to 2 mm anterior to the rib head in the midpart of the vertebral body with a gentle anterior angulation of approximately 10° to avoid penetration of the spinal canal. If the rib head has been removed to facilitate release of the spine, the surgeon must identify the posterior border of the vertebral body to avoid penetration into the spinal canal. The surgeon must avoid a tendency to place successive screws increasingly anterior in the vertebral body as this may result in poor bone purchase and perhaps protrusion of too long a portion of a screw in the vicinity of the aorta[6]. Proper screw placement facilitates restoration of physiologic kyphosis. A pilot hole is created first with an awl and then with a tap under image-guidance. The tap is undersized by 1 mm compared with the screw. Typically, a 6.5 or 7.5-mm-

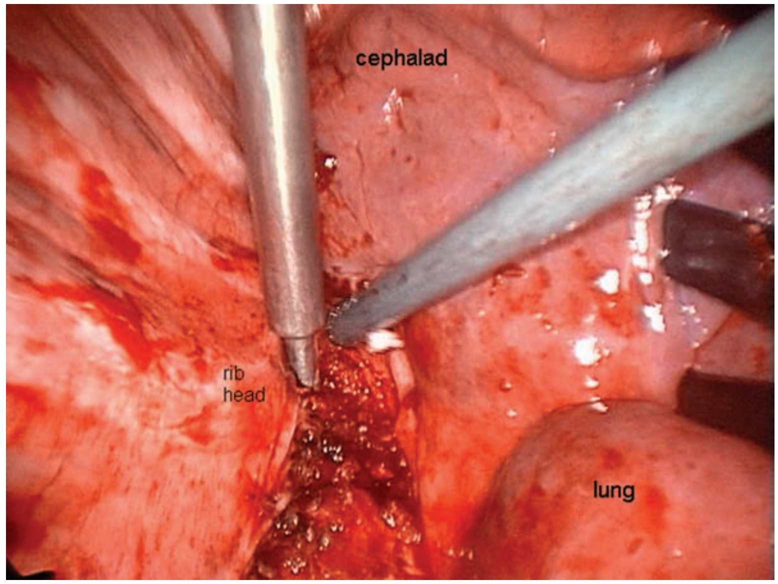


FIG. 5-A

A pilot hole is created for placement of a vertebral body screw.

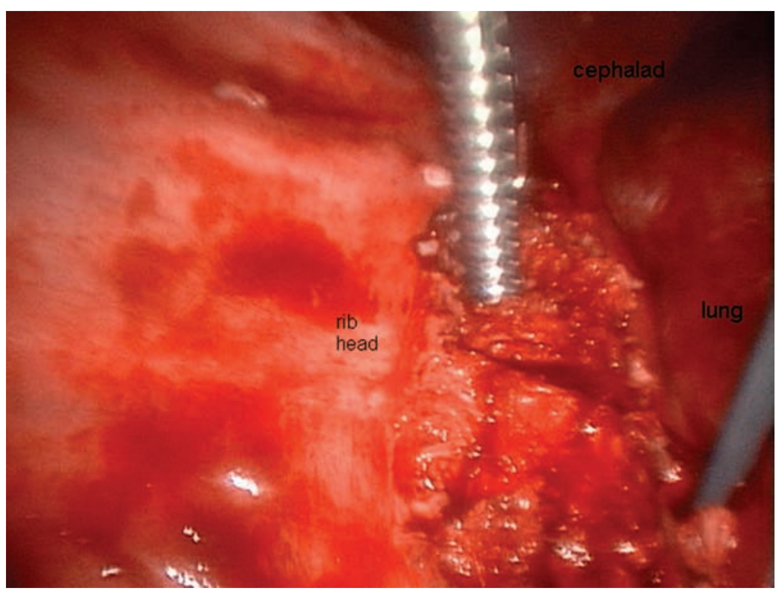


FIG. 5-B

Tapping.

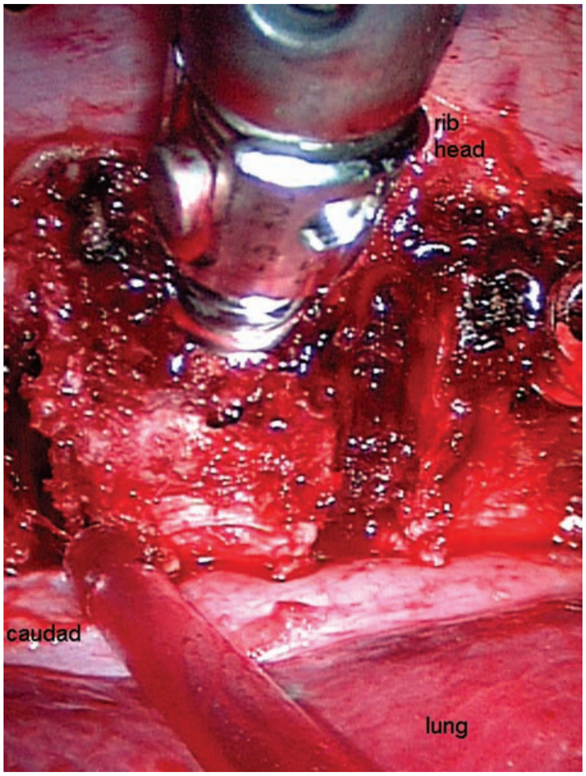


FIG. 5-C

Screw placement.

diameter screw is placed into the vertebra (Figs. 5-A through 5-D). The screw has a unicortical design, but we prefer bicortical purchase with one or two screw threads protruding to achieve maximum purchase. The screw is oriented perpendicular to the vertebral body. Often, in order to obtain the proper trajectory, the surgeon must dissect on the side of the rib opposite to that of the initial portal placement. Anteroposterior and lateral fluoroscopic imaging confirms proper screw placement.

Following confirmation of the screw position, the imaging unit is removed. A calibrated rod-measuring device, containing a cable with a ball tip that inserts into the most cephalad screw and with the inserter itself ending in a ball tip that is inserted into the most caudad

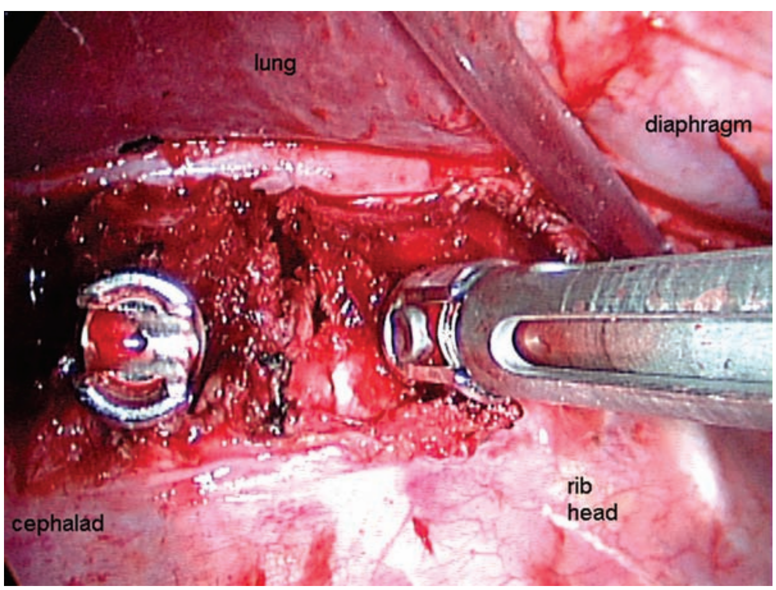
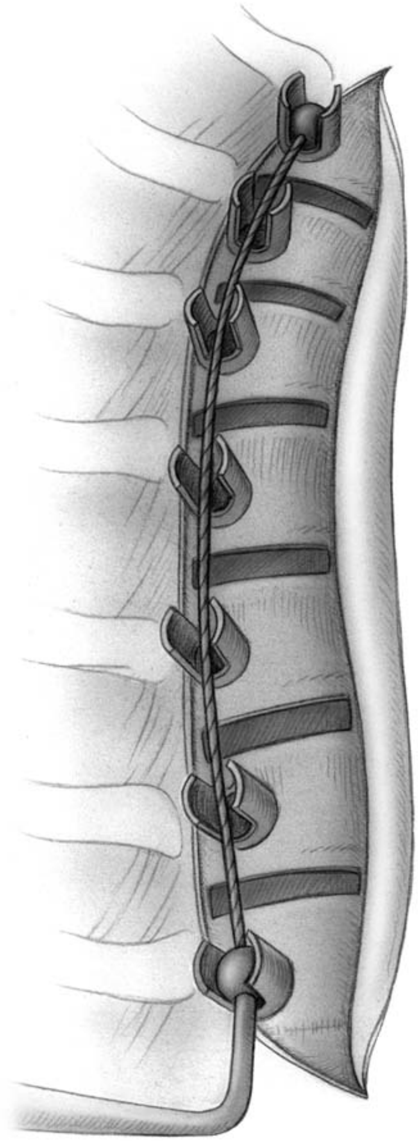


FIG. 5-D

Collinear placement of screws facilitates rod placement.



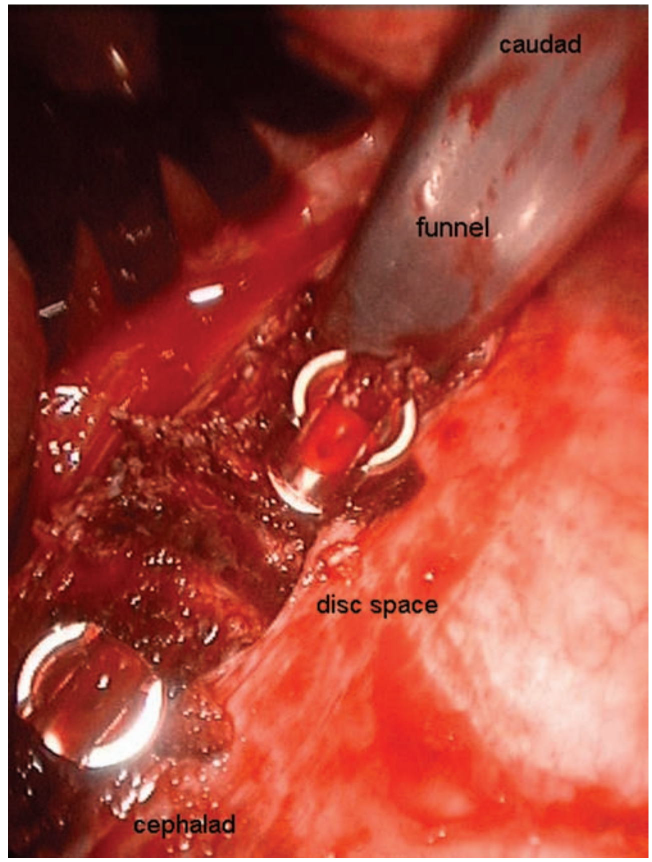


FIG. 6-A FIG. 6-B

Fig. 6-A Rod length is determined with use of a rod-measuring device. **Fig. 6-B** A funnel facilitates placement of rib autograft.

screw, is utilized (Fig. 6-A). A rod of appropriate length is then cut.

Final disc and end-plate preparation, to ensure complete removal of disc material from the end plates, and bone-grafting are then done with use of a funnel that guides the graft material into the disc space (Fig. 6-B). Rib autograft is utilized and is augmented with demineralized bone matrix in a putty form. The rod is then introduced into the cephalad two screws by inserting it in a cephalad direction through the most caudad posterior portal. The rod is manipulated with a rod-grasper. Set screws are applied through a cannulated tube that sits over the rod and screw head to guide set-screw placement. The second set screw is then fi-

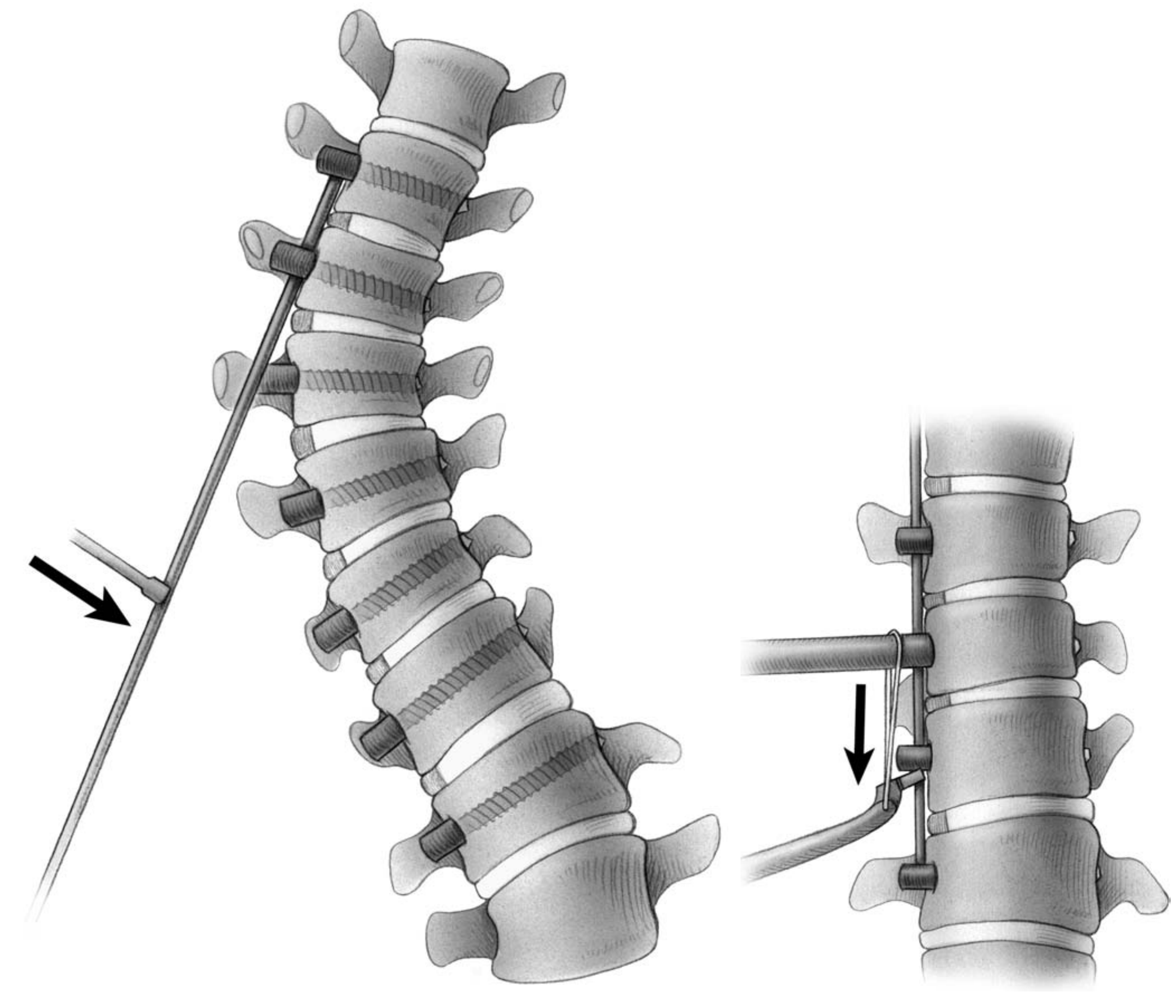


FIG. 6-C FIG. 6-D

Fig. 6-C Rod reduction. **Fig. 6-D** Segmental compression is performed with use of a cable compressor at each instrumented level.

nally tightened with use of a torque screw driver. A cable compressor designed specifically for the thoracoscopic procedure is used to compress the first two screws, which closes down the disc space, and the cephalad set screw is finally tightened. The caudad end of the rod is then reduced to the more caudad vertebral screws in a cantilever fashion, and set screws are sequentially placed. Again, compression of each segment is performed, and final tightening is done with the torque screw driver. The chest tube is then placed under direct visualization, and it is usually placed in the caudad anterior portal up to the cupola of the thoracic cavity. Irrigation is performed with an endoscopic suction-irrigator. Final radiographs are made to

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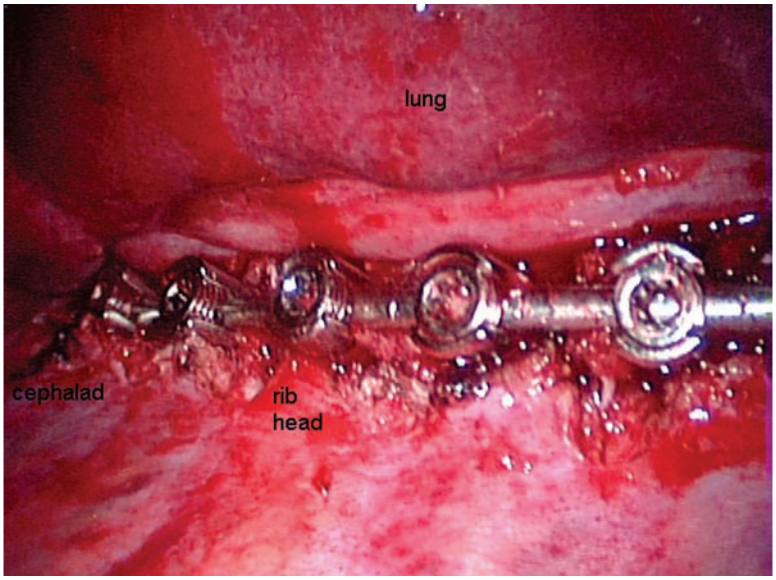

FIG. 6-E

Final construct.

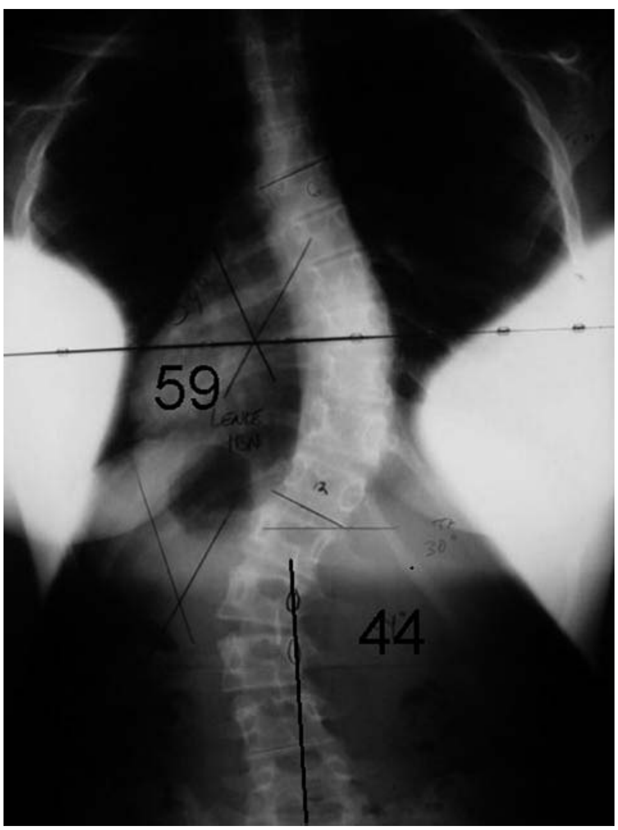

FIG. 7-A

FIG. 7-B

Figs. 7-A through 7-E An adolescent girl with a structural thoracic curve and a compensatory lumbar curve that crossed the midline was treated with thoracoscopic spinal arthrodesis and instrumentation, resulting in balanced correction. **Figs. 7-A and 7-B** Preoperative posteroanterior and lateral radiographs.

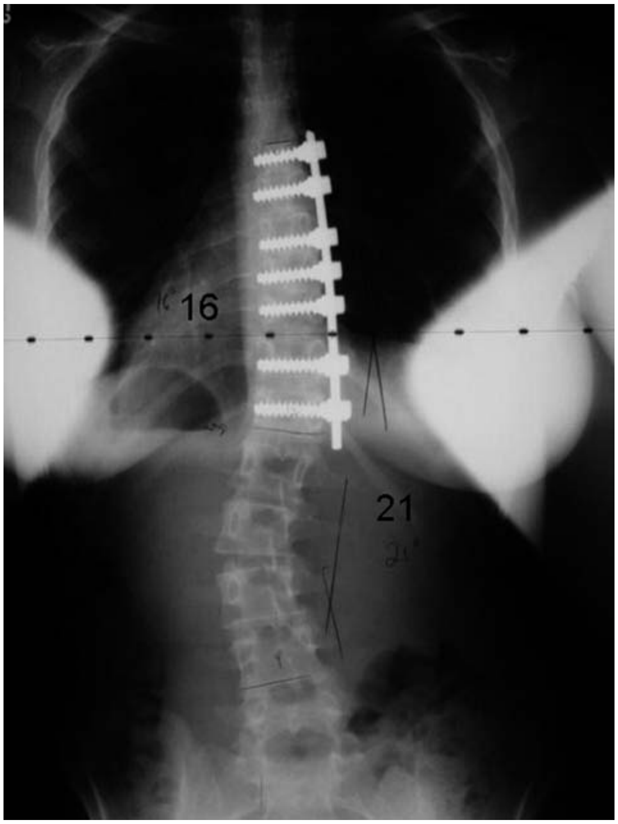

FIG. 7-C

FIG. 7-D

Postoperative posteroanterior and lateral radiographs.

FIG. 7-E

Portal scars at the first postoperative visit.

check instrumentation placement and curve correction. The metal portals are removed, and the lung is inflated gradually with release of the right mainstem bronchial cuff and application of positive pressure ventilation. Lung expansion is observed under endoscopic guidance. The anesthesiologist aggressively suctions the trachea and bronchi and may use the bronchoscope to do this, especially at the end of a prolonged procedure, in which mucous congestion may be greater. Each portal is closed in three layers, including the fascia and intercostal muscle, the subcutaneous tissue, and the skin. A purse-string suture is placed around the chest tube so that, with removal, the direct conduit to the chest cavity is closed down rapidly in order to avoid creating a pneumothorax.

A typical case is illustrated by the radiographs in Figures 7-A through 7-E.

The patient is mobilized to a chair on the first postoperative day. The chest tube is removed on the second or third postoperative day, when drainage is <200 mL in a twenty-four-hour period and a chest radiograph reveals the absence of substantial pneumothorax or pleural effusion. After the chest tube is removed, the patient wears a custom-molded clamshell thoracolumbosacral orthosis, when out of bed, for three months. Sports, bending, and lifting activities are restricted for three to six months or until a solid fusion is documented on follow-up radiographs.

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