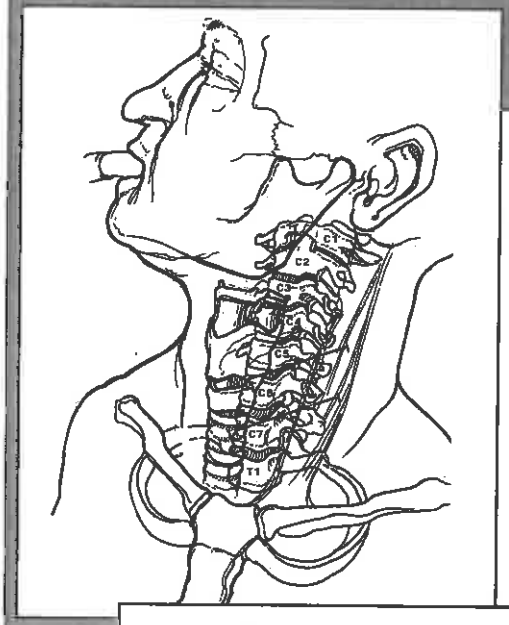
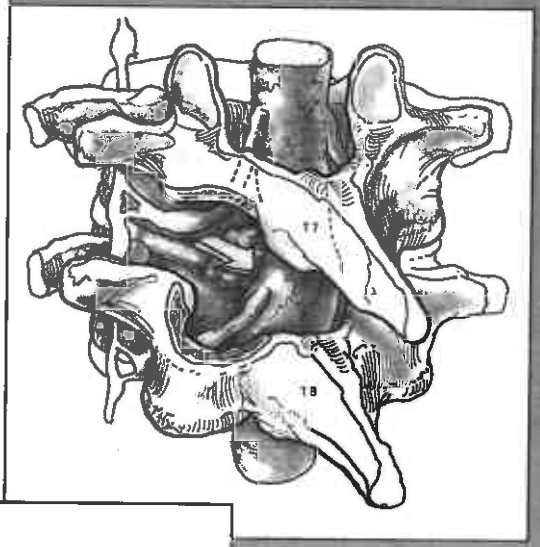
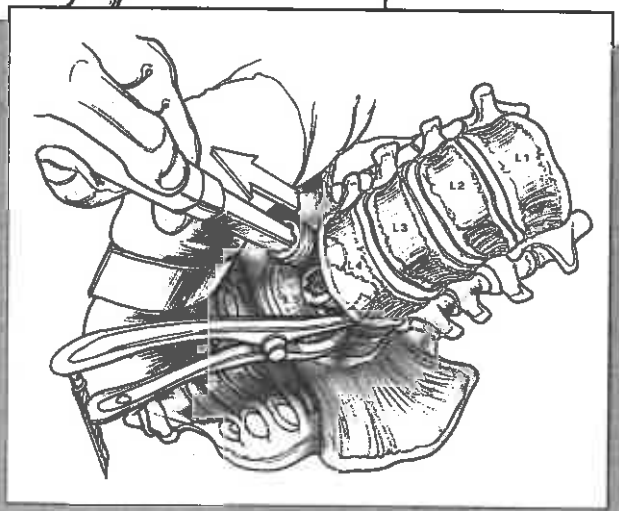
Surgical Techniques for the Spine

Thomas R. Haher
Andrew A. Merola







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To my wife Mary Jane and my sons Brendan and Brian.
Thomas R. Haher

To my wife Christine and my children Olivia and Nicholas.
Andrew A. Merola

In Memory of Laura B. Flawn, M.D., a vibrant young woman, whose contributions to orthopaedic surgery will be greatly missed.

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4. Loss of fixation/screw loosening: most commonly at the most cephalad or caudal hole; replace screw with larger diameter screw or remove plate if fused.
5. Screw/plate breakage: remove if symptomatic.
6. Vertebral artery injury.
7. "Creeping" fusions: avoid unnecessary dissection of the spine beyond area of fusion.
8. Damage to facet joint.
9. Iatrogenic foraminal stenosis: lateral mass shifts dorsally due to a lag screw effect. Foraminal narrowing may be prevented by placing a corticocancellous bone graft between the plate and the lateral mass.
0. Infection.
1. Pseudarthrosis: may present as hardware loosening, breakage; rarely gross instability. Treatment is anterior fusion.
2. Adjacent segment degeneration.
3. Loss of reduction.

Postoperative Care

1. Anteroposterior (AP) and lateral radiographs in operating room.
2. A subfascial drain is left in place for 48 hours or until output is less than 30 cc per 8 hours.
3. Antibiotics administered preoperatively and for 48 hours postoperatively.
4. The patient may be out of bed night of surgery and ambulation is encouraged.
5. Postoperative immobilization depends on the surgeon's satisfaction with fixation.
6. If rigid fixation with intact anterior column, only a soft cervical collar is required for comfort for 1 to 2 weeks.
7. For slightly more protection, a rigid cervical collar may be used.
8. If fixation is not rigid and facets or anterior column are incompetent, halo immobilization is recommended.
9. Activity is restricted until signs of fusion healing. Avoidance of heavy lifting, manual labor, bending, twisting, etc. Ambulation is encouraged.
10. Follow-up visits at 2 and at 6 weeks postoperatively, as well as 3 and 6 months.

Suggested Readings

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13 Anterior Cervical Disc Surgery
Technical Challenges

William Dillin

Goals of Surgical Treatment

To alleviate cervical nerve root generated arm pain and/or weakness secondary to mechanical pressure from a disc herniation or osteophyte. To remove mechanical pressure on the spinal cord secondary to posterior osteophytes at the disc space level or a herniated disc.

Diagnosis

Cervical Radiculopathy

1. The diagnosis is made on the basis of the history and physical and diagnostic studies.
2. The most reliable history for cervical nerve root compression is the development of arm pain, arm weakness, or numbness in the distribution of a single nerve root.
3. The physical examination may reveal a specific motor deficit or sensory deficit.
4. The arm pain often is exacerbated with hyperextension of the neck and rotation to the involved sign. This arm pain may be relieved by shoulder abduction.
5. Imaging studies such as a magnetic resonance imaging (MRI) scan may reveal an unequivocal structural abnormality (disc herniation, osteophyte, foraminal stenosis) correlating with the patient's clinical complaints and physical examination.
6. Other studies may be necessary, however, to confirm the presence of pathologic correlate and a symptomatic nerve root. This could include a cervical myelogram, combined with a contrast-enhanced computed axial tomography (CAT).

Cervical Myelopathy

1. The diagnosis is made on the basis of the history and physical and diagnostic studies.
2. The most reliable history for spinal cord compression is the development of a sense of balance loss, unsteadiness of gait, or unusual sensory disturbances in the lower extremities.
3. Upper extremity involvement may involve numb, clumsy hands or a radicular component.
4. The physical examination may reveal a hyperactive reflexes, nondermatomal sensory changes, and pathologic reflexes (Babinski, Hoffman's). Myelopathy in its earlier stages, however, may not reveal symptoms on physical examination.
5. Neck motion may produce a shock-like feeling in the torso or extremities.
6. Imaging studies such as an MRI scan may reveal an unequivocal structural abnormality (disc herniation, osteophyte) with spinal cord compression.

Indications for Surgery

1. Cervical radiculopathy with compression at the interspace level
2. Cervical myelopathy with compression at the interspace level
3. Unacceptable arm pain
4. Progressive symptoms with a gait disorder
5. Progressive weakness in involved upper extremity
6. Progressive symptoms with numb, clumsy hands
7. Loss of control of bowel and bladder symptoms
8. Cord syndromes such as an anterior cord syndrome, central cord syndrome, Brown-SUquard syndrome

Contraindications

1. Posterior pathology as the compressive agent.
2. Patient is not a candidate for surgery because of medical reasons.

Advantages

1. Direct visualized decompression of the offending pathology, which is commonly located anteriorly.
2. Indirect decompression with restoration or amplification of disc space height, which may increase foraminal size, and canal size.

Disadvantages

1. The potential for further destabilization of a motion segment in the spine at an adjacent level, leading to pain and disability and possible further surgery.
2. The anterior approach involves structures that might be infringed upon: recurrent laryngeal nerve, the trachea, the sympathetic trunk, the vagus nerve, the carotid sheath, the internal jugular vein.

Procedure

Technical Goal

To decompress the cervical spinal nerve and/or spinal cord due to a disc herniation or osteophyte.

Technical Challenge

Precision surgery aided by magnification and illumination.

Technical Principles

1. Approach to establish safe and secured anatomic plane for decompression and fusion.
2. Maintain optimum access to provide adequate decompression and stabilization.

Decision Making

1. Is the pathology actually represented on the preoperative films discovered in the operation?
2. Is the patient adequately decompressed?

Position and Exposure

1. Supine position, chest roll under posterior upper back to facilitate a neck neutral to slightly extended position. Radiolucent table to facilitate use of fluoroscopy in surgery. Arms tucked in at side, Boger straps placed but not tightened to provide visualization of C7 when needed for intraoperative x-ray.
2. Hypotensive anesthesia to reduce bleeding.
3. Preincision x-ray with sterile paper clip used as marker if there is any doubt about landmarks.
4. Incision (transverse for single level, transverse and/or oblique incision along medial sternocleidomastoid border for more than one level). Landmarks include cricothyroid membrane for the C5-C6 level and then estimate distance if superior or inferior levels need the approach. X-ray verification if there is any question prior to incision (Fig. 13–1).
5. Skin incision with superficial hemostasis. Placement of skin retractors allows for dissection in subcutaneous plane. Avoid separating subcutaneous tissue from skin.
6. Platysma is identified and divided either longitudinally or transversely.
7. Identify the medial border of sternocleidomastoid muscle and palpate the vertebral bodies with a gloved finger.
8. Place a hand-held Cloward retractor against the bone surface, trapping the middle colic and deep colic fascia against the vertebral body.
9. Gently tease through the fascial layers with peanuts, utilizing the bony surface as a background for dissection. If the fascia is tough, a small aperture may need to be created to allow cephalad and caudad exposure. This may be done with a Metzenbaum scissors, and then the peanut for further blunt dissection.
10. Identify both side of the longus coli muscle and obtain hemostasis while still using the hand-held retractor.
11. Place a needle into the interspace that is the likely target (hills are the discs, valleys are the vertebral bodies). Either clamp the needle or bend it into a staircase configuration to prevent the needle from being inadvertently pushed through the disc space into the spinal canal. Once the fluoroscopic verification has taken place, inject indigo carmine into the disc space to preserve the identity after replacement of the hand-held Cloward retractor.
12. The longus coli muscles are reidentified and the medial borders cauterized with the bipolar to prevent bleeding and allow mobilization.
13. The Trimline retractor blades are carefully inserted against and under

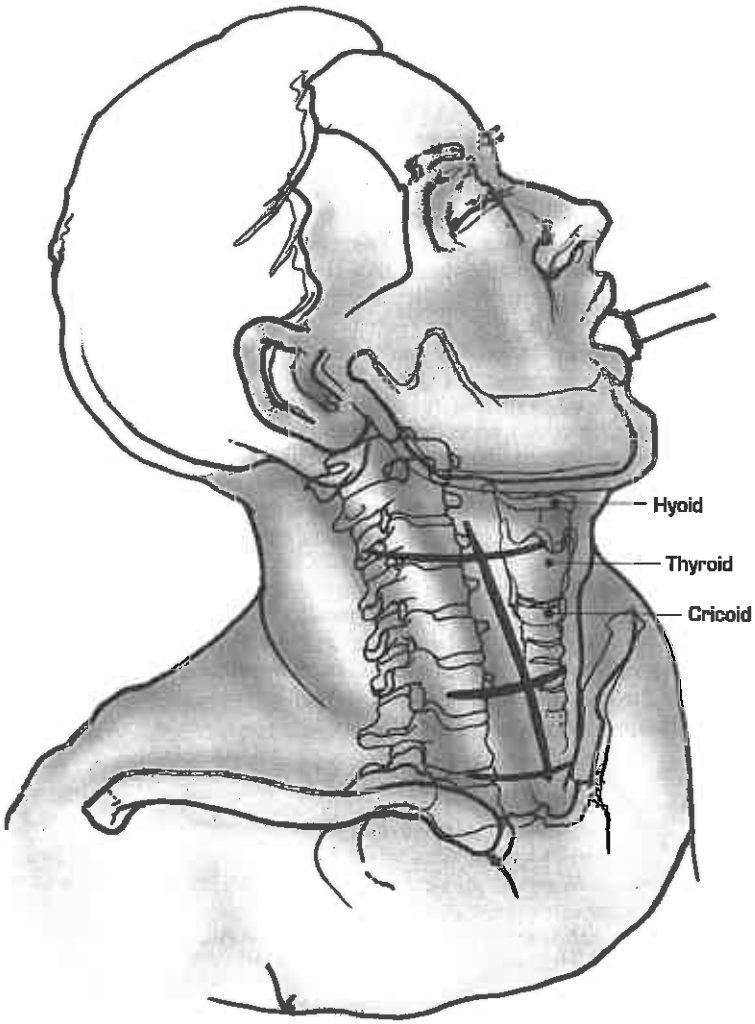

Figure 13–1

Landmarks and levels of surgical incision to expose the cervical spine from C2-C3 through C7-T1.

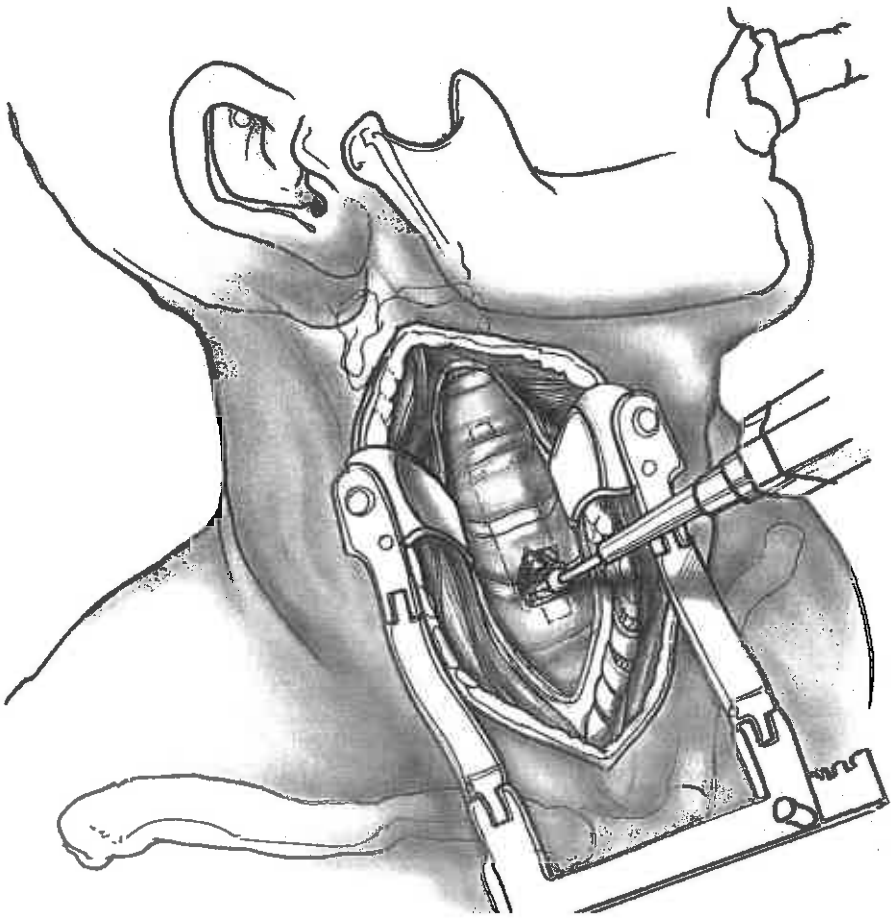

Figure 13–2

Exposure of cervical spine. A 5-mm burr is used to remove the disc and prepare end plates.

14. For a single-level procedure, the intravertebral pins are used with the Caspar set, and each pin is placed in the center of the vertebral body above and below the corresponding disc space parallel to the end plates. Once placed, the external distractor slides over the pins and is opened gently.

Discectomy and Osteophytectomy

1. An incision into the disc space identified by the indigo carmine allows further distraction. With the initial incision made, curets are used to scrape the disc material off the end plates and into the upper part of the disc space to facilitate removal with the micropituitary.
2. Further exposure may be obtained by using a small Schlesinger rongeur to remove any overhanging bone at each lip of the vertebral body.
3. Removal of disc material proceeds from the anterior aspect of the disc space to the posterior aspect of the disc space, maintaining the full width of the disc space in the disc removal. This prevents becoming tunneled with a deeper penetration to the posterior vertebral space without adequate side-to-side disc removal. At the posterior aspect, curets remove disc in a side-to-side sweep, or with gentle placement in the posterior aspect, a back-to-front sweep.
4. A high-speed drill (diamond tip is consideration) is now utilized in a side-to-side sweeping motion along the end plates to bur the plates to the bleeding surface and to rectangularize the space for future graft fit.
5. If the pathology consists of posterior spurring of the back of the vertebral disc space at the posterior aspect of each vertebral body, a trough (2 to 4 mm?) along this osteophyte can be created so that the osteophyte is exquisitely thin and can then be removed with microcurets or micro-Schleshingers. This effectively reduces uncinate spurring.
6. The central canal provides an excellent entry point unless the injection of indigo carmine has demonstrated a clear tract and defect through the posterior longitudinal ligament. The posterior annular fibers can be detached from bone and a position behind the vertical stripes of posterior longitudinal ligament obtained with a microcuret. It is possible to use the back of the vertebral body to advantage if the surgeon uses a thin micro-Schlesinger rongeur to facilitate removal of the posterior longitudinal ligament behind the disc space.
7. Once adequate visualization of the canal is obtained, the pathology can be assessed if not apparent. Further spur resection can be accomplished at the posterior vertebral margin and carried into the medial foramen as indicated utilizing microcurets or the micro-Schlesinger. The foraminal aperture sounded to assess the adequacy of decompression. The micronerve hook is used to search for disc fragments in the foraminal aperture in the sweep behind the vertebral body. The nerve hook is a valuable tool in finding and retrieving disc fragments.

Bone Graft Insertion

1. Once the pathology has been found and addressed, the disc space is reinspected to assess spatial symmetry, rectangularization, and adequate symmetrical width. The drill is helpful in any sculpturing to achieve these goals.
2. The measurement of depth and height of the graft to be inserted is determined off of precalibrated measuring sticks placed in the disc space.
3. A graft is cut from cadaver iliac crest bone graft on the back table to conform to the controllable measurements of height and depth. Width contouring involves the sacrifice of cortical bone on the rim of the horseshoe, and if this is necessary, we choose another graft.
4. The end plates have been previously decorticated. The graft is inserted with the cortical rim directed posteriorly in most cases and is countersunk behind the anterior vertebral margin. Any protuberant spur is removed to determine the anterior vertebral margin.
5. With the vertical retraction released, a fluoroscopic x-ray is taken to identify the placement of the graft and is inspected for graft fit in the interspace and graft placement depth.
6. If the x-ray shows good graft position, then the vertebral body pins and the companion external sleeve distractor are removed and vertical distraction no longer is possible.
7. Selection of the plate is based on the following criteria: a plate long enough to allow placement of the screws, preferably with variable angle, into the vertebral bodies adjacent to the disc space but short enough not to overhang an adjacent disc space.
8. With the vertical pins removed, any bony contouring of the anterior surface to allow the plate to sit down on the bone is accomplished. An option is to bend the plate for contouring if necessary, and then to place it where the surgeon anticipates placing the screws, and take a fluoroscopic x-ray to review this position and plate length.
9. If the plate length is satisfactory, the orientation of the plate to vertica is eyeballed.
10. One variable angled system allows placement of a holding pin so tha the plate is fixed at one end to the bone and allows the placement o other screws controlling for vertical tilt.
11. The first screw into the four-hole plate is an anchor about which th plate becomes a small pivot.
12. The sequence of screw placement is drill, tap, and insert screws o variable length: 12, 13, and 14 mm.
13. Once the first screw is in place, but not fully tightened down, reassessing the plate position and placing a screw on the side opposite and inferior or superior to the initial screw fixes the plate in its final position The remaining screws are placed with the standard technique described above. The holding pin would have been removed to facilitate one screw's placement (if utilized).
14. An x-ray is taken to verify position of the screws. Ensure that they are not in the graft or in an adjacent disc space, but are anchored in the appropriate vertebral body. All screws are then tightened and the locking screws tightened. All retractors are removed and final x-rays in both the anteroposterior (AP) and lateral plane obtained so that they may be reviewed before the patient awakens.

Closure

The wound is irrigated with antibiotic solution, the hemostasis is reviewed, a Hemovac drain is placed, and then layered closure of the platysma muscle and the subcutaneous tissue and the skin is completed. The final x-rays are reviewed and the preoperative films correlated with the intraoperative x-rays.

Pitfalls

1. Assessment of cervical disc herniation
   a. The correct patient: ideal arm pain
   b. The nerve root may have intrinsic injury that is immeasurable and therefore repeat surgery is not valuable? No pain-free interval means nerve root injury from index pathology, retained compressive pathology, wrong initial diagnosis, or surgery performed at the wrong level.
2. Diagnostic problems
   a. Physical examination is not as reliable as initial surgery.
   b. Enhanced imaging studies are frequently falsely positive in the first 6 months after surgery.

Complications

Approach

Structures injured on approach and securing and maintaining an adequately exposed surgical field include the recurrent laryngeal nerve, the trachea, the esophagus, the sympathetic chain, the carotid artery, the jugular vein, and the vagus nerve.

Intraoperative

Nerve root injury, spinal cord injury, dural tear, vascular injury (vertebral artery), malplacement of screws.

Postoperative

Wound infection, wound dehiscence, discitis, graft dislodgment, plate or screw failure.

Postoperative Care

Soft collar or Philadelphia collar for a variable postoperative period (depending on the surgeon's judgment of quality of fixation).

Suggested Readings

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14 Revision Disc Surgery
Technical Challenges

William Dillin

Goals of Surgical Treatment

To alleviate nerve root generated leg pain and/or weakness secondary to mechanical pressure from a recurrent disc herniation.

Diagnosis

- The diagnosis is made on the basis of the history, physical examination, and diagnostic studies.
- The most reliable history is the sudden onset of leg pain in a patient with a previously successful discectomy with a time interval separating the index procedure and the new symptoms that is clearly definable.
- The physical examination may not be helpful because the straight leg-raising test is not always positive and neurologic deficits may derive from the index herniation.
- Imaging studies such as a gadolinium magnetic resonance imaging (MRI) scan may reveal a clear-cut recurrent disc herniation, or other studies may be necessary to confirm the presence of a disc herniation and a symptomatic nerve root (Fig. 14–1).
- Studies could include a lumbar myelogram, contrast-enhanced computed tomography (CT) scan, CT discography, and selective nerve root block.

Indications for Surgery

- Loss of control of the bowel and bladder
- Progressive lower extremity weakness
- Unacceptable leg pain

Contraindications

- The inability to verify a recurrent disc herniation to the surgeon's satisfaction.
- Scar as the sole diagnosis, not recurrent disc herniation or stenosis.
- Patient is not a candidate for surgery because of medical reasons.

Advantages

- Relief of leg pain with very reasonable probability of success
- Attempted restoration of motor function

Disadvantages

- The potential for further destabilization of a motion segment in the spine, leading to pain and disability and possible further surgery.
- More diagnostically difficult assessment with potential for selection error for surgery.

Procedure

Technical Goal

To identify the spinal nerve under compression from a recurrent disc herniation and to safely remove the herniated disc.

Technical Challenge

Scar tissue formed from the previous surgical intervention obscures the normal anatomy, challenging the surgeon to expose and verify the anatomy.

Technical Principles

- Operate from identifiable anatomy to help recognize the obscured structures. Avoid a direct assault on scar tissue.
- Utilize the bony structures to take down scar.
- Clearly identify the nerve root and its course prior to any surgical maneuver.

Decision Making

- Does the remnant anatomy allow the surgeon access from a superior or inferior hemilamina?
- If a total laminectomy or unilateral hemilaminectomy has been performed, does the operating surgeon use a technique addressing the scar tissue as it attaches to the lateral border of the remnant facet?

Position and Exposure

1. Kneeling position on the Andrews frame to facilitate decompression of the abdomen and secondarily the epidural veins.
2. Hypotensive anesthesia to reduce bleeding.
3. Preincision x-ray with spinal needles used as markers if there is any doubt about the position of the prior incision and the site of the intended revision discectomy.
4. Incision encompassing old scar and extended proximally and distally depending on the exposure need and length of prior surgical scar.
5. Vigorous hemostasis in the superficial wound layers.
6. Fascial incision with cautery and then hemostasis in the subfascial tissue. Remove any visible suture from prior surgery.
7. Identification of remnant bone:
   a. Careful inspection of plain x-rays (postoperative) and imaging studies to assess the extent of prior surgery and the amount and location of bone present for the intended operation.
   b. Feel the hemilamina above and below and elevate adherent scar and remove scar with a Cobb elevator, large curet, and rongeur to verify and expose bony levels. Put a McCullogh retractor in at a depth that provides exposure but does not interfere with the exposure.
   c. Cut down excessive scar to just above the height of the bony levels (exposed remnant lamina).
   d. Remove scar to expose the lateral bone working from a superior to inferior position or vice versa. This lateral bone is the facet joint.
   e. Once the **U**-shaped operative site is present; upper hemilamina, facet, and lower lamina as exposed bone, insert the McCullogh retractor to the level of the lamina for full operative site exposure.
8. Interspace identification: if there is any question about the level, take an x-ray.
9. Canal entrance and nerve identification:
   a. Starting either at the inferior surface of the superior hemilamina or the superior surface of the inferior hemilamina, use a small angled or straight curet to detach scar from bone. This is greatly facilitated by removing some bone when the initial scar take down allows the surgeon to see the dura.
   b. Since the goal is the exposure of the nerve root, the tactic can produce an exposure from an inferior and superior perspective. Superior scar take-down prepares the surgeon to access the nerve root shoulder. Inferior scar take-down prepares the surgeon to perform a small entrance foraminotomy, identify the nerve in the foraminal entrance, and find the pedicle. This clearly puts the surgeon lateral to the nerve root.
   c. Working from an inferior position, a microcottonoid can be placed in the foraminal entrance lateral to the nerve and serves as a marker. Working from the superior position, the hemilamina is squared off to allow entry to the lateral aspect of the nerve root shoulder.
   d. By taking down the scar at this superior position, the floor of the spinal canal can be found lateral to the nerve. It is always deeper than you think! Once the floor is identified and the lateral edge of the nerve, then a microcottonoid is placed there to medialize the root.
   e. The lateral scar can now be taken down from the bone in the direction of the course of the nerve and can be visualized from its foraminal entrance to the shoulder. Frequently, the surgeon takes the scar down by further resection of the medial aspect of the facet joint. This ensures a safer lateral view, and further removes any possible lateral recess as a contribution to nerve root compression. Remember: take down the scar relevant to the operation. Frequently the dorsal dural scar can remain. It is the scar that obscures access to the lateral position to the nerve that is important.
   f. Once the nerve root is fully visualized, from its shoulder takeoff into its foraminal entrance, the strategy shifts to identification of the site and anatomy of compression.

Discectomy

The [illegible] is further defined. In the presence of revision

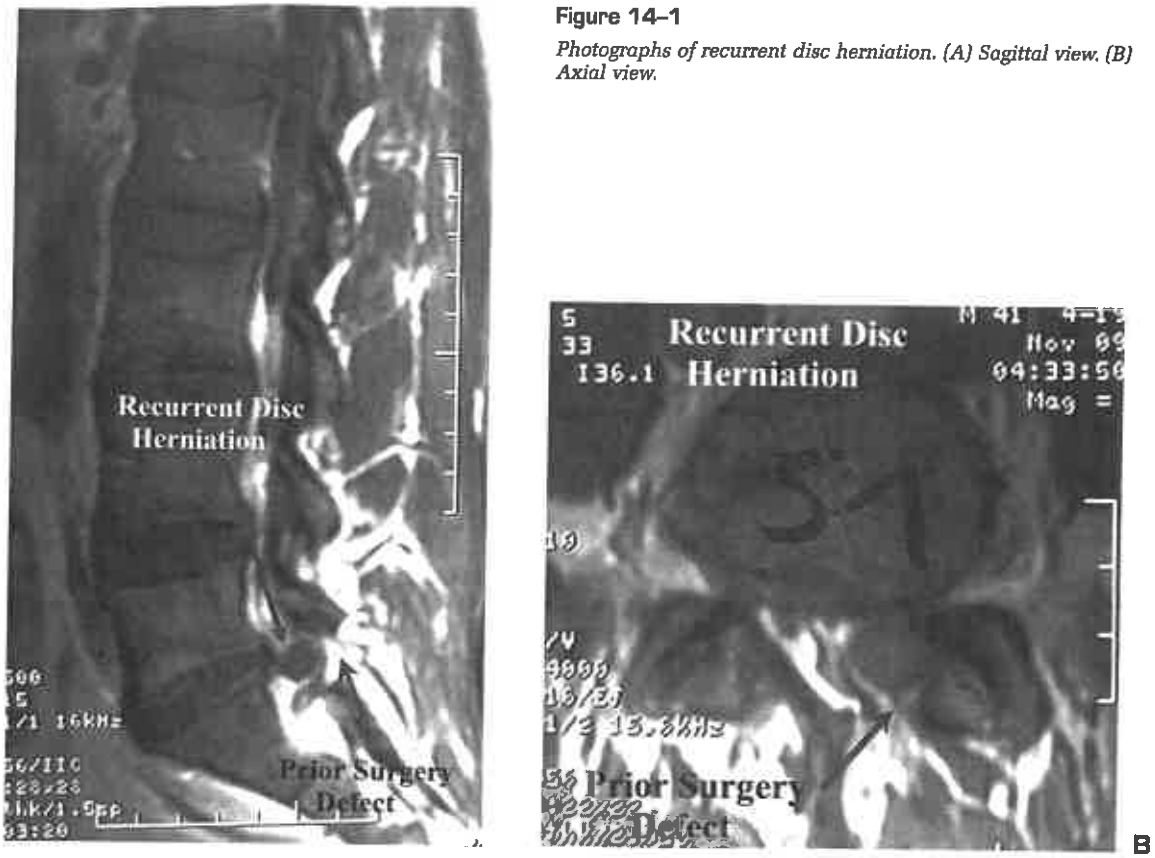

Figure 14–1

Photographs of recurrent disc herniation. (A) Sagittal view. (B) Axial view.

ıerve root, and hiding significant pathology. The goal of decompressing he nerve is to remove the offending compressing agent and ensure the mo-ıility of the nerve.

Assess the imaging studies for any clue about location and anatomic ype of the disc herniation. The visualized picture is helpful but not as :learly predictable as the virgin operation. Frequently, the nerve root is lomed over extruded disc material buried in scar, and the question to the ;urgeon becomes the assessment of the transitional point of the inferior ateral edge of the nerve to the underlying structure such as disc, scar, and ıdhesed posterior longitudinal ligament. This answer is the critical deci-:ion in revision disc surgery. If the lateral inferior border is difficult to ıssess and the nerve is clearly nonmobile, the placement of a Penfield No. ł in the disc space and the gentle levering toward a vertical position may ɔrovide clarity.

The subannular disc space can be entered and any free material re-noved. The Penfield may then be advanced more medially in the edge of he disc space, which may allow better visualization superior and inferior o the disc space. The search for fragments is a question of feel and tried naneuvers. The 180-degree arc from the lateral position of the nerve root houlder to its foraminal entrance comprises some poorly visualized terri-ory medial to the root and in the axillary area. By utilizing a nerve hook ınd a Frazier or Woodson, the surgeon can develop a feel for these poten-ial hidden areas. Simply pushing down gently from a position underneath he nerve with a Frazier may extrude hidden disc material.

When is the operation over? It is over when the surgeon is satisfied that the ıerve root is decompressed and mobile. Frequently, scar adheres the nerve o the undersurface of the vertebral body. Utilizing a nerve hook or Frazier, . systematic sweep of the 180-degree arc from shoulder of the root to oraminal entrance occurs. By bringing tethering elements to the nerve ateral edge, scar can be resected to allow the surgeon to judge the freedom ıf the nerve and search for any hidden fragments. Small dental instru-nents are helpful but frequently scar is incised as it is tented over the 'razier.

The checklist for decompression is simple:

- Has the surgeon found what he/she expected to find? If not, why not? Review the imaging studies, review the preoperative decision making? Take an x-ray and reverify the level.
- Is the root mobile? Sweep under the root with the nerve hook and/or Frazier to assess. If unsure, mobilize the root enough by resecting scar to decide.
- What does the root look like? If the root is fat, make sure that there is not an adhesed fragment to the root or that a conjoint root exists.
- Verify the freedom of the nerve for its entire course laterally and in the foramen. Frequently, the exposure will have eliminated any lateral recess stenosis. The foramen can be sounded from the same side of the table, but if any question exists, the surgeon might prefer to feel the nerve from the opposite side of the table.
- An intraoperative lateral x-ray with a Penfield No. 4 in the disc space verifies the level operated.
- Have the patient perform a Valsalva maneuver with the wound dry; assess the exposure for a hidden dural leak.

Closure

1. Irrigation with antibiotic saline
2. Assessment of hemostasis
3. Placement of a medium Hemovac drain
4. Closure of the muscle if possible in an interrupted fashion
5. Closure of the fascia in an interrupted fashion. Does the surgeon add a running locking fascial closure?
6. Closure of subcutaneous tissue in an interrupted suture
7. Closure of the skin with a subcuticular suture or interrupted suture

Pitfalls

Assessment of Recurrent Disc Herniation

1. Understand the reason for failure: Was the indication correct for the index surgery? Was the time interval from onset of symptoms to index surgery to long? Did the patient achieve relief of leg pain with the initial operation and for how long? Did the patient have residual neurologic deficits after the index procedure, what were they, and how does repeat surgery potentially effect those symptoms?
2. The nerve root may have intrinsic injury that is immeasurable, and therefore repeat surgery is not valuable? No pain-free interval means nerve root injury from index pathology, retained compressive pathology, wrong initial diagnosis, or surgery performed at the wrong level.

Diagnostic Problems

1. Physical examination is not as reliable as initial surgery.
2. Enhanced imaging studies are frequently falsely positive in the first 6 months after surgery.

Complications

Wound infection, wound dehiscence, discitis, epidural abscess, arachnoiditis, nerve root injury, dural tear with cerebrospinal fluid (CSF) leak, pseudomeningocele, or vascular injury from penetration of anterior annular wall, peripheral nerve, or brachial plexus injury from surgical position.

Postoperative Care

A trunk-strengthening and rehabilitation program gives the physical benefit of a stronger trunk and capacity to handle a load, and the psychological benefit of a demonstration of physical capacity in a patient who has just experienced significant pain and is concerned about redeveloping the pain with activity.

Attempt to educate the patient regarding repeat exposure to environmental factors: sitting, repeated lifting, and twisting.

Suggested Readings

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Jonsson B, Stromqvist B. Repeat decompression of lumbar nerve roots: a prospective 2 year evaluation. J Bone Joint Surg Br 1993;75:894–897.

15 Cervical Thoracic Fixation Techniques

Marshal D. Peris and William F. Donaldson

Posterior Approach

Goals

Gain access to the cervical and thoracic spine for purposes of decompression, fusion, and instrumentation.

Diagnosis

X-ray, magnetic resonance imaging (MRI), computed tomography (CT) scans, and clinical assessment can be used.

Indications

1. Posterior cord compression
2. Instability without anterior cord compression
3. Trauma without anterior cord compression
4. Kyphosis usually in conjunction with anterior surgery
5. Following anterior decompression for infection, tumor, or trauma to supplement stability

Contraindications

1. Medical instability
2. Skin problems over the proposed surgical site (skin infection, ulcer, and necrosis)
3. Ongoing or systemic infection (relative)

Advantages

1. Large exposure of the entire posterior spine
2. Improved stability from instrumentation techniques
3. Improved correction of deformity
4. Relatively safe approach surgically

Disadvantages

1. Risk of increased blood loss due to muscle dissection
2. Risk of neurologic injury using instrumentation
3. Risk of dural tears and neurologic injury performing decompression
4. Risk of infection from large exposure
5. Higher incidence of postoperative back pain from muscular dissection
6. Cannot completely access the vertebral bodies or disc spaces

Procedure

Positioning

Prone with chest rolls or chest and pelvic pads on a radiolucent table. Skull pins or traction may be necessary.

Approach

1. Midline incision carried down to dorsal fascia.
2. Subperiosteal dissection of paraspinal musculature off the spinous processes.
3. Blunt dissection with Cobb elevator of musculature off the lamina.
4. Dissection with electrocautery around facet joints and transverse processes.
5. If laminectomy is to be performed, use a 3-0 curved curet to define the lower border of the lamina to be removed. Then use a Kerrison to remove lamina centrally and laterally, protecting the dura/cord at all times.
6. If using instrumentation requiring sublaminar hooks or wires, a window of ligamentum flavum is removed and a small laminotomy is made at each level required.
7. If using pedicle screw systems, a laminotomy needs to be performed to feel the pedicle at each level. Guide wires are placed in the pedicles and anteroposterior (AP) and lateral radiographs or fluoroscopy is used to ensure correct positioning.
8. If using plates and screws in the cervical spine, the screws should be started just medial to the lateral mass and directed 25 to 30 degrees superiorly and laterally. This may need to be altered to parallel the plane of the facet joint and to stay out of the foramen or canal.

Instrumentation

1. Pedicle screws
2. Luque rectangle and sublaminar wires
3. Lateral mass plates connecting with rods
4. Hooks and rod system with sublaminar wires

Pitfalls

There are technical difficulties in placing pedicle screws at C7 and T1 (see Fig. 12–5 in Chapter 12).

Complications

1. Excessive blood loss
2. Dural tears and spinal fluid leak
3. Neurologic injury from incorrect screw placement or wire passage
4. Infection
5. Vascular injury (vertebral artery)

Postoperative Care

The patient is left on bed rest for the first 12 to 24 hours postoperatively. Patients are allowed out of bed on postoperative day 1 and are typically fit with an orthosis. Once the orthosis is on, the patient may go to physical and occupational therapy for progressive ambulation and activities of daily living training. The drain is removed on postoperative of day 2 or until the drainage is less than 50 cc per 8-hour shift. Inpatient rehabilitation may be necessary for many patients.

Anterior Approach: Sternal Splitting

Goals

Gain access to the anterior cervical thoracic junction safely.

Diagnosis

X-ray, MRI, CT scans, and clinical assessment can be used.

Indications

1. Anterior cord compression
2. Instability
3. Kyphosis
4. Infection in the vertebral body or disc with abscess or cord compression
5. Tumor with instability or cord compression
6. Trauma

Contraindications

1. Medically unstable.
2. Previous median sternotomy makes approach more difficult.
3. Ongoing or systemic infection (relative).
4. A more limited approach may be used alternatively.

Advantages

1. Exposure of the cervical thoracic junction down to T3
2. Improved access to vertebral bodies
3. Direct access to disc spaces
4. Direct reconstruction of anterior column
5. Less muscle dissection

Disadvantages

1. Only allows access to T3
2. Risk of vascular injury
3. Morbidity of a thoracotomy and sternotomy

Procedure

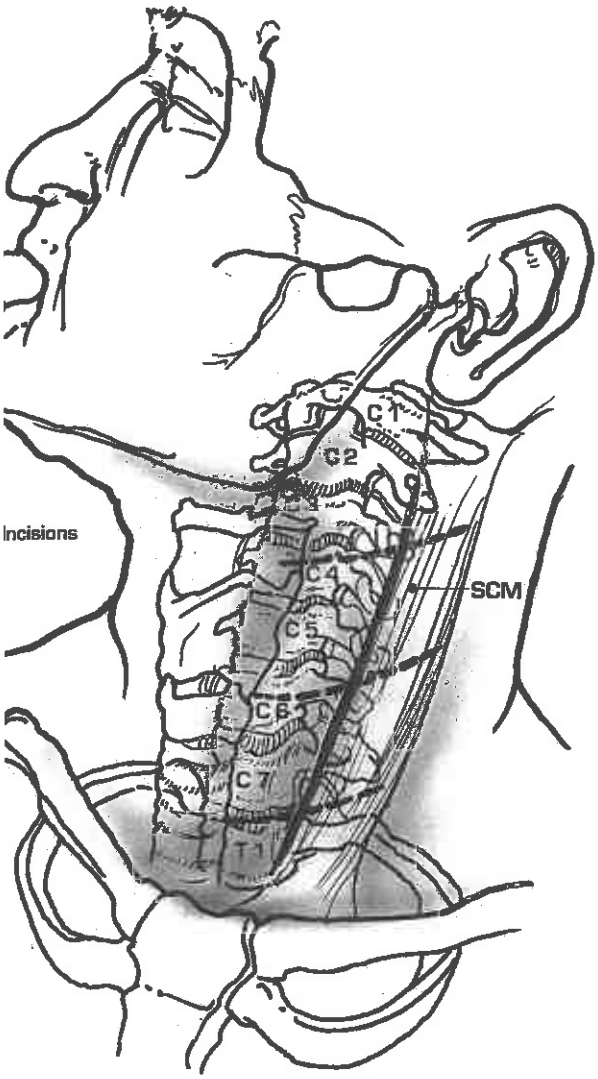
Positioning

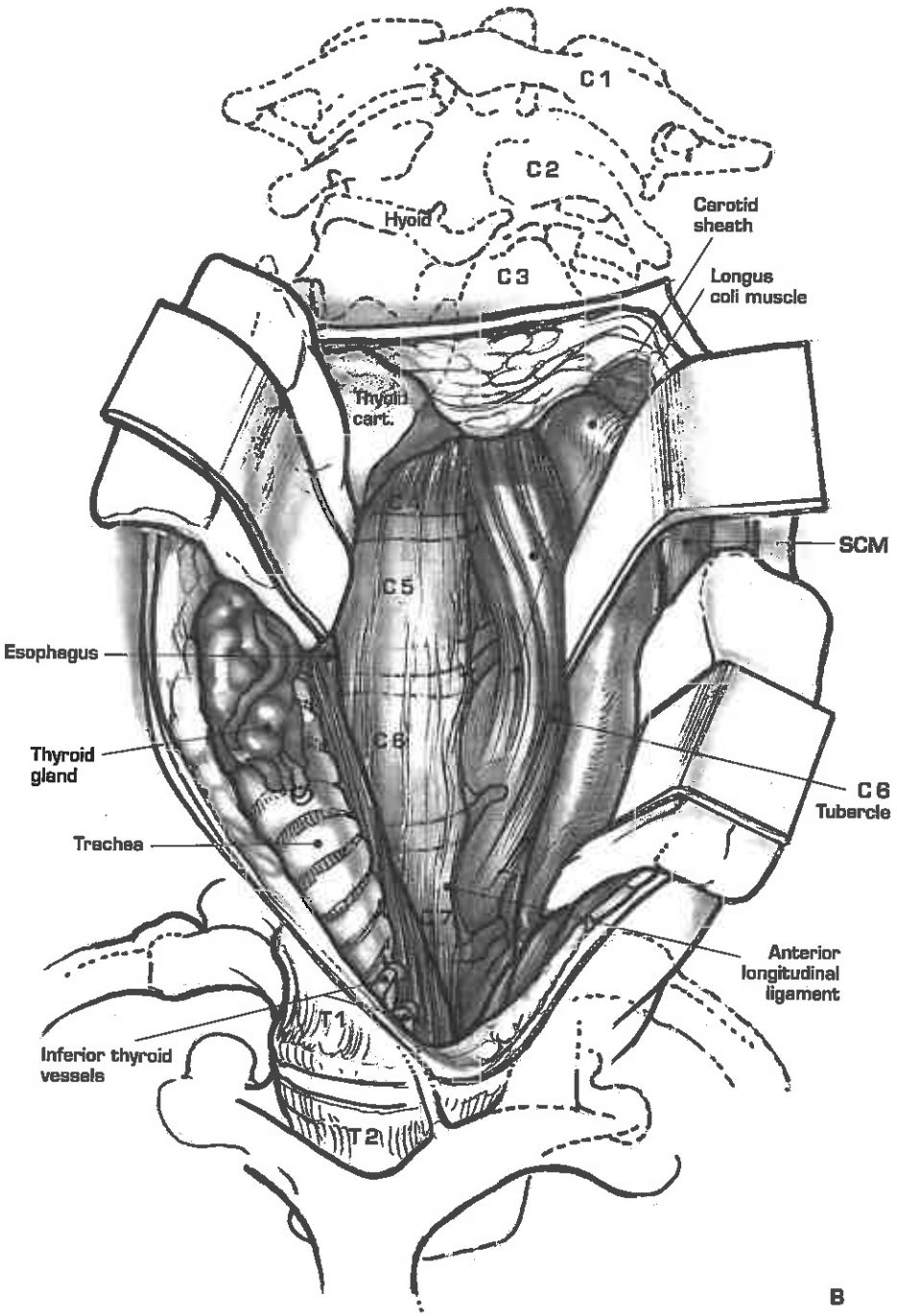
1. Supine with shoulders pulled down and arms at side
2. A roll is placed between the shoulder blades

Approach

Cervical: Along the anterior border of the sternocleidomastoid muscle for extensile approaches and oblique 1 cm proximal to the clavicle for the C5-C7 approach.

1. Divide the platysma in line with the incision and open the deep cervical fascia along the medial border of the SCM. Divide the omohyoid if necessary (Fig. 15–1A).
2. Retract the carotid sheath laterally/posteriorly using blunt dissection and retract the trachea and esophagus medially/anteriorly (Fig. 15–1B).





ure 15–1

B) Anterior exposure to the cervical spine.

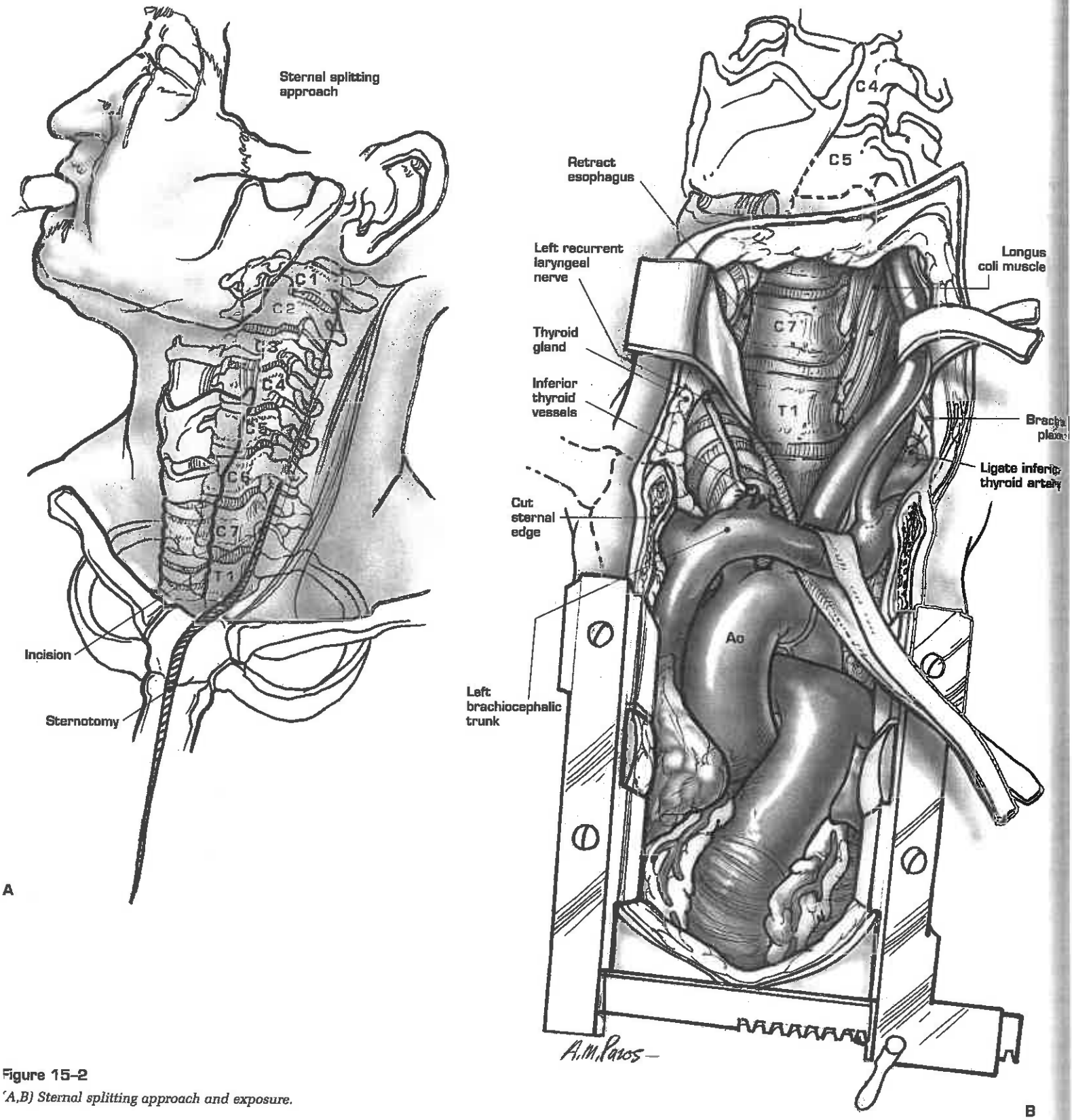
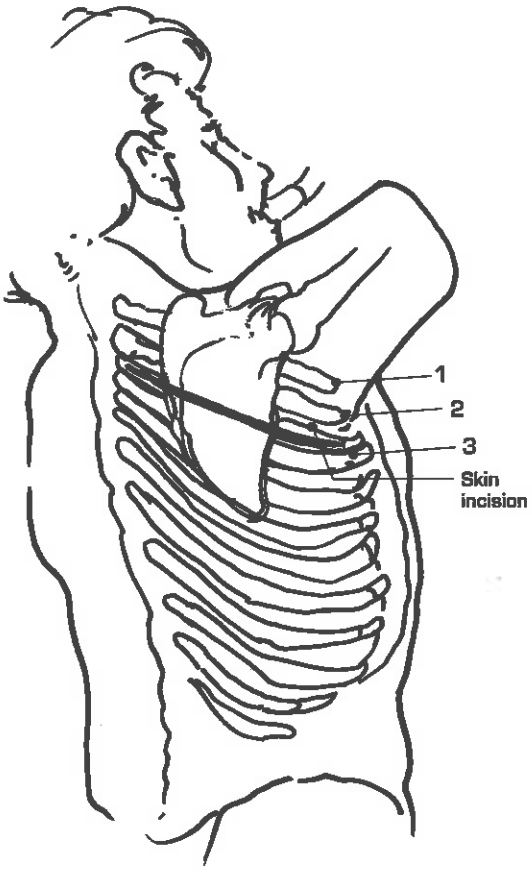
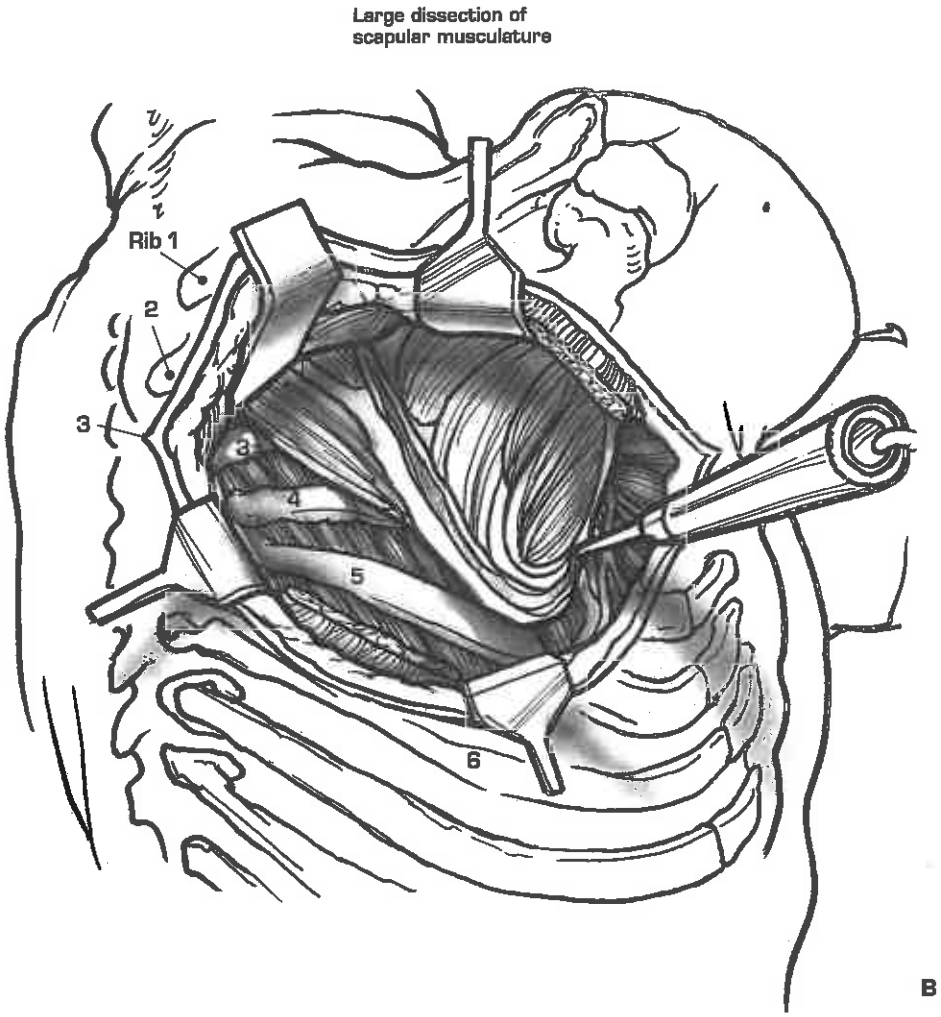


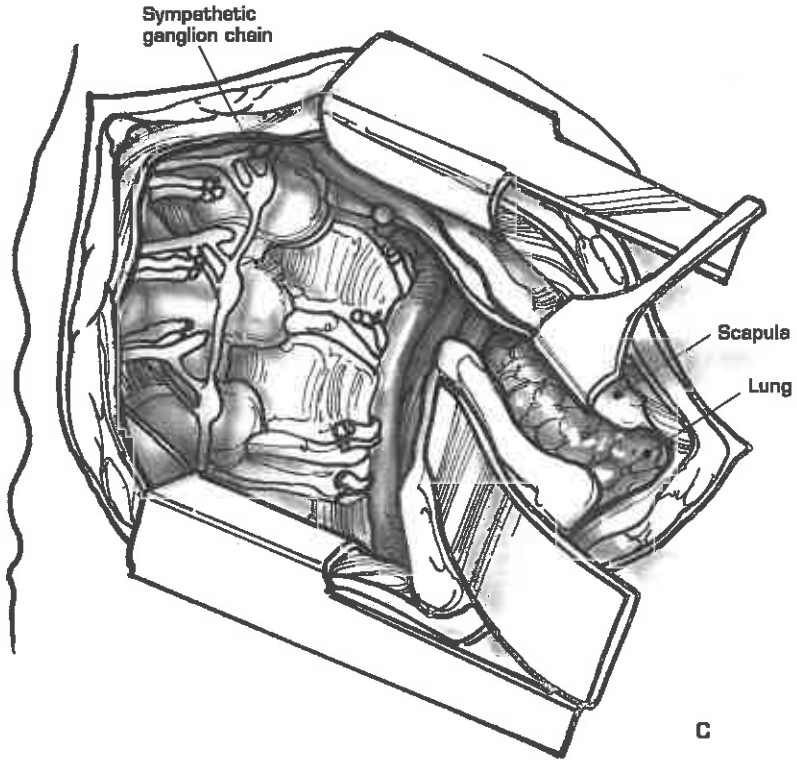
Figure 15–2

(A,B) Sternal splitting approach and exposure.





B



C

gure 15–3

–C) Anterolateral exposure of the upper thoracic spine showing scapular mobilization.

3. The inferior thyroid artery may need to be ligated as it passes C6–7 and proximally the superior thyroid artery and vein may need to be ligated. The superior laryngeal nerve may need to be retracted.
4. Remove the prevertebral fascia and anterior longitudinal ligament from the anterior vertebral bodies.
5. Use a needle bent in the disc space to identify the level.

Thoracic: Midline for the sternal splitting approach.

1. Divide the sternum using an oscillating saw (Fig. 15–2A).
2. Mobilize the great vessels (Fig. 15–2B).
3. Dissect off the anterior longitudinal ligament and the prevertebral fascia.

Instrumentation

1. Anterior plate fixation
2. Cage or mesh construct
3. Auto- or allograft

Pitfalls

Recognize changes from lordosis to kyphosis when placing structural graft.

Complications

1. Laryngal nerve injury
2. Pneumothorax
3. Horner syndrome
4. Pneumonia
5. Great vessel injury
6. Esophageal injury
7. Chylothorax
8. Pulmonary injury
9. Hemothorax
10. Infection

Postoperative Care

If a chest tube is placed, it is initially placed on 20-cm suction and then placed to a water seal on postoperative day 1 or 2. It is discontinued when the chest radiographs show no pneumothorax and output is less than 100 cc per day. See Postoperative Care for Posterior Approach.

Anterolateral Approach

Goals

Access to the cervical thoracic spine anteriorly and extensively.

Diagnosis

X-ray, MRI, CT scans, and clinical assessment can be used.

Indications

See Anterior Approach: Sternal Splitting.

Contraindications

See Anterior Approach: Sternal Splitting.

Advantages

1. Large exposure from C3 to T9 anteriorly
2. Improved correction of deformity
3. Access to vertebral bodies
4. Access to disc spaces

Disadvantages

1. Increased work required for exposure
2. Risk of pulmonary or great vessel injury
3. Morbidity of a thoracotomy
4. Large dissection of scapular musculature and resultant pain with need for shoulder therapy

Procedure

Positioning

Lateral decubitus with beanbag, axillary roll, left side up.

Approach

1. Cervical—see Anterior Approach: Sternal Splitting.
2. Thoracic—incision over third rib.

Subperiosteal dissection of the third rib and excision. Mobilize scapula by dissecting the periscapular muscles off (Fig. 15–3A,B). Retract the lung inferiorly (Fig. 15–3C). Open the parietal pleura longitudinally over the anterolateral margin of the thoracic vertebrae. Preserve the sympathetic chain and ligate the segmental vessels.

Instrumentation

Anterior plate fixation.

Complications

See Anterior Approach: Sternal Splitting.

Postoperative Care

See Anterior Approach: Sternal Splitting.

Suggested Readings

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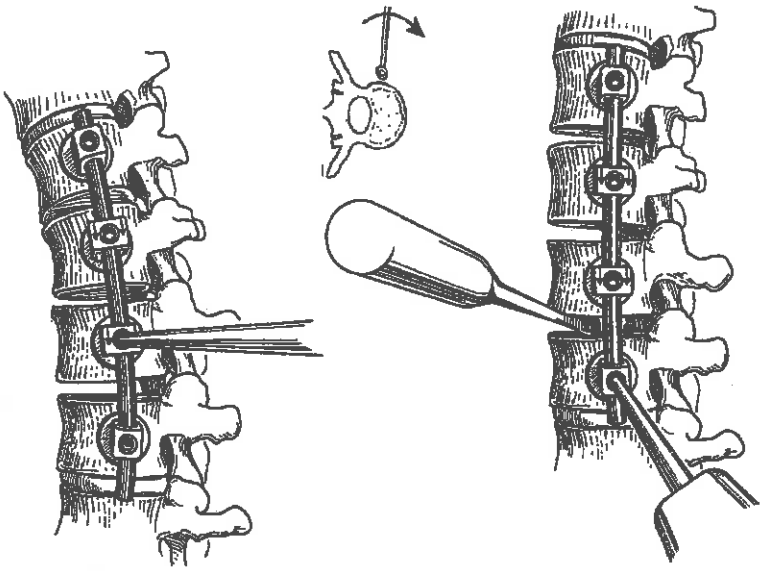


Figure 42–1

The rod is rotated to a lordotic orientation, to be placed in the sagittal plane. Open screws in the middle vertebrae are demonstrated.

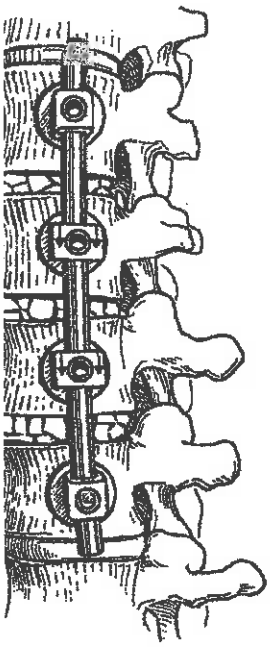


Figure 42–2

A final assembly of a construct with titanium cages and bone graft. Open screws in the middle vertebrae are demonstrated.

43 Microdiscectomy

David Lee Spencer and Avi J. Bernstein

Goals of Surgical Treatment

Microdiscectomy allows the surgeon to perform all of the maneuvers of the routine hemilaminotomy and discectomy procedure with the aid of improved illumination and magnification. Table 43–1 is a list of favored instruments. Familiarity with draping, positioning, and adjusting the operating microscope is necessary before the surgeon attempts to perform the procedure. The use of operating loupes and a head lamp is a viable alternative to the operating microscope; however, the operating microscope has distinct advantages.

Indications for Surgery

1. Radicular signs and symptoms of nerve root compression due to a disc herniation.
2. Unresponsive or inadequately responsive to symptomatic nonoperative treatment.
3. The offending disc herniation with nerve root compression must be demonstrated on a magnetic resonance imaging (MRI) scan, a computed tomography (CT) scan, or a myelogram.

Contraindications

1. Inconclusive diagnosis of herniated nucleus pulposus (HNP)
2. Symptom amplification

Advantages

1. Allows the surgeon to perform the procedure with greater accuracy and with less risk of complications due to the surgical misadventures of excessive bleeding, nerve root damage, dural lacerations, and missed and retained disc fragments.
2. The postoperative course is so predictable and benign that the surgeon can confidentially release the patient from the hospital the day of surgery, making this truly an outpatient surgical procedure.
3. Relatively few instruments are required for the procedure.

Procedure

The description of the technique that follows is a step-by-step guide that applies to the routine disc herniation (Fig. 43–1). The following special situations require deviations from the standard technique and are described separately:

1. Foraminal herniation
2. Far lateral herniation
3. Completely extruded fragment
4. Recurrent herniation

The surgery is usually performed with the patient in a prone position under general anesthesia. It is possible to use spinal, epidural, or local anesthesia; however, the benefits are not worth the added complexity and the occasional unpredictability of these regional anesthetic techniques. The patient is placed prone on any operating frame that allows abdominal decompression and flexion of the lumbar spine. The Wilson frame is the simplest, most readily available frame that meets these two criteria. The surgeon usually operates from the side of the disc herniation with the microscope positioned at the head of the table on the opposite side.

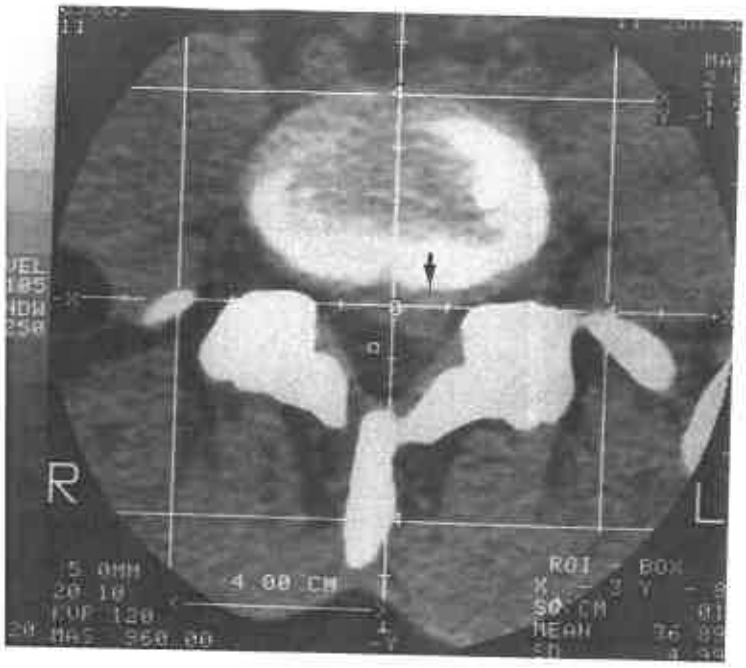
When the patient is anesthetized and positioned prone on the Wilson frame, in maximum flexion, the back is prepped and draped in routine fashion. A spinal needle is placed into the back at a location presumed to be the level of the disc herniation, and a lateral x-ray is taken to identify the exact surface location for the incision over the disc herniation. The opportunity to misinterpret the localizing x-ray, especially with nonstandard anatomy or obesity, must not be underestimated. Surgically exposing the wrong level is one of the most common surgical misadventures. When necessary, repeat x-rays must be taken, not only initially but also during the procedure to document absolutely the appropriate location of the surgical exposure. The skin incision size depends on the obesity of the patient; the more obese the patient, the larger the incision must be to allow access in the depths of the wound. Generally speaking, the incision is 1 to 2 inches in length. The size of the skin incision, however, is the least relevant aspect of the surgical procedure. It has never been reported that favorable results of discectomy surgery correlate with the length of the skin incision. The skin incision is in the midline; however, the fascial incision is made just lateral to the spinous processes, preserving the supraspinous and interspinous ligaments. Maintaining the interspinous and supraspinous ligaments is important to provide countertraction for the microdiscectomy retractor. With a Cobb elevator and digital dissection, the appropriate interlaminar space is exposed, palpated, and the facet identified. The microdiscectomy retractor is inserted. There are several retractors on the market that are adequate. The McCullough retractor with its blades of variable width and length is an excellent retractor system for this surgical procedure.

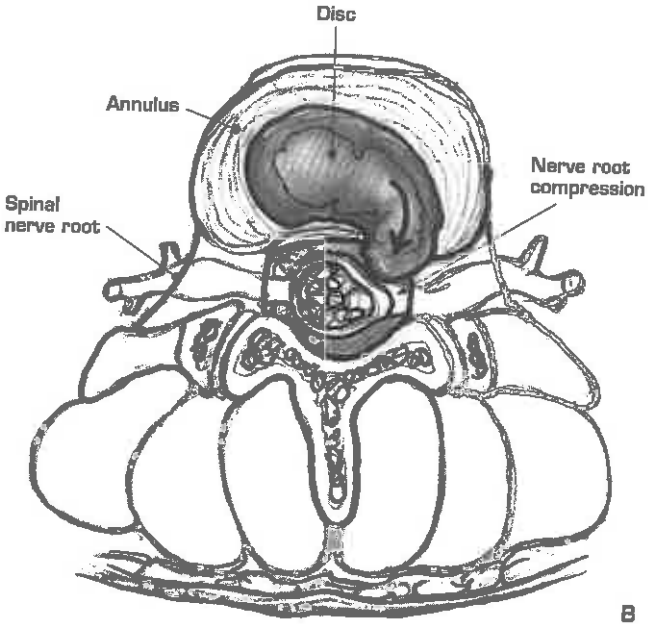
After insertion of the microdiscectomy retractor, the previously sterilely draped operating scope is brought into the field for the remainder of the procedure. The operating scope optimal for the microdiscectomy procedure must have a stand that is high enough to provide enough elevation to clear the patient's back on the Wilson frame and focus in the depths of the wound with at least a 300-mm focal length objective lens. The focal length of the objective lens determines the space between the microscope and the surface of the back. Objective lenses of less than 300 mm do not provide enough space between the microscope and the back to perform surgery. Lenses over 350 mm are so far away from the back that the surgery can be awkward. The optimal focal length objective lenses depending on the size of the patient is 300 to 350 mm. The microscope head must also be adjustable in all planes with a universal joint. The surgeon must be able to angle the microscope head when necessary in every direction to obtain appropriate visualization. The initial view through the microscope of the operative field is frequently a confusing array of fat, muscle strands, and bleeding. Muscle and fat debris must be removed with a pituitary rongeur and bleeding controlled with electrocautery. Meticulous hemostasis is mandatory when performing this procedure. The facet joint is the most readily identifiable local anatomic landmark and is the key to surgical exposure. The inferior medial margin of the facet joint must always be identified. This is most expeditiously done by removing the falciform flavum and the inferior medial facet capsule with a 3-mm, 40-degree Kerrison rongeur. Except at the LS-S1 level, it is always necessary to perform a partial medial facetectomy of both the inferior and the superior facet. The use of a high-speed drill bur is frequently recommended for this bone removal; however, it is not necessary and invites excessive and unnecessary bone removal. The 3-mm, 40-degree Kerrison rongeur is the only instrument necessary for bone and ligamentum flavum removal.

After identifying the facet joint, the 40-degree rongeur is inserted

Table 43–1. Preferred Instruments for Microdiscectomy Surgery

McCullough retractor set
Frazier suction tip, No. 4 or No. 12
Love 90-degree nerve root retractor
Criles small-narrow 90-degree Love nerve root retractor
Mallis bipolar forceps
Extra-long 90-degree Love nerve root retractor
30-cc syringe
Standard Freer elevator
Small Freer elevator
Laryngeal cannula
Nerve hook
Caspar hooks-short tip, medium tip, and long tip
Caspar grasping pituitary rongeur, 12 × 3 mm
Cushing rongeur str., 7″, 3 mm
Cushing rongeur str., 5″, 3 mm
Cushing rongeur up-biting, 5″, 3 mm
Kerrison rongeur, 7.5″, 40 degrees, 3 mm
Kerrison rongeur, 7.5″, 40 degrees, 1 mm
Kerrison rongeur, 40 degrees, emm x-long shaft
Cobb spinal elevator, 11″
Cobb spinal curet, No. 4
Knife handle, No. 3
Knife handle, No. 7
Short tissue forceps with teeth
Adson tissue forceps





e 43–1

xial computed tomography (CT) scan demonstrating left-sided disc herniation. (B) Diagrammatic representation of lumbar disc herniation.

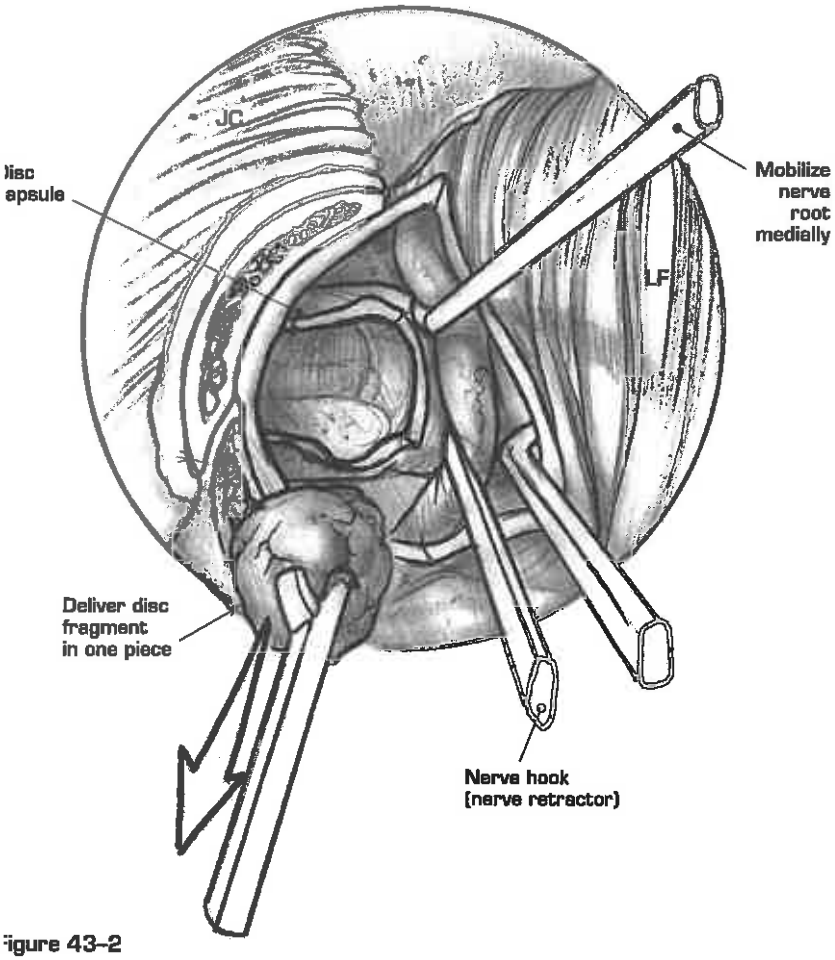


Figure 43–2

Laterally placed hemilaminotomy allows retraction of nerve root and disc herniation removal without even visualizing the dural sac.

Figure 43–3

Proximally extruded disc herniation.

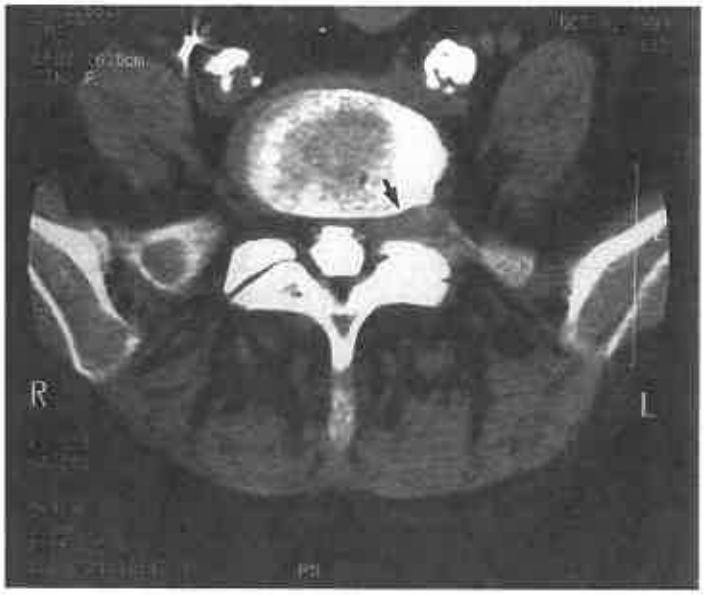


Figure 43–4

Foraminal disc herniation.

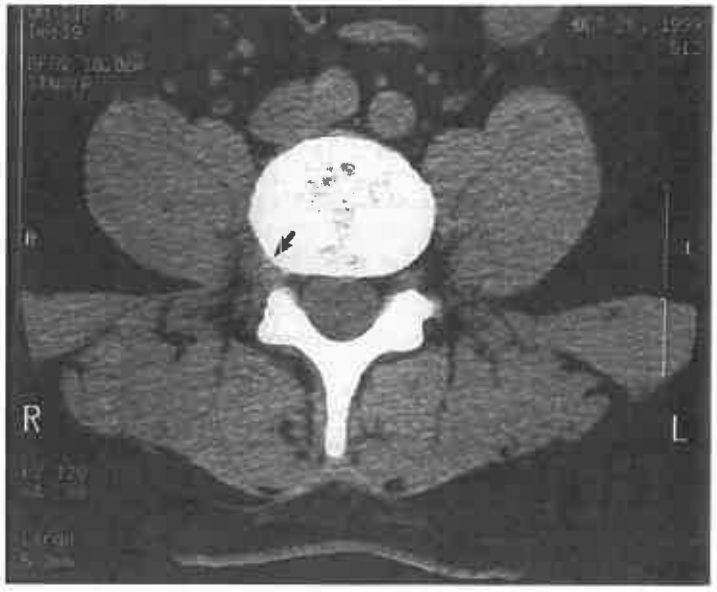


Figure 43–5

Far lateral extraforaminal disc herniation.

perior facet. It is readily identifiable by the glistening articular facet surface. The exact interface between the ligamentum flavum where it attaches to the superior lateral margin of the superior lamina is identified by mobilizing the ligamentum flavum with a medium-sized curet. This exposes the exact inferior and lateral margin of the ligamentum flavum. The recommended surgical entry into the spinal canal is always at this point. Having identified the exact margin between the ligamentum flavum and its attachment to the superior lamina, the 3-mm, 40-degree Kerrison rongeur is carefully insinuated into the spinal canal underneath this bony margin. The laminotomy can then be performed by removing as much ligamentum flavum as necessary superiorly and medially, and bone laterally, superiorly, and inferiorly. Just how much bone and or ligamentum flavum is removed depends on the local anatomy and the location of the disc fragments to be removed. For example, an inferiorly extruded disc may require virtually no superior medial ligament removal but extensive inferior bone removal to allow access to the fragment that is opposite the pedicle. The laminotomy should be situated lateral enough in the canal to provide direct exposure of the nerve root without any overhanging lateral bone. The main dural sac may never actually be visualized medial to the nerve root through the laminotomy exposure (Fig. 43–2). This lateral positioning of the laminotomy helps to prevent inadvertent dural lacerations and nerve root injury from overretraction. Once the laminotomy has been performed, it is imperative to identify the nerve root.

Dissection through the epidural fat with bipolar forceps and coagulation of veins with bipolar cautery is frequently necessary. Whenever there is difficulty identifying or locating the nerve root, it is always helpful to identify the pedicle. Identifying the pedicle by palpation with a nerve hook will always lead one to the appropriate location of the nerve root. If the nerve root is not properly exposed, the laminotomy needs to be expanded by more bone removal laterally or superiorly to safely identify the nerve root. Medial mobilization of the nerve root off of the disc herniation is sometimes very difficult. The nerve root is frequently stretched tautly over a disc herniation making it difficult to even identify the interface between the nerve root and the disc, much less to mobilize and retract the nerve root without potential nerve root damage. The Adson blunt nerve hook is an ideal tool for mobilizing the nerve root. It is always safest to mobilize the nerve root from the caudal to cephalad direction in the line of the nerve root rather than from lateral to medial.

Identify the nerve root caudal to the point of impingement from the disc herniation. This location allows easy identification of the ventral surface of the nerve root. Working cephalad underneath the nerve root with an Adson blunt nerve hook, the nerve root can be mobilized off of the disc herniation without risk of penetrating the nerve root or damaging it. On the other hand, trying to dissect the nerve root off of the disc herniation at the point of contact by working from lateral to medial may injure the nerve root because of the poor demarcation between the nerve root and disc herniation and the local adhesions. It is also frequently advisable to insert the Love nerve root retractor underneath the nerve root caudal to the disc herniation and then gradually work the nerve root retractor cephalad. This also is a safe way of mobilizing the nerve root with less risk of nerve damage. Of the various nerve root retractors available, the right-angle Love nerve root retractor is optimal because the retractor is not sticking straight up toward the microscope interfering with vision and with the operating surgeon.

Preventing and controlling bleeding is one of the key aspects of an expeditious and safely performed discectomy operation. Bipolar cautery of epidural veins is mandatory. The epidural veins are frequently strapped over the disc herniation and are exsanguinated and are not necessarily obvious. Incision of these exsanguinated veins can result in an unexpected and annoying rush of venous blood. To prevent this, carefully scrape the surface of the disc herniation with the bipolar forceps, cauterizing these exsanguinated veins prior to incising the disc herniation. This will usually prevent the annoying bleeding that can otherwise occur with the incision of the capsule of the disc herniation. If for some reason there is continued annoying bleeding, the spinal canal can be carefully packed with small thrombin-soaked Gelfoam pledgets and cottonoid patties above and below the disc herniation to control the bleeding during the discectomy procedure.

After incising the capsule of the disc herniation, it is helpful to mobilize the fragment of the disc with a variety of nerve hooks prior to extraction. This improves the likelihood of delivering the fragment in one piece rather than breaking the fragment and removing it in a piecemeal fashion. Decker and pituitary rongeurs are necessary for fragment removal. Once the fragment is removed from the spinal canal, the disc space itself is debrided of loose disc material with a variety of pituitary and Decker rongeurs. It is overhanging lip of the posterior vertebral body, which makes entry into the disc space difficult, can be partially removed with a 3-mm, 40-degree Kerrison rongeur, facilitating disc space debridement. Forceful irrigation of the disc space helps to mobilize unrecognized hidden intradiscal fragments and facilitate their removal. Simple debridement of the disc space with Decker and pituitary rongeurs and a ring curet and nerve hooks cannot be relied on to identify all loose intradiscal fragments. Forceful irrigation with a 30-cc syringe and a laryngeal cannula may mobilize and identify a previously unrecognized fragment. Using an antibiotic saline mixture also is an effective means of delivering interoperative antibiotics to the relatively avascular disc space, thereby, it is hoped, reducing the risk of discitis. The goal of disc space debridement in this operation is not to remove as much disc material as possible but to identify those loose or partially loose intradiscal fragments that may result in a recurrent disc herniation at some later date. Intradiscal irrigation will flush loose fragments out of the disc into the laminotomy site. If the fluid disappears, there must be an anterior perforation of the disc with possible damage to retroperitoneal structures.

When no further loose disc fragments are retrievable from the disc space or the epidural space, all cottonoid patties and Gelfoam pledgets that may have been used for hemostasis are removed. Additional coagulation of epidural veins is performed if necessary. The dura is inspected for tears and spinal fluid leakage and the nerve root is inspected for any residual compression from either unrecognized disc fragments or bony stenosis. The lateral recess is routinely decompressed in this surgical procedure by virtue of the removal of the medial bony lip of the superior facet with the 3-mm, 40-degree Kerrison rongeur in the process of performing the laminotomy. The disc space and the epidural space can be irrigated with a dilute solution of Marcaine (0.125 %) for postoperative analgesia. Duramorph may also be locally applied to the nerve root prior to closure. The skin and subcutaneous tissue are locally infiltrated with Marcaine for postoperative analgesia. Ten milligrams of Decadron IV push in the recovery room is helpful for management of postoperative pain.

The generic technical description outlined above applies to the disc herniation in the routine location (Fig. 43–1) and emphasizes the following important points:

1. Absolutely accurate determination of the correct level.
2. Lateral placement of the laminotomy to minimize risk of dural tears and nerve root injury by overretraction and manipulation.
3. Minimize bleeding by identifying and bipolar coagulating veins before they are severed and bleed.
4. Aggressive irrigation of the disc space to mobilize hidden and sequestered disc fragments that may result in a recurrent disc herniation if not recognized and removed.

Special Situations

Extruded Disc

When the herniated disc fragment is completely extruded and migrated away from the disc space, it is a special situation. It is not necessary or advisable to expose the disc space and enter and debride it as is routinely required when the disc herniation is in continuity with the disc space. For example, for a fragment migrated proximally from the L4–5 disc space residing opposite the L4 pedicle with L4 nerve root compression (Fig. 43–3), the surgical approach should be at the L3–4 interspace, not the L4–5 disc level. The level of surgical exposure is based on where the disc fragment is at the time of surgery, not where it originally came from. Entering the spinal canal at L3–4 at the level of the inferior lateral margin of the ligamentum flavum as described above is exactly at the level of the L4 pedicle. Extending the laminotomy caudally by removing portions of the superior lateral lamina of L4 provides excellent exposure of the disc herniation without any removal of facet joint or ligamentum flavum. The proximally migrated fragment is always medial to the nerve root, and therefore the laminotomy needs to be extended caudally and medially enough to allow retrieval of the disc herniation medial to the nerve root through the so-called axillary approach. There is no need to enter the L4–5 disc space when the herniated fragment has completely extruded from the disc space and has migrated away from the disc.

Foraminal disc herniations (Fig. 43–4) are a second special situation that can be especially difficult to access, and they require significant bone and facet removal. In these cases it is optimal for the surgeon to stand opposite the disc herniation to facilitate working under the facet in the foramen for disc herniation removal. Significant bone must be removed from both the inferior and superior facet to expose the exiting nerve root and identify and retrieve the herniated fragment. It is not at all uncommon for

pedicle with nerve hooks must be performed to avoid missing these small hard-to-find fragments. The fragments are frequently not continuous with the disc space, and therefore simple debridement of the disc space in the foramen does not lead to identification and removal of the fragment. Foraminal disc herniations in general are the most difficult fragments to identify and remove. This is largely a result of the surgeon's desire to limit the exposure as much as possible by removing as little of the facets as necessary. Despite this desire to maintain the facets, it is very often necessary to remove a very large portion of both the superior and the inferior facet.

Lateral extraforaminal disc herniations are another special situation (Fig. 43–5). The most direct access to a far lateral disc herniation is through a paramedian muscle splitting approach. The skin incision is made two fingerbreadths lateral to the midline and opposite the disc herniation and carried down through the intermuscular septum by blunt dissection. The same microdiscectomy retractors that are used for a routine microdiscectomy procedure are used here too, as is the operating microscope. The transverse process of the vertebral body just proximal to the disc herniation is identified. The inferior medial margin of the transverse process where it blends with the pars interarticularis is the critical angle to identify. The intertransverse membrane is incised along this margin of the transverse process. The 3-mm, 40-degree Kerrison rongeur is then used to remove a very small portion of the medial inferior transverse process margin. The rongeur can also be used for bony removal of a small portion of the lateral aspect of the facet to facilitate exposure. Careful dissection underneath the base of the transverse process results in identification of the nerve root. Arterial and venous vessels in this location need to be meticulously identified and coagulated to prevent excessive bleeding. Dissection medial to the identified nerve root provides access to the lateral margin of the disc. With careful lateral mobilization of the nerve root, the disc fragments should be identifiable and mobilizable with nerve hooks. Retrieval of the disc fragment results in decompression of the nerve root. The disc space itself can be minimally debrided through this approach when necessary with a Decker and pituitary rongeurs.

Repeat microdiscectomy surgery at the site of previous surgery is also a special situation. Scar tissue can make it difficult to identify the normal anatomic landmarks and in some cases, the bony landmarks have been removed in the original operation. The interlaminar space is exposed once again with a Cobb elevator by identifying the superior lateral margins of the inferior spinous process. The dissection is carried down to the lamina subperiosteally. These bony landmarks will allow the dissection to then proceed cephalad, exposing the facet joint and the lateral margin of the previous laminectomy defect. Being absolutely certain where the bony margin of the previous laminectomy defect is will help prevent inadvertent dural lacerations and nerve root injuries. A large curet can also be helpful in dissecting the dense scar tissue off of the bony margin. In general, the larger the instrument used, the less the likelihood of inadvertently penetrating scar tissue and dura. After definitively identifying the facet joint, the 3-mm, 40-degree Kerrison is insinuated into the facet joint and a partial medial facetectomy of the inferior facet is performed. This helps to clearly expose the medial aspect of the superior facet and the lateral margin of the previous laminectomy defect. The rongeur can then be safely insinuated into the spinal canal at the inferior lateral margin of the laminotomy defect. Additional bone is removed inferiorly, laterally, and superiorly as needed for access to the spinal canal. The amount of spinal canal access at the level of the pedicle is limited by the pedicle and cannot extend laterally beyond the medial margin of the pedicle. This can provide very limited exposure in the face of dense intraspinal adhesions. Further access to the spinal canal can always be achieved proximal to the pedicle by removing bone superior and lateral to the medial margin of the pedicle with a 40-degree Kerrison rongeur. Most recurrent disc herniations do not migrate away from the disc space due to epidural scar tissue. Accessing the disc space superior to the pedicle and lateral to the scar tissue encompassing the dura and the nerve root is an excellent way to avoid inadvertent damage to the nerve root and dura that is obscured by the scar tissue. It is frequently impossible to identify the nerve root and dura in the encased scar tissue. It is not advisable to attempt sharp dissection of the scar tissue to identify the dura and the nerve root. Without direct visualization of the nerve root and/or the dura, the disc space is entered lateral to the herniation superior to the pedicle and lateral to the dura and the nerve root.

Once the disc space is entered, using pituitary and Decker rongeurs the disc space can be aggressively debrided and the herniated fragments mobilized, retrieved, and removed without ever visualizing the dura and the nerve root. Exploration of the disc space with variable-length nerve hooks and forcible irrigation with antibiotics irrigation are absolutely mandatory when retrieving these herniated discs from the unseen recesses of the epidural space underneath the scar tissue encasing the dura and the nerve root. In this fashion, repeat microdiscectomy surgery can be performed without disrupting the dura and the nerve root and the encasing scar tissue. This not only significantly reduces the risk of nerve root and dura injury at the time of surgery but also reduces the probability that additional scar tissue will form around the dura and the nerve root. Repeat microdiscectomies performed in this fashion do not necessarily produce any increased scar tissue around the dura and the nerve root at the location of the recurrent disc herniation.

In summary, the special situations identified include the disc fragment migrated cephalad away from the disc space, the foraminal disc herniation, the lateral extraforaminal disc herniation, and finally the recurrent disc herniation at the site of previous surgery. These special situations demand slightly modified surgical techniques compared to the routine disc herniation.

Postoperative Care

Postoperative management usually requires no organized therapeutic regimen. Rapid return to activities of daily living, including light to sedentary work beginning within the first postoperative week, is the standard. Walking is therapeutic in an attempt to maintain mobility of the nerve roots postoperatively and minimize scarring. Gradual increase in physical activities of bending, lifting, and twisting usually allows the individual to resume full, unrestricted activities at 4 to 8 weeks following surgery. Patients on workers' compensation always request and require longer recovery times before returning to work, partly because of the genuine desire to prevent reinjury and partly because they enjoy the extended paid vacation. Postoperative activity status, rehabilitation, and work restrictions do not correlate with any increased or decreased incidence of recurrent disc herniations.

Pitfalls

Failure to achieve the expected pain relief that should occur in at least 90% of patients is due to a variety of causes. Not removing any or all of the disc herniation for whatever reason is the most obvious but the least frequent cause of failure. Most commonly, the patient has preoperatively a variety of symptoms including back pain and leg pain and an abnormality on an imaging study that is interpreted as a disc herniation but in fact is not causing symptomatic nerve root compression. Removing an asymptomatic disc herniation that is not producing any nerve root compression cannot be expected to improve the patient's clinical condition. It is also well recognized that patients with secondary gain continue to complain of pain postoperatively. Perineural and peridural scar tissue is always a suspected culprit in persistent postoperative pain. Despite the intuitive appeal of scar tissue as being an explanation for persistent postoperative pain, it is not a proven fact that scar tissue alone results in significant symptoms following a simple uncomplicated microdiscectomy procedure. On the other hand, dense perineural scar tissue certainly makes reoperation more difficult. Scar tissue also may tether the nerve root, making it more vulnerable to compression than it otherwise would be.

In conclusion, with the benefit of preoperative pinpoint localization of a disc herniation with a CT scan or an MRI scan, microdiscectomy surgery as described can routinely be performed on an outpatient basis with a safety and efficacy rate that exceeds 90 %. Microdiscectomy surgery is currently the gold standard for the surgical treatment of an individual with sciatic pain due to a disc herniation unresponsive to symptomatic treatment.

Suggested Readings

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Postoperative Care

Postoperative care consists of maintaining a subfascial lumbar drain for 24 to 48 hours and ambulating the patient 1 day postoperatively. Patients are typically hospitalized for 2 to 3 days with routine laminectomy surgery and are discharged once they are safely ambulatory and weaned from parenteral narcotic medication. Braces and corsets are not required. Patients are allowed to begin showering immediately on their return home. Sutures are discontinued 10 days to 2 weeks following surgery. The patient is cautioned against any significant or repetitive bending, lifting, or twisting for approximately 6 weeks, at which point they resume normal activities. Perioperative antibiotics are used prophylactically until the patient's drain is discontinued.

Suggested Readings

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46 Lumbar Pedicle Fixation

Vincent J. Devlin and Marc A. Asher

Goals of Surgical Treatment

1. Correct spinal deformity.
2. Enhance spinal fusion rates.
3. Facilitate decompression of neural elements.
4. Preserve or enhance lumbar lordosis.
5. Facilitate rehabilitation following surgery.

Indications

The pedicle is the anchor site of first choice for achieving spinal fixation in the lumbar region. The indications for pedicle fixation include the full spectrum of lumbar spinal disorders requiring spinal stabilization:

1. Spinal instabilities due to lumbar degenerative disorders
2. Spinal instabilities resulting from lumbar decompression procedures
3. Stabilization following corpectomies for tumor
4. Stabilization following anterior discectomies or corpectomies for infection
5. Lumbar scoliosis
6. Lower thoracic or lumbar fractures
7. Spondylolisthesis
8. Lumbar osteotomies
9. Repair of lumbar pseudarthroses

Contraindications

1. Absent, fractured, or atrophic pedicles
2. Severe osteopenia that limits secure screw purchase (insertion torque less than 4.0 inch-lbs)

Advantages

1. Pedicle fixation provides for rigid segmental immobilization of the spinal column.
2. The pedicle is frequently the only intact anatomic structure that can be used for fixation following a laminectomy. Pedicular fixation permits instrumentation and fusion to be limited to prior surgical levels.
3. Pedicle screws provide excellent fixation without spinal canal encroachment.
4. Pedicle fixation increases the rate of arthrodesis in lumbar fusion procedures.
5. Pedicle screws provide an excellent means for obtaining sacral fixation.
6. Pedicle fixation enhances preservation of sagittal contour.
7. Pedicle fixation minimizes the need for postoperative immobilization.

Disadvantages

Pedicle fixation procedures are not without disadvantages. Some disadvantages associated with lumbar pedicle procedures include:

1. Increased blood loss
2. Increased operative time
3. Increased risk of postoperative wound infection
4. Implant bulk may cause soft tissue irritation
5. Implant rigidity may lead to transition syndromes as levels above or below the instrumented levels undergo accelerated degenerative changes due to stress transfer
6. Risk of neurologic injury

Procedure

Preoperative Planning: Review the Anatomy of the Pedicle

Prior to surgery, the patient's radiographs (Fig. 46–1) and neurodiagnostic imaging studies [computed tomography (CT), magnetic resonance imaging (MRI)] are reviewed to assess pedicle diameter, length, and orientation. Abnormalities such as pedicle dysplasia or pedicle fracture are identified, and a strategy is developed to achieve optimal spinal fixation in the face of these challenges. Knowledge of normal pedicle anatomy is essential to proper placement of pedicle screws.

The pedicles form the superior and inferior boundaries of the intervertebral foramen with the exiting nerve root in close proximity to the inferior medial borders of the pedicle. In the foramen the nerve root lies 0.4 to 0.5 cm superior to the upper border of the caudal pedicle. Avoiding placement of the pedicle screws too inferiorly will protect against injury to the nerve root.

The lumbar pedicles are oval in cross section with the medial-lateral width smaller than the sagittal width except at L5. The medial-lateral width determines the maximum allowable screw diameter. T decreasing medial-lateral pedicle width from L5 to L1 with the 18 mm at L5 and 10 mm at the L1 pedicle. The mean sagittal widt 15 mm, diminishing to a mean of 14 mm at L5.

The pedicles are directed from a posterolateral to an anteromec tion. The transverse plane angle between the long axis of the pedic midsagittal line increases from L1 to L5 with a mean of 12 degrees 30 degrees at L5. The sagittal pedicle angle is less variable than t verse angle, with less than a 10-degree difference between L1 and distance from the anterior cortex of the vertebral body to the post trance point to the pedicle is approximately 50 mm at each lumba

Technique

Patient Positioning and Exposure

The patient is positioned prone on a radiolucent table (e.g., Jackso A radiolucent frame facilitates imaging. The abdomen is permitted freely. The hips are extended to enhance lumbar lordosis. A midlin rior approach to the spine is performed with subperiosteal exposu posterior bony elements to the level of the transverse processes. taken to preserve the facet joint capsules until the surgical leve fused are confirmed either anatomically or with a radiograph. If decompression is required, screw placement can either precede o lumbar decompression based on surgeon preference. Our practi place screws prior to performing decompression except in unusu such as high-grade spondylolisthesis where partial reduction of make placement of the L5 pedicle screw easier.

Pedicle Localization

In the lumbar spine, the entry point to the pedicle is located at the ju of the pars interarticularis, midpoint of the transverse process and aspect of the superior articular process. At the superior screw s entry point is modified to prevent impingement on the adjacent fac which is not included in the fusion. Select an entrance point slightl lateral at the base of the transverse process. The entry site for S1 scre tion is at the base of the superior facet of S1 (Fig. 46–2A).

Pedicle Access, Pedicle Preparation, and Screw Placement

A visual-tactile-anatomic approach to pedicle screw placement is u A drill is not utilized. The cortical bone overlying the entry poin moved to expose the underlying cancellous bone. This may be perf with the surgeon's instrument of choice (rongeur, gouge, awl, mot burr) (Fig. 46–2B).

Next, a curved probe with depth markings along its shaft is in down the path of the pedicle (Fig. 46–2C). The passage line is perpe lar to a line joining similar points on adjacent lamina in the sagitt coronal plane. The probe is directed from lateral to medial to accomm the transverse plane angular position of the pedicle. This is typicall 20 degrees depending on the spinal level. The probe will follow the way of least resistance and guide the surgeon into the cancellous bo the vertebral body.

The motion used to advance the pedicle probe is a swirl and a wig produce a round hole at the opening and an oval hole in the pedicle. sistance is suddenly lost during insertion, it is likely that the probe h ited the cortical tube leading into the pedicle or has breached the pe wall. The probe should be removed and the hole palpated with the flexible ball-tip probe to determine the direction of penetration (sup inferior, medial, lateral). After this has been ascertained, the pedicle can be properly redirected into the pedicle isthmus.

Next, the channel, which has been created within the pedicle, is pated with the ball-tip probe to ascertain the integrity of the four wa the pedicle as well as the presence of bone at the floor of the hole (Fig 2D). Next, the pedicle entry hole is plugged with a small piece of bone and the 30-mm end of a pedicle marker. The sequence is repeated levels where screws are to be placed. Posteroanterior and lateral r graphs or image intensification are used to assess marker position alignment.

Each pedicle hole is tapped with an auger type tap (Fig. 46-2E). tapered tap will pull itself into the hole and merely needs to be gui Only the pedicle isthmus needs to be tapped. The tap used is gene slightly smaller than the screw to be placed. A screw is now inserted ur strong resistance to torque is encountered (Fig. 46–2F).

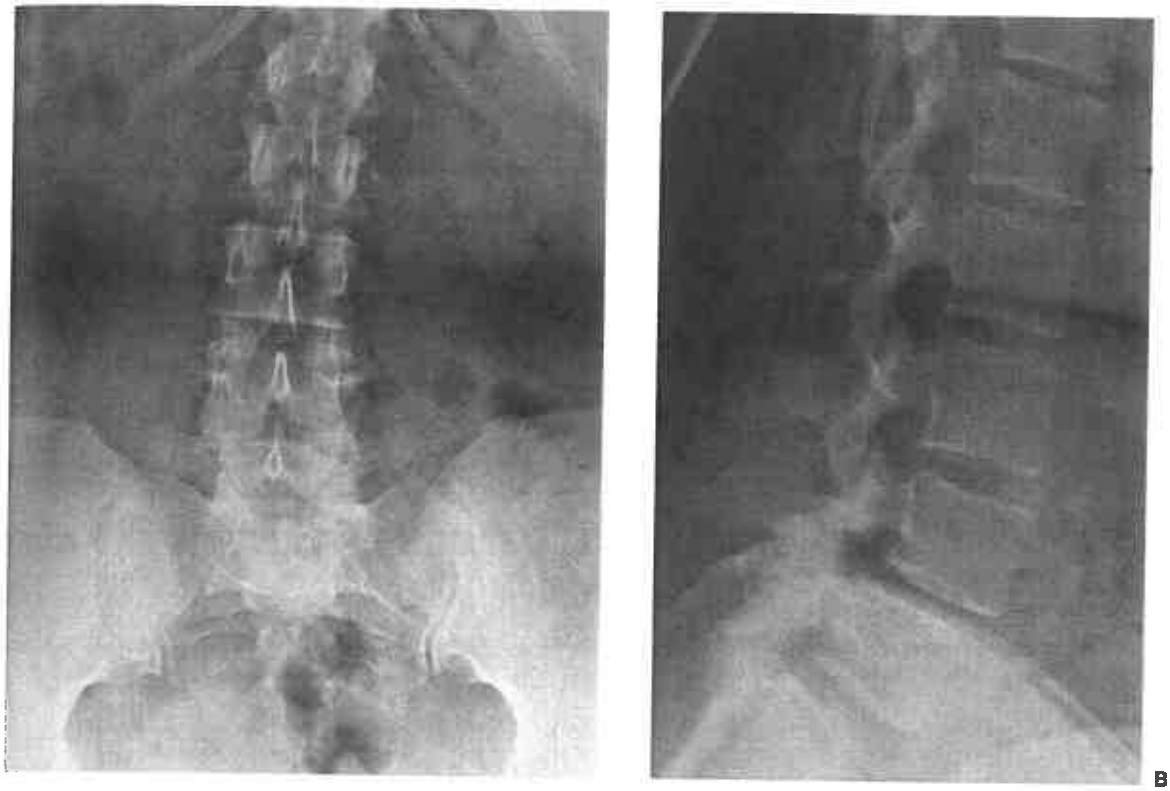
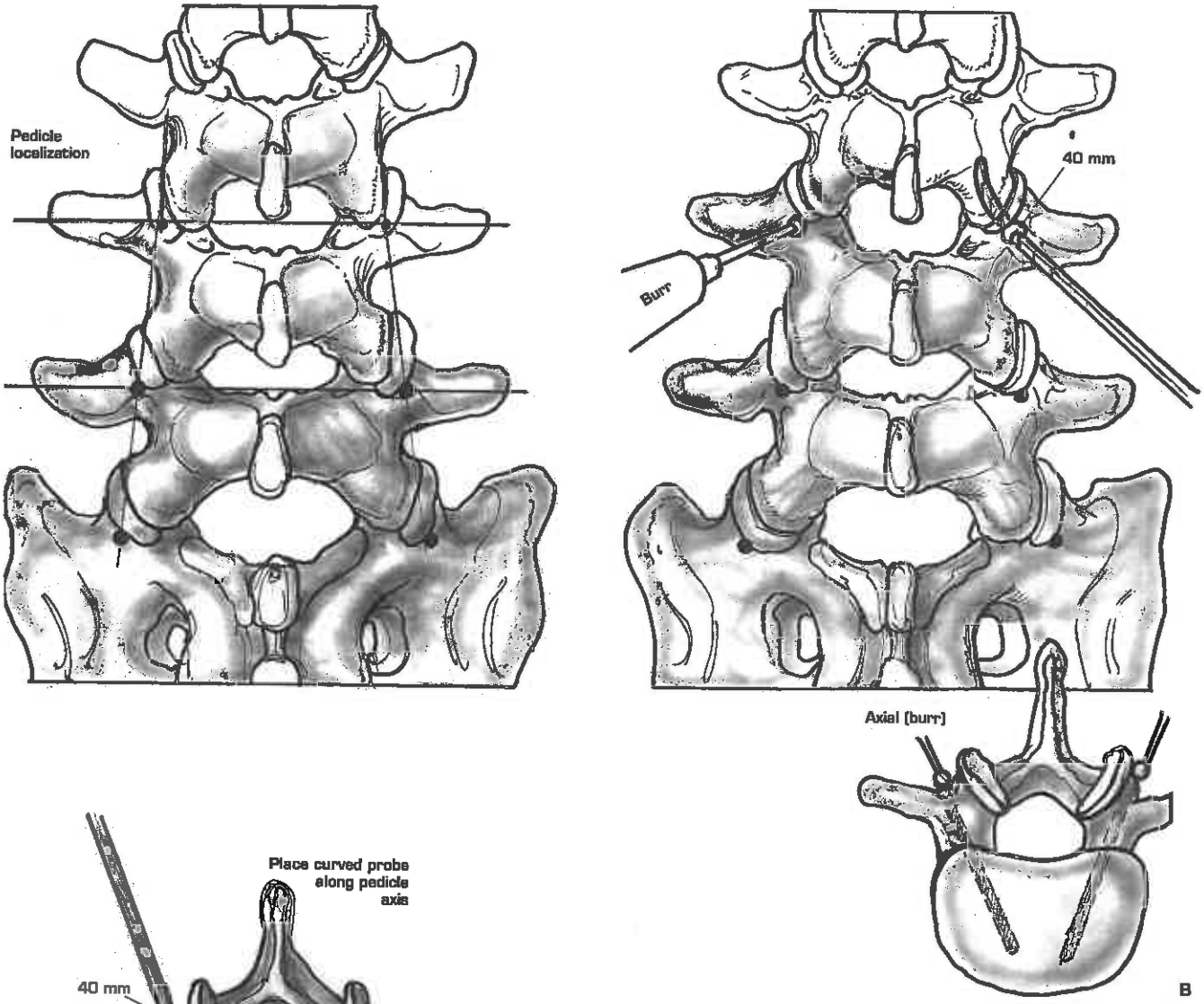


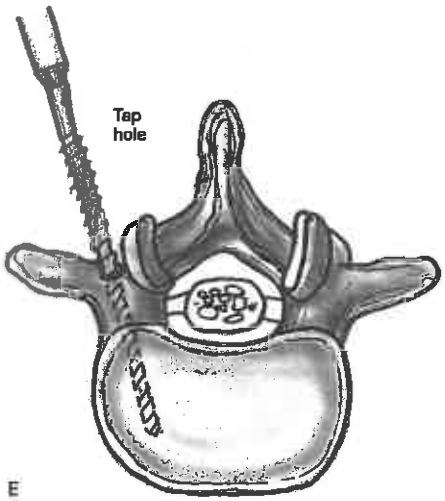
Figure 46–1

(A,B) Preoperative anteroposterior (AP) (A) and lateral (B) lumbar radiographs.

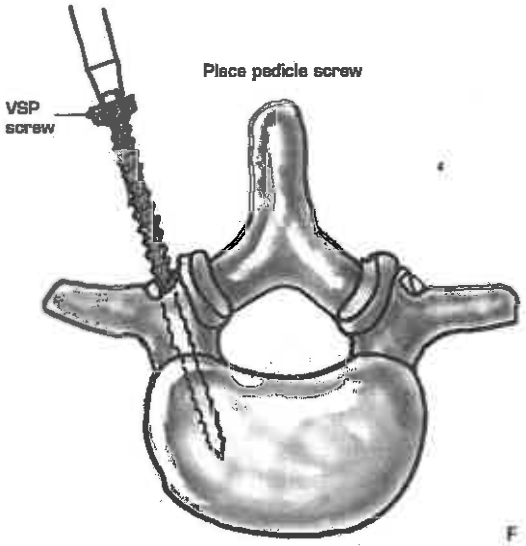


jure 46–2

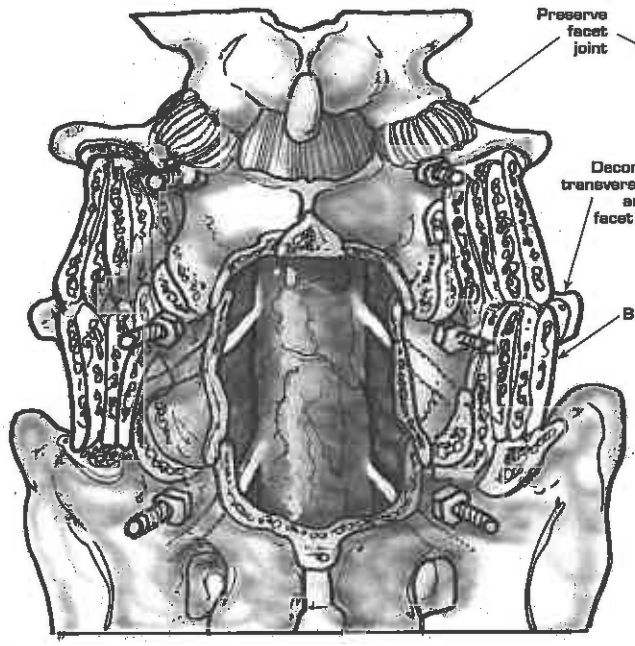
-H) Intraoperative drawings demonstrating the steps of lumbar pedicle screw ıcement.


Tap
hole

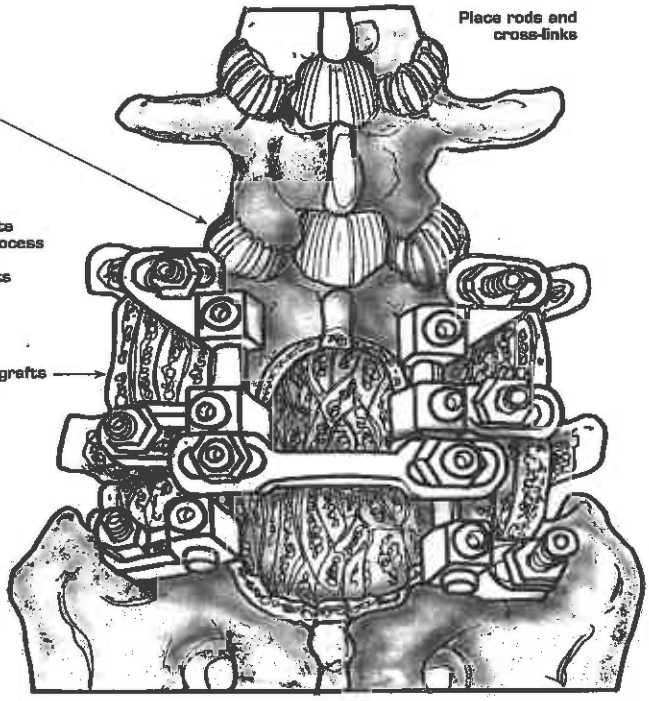
E


Place pedicle screw
VSP
screw

F


Preserve
facet
joint
Decorticate
transverse process
and
facet joints
Bone grafts

G


Place rods and
cross-links

H

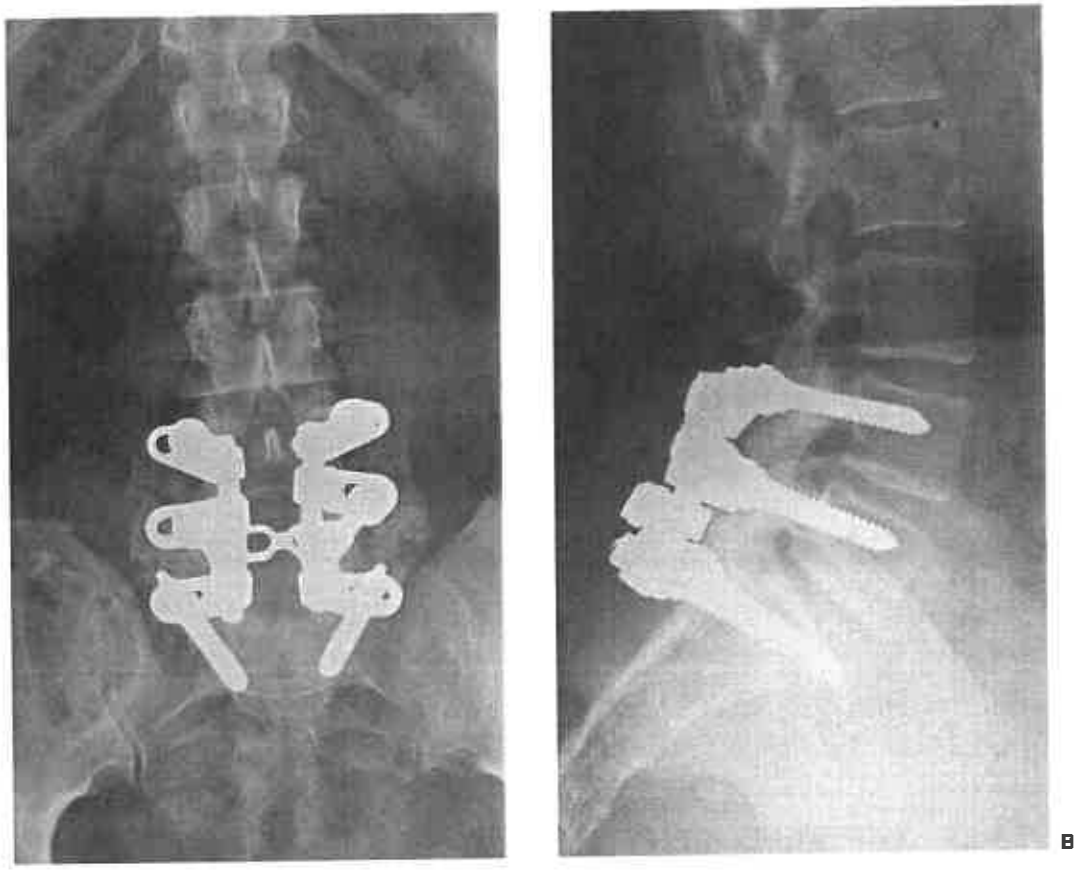


Figure 46–3

(A,B) Postoperative radiographs demonstrating appropriate implant placement and a solid posterior arthrodesis.

The S1 screw site preparation is slightly different. A medially directed bicortical S1 screw aimed toward the sacral promontory provides the strongest site for S1 screw fixation. The dorsal cortex at the base of the S1 facet is removed with a rongeur or bur. An awl is positioned perpendicular to the sacrum and angled medially and used to penetrate the dorsal sacrum. The pedicle probe is used to deepen the hole taking care to aim the tip of the probe toward the S1 end plate.

Next, a 3.2-mm calibrated Steinmann pin is used to penetrate the anterior sacral cortex. Both tactile and auditory feedback are critical to this step. As the pin approaches the anterior wall of the sacrum, the sound of the mallet striking the pin becomes higher in pitch. When the pin passes through the anterior sacral cortex, there is an immediate decrease in pitch and a palpable decrease in resistance to passage advancement of the pin. After the anterior cortex is penetrated, a ball-tip probe is used to confirm proper screw channel placement and anterior cortical perforation. At this point, the S1 screw is inserted. If fluoroscopy is available during this part of the procedure, an alternate technique can be used to achieve S1 bicortical screw placement. After removing the cortex at the base of the S1 facet, a 5.5-mm tapered tap can be used to perforate the anterior S1 cortex under fluoroscopic guidance. It is crucial to remember that the distance to the S1 anterior cortex does not generally exceed 50 mm. After checking the integrity of the screw hole with a ball-tip probe, a 7.0-mm VSP screw can be placed to achieve bicortical purchase.

Fusion Bed Preparation and Placement of Final Implants

All exposed bony surfaces are decorticated to prepare the fusion bed including the lateral gutter (transverse processes, lateral aspects of facet joints, sacral ala) and facet joints (Fig. 46–2G). Abundant autogenous iliac bone graft is placed over these exposed surfaces and meticulously packed into each facet joint that is to undergo arthrodesis. Next, the linkage between the pedicle screws and longitudinal member is created using a rod with appropriate screw-rod connectors or a plate. Then a cross-link device is placed between the rods or plates to complete the construct (Fig. 46–2H). If a laminectomy has been performed, the spinal canal, nerve roots, and neural foramen are inspected at this time to check for displaced bone graft or foraminal stenosis, which has developed following implant placement (Fig. 46–3).

Technical Tips

Difficult Screw Insertion

If there is difficulty is placing a screw in a particular pedicle, it is quite easy to create a small laminotomy and visualize the medial wall of the pedicle at that level. Direct visualization and palpation of the pedicle is then used as a definitive guide to screw placement.

Modification of Screw Insertion Technique

Depending on pedicle size, bone density, and patient age, the technique of insertion may require modification. In the adult with capacious pedicles and soft bone, the pedicle probe will easily sink into the cancellous bone of the pedicle with minimal resistance. There is generally a distinct tactile difference between the path of least resistance through the cancellous bone in the center of the pedicle and the firm surrounding cortical wall.

In the pediatric and young adult patient with dense cancellous bone and small pedicle diameter, the blunt-tip pedicle probe may not easily follow the course of the pedicle. This situation is addressed by using a 3–0 straight microcuret under headlight illumination to gently enter the pedicle. The curet is gently guided down the pedicle until it passes the pedicle isthmus into the vertebral body. Sequentially larger curets are used to enlarge the channel in the pedicle until the standard pedicle probe can be placed down the pedicle axis into the vertebral body.

Pitfalls

Use of Pedicle Screw Constructs When Anterior Spinal Column Insufficiency is Present

Despite the strength and rigidity of pedicle screw constructs, they do not possess sufficient fatigue life and strength to compensate for loss of anterior column load sharing. It has been determined that approximately 80 % of the compressive load in the spine is transmitted through the vertebral bodies in a correctly instrumented three level pedicle screw construct. Pedicle fixation will fail unless the anterior spinal column is reconstructed with a structural graft or spacer in situations such as comminuted vertebral body fractures and high-grade spondylolisthesis.

Complications

Pedicle Screw Misplacement

Many potential complications may result from screw misplacement. Superior violation of the pedicle cortex results in penetration of the intervertebral disc with suboptimal screw purchase. Inferior violation of the pedicle cortex places the nerve root at risk of injury. If the medial cortex of the pedicle is disrupted, the neural canal is entered and the adjacent neural structures are at risk of injury. Lateral screw misplacement results in poor screw purchase and potentially can injure the segmental vessels and retroperitoneal structures. Excessively long screws may protrude beyond the anterior vertebral cortex and potentially injure the great vessels. Adequate exposure of bony landmarks, radiographic monitoring, and knowledge of spinal anatomy help minimize complications. Use of spinal monitoring techniques such as triggered electromyography (EMG) stimulation of pedicle screws can identify screw misplacements that compromise neural structures and provide the surgeon the opportunity to correct these problems intraoperatively.

Device-Related Complications

Screw breakage, rod-connector-screw loosening or dislodgment, and rod breakage may be noted following surgery. Early failures are most commonly the result of failure at the bone-metal interface or failure to maximally tighten the fastening components of the spinal system. Late fixation failures are most commonly due to fatigue failure and frequently are associated with pseudarthrosis.

Implant Interference with Adjacent Spinal Levels

This problem is most commonly noted at the superior end of the implant construct where there is close proximity between the pedicle and the first unfused facet joint above the instrumentation. Precautions that aid in preventing this problem include selection of a more lateral and inferior entry site for screw placement at this level, use of a washer on the most proximal screw to raise the longitudinal member above the level of the facet joint, and use of a specialized connector that avoids placing a rod in the vicinity of this facet joint.

Postoperative Care

A postoperative physiotherapy program is initiated and continued after hospital discharge. Postoperative immobilization is utilized based on the nature of the underlying spinal pathology, patient bone quality, screw purchase noted at the time of surgery, as well as surgeon preference. The current trend is to manage patients without postoperative immobilization except in unusual circumstances.

Suggested Readings

Asher MA. Isola spinal instrumentation system for scoliosis. In: Bridwell KH, DeWald RL, eds. The Textbook of Spinal Surgery. 2nd ed. Philadelphia: Lippincott-Raven; 1997:569–609.

Calancie B, Madsen P, Lebwohl M. Stimulus-evoked EMG monitoring during transpedicular lumbosacral spine instrumentation: initial clinical results. Spine 1994;19:2780–2786.

Steffee AD, Biscup RS, Sitkowski DJ. Segmented spine plate with pedicle screw fixation: a new internal fixation device for disorders of the lumbar and thoracolumbar spine. Clin Orthop 1986;203:45–53.

Steffee AD, Brantigan JW. The variable screw placement spinal fixation system: report of a prospective study of 250 patients enrolled in Food and Drug Administration clinical trials. Spine 1993;18:1160–1172.

Weinstein J, Spratt K, Spengler D, et al. Spinal pedicle fixation: reliability and validity of roentgenogram-based assessment and surgical factors on successful screw placement. Spine 1988;13:1012–1018.

Zindrick M, Wiltse L, Doornik A, et al. Analysis of the morphometric characteristics of the thoracic and lumbar pedicles. Spine 1987;12:160–165.

47 Lumbar Corpectomy

Patrick J. Connolly

Goals of Surgical Treatment

1. Decompression of spinal canal
2. Removal of pathologic tissue (tumor, infection, fracture fragments)
3. Restoration of lumbar lordosis
4. Direct stabilization of the anterior column of the lumbar spine

Diagnosis

1. Primary or metastatic disease
2. Infection
3. Fracture
4. Posttraumatic kyphotic deformity
5. Congenital or acquired spinal deformity
6. Multilevel upper lumbar disc herniation

Indications

Anterior release; decompression and anterior column reconstruction for tumor (primary or metastatic); fracture; deformity; or degenerative disease.

Absolute Indications

1. Pelvic or abdominal tumor
2. Multiple prior abdominal surgeries

Relative Indications

1. Prior radiation
2. Significant aorta or femoral vascular disease
3. Prior abdominal surgery
4. Obesity

Advantages

1. Sutton's law: direct removal of offending tissue
2. Mechanical advantage for maintaining restoration of anterior column and lumbar lordosis
3. Improved wound healing

Disadvantages

1. Anterior exposure of the upper lumbar spine may require a thoracotomy.
2. Familiarity with approach.
3. Requires knowledgeable assistant.

Procedure

In the preoperative planning of an anterior lumbar corpectomy, the surgeon should divide the operation into the three essential parts: approach, decompression, and stabilization. Ultimately the patient's unique anatomy and pathology, along with the individual surgeon's skill, will determine the most appropriate technique.

Approach

There are two essential variations of the surgical approach for lumbar corpectomy: anterior lateral and straight anterior. The anterior lateral approach provides easier access to the upper lumbar spine (L1, L2, and L3) via a retroperitoneal approach. It provides a more lateral orientation for decompression and anterior column reconstruction. The straight anterior approach is a more user-friendly approach for the lower lumbar spine (L4, L5, S1). It provides a straightforward anterior/posterior orientation to the spine. I find the direct anterior approach more suitable for placement of structural grafts when I am attempting to improve lumbar lordosis. This approach does not utilize a thoracotomy or rib incision. I have not been able to get adequate exposure higher than the L2-L3 disc with this approach (even in very thin patients!).

The incision for the anterior lateral approach can be extended into a direct anterior incision and ultimately can help you get anywhere in the lumbar spine. Exposure of L1 or L2 usually requires a rib excision with a T10, T11, or T12 being excised. L3 and L4 can be exposed with a flank incision without thoracotomy. The anterior lateral approach is more user friendly if you plan to utilize an anterior lateral plate for the anterior column reconstruction.

Anterior: The patient is supine. The skin incision may be longitudinal, oblique, or transverse, and is dependent on the surgeon's choice, patient's size, and cosmetic concerns (Fig. 47–1A). Classically the anterior rectus sheath is opened on the patient's left side two to three fingerbreadths from the midline (Fig. 47–1B). The lateral border of the rectus abdominus muscle is delineated and then retracted toward the midline (note: some surgeons prefer to delineate the medial border of the rectus and retract laterally).

Once the rectus is retracted, the posterior sheath is identified. At the inferior border of the posterior sheath (about midway between the umbilicus and the symphysis pubis) is a thickening called the arcuate ligament. Immediately below the arcuate ligament is the entry to the retroperitoneal space. With a moist lap or sponge stick, sweep away the transversalis fascia, retroperitoneal fat, and peritoneum. Start lateral and go medial to avoid tearing the peritoneum. After clearing off the undersurface of the arcuate ligament and the posterior rectus sheath, divide the sheath laterally to gain full exposure. Initially use hand-held retractors (beaver or Harrington) and identify the psoas. The psoas is the key; once it is identified, sweep with a moist lap the peritoneal contents. The ureter almost always is swept along with the peritoneum. Identify the great vessels and then place the appropriate blades for the Bookwalter retractor. Note: Do not use the self-retaining retractors to retract the great vessels.

Identify the bifurcation of the aorta, which is usually at the L4–5 disc space. Underneath the aortic bifurcation, usually just a little lower at the level of the superior half of L5 vertebral body, is the bifurcation of the vena cava. A vessel loop around the left common iliac artery aids in the retraction and dissection, so place this first. Mobilize the artery using 2-0 silk ties, vessel clips, or bipolar electrocautery. After the artery has been mobilized, mobilize the vein. At this point, to fully mobilize the vessels to perform a corpectomy of L5, do the following:

1. Ligate, clip, or use bipolar electrocautery on the middle sacral vessels.
2. Ligate or clip the iliolumbar vein and its branches (note: do not consider bipolar electrocautery on this vessel).
3. Ligate or clip the segmental vessels at L4.
4. Mobilize the back wall of the left common iliac vein off the body of L5.
5. When operating in the bifurcation (e.g., an L5/S1 discectomy), avoid retracting both common iliac veins at the same time because it might create a tear in the crotch of the vein.

Anterior lateral: The patient is in the decubitus position with the left flank (down side) position over the table break. The incision is aligned with the rib (10th, 11th, or 12th) extending from the costotransverse junction to the lateral border of the rectus (Fig. 47–2A). Subperiosteal dissection allows removal of the rib without violation of the pleural cavity. Cut the rib at the costotransverse junction and at the tip. Note the diaphragm and abdominal wall muscular insertions; blunt dissection will help in locating the retroperitoneal space via identification of the retroperitoneal fat.

Bluntly dissect the peritoneum off the undersurface of the abdominal wall with a sponge stick, thus allowing division of the external and internal oblique muscles (Fig. 47–2B). With a moist lap sweep the retroperitoneal fat and peritoneum anteriorly and identify the psoas. Check to make sure you have not entered the pleural cavity; if so, a chest tube will need to be inserted at the end of the procedure. Identify the discs (remember, the discs are the bumps not the valleys); often in males the psoas will go past the midline in the upper lumbar spine and completely cover the spine. In this case, blunt dissection with a "peanut" will allow you to visualize the disc. Once it is identified, take a radiograph. Remember, the disc above and the disc below the corpectomy need to be cleared prior to the decompression. At L1 and L2 the crus of the diaphragm needs to be divided for exposure and subsequently repaired at the end of the procedure.

Decompression

The key to the lumbar corpectomy is the disc! When one first sharply resects the disc directly above and below the vertebral body, the blood loss is minimal and you can visualize the posterior longitudinal ligament (PLL). The next step is to take down a portion of the PLL to identify the plane of the dura. (I utilize a Penfield No. 4 to separate the PLL fibers and carefully resect the PLL, initially with a long length 2-mm Kerrison rongeur.) This can be done above and below the vertebral body. Once the dural plane has been delineated, the corpectomy can be carried out with relative ease using a high-speed bur or rongeurs down to a thin shell of bone overlying the remaining PLL.

When performing a corpectomy from the anterior lateral approach, I utilize a wide osteotome and start at the base of the pedicle and come directly across. This shell is then resected along with the PLL for the entire

50 Pedicle Subtraction Osteotomy

Courtney W. Brown and Douglas C. Wong

Goals of Surgical Treatment

To achieve sagittal balance of the spine with a single-stage posterior osteotomy where a plumb line from C7 is at or behind the posterior superior edge of the S1 body.

Diagnosis for Flatback Syndrome

1. The patients complain of chronic back pain with associated hamstring tightness. Patients must flex their knees to look forward.
2. Physical examination reveals forward flexion of the trunk when the knees are extended. Standing anteroposterior (AP) and lateral x-rays show anterior sagittal imbalance with loss of lumbar lordosis.
3. Plumb line from C7 on the lateral film is anterior by over 6 cm to the posterior superior edge of the S1 body.

Indications for Surgery

Loss of lumbar lordosis (flat back) with associated complaints and physical findings as mentioned above.

Contraindications

1. History of ongoing infection from previous surgery
2. Severe osteoporosis, which could lead to implant loosening
3. Severe comorbidities

Advantages

1. Elimination of the need for multiple posterior osteotomies.
2. Anterior disc space is not opened as a result of the posterior closure of the posterior elements.
3. Elimination of an anterior procedure.
4. Biplanar osteotomy may be performed if coronal decompensation exists.

Disadvantages

1. Coronal decompensation may occur if the osteotomy cuts are not parallel.
2. Blood loss, dural rents, and neurologic compromise.

Preoperative Evaluation

Upright AP and lateral long cassette radiographs are taken with the knees straight and the feet facing forward to evaluate the amount of sagittal and coronal decompensation. With these radiographs, a tracing on clear x-ray film can be cut to determine the size and location of the osteotomy to restore normal sagittal alignment. Spinal fixation points such as hook or pedicle screw sites can be planned. If feasible, the osteotomy should be performed at L2 or below to avoid risk of spinal cord injury. A C-arm or computed tomography (CT)-guided navigation (e.g., STEALTH), should be used to assist with placement of pedicle screws and localization of the osteotomy site. Spinal cord monitoring should be used: electromyograms (EMGs) at L2 or caudal and motor-evoked potentials (MEPs) and somatosensory evoked potentials (SSEPs) above L2. As this operative procedure can involve significant blood loss, three to four units of autologous blood should be collected preoperatively. A cell saver should be used intraoperatively.

Intraoperative

After adequate general endotracheal anesthesia, the patient is placed prone on a four-poster spine frame on an operating room table equipped with an elevating kidney rest. The kidney rest should be at the level of the patients' distal thighs or knees (Fig. 50–1). Elevating the kidney rest intraoperatively facilitates closure of the osteotomy site by extending the pelvis through the hips (Fig. 50–2). Another technique involves the use of a bent/flexed operating room table with two separate four-poster spine frames. Straightening the table closes the osteotomy site.

After sterile prep and draping, the spine is exposed through a standard posterior approach. The paraspinous muscles are stripped off the posterior elements or fusion mass out to the transverse processes and deep retractors are placed. If CT-guided navigation is to be used, it is important not to disturb the bony architecture of the fusion mass. This will allow accurate registration. Bovie electrocautery may be used to separate the soft tissue from the fusion mass.

Once the lumbar site is prepared, the fixation points are obtained. We seek to obtain two levels of pedicle screw or hook fixation above and below the osteotomy site. C-arm may assist in the placement of pedicle screws. This can be quite difficult in a fused spine due to the loss of the normal bony architecture and occasional rotation of the vertebral bodies. CT-guided navigation (e.g., STEALTH) has made the location of the pedicles in this situation significantly easier and faster. Once the fixation points are obtained, the osteotomy can be performed.

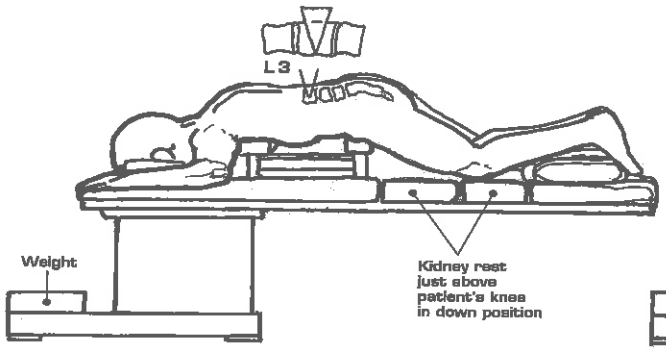
The osteotomy is a closing wedge hinged at the anterior cortex of the vertebral body. The osteotomy should encompass the pedicles as well as the posterior wall of the vertebral body. In the coronal plane, the cranial and caudal ends of the osteotomy site should end up being parallel to prevent coronal decompensation. A biplanar osteotomy may be performed if preoperatively the patient has coronal decompensation or scoliosis.

The dorsal margins of the osteotomy site are identified and bone from the fusion mass is carefully removed (Fig. 50–3). We prefer to use straight and curved osteotomes; others prefer the use of a high-speed burr. Once the spinal canal is identified, a Penfield No. 4 or dental is used to carefully separate the dural sac from the bone as adhesions occasionally develop. The osteotomy site is widened bilaterally with Kerrison punches; this is then carried out cranial and caudal to the pedicles, which isolates the pedicles bilaterally. Using increasingly larger curets, the cancellous bone within the pedicle is removed, thus leaving only the wall of the pedicle (Fig. 50–4). This can then be imploded and removed piecemeal while the inferior nerve root is protected with a Penfield No. 4 or similar retractor. At this stage in the operation, significant bleeding may occur from the cancellous bone and requires packing of the bleeding surfaces with thrombin-soaked Gelfoam or Flo-seal to obtain hemostasis. If one side starts to bleed, it can be packed while the other pedicle is decancellized. The remains of the pedicle are removed with pituitary rongeurs.

After both pedicles are removed, the osteotomy is carried out through the posterior wall of the vertebral body. A dural retractor is used to medially retract the dura and nerve root. A one-quarter-inch to one-half-inch osteotome may be used to cut the posterior cortex of the vertebral body. Footed tamps are placed anterior to the dura, thus impacting any remaining portion of the posterior vertebral wall anteriorly. The cortical fragments are removed and the same procedure is carried out on the contralateral side. Straight osteotomes are used to extend the cranial and caudal sides of the osteotomy anteriorly into the vertebral body. Curets are used to remove the cancellous bone from the vertebral body up to the anterior one third of the body. Only two thirds of the vertebral body bone needs to be removed; the rest can be fractured when the osteotomy is closed (Fig. 50–5). The lateral walls of the body need to be carefully separated from the surrounding soft tissue with a small Cobb elevator and then removed with a pituitary rongeur. Lateral C-arm should be used to identify the depth of the osteotomy anteriorly and to determine how far and how much bone needs to be removed. Gelfoam is placed over the bleeding surfaces. The cranial and caudal ends of the posterior edge of the spinal canal are undercut with a Kerrison punch to decrease the chance of impingement of the dura when the osteotomy site is closed.

After acceptable removal of bone from the osteotomy site, the Gelfoam is removed and the kidney rest is elevated or the bent table is straightened. This, along with compression between the cranial and caudal pedicle screws, provides closure of the osteotomy site. Occasionally, an audible "crack" can be heard when the osteotomy site is closed. The ends of the now "closed" osteotomy site should oppose each other tightly. If not, there could be some loose bone blocking the closure. This requires opening the osteotomy and checking for bone fragments, removing the loose bone, and subsequently closing the site. If the closure is still not very tight, autograft bone may be packed over the surfaces. Rods are placed bilaterally and secured to the pedicle screws or hooks (Fig. 50–6). Further compression can enhance closure of the osteotomy site. As the osteotomy site is being closed, monitoring of the nerve roots will allow the detection of impingement. If there is firing of a nerve root, the osteotomy site should be opened and the foramen explored for retained fragments of bone. Routine multilayered closure over a Hemovac drain is then performed.

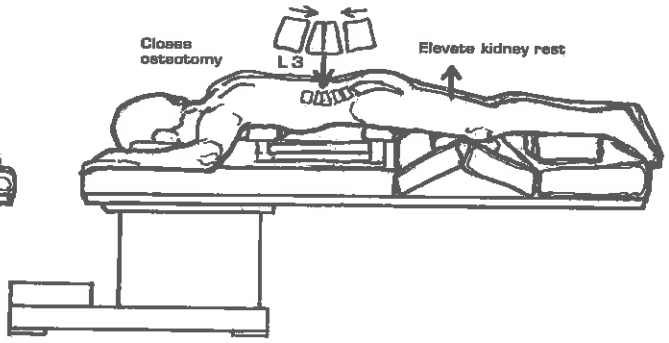
The use of CT-guided navigation has greatly improved the ease with which the pedicle is entered in a postfusion or ankylosed spine. The postfusion spine has loss of normal spinal architecture, which makes locating the pedicle much more difficult. There can also be some element of rotation of the fused vertebrae, which makes localization of the pedicle with C-arm/fluoro challenging. CT-guided navigation has increased the speed and safety of placement of pedicle screws in these patients (Wong, 1999). One-millimeter CT cuts through the operative area are obtained. These are entered through optical disc into the CT guidance device (e.g., STEALTH,



(Position of patient prior to surgery)

Figure 50–1

Position of patient prior to surgery. Note the kidney rest in the down position, just above patient's knees. The cantilever aspect of the table allows C-arm visualization of the spine.



Elevation of kidney rest assists in closing the osteotomy

Figure 50–2

Elevation of the kidney rest assists in closing the osteotomy.

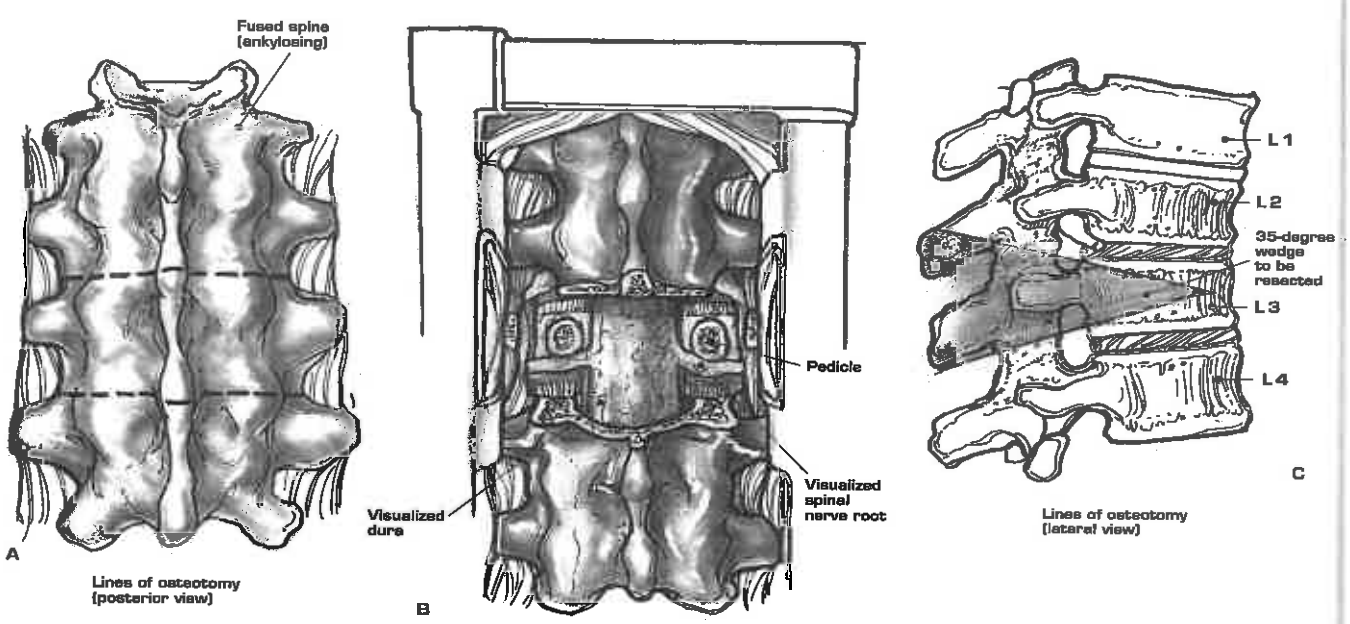


Figure 50–3

(A) Lines of osteotomy (posterior view). (B) Posterior view after laminectomy. (C) Lines of osteotomy (lateral view).

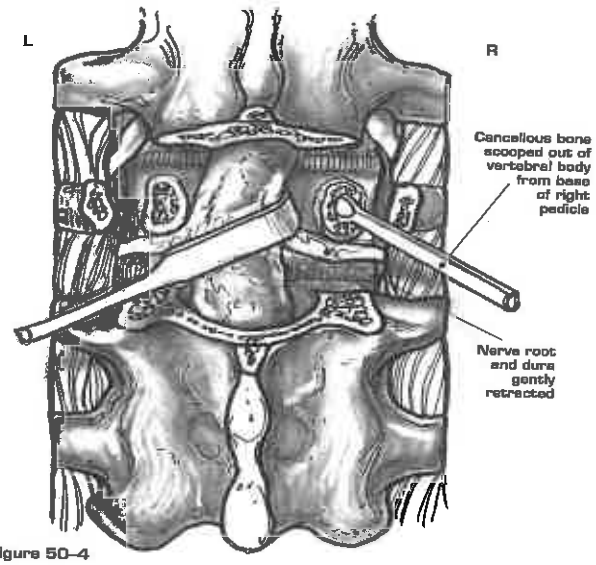


Figure 50–4
Gentle retraction of nerve root and dura during decancellization of the pedicle.

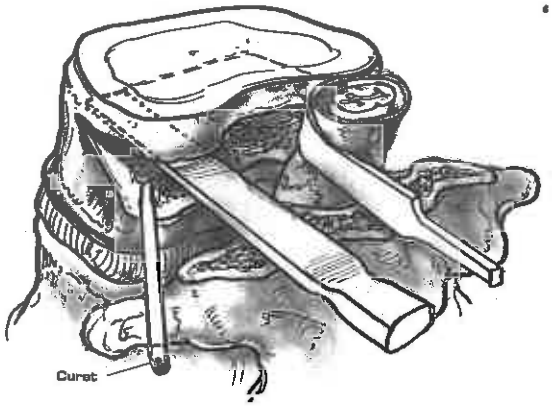
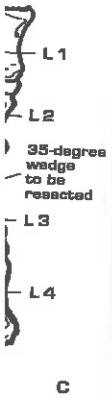


Figure 50–5
Excision of wedge with osteotome and curet.



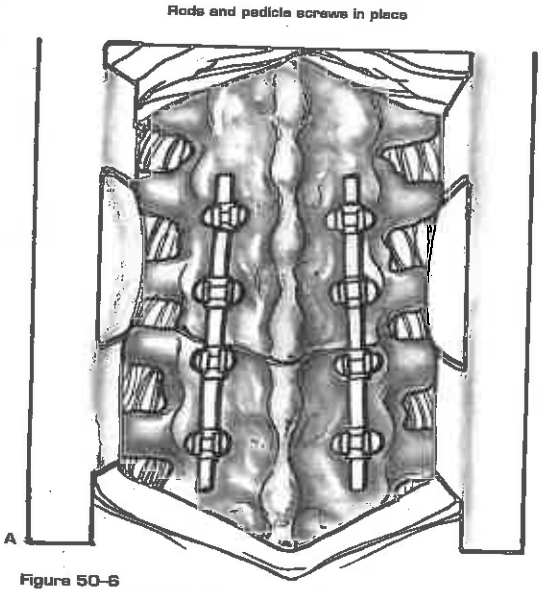
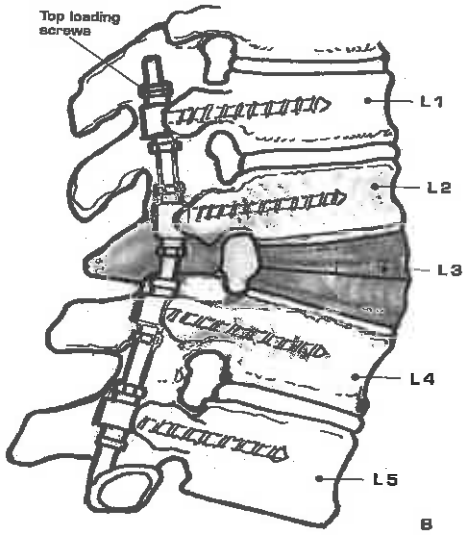


Figure 50–6
(A) Posterior view of closed osteotomy. (B) Lateral view of closed osteotomy.



Sofamor Danek). The standard posterior approach is performed. Stripping of the paraspinous muscles with an electrocautery prevents alteration of the bony architecture in the field. This allows an accurate registration of the operative field to model built in the CT guidance. CT guidance is then used to locate and place the pedicle screws. It can also be used to help identify the osteotomy site.

Pitfalls

1. Placement of screws can be quite difficult in a fused spine due to the loss of the normal bony architecture and occasional rotation of the vertebral bodies.
2. The cranial and caudal ends of the osteotomy site must be parallel to prevent coronal decompensation.
3. Inferior nerve root damage may occur when the wall of the pedicle is removed.
4. Impingement of the dura when the osteotomy site is closed.
5. Loose bone blocking the closure of the osteotomy.
6. Nerve root impingement with closure of the osteotomy site.

Postoperative Care

The patient is fit with a custom molded TLSO, or Jewett brace with a posterior gibbous pad, and mobilized once the brace is in place. The patient is kept in the brace when out of bed for a total of 8 weeks, or until the osteotomy site is healed. This should first occur anteriorly.

Suggested Readings

Thomasen E. Vertebral osteotomy for correction of kyphosis in ankylosing spondylitis. Clin Orthop 1985;194:142–151.

Wong DC. The use of CT guidance in the operative treatment of post-fusion spinal deformity. Presented at the IMAST meeting, Vancouver, BC, Canada, July 10, 1999.

51 Anterior Lumbar Interbody Fusion

Anthony P. Dwyer and J. Paul Elliott

Goals of Surgical Treatment

To achieve a solid stable interbody fusion.

Diagnosis

Chronic mechanical low back pain, often with intermittent episodes of more severe low back pain. Physical examination reveals tenderness over the lumbosacral junction, and possibly anterior spinal tenderness on abdominal examination, painful limitation of active lumbosacral range of motion as well as signs suggesting spinal instability. Neurologic examination may reveal no objective deficits. Radiologic studies may demonstrate loss of intervertebral disc height with signs suggestive of lumbar spondylosis. Stress discography, with or without postdiscogram computed tomography (CT), reveals an abnormal nucleogram dye pattern and concordant symptom reproduction.

Indications for Surgery

1. Internal disc disruption
2. Isolated disc resorption
3. Failed spinal surgical syndrome

Contraindications

1. Unrealistic expectations or marked functional overlay
2. Previous retroperitoneal exposure and dissection
3. Retroperitoneal fibrosis and adhesions
4. Previous anterior lumbar interbody fusion
5. Anomalies of the aorta and inferior vena cava as well as its branches
6. Deep venous thrombosis of the iliofemoral veins
7. Markedly obese patients

Advantages

1. The ability to perform a complete disc excision
2. Large area of bone available for fusion
3. The avoidance of epidural scarring and fibrosis associated with intrusion into the epidural space
4. The avoidance of "postfusion syndrome" associated with a posterior surgery
5. A greater facility to restore lumbar lordosis and appropriate sagittal alignment

Disadvantages

1. Decreased ability to deal with spinal canal pathology.
2. The use of internal fixation in the lower lumbar spine, particularly at L5-S1, is limited because of the proximity of major arteries and veins, as well as the anatomic orientation of the lumbosacral disc.
3. The relative osteopenia of the anterior and middle column compared to the posterior column, namely, lamina and pedicles.

Procedure

Preoperative

Appropriate preoperative medical and anesthetic assessment is done, with special attention to the cessation of all medications that may interfere with the clotting process (e.g., aspirin). Preoperative bowel preparation should be considered, including the use a bowel prep enema the night prior to surgery as well as appropriate bathing and body cleansing. All preoperative radiologic studies should be available.

Intraoperative

The recommended anesthetic technique includes:

1. Perioperative prophylactic antibiotics.
2. Relative hypotension compatible with the patient's cardiovascular function.
3. Muscle relaxation.
4. A radiolucent operating table that can be hyperextended.
5. A bean bag is routinely used.
6. The use of the atraumatic rectus splitting approach to the lumbosacral junction requires the patient be placed supine on the table and positioned appropriately with the break of the table at the level of the iliac crests.
7. Gel pads of various sizes can be used to support and place the sacrum and pelvis in the appropriate position to aid access to the lumbosacral junction. Compressive calf stockings are required to provide deep vein thrombosis prophylaxis.
8. In those patients where the rectus splitting approach is not recommended or difficult (e.g., from significant obesity), a lateral abdominal approach with muscle splitting dissection is required, and the patient must be positioned in the left lateral decubitus position.

Surgical Incision Approach and Dissection

A left transverse abdominal incision at the level indicated by the assessment of the radiologic studies noting the relationship of the iliac crest to the lumbosacral junction. A left paramedial vertical incision may be required for a more extensile approach in larger patients or where dissection is difficult.

A transverse incision is made through the anterior rectus sheath with a medial caudal extension and a lateral cephalic extension (Fig. 51–1). Medial retraction of the rectus muscle is aided by division of the neurovascular bundle (avoid the division of more than two contiguous neurovascular bundles, which may result in denervation) (Fig. 51–2A). Division of the lateral posterior rectus sheath is made with a lateral vertical incision (to prevent simultaneous incision of the anterior peritoneum) (Fig. 51–2B). Blunt dissection (with swab sticks or fingers) laterally toward the psoas muscle mobilizes the peritoneal sac from the psoas muscle. Continue the dissection, pulling up the peritoneal contents away from the perivertebral area and across to the midline and to the right.

The ureter should be carried forward with the posterior peritoneal sheath. Avoid interference and damage to the ilioinguinal and genitofemoral nerve. Identify the aortic bifurcation with palpation of the pulse. Palpate the more prominent lumbosacral disc in the bifurcation of the aorta. Mobilize the area of the aortic bifurcation first in the cephalic direction and then to the right and to the left. Use blunt-tipped retractors (e.g., modified Hibbs retractors). Use peanuts or Kitner dissectors held in long vascular clamps to continue the atraumatic blunt dissection of the lumbosacral disc. The blunt dissection should start on the right-hand side of the left iliac vessels and then proceed to sweep from the left to the right across the disc space, with strict avoidance of electrocautery for hemostasis in male patients. The use of appropriate-sized Hemaclips allows control with division of the vertically running median sacral artery and vein (if prominent). Use pressure to control small vessel hemorrhage during the dissection and clearance of the lumbosacral disc.

Control and Mobilization of the Blood Vessels

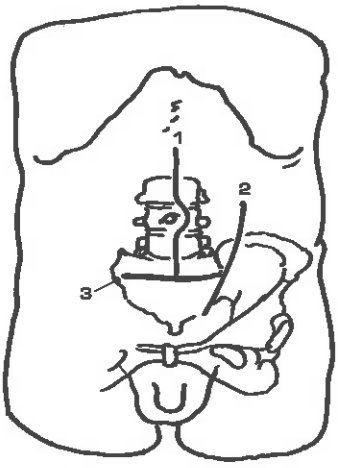
It is expected that the bifurcation will be at the L4-L5 disc. A higher bifurcation makes the approach to the L5-S1 disc easier, whereas a lower bifurcation may result in the inability to have adequate clearance at the bifurcation and a left lateral approach to the disc may then be required. The common iliac vein beneath the aortic bifurcation (running diagonally to the left) is most at risk. There may be short venous structures running from the anterior longitudinal ligament to the common iliac vein that may require ligation and control. The mobilization of the bifurcation of the aorta and the common iliac arteries is less of a problem, except in cases where calcification (as seen on x-ray) may render the arteries rigid and less amenable to dissection and mobilization, and increase the possibility of thrombosis and embolism. If a left lateral approach is used or required, it is essential to identify, isolate, and control the iliolumbar, ascending lumbar, and fifth lumbar veins. These veins, particularly the lumbar and ascending lumbar veins, require double ligation (with a ligature and a stitch ligature) rather than the use of a Hemaclip. These vessels may have a short, wide bore and may have immediate double or triple divisions with one or more deep in the psoas. If uncontrolled, they can cause dangerous and rapid blood loss. The arteries and veins can then be mobilized from the left to the right, exposing adequate access to the left anterolateral aspects of the lumbosacral disc.

Retraction

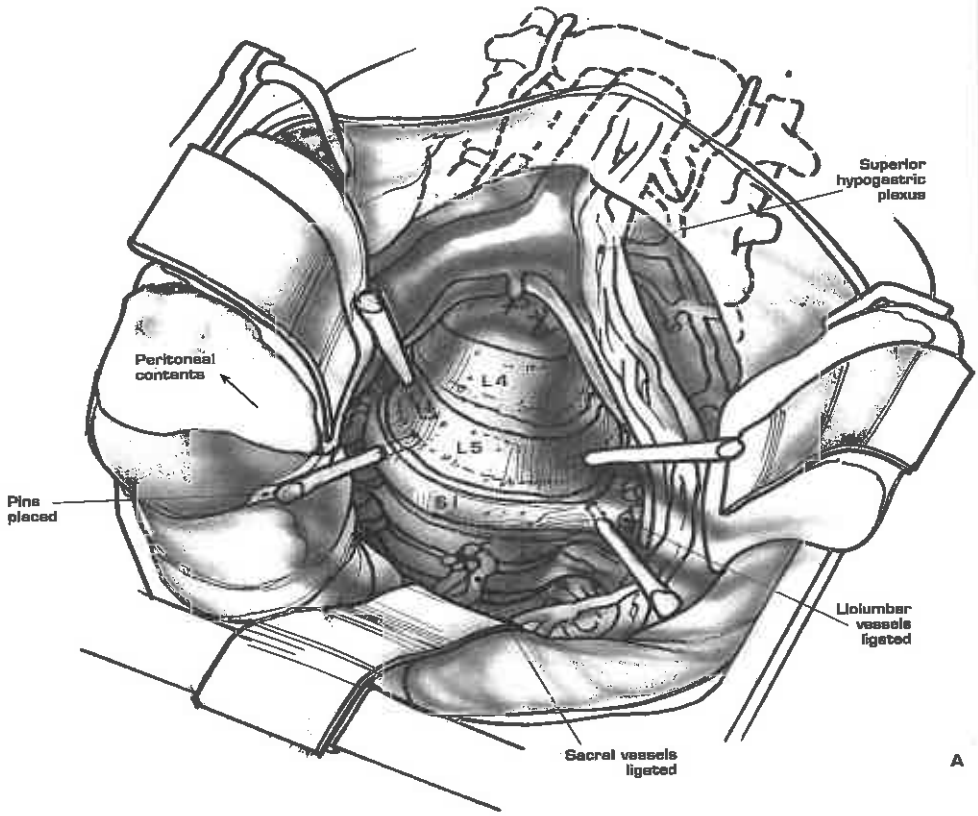
Safe, adequate retraction of the major blood vessels is an essential part of performing an anterior lumbar fusion at L5-S1. Such retractors include malleable ribbon retractors, modified Deever retractors (with a smooth excavated end), and the Oswestry O'Brien retractors; Steinmann pins are used, which are protected with red Robinson catheters.

Figure 51–1

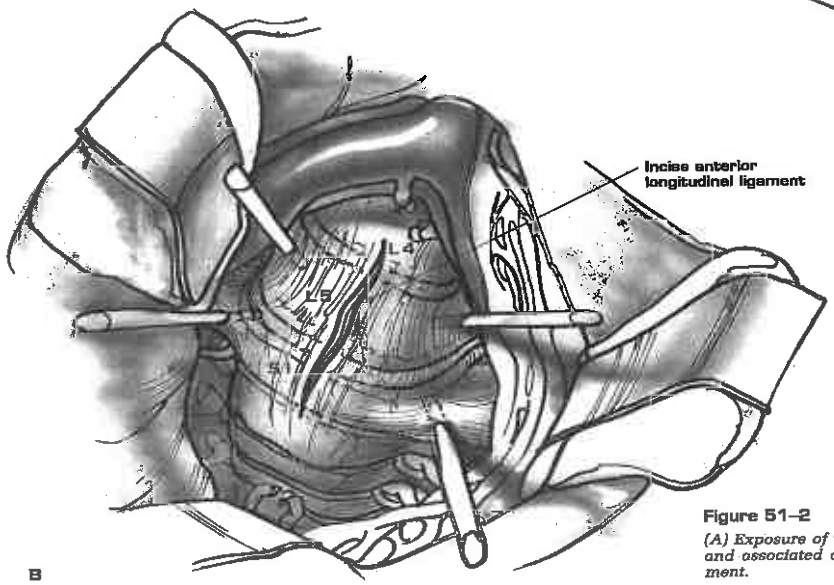
Skin incisions as related to the spine level, iliac crest, and pubic symphysis.



Skin incisions
1. Midline
2. Paramedian
3. Transverse



A

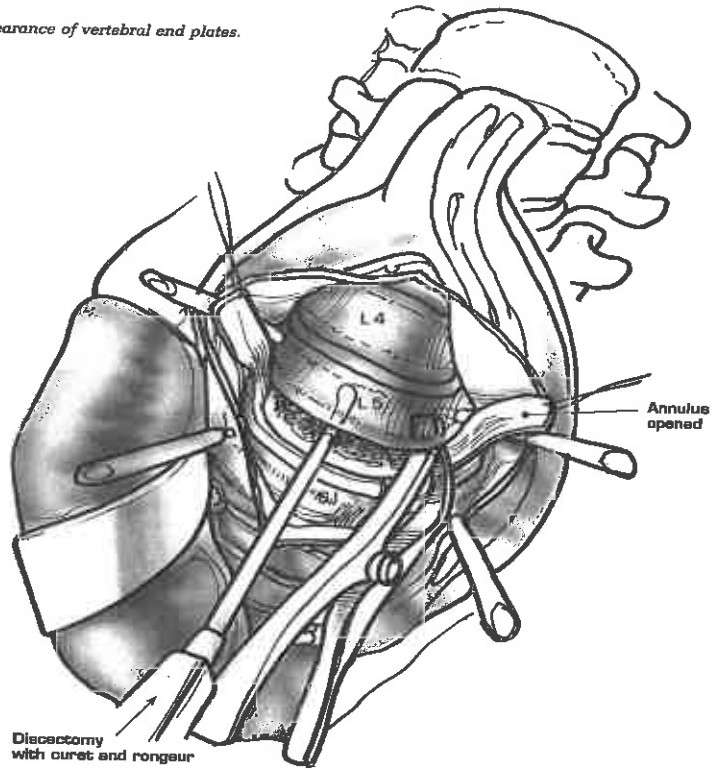


B

Figure 51–2

(A) Exposure of the lumbosacral junction, showing placement of pin retractors and associated anatomic structures. (B) Incision of anterior longitudinal ligament.

Figure 51–3
Excision of disc material and clearance of vertebral end plates.



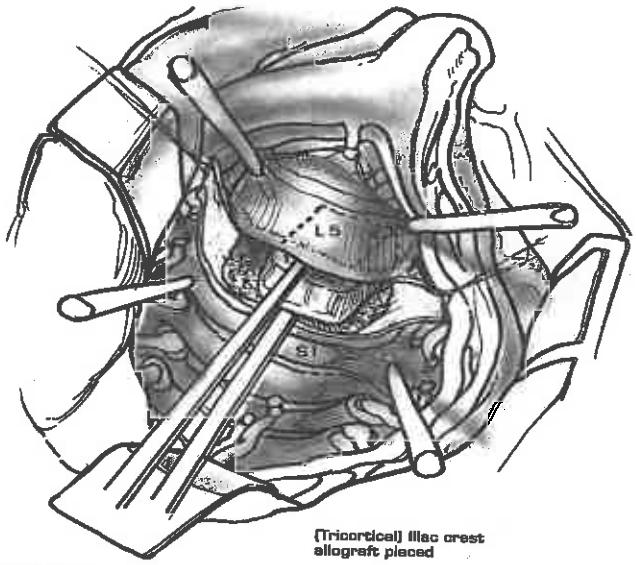


Figure 51–4
Placement of tricortical allograft in the midline and under the anterior cortical ring.

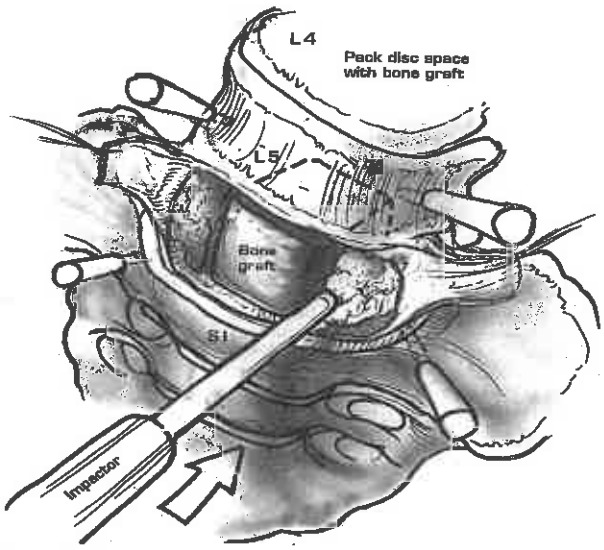


Figure 51–5
Packing of morselized autograft laterally and posteriorly. The bone grafting will be completed by placing bicortical autograft laterally alongside the midline tricortical allograft.

Pin Retraction

After appropriate mobilization of the bifurcation and the common iliac vein and iliac veins, the placement of the pins is planned to provide safe retraction of these vessels and adequate exposure of the lumbosacral disc. It is recommended that the first pin be placed into L5 on the right and the second pin be placed into L5 on the left. The third pin should be placed into S1 on the right, and finally, if needed, the last pin is placed into S1 on the left. It is important to protect the venous structures, particularly the common iliac vein, by having the surgeon's fingers retracting the veins and allowing access to the appropriate bony point for insertion of the pin. The pin should be first placed in a radial direction to avoid any skipping off and then placed in the appropriate final direction. The pin should be placed in the direction that provides maximum exposure to the disc and access to surgical instruments (usually with the tips converging), and it is important to avoid such an angle that the pin will penetrate the end plate and be in the intervertebral disc, which will prevent appropriate disc end-plate clearance and placing of grafts. After the pins have been inserted, it is important to test their stability (Fig. 51–2A).

Disc and Anulus Excision

The anterior longitudinal ligament needs to incise in a transverse direction at the vertebral margin. There will be grayish lines demarcating the upper and lower outer margins of the disc. This division of the anterior longitudinal ligament can be done with electrocautery as long as there has been safe clearance of all soft tissue from the anterior longitudinal ligament, particularly the hypogastric sympathetic plexus. Once the bone-disc interface has been clearly demarcated, the disc and cartilaginous end plates are removed from the vertebral end plate by the use of a large periosteal elevator (the O'Brien/Oswestry dissector). The separation of the cartilaginous end plates proceeds to the posterior aspect of the disc space. A No. 11 scalpel blade on a large handle is then used to make vertical incisions on the left and the right extremes of the exposed L5-S1 disc. The disc is grasped with a Kocher, and further dissection is carried out with a large periosteal elevator to free its attachments. Any disc material is removed using a variety of rongeurs (e.g., Hodgson rongeur) and large pituitary rongeurs. The end plate is then further cleared of any remaining cartilage and disc using ring curets (Crock double-angled ring curet, the O'Brien/Oswestry uterine curet). These curets allow safe placement into the posterior aspects of the disc space and provide controlled safe removal of the cartilage (Fig. 51–3).

Care must be taken to consider the direction of any unexpected rapid removal of a curet, such that it will not place the surrounding venous structures at risk. The preparation of the end plates can be checked with a heated dental mirror, which gives visualization of the lower end plate of L5. A vertebral spreader is used to open the disc space further and to allow further clearance of the vertebral end plates, taking care not to penetrate the subchondral bone.

The depth of the disc space is measured, taking care that any osteophytes are removed to obtain an accurate measurement of the real anterior posterior diameter of the disc. The axial CT images can be measured to obtain the anteroposterior (AP) and lateral dimensions of the disc space. Rectangle spacers (O'Brien/Oswestry) are then used to measure the disc space both in its anterior and posterior aspects, and the angulation lordotic aspects of the disc are checked on x-ray. The largest spacer is used in the midline, and the right and left lateral spacers are smaller.

Preparation of a Graft Bed

Once the vertebral end plates are cleared of all cartilage (and as complete as possible disc removal has been performed, only leaving the lateral anulus intact), the graft bed is prepared. The appropriate-sized spacers are then inserted into the disc space to prepare the surface of the vertebral end plates without penetrating into the weaker cancellous bone. It may be appropriate to have an appropriately sized wedge-shaped spacer to allow for preservation and/or increase of the lordosis. Alternatively, the rectangular spaces can be used anteriorly in the anterior two thirds of the disc space only and the posterior third to remain in its more narrowed position and to be filled with cancellous or nonstructural bone graft. The placement of the larger structural grafts in the anterior two thirds of the disc space best provides appropriate lordosis as well as being in the optimal load-sharing position.

Graft Harvesting

It is recommended that a combination autograft and allograft be used. The autograft is harvested from the outer table of the iliac crest, providing bicortical structural grafts, and the allografts are in the form of tricortical structural iliac crest grafts. The use of the atraumatic rectus sheath splitting approach does not provide ready access to the inner table of the iliac crest, so the outer table has to be accessed. An appropriate oblique incision is made at a distance from the iliac crest (to prevent painful adhesion to the crest) starting at least 2 cm proximal to the anterior superior iliac spine (to avoid damage to the lateral cutaneous nerve of the thigh).

The outer table of the iliac crest is then exposed, and the graft is taken from below the iliac crest. Atraumatic dissection is carried down to the periosteum on the outer table of the iliac crest. The iliac crest is left intact and the graft is harvested below the iliac crest. This avoids any cosmetic problem and decreases abductor morbidity. Use a Midas Rex AM 3 to produce four drill holes in the appropriately cleared outer table, and then use a laminectomy attachment or a saw to cut out the defined rectangle of bone. The shoe of the laminectomy B1 attachment avoids major soft tissue penetration deep to the inner table of the iliac crest. Cancellous graft is also harvested for placement into the posterior third of the disc space. All sharp bony points are then smoothed with a rongeur, and a large piece of thrombin-soaked Gelfoam is placed in the graft site to obtain hemostasis prior to wound closure. The graft site harvest site is closed after appropriate irrigation of the wound and muscle suture over the defect, and the wound is closed in layers with appropriate absorbable suture. If there is any doubt as to whether there is a continuing hemorrhage, a surgical drain is inserted at the graft site. The skin is closed with a subcuticular suture or staples as appropriate.

Graft Preparation

The bicortical autograft is then cut and shaped to match the previously used spacers that have prepared the graft site within the anterior two thirds of the disc space. The tricortical iliac crest allograft is then selected and shaped to fit the spaces as well (Fig. 51–4). It is important to place the allograft tricortical iliac crest in the midline and to place the bicortical autograft on each side. The tricortical allograft provides appropriate strength to maintain the height of the distracted lordotic disc space. (Avoid overdistraction of the disc space, as this commonly leads to subsidence of the grafts into the subchondral cancellous bone.) Complete filling of the prepared disc space with bone graft is essential (Fig. 51–5).

Closure

The retractors and Steinmann pins are carefully and gently removed. Inspection of the operative field is done to make sure there are no significant bleeders. If significant oozing continues, then wound drainage should be considered. The closure is an anatomic closure using running absorbable sutures for the posterior rectus sheath, the anterior rectus sheath, subcutaneous tissue, fascia, and skin. The skin is closed with subcuticular suture or staples as indicated.

Anterior Lumbar Fusion at L4-L5

Anterior lumbar interbody fusion at L4-L5 is different only in its approach, which is from a left lateral approach with dissection, ligation, and control of the ascending lumbar iliolumbar and the fifth lumbar veins.

Exposure Pearls

1. The straumatic rectus splitting approach, as described by Fraser (1982) and Selby and Henderson
2. Double ligation technique to control the iliolumbar and ascending lumbar vein, as described by Crock (1993)
3. The use of the Crock curets
4. The use of the O'Brien/Oswestry instrumentation, namely, the elevator to separate the disc from the end plate, the disc spacers, the large long-handled instruments including atraumatic dissectors retractors, and modified uterine curets.
5. The use of a heated dental mirror to visualize the end plate at L5 (in checking for its appropriate clearance of the cartilaginous end plate)
6. The management of hemorrhage from the Steinmann pin sites with bone wax or rolled pieces of Gelfoam

Pitfalls

1. Appropriate patient selection remains the mainstay to avoid the pitfalls and complications.
2. Appropriate surgical training is necessary.
3. Adequate practice of the surgical procedure on cadavers.
4. Appropriate surgical procedure and approach selection (anterior vs. posterior approach, the use of the midline rectus approach or the more extensile lateral trunk approach).
5. The decision to operate with attention to anatomic structures and the use of an atraumatic approach with circumspection rather than speed.
6. Operate defensively to avoid surgical misadventures and injuries to the surrounding structures (inferior vena cava).
7. The adoption of safety-first surgical techniques, especially when using large elevators and dissectors, by:

a. Adopting a two-hand approach, with one hand holding the instrument steady and limiting its excursion, and the other hand providing the appropriate use (the force mallotal hammer).
b. Placing the protective hand on the patient's side to limit the excursion of instrument.
c. Having one's elbows tucked into the side to again limit the extension excursion of instruments and over penetration.
d. Being aware of the potential for sudden unexpected movement of an instrument, making sure this will be away from the structures at risk, especially the large adjacent arteries and veins.
e. Avoiding the "crash and burn" syndrome by disaster and crisis planning.
f. Considering the potential maneuvers and procedures in a crisis situation; e.g., What would I do if I cut the common iliac vein?
g. Being prepared to stop the procedure if the vascular anatomy prevents safe clearance of a disc space and proceeding safely.
h. Being aware of and having preoperative planning of possible problems (large osteophytes, aortic calcification).
i. Being aware of the dangerous parts of the procedure (e.g., the placement and removal of the Steinmann pins, the posterior disc clearance).

Complications

1. Blood loss (avoidance of iliac venous system damage, use of appropriate-sized Hemaclip).
2. Atraumatic dissection (other vascular complications).
3. Occlusion or thrombosis of the iliac artery with damage to the intima, emboli from calcified arteries (these can be avoided with atraumatic use of the retractors and regular removal of the retractor pressure). The pulses of exposed arteries need to be checked at the end of the procedure so that any serious arterial complications can be recognized before the wound is closed. It is also important to test the pulses in the legs, particularly the left, and check with Doppler.
4. Impotence (from damage to the splanchnic nerves). Avoid dissection below and distal to the sacral promontory and damage to the sacral plexus.
5. Retrograde ejaculation (damage from the hypogastric sympathetic trunk). Avoid the use of electrocautery in the area of the bifurcation before complete soft tissue clearance has been obtained.
6. Reflex sympathetic cordalgia and reflex sympathetic syndrome (from the damage but not division of the sympathetic trunk).
7. Postsympathectomy syndrome (from transection of the sympathetic trunk). This results in a sympathetic effect, usually in the left leg. The postsympathectomy syndrome is manifested by increased blood supply to the skin. The patient complains of a feeling of increased warmth or discomfort in the leg. It is important to instruct the postanesthetic care unit nurses that this will occur, because it is not uncommon for coldness in the right leg (i.e., the normal leg) to be reported. This syndrome can persist for up to 12 months. The recommended treatment includes elevation and the wearing of support stockings.
8. Serum sickness syndrome, an uncommon complication manifested by recurrent spiking temperatures with profuse sweating, feeling of malaise, and a flu-like syndrome presentation. It can be managed with an intramuscular injection of 50 mg of methylprednisolone. This syndrome is thought to be of a serum sickness variety associated with an immune response to the previously unexposed protein of the disc or the retained foreign protein in the allografted bone.
9. Inguinal pain associated with the hematoma or seroma in the retroperitoneum, with resultant irritation of the genitofemoral and ilioinguinal nerves.
10. Interbody graft displacements (usually occur in the first 3 weeks and can be replaced within this 3-week period).
11. Psoas abscess (considered secondary blood-borne seething from gastrointestinal tracts). It is recommended that preoperative bowel preparation of Fleet enemas be given to try and reduce this complication and to make sure that the patient has a bowel motion prior to discharge.
12. Deep vein thrombosis.
13. Nonunion.
14. Infection (iliac crest bone graft sites).
15. Iliac crest fracture.
16. Postoperative entrapment of lateral cutaneous nerve of the thigh.
17. Although deep vein thrombosis and pulmonary embolism are not common occurrences following spinal surgery, the anterior lumbar antibody fusion is associated with the highest incidence of these complications (due to the dissection retraction of the vena cava vena system), and patients with an associated increased risk of deep vein thrombosis (e.g., smokers, birth control pill users, and patients with a positive past history) require prophylactic protection with the use of subcutaneous heparin as well as the use of compression stockings and calf stimulation during surgery.

Postoperative Care

1. Appropriate use of patient-controlled analgesia and postoperative monitoring.
2. All fluids are restricted until bowel sounds return, to prevent the occurrence of ileus.
3. The patient is up out of bed by the following day, having some support in a lumbosacral support or binder.
4. Appropriate bowel management to obtain successful bowel motion.
5. Discharge when the patient successfully passes physical therapy and occupational therapy, ambulation, and activities of daily living criteria.

Follow-Up Schedule

1. Wound check and x-ray 2 weeks postoperation and recommendation for increasing walking and aerobic activity and aquatics.
2. X-ray at 6 weeks, 3 months, 6 months, and 12 months postoperatively.

Postoperative Activity

1. Walking as soon as possible after surgery.
2. Aquatic therapy after the wound is healed at approximately 2 weeks postoperative.
3. Further increasing aerobic activity until 6 weeks postoperation, and then the start of spinal rehabilitation program with gentle isometric exercises progressing through to work hardening when appropriate.
4. Expect that the patient will be at maximum medical improvement from the procedure at 12 months.

Suggested Readings

Crock HV. A Short Practice of Spinal Surgery. 2nd ed. New York: Springer-Verlag; 1993.

Fraser RD. A wide muscle-splitting approach to the lumbosacral spine. J Bone Joint Surg Br 1982;64:44–46.

Henderson RJ. Anterior approach for lumbar fusions and associated morbidity. In: White AH, ed. Spine Care. St. Louis: CV Mosby; 1995.

Hodgson R, Yau ACMC. Anterior surgical approaches to the spinal column. In: Apley AG, ed. Recent Advances in Orthopaedics. New York: Churchill Livingstone; 1969.

52 Transforaminal Lumbar Interbody Fusion

David W. Polly, Jr. and Jürgen Harms

Goals of Surgical Treatment

Achieve a solid, pain-free arthrodesis with optimal sagittal alignment and minimal tissue disruption.

Diagnosis/Indications for Surgery

1. One- or two-level spinal fusion below T10
2. Spondylolisthesis
3. Spinal instability
4. Failed discectomy
5. Discogenic low back pain

Contraindications

1. Patient who is not a surgical candidate
2. Previous anterior discectomy
3. Possibly current active infection
4. Conjoined nerve root

Advantages

1. Improved biomechanics (6 to 18 times stiffer than posterior pedicle screws only)
2. Improved biology (greater area for fusion than intertransverse process fusion)
3. Improved sagittal contour
4. Less dural mobilization than conventional posterior lumbar interbody fusion (PLIF)

Disadvantages

1. Potential dorsal root ganglion irritation
2. Technically more demanding than posterolateral fusion

Procedure

Fusion Levels

As indicated by the diagnosis.

Patient Positioning

1. The patient is positioned prone with the abdomen decompressed to minimize epidural bleeding.
2. Options include placing the patient with the lumbar spine flexed for screw placement, discectomy, and interbody graft placement, and then extending the patient for compression and restoration of normal sagittal contour. If this is done, the table is jackknifed for the initial part and then flattened out or reverse jackknifed for the compression.
3. The patient can be placed on a Jackson spinal table with the hips extended. This makes the distraction slightly more difficult, but then anteroposterior (AP) and lateral fluoroscopy can be used. Compression for lordosis is then easily applied.
4. Some surgeons use a radiolucent Wilson frame flexed for the initial part and then flattened out for the final compression.

Surgical Technique/Exposure Secrets

1. A slightly longer incision is helpful.
2. Have a retractor that opens up wider than usual for a typical decompression operation. A "sprung" Gelpi-type retractor is useful to give adequate retraction and not interfere with pedicle screw placement.
3. After routine exposure, place the pedicle screws and then resect the facet joints. At this point distract across the segment (preferably between the spinous processes). Distraction on the screws may cause them to fail if the bone quality is poor. Use the screws to hold the distraction rather than to obtain the distraction.
4. Resect the facet joint completely on one side. We are right handed and prefer to resect the left facet. Resect it in line with the superior border of the subjacent pedicle and with the inferior border of the suprajacent pedicle. Resect the facet capsule as it blends with the ligamentum flavum.
5. Control the epidural veins. A cottonoid can be used to sweep the contents cephalad, and this can minimize dissection of the microenvironment of the dorsal root ganglion.
6. Do not beat up the dorsal root ganglion! It is particularly sensitive, and if abused can cause intractable postoperative lower extremity pain.
7. Protect the dura medially (only minimal retraction if any is necessary). Protect the dorsal root ganglion superiorly and laterally.
8. Incise and resect the disc down to the anterior annulus or to, but not through, the anterior longitudinal ligament. Do not violate the anterior longitudinal ligament. This can be well seen because of the distraction, which opens up the working area to access the disc space (Figs. 52–1 and 52–2). Also resect the posterior superior corner of the subjacent vertebra with an osteotome. Again this will also aid access, visualization, and ease placement of a structural interbody support.
9. You are anterior enough in the discectomy when you encounter the scar of the ring apophysis (Figs. 52–3 and 52–4).
10. Once the discectomy is complete, decorticate the anterior part of the disc space (Fig. 52–5). This can be done with an angled osteotome, a high-speed bur, or an angled curet. Surgeons should use whichever technique is safest and best in their hands. Pack autogenous cancellous bone anteriorly using bone tamps (Figs. 52–6 and 52–7).
11. Place the structural interbody support (Figs. 52–8, 52–9, and 52–10). This can be titanium mesh, other compatible devices or substances, or structural bone (allograft or structural autograft). It must serve as a pivot point to restore lordosis and function as a load-sharing device for 6 to 12 weeks until the bone has healed enough to be load bearing.
12. Location of structural interbody support: If placed anteriorly, it functions better biomechanically. If placed posteriorly, it allows for greater sagittal plane realignment. Wherever it is placed, the end plate should be spared if possible to prevent settling. Use of allograft bone may decrease settling because of the greater surface area for load bearing.

Pitfalls

1. Beware the dorsal root ganglion; it must be treated gently.
2. Be meticulous in resecting as much disc material as possible. The far-side posterior quadrant is where most disc will be left behind. If you cannot get enough out, consider a bilateral approach.
3. Decorticate enough of the interspace and place enough bone graft to achieve at least a 30% cross-sectional area fusion. This is what is needed to have adequate bone to transfer the load in the lumbar spine.

Complications of Procedure

1. Inadequate disc resection and inadequate bone grafting leading to pseudarthrosis
2. Abuse of the dorsal root ganglion causing postoperative pain
3. Toggling of the screws due to poor bone density or excessive force application on the pedicle screws

Postoperative Care

1. Out of bed in a chair on day 1.
2. Ambulate on day 2.
3. The patient may be more aggressively rehabilitated than for a posterolateral fusion because of the stability of the reconstruction. Unless the bone stock is very poor, bracing is not necessary.
4. Pool therapy can begin at 3 weeks postoperation.
5. The lumbar stabilization program as espoused by Watkins works very well in these patients.
6. Have the patient do hamstring stretches on the side of the transforaminal lumbar interbody fusion (TLIF) to mobilize the nerve root and minimize postoperative scarring.
7. At 3 months, most patients will show bridging trabecular bone by computed tomography scan sagittal reconstructions.
8. Any progressive halo formation about the pedicle screws indicates loosening and probable pseudarthrosis formation. These patients should be revised early rather than later. Performing a TLIF from the contralateral side can be relatively straightforward.

Important Note

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

Suggested Readings

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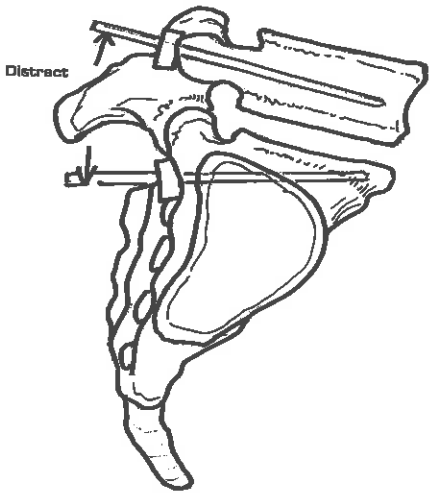


Figure 52–1
Pedicle screws are placed in the usual fashion.

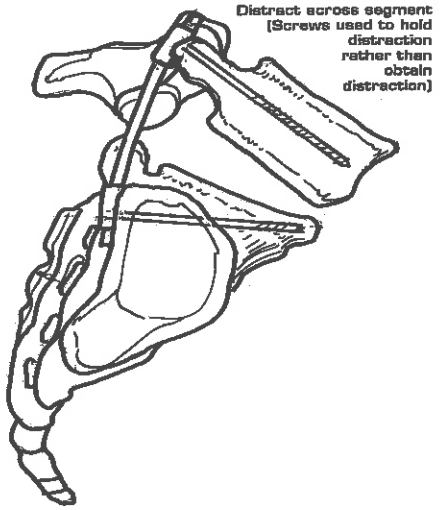


Figure 52–2
Distraction is applied, inducing kyphosis and opening up the posterior disc space. This increases the area of the transforaminal lumbar interbody fusion (TLIF) working zone.

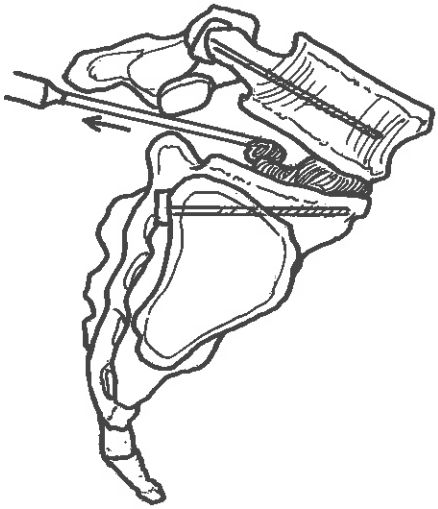


Figure 52–3
An aggressive discectomy is performed removing all disc material that can be safely removed.

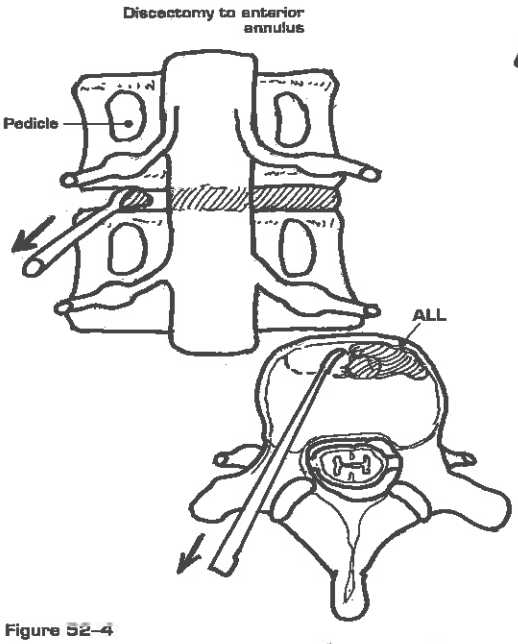


Figure 52–4
The unilateral TLIF working zone through which the discectomy is performed.

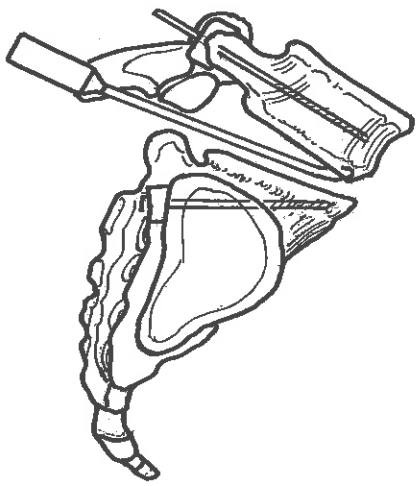


Figure 52–5
The anterior part of the interspace is decorticated.

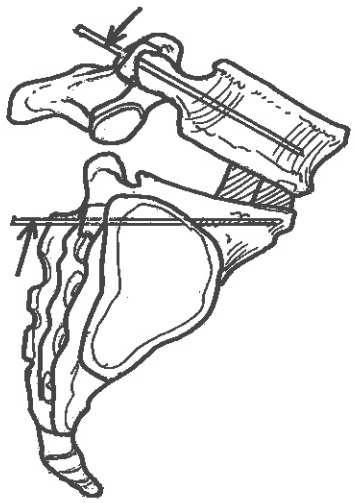


Figure 52–6
Autogenous bone graft is placed anteriorly in the interspace.

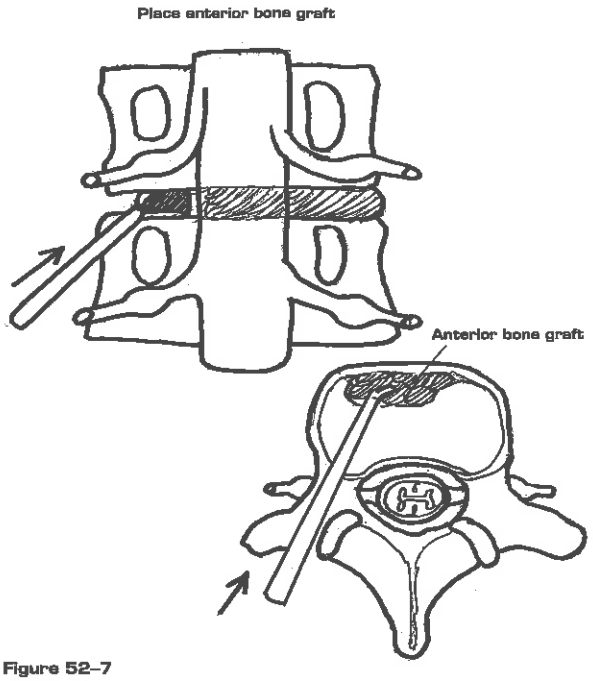


Figure 52–7
Decortication is performed and autogenous cancellous bone is packed anteriorly.

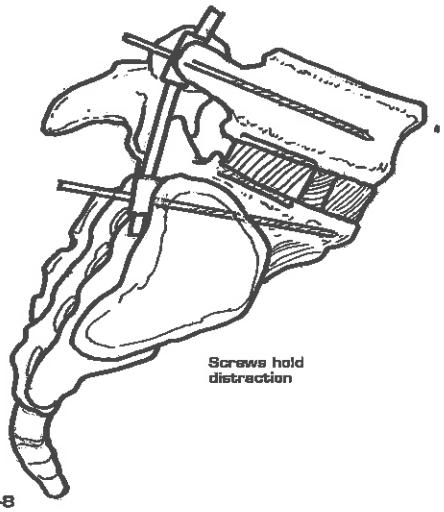


Figure 52–8
A structural graft/support is placed in the interspace. Compression is now applied across the pedicle screws, removing the kyphosis and inducing lordosis.

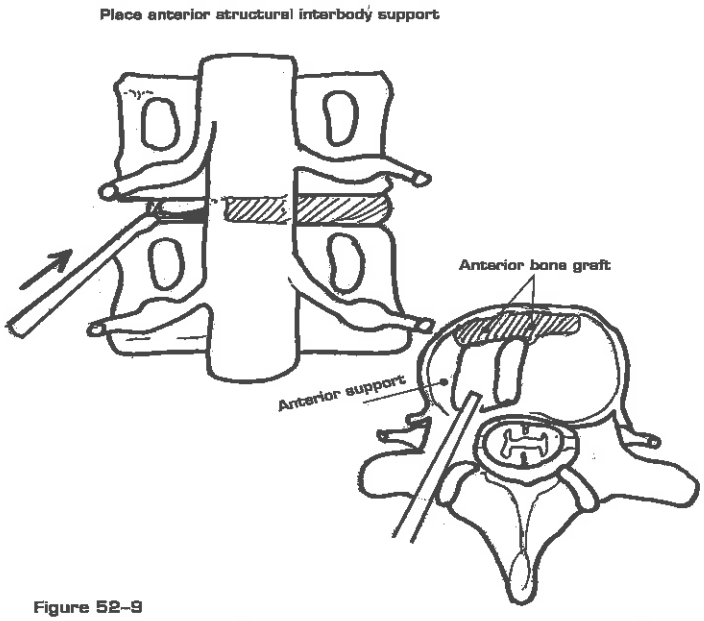


Figure 52–9
A structural interbody graft/support is placed in the interspace and seated on the contralateral side.

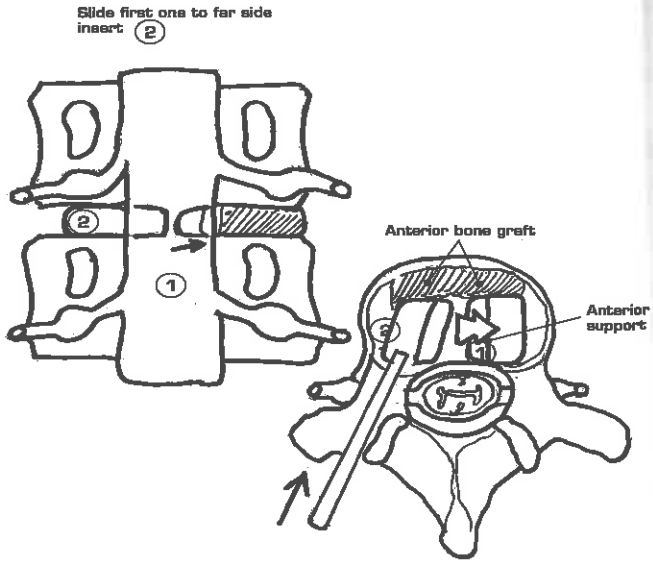


Figure 52–10
A second structural interbody graft/support is positioned unilaterally.

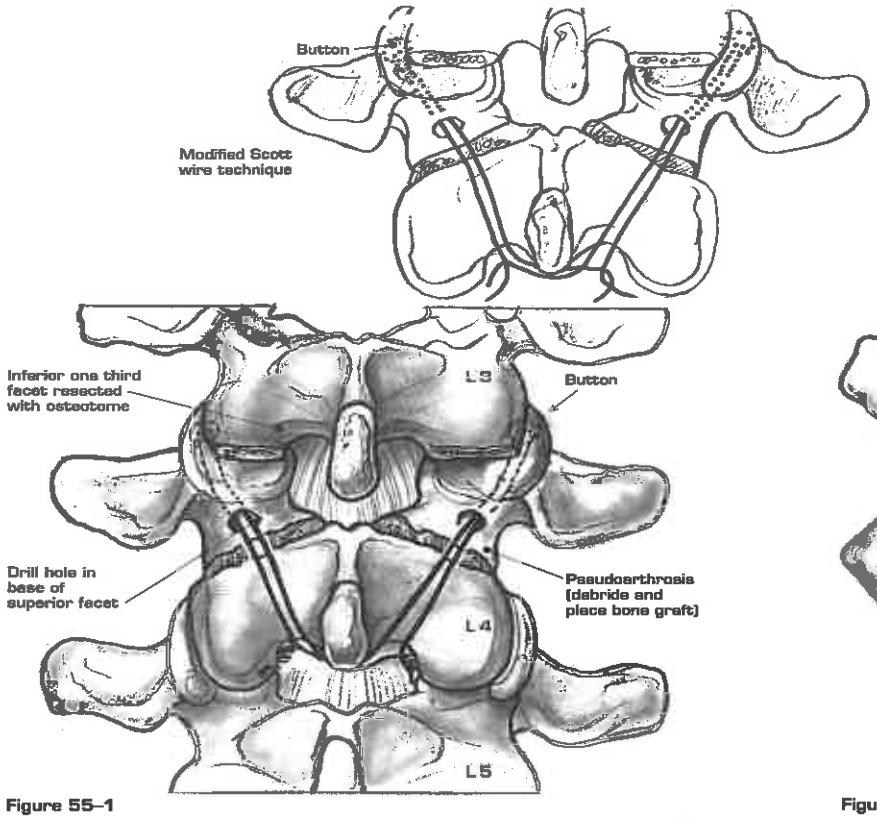


Figure 55–1

Anteroposterior diagram of modified Scott wire technique demonstrates the resection of the inferior facet and placement of the wires.

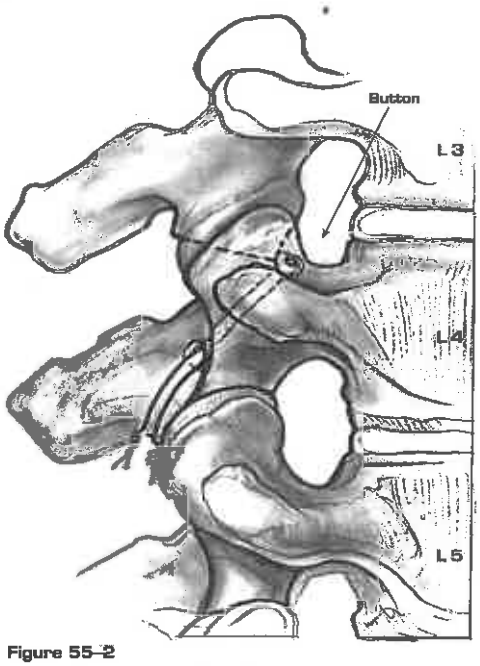


Figure 55–2

Lateral diagram of modified Scott wire technique demonstrates the course of the wire through the facet/pedicle and the position of the button.

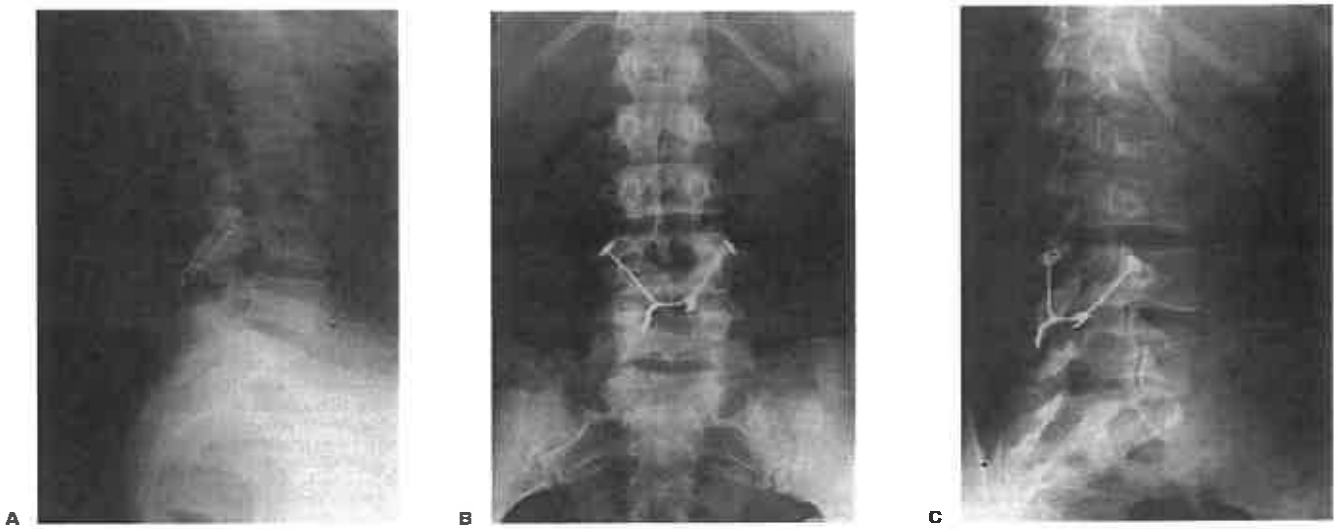


Figure 55–3

Lateral (A), anteroposterior (B), and oblique (C) radiographs of a healed spondylolytic defect using the modified Scott wire technique.

56 Decompression for Lumbar Fractures
Posterior

Behrooz A. Akbarnia

Goals of Surgical Treatment

1. The goals of surgical treatment, which are decompression, realignment, and stabilization, can be reached through this single posterior incision.
2. To improve neurologic recovery when it is done in a timely manner (Ciappetta et al, 1996; Clohisy et al, 1992; Dendrinos et al, 1995; Dimar et al, 1999).
3. To stop the deterioration of neurologic function when the deficit is progressive.
4. To restore sagittal alignment and stability.

Diagnosis

A careful clinical assessment of neurologic function is essential. Plain radiographs and other imaging studies such as computed tomography (CT) scan and magnetic resonance imaging (if soft tissue or disc injury is suspected) are the most helpful studies.

Indications for Surgery

Posterolateral decompression is used in the following conditions:

1. Spinal canal compression caused by bony fragments in patients demonstrating worsening of the neurologic deficit.
2. In patients with incomplete deficit in whom neurologic function has reached a plateau.
3. In patients with normal neurologic function and significant canal compromise (more than 60%), as well as kyphosis requiring anterior column support to achieve spinal stability. This support is accomplished through a posterior interbody grafting.
4. In some patients with incomplete but nonprogressive neurologic deficit or patients with canal encroachment but intact neurologic function, the natural history of neurologic improvement may not be altered by decompression.

Contraindications

1. When there is a significant comminution (McCormack et al, 1994) of the vertebral body, loss of anterior height (more than 50%), and kyphosis, especially in the thoracolumbar junction, the anterior approach for decompression and structural grafting may be more appropriate.
2. Mild kyphosis, minimal comminution, no significant canal compromise, and no neurologic deficit.
3. Old posttraumatic kyphosis.

Advantages

1. Posterolateral approach allows decompression and stabilization to be accomplished through a single approach.
2. It provides an alternative when anterior approach carries a higher risk, because of patient's general condition, associated trauma, and previous abdominal surgery.
3. It provides better visualization of the nerve roots, especially when there is a possibility that they are entrapped in the laminar fractures.
4. In the lower lumbar spine anterior decompression and instrumentation may not be feasible because of vascular proximity, and therefore the posterior approach may be preferable.
5. For lower lumbar spine burst fractures with neurologic deficit, posterolateral decompression is ideal because the spinal canal is wide and the sagittal alignment is not significantly altered.
6. The laminar fractures and entrapment of the neural elements are also more common in the lower lumbar spine burst fractures, which are more accessible posteriorly. Dural tears could be repaired through this approach.

Disadvantages

1. It is not clear whether the presence of fragments in the canal may cause problems such as spinal stenosis at a later date.
2. Because there is no correlation between the degree of canal compromise and the neurologic deficit, especially in the absence of neurologic deficit, removal of bone fragments may be unnecessary (Fidler, 1988).
3. For severe kyphotic deformity requiring strut grafting, the anterior approach is more feasible.

Procedure

The posterolateral approach has been described for decompression of the spinal canal and the removal of retropulsed fragments caused by burst fractures. These techniques have not included extensive removal of the pedicle on a routine basis (Flesch et al, 1977; Garfin et al, 1985). It is difficult to achieve full access to the anterior and middle columns of the spine without removing the major part of the pedicle. Therefore, the technique described in this chapter has been developed to allow better exposure and more effective decompression and grafting via the posterolateral approach.

Using plain radiographs, CT, and other imaging studies, as well as clinical assessment, the pedicle to be approached is selected. This is usually on the side with the worse neurologic deficit. If neurologic deficit is the same bilaterally or in patients with normal neurologic function, the side with more bony fragments or with a larger degree of compression is selected. Surgical approach through a single pedicle is sufficient in most cases. The opposite pedicle is left intact for the purpose of instrumentation. The comminution of the opposite pedicle is determined by preoperative CT scan and is often possible to use this pedicle as a site of a pedicle screw. It may be necessary to extend instrumentation if more than one level of decompression is required (Akbarnia, 1997).

If there is laminar fracture, more extensive decompression should be planned. Intraoperative imaging may include plain radiographs, myelogram, and ultrasonography. Special instruments are required for this procedure to access the entire canal reaching the medial cortex of the opposite pedicle (Fig. 56–1).

Technique Secrets

The patient is taken to the operating room and, depending on the stability of the fracture, is placed over rolls or a frame of choice, with the usual precautions. Spinal cord monitoring and cell-saver techniques are used when possible. Once the usual posterior midline approach to the spine is made, the level of fracture and the pedicle to be decompressed are identified by an intraoperative lateral radiograph. The following is the technique sequence:

1. Temporary reduction and stabilization. The spine is temporarily stabilized on one side by the appropriate implants to prevent unnecessary motion during the decompression. Partial or complete reduction of the sagittal deformity can be achieved during this stage. If pedicle screw fixation is planned, the opposite pedicle may be used for insertion of an additional screw for more stability (Fig. 56–2).
2. Removal of the pedicle. The pedicle to be removed is identified at the junction of the superior articular process, lamina, and transverse process. The transverse process is fully exposed. The entrance of the pedicle is removed by a power drill or a rongeur and the pedicle is probed. The lack of resistance at the burst fracture site is noted. The base of the transverse process is then osteotomized by removing the posterior cortex of the transverse process with a Leksell rongeur and then the anterior cortex using a Kerrison rongeur. Once the osteotomy is completed, the transverse process is left floating with its soft tissue attachments.

   The direction of the pedicle is verified again using a pedicle probe, and the lateral cortex of the pedicle is identified and removed using rongeurs. The medial and inferior wall is usually preserved. By staying next to the cortex, injury to the segmental vessels at the waist of the vertebral body is avoided and the nerve roots are protected. It is often possible to preserve the inferior articular process and avoid damage to the facet joint. If a more extensive posterior decompression is needed, however, the inferior articular process can also be removed.

   The cancellous bone of the pedicle is identified and gradually removed by enlarging the opening. Initially, a straight curet, followed by right- and left-angled curets (Fig. 56–3), is used to provide access to the vertebral body. The medial and inferior cortices of the pedicle are usually left intact to protect the dura during this stage of the procedure.
3. Decancellization of the vertebral body. Using special right- and left-angled curets, the cancellous bone anterior to the posterior cortex of the vertebral body (and fragments) is gradually removed to create space so the fragments can be reduced (Fig. 56–4). These curets are used with two hands in a rotary motion (Fig. 56–5). The cup of the curet always moves away from the posterior cortex and the dura. A

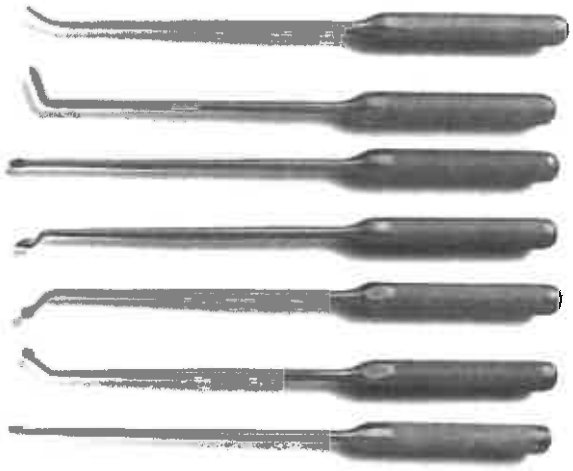
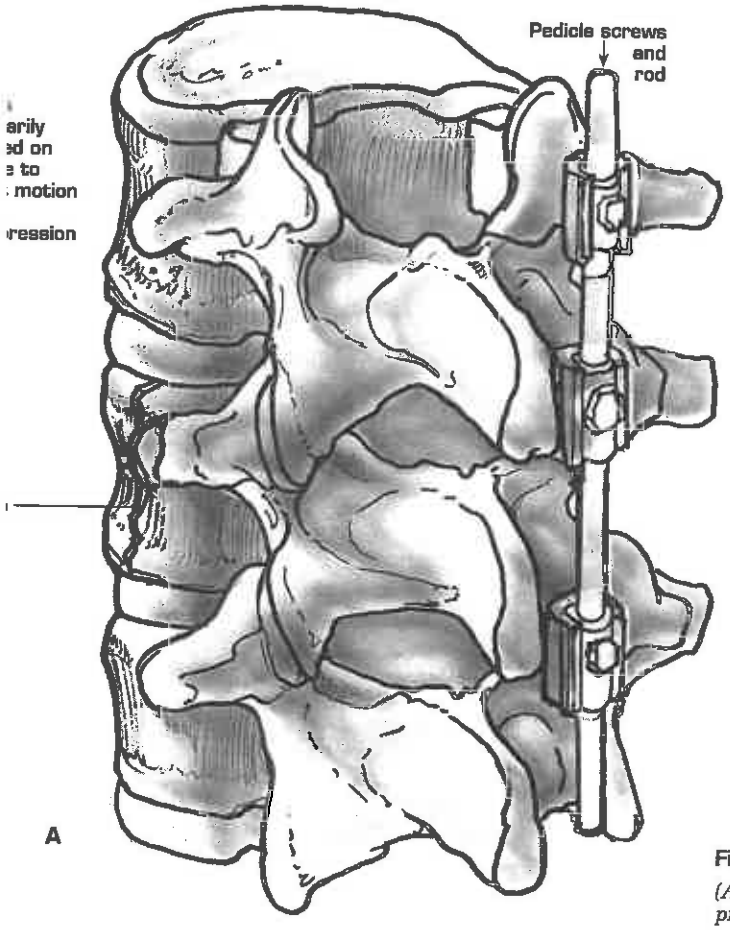


Figure 56–1
Set of specially made long-handle instruments for posterolateral decompression.



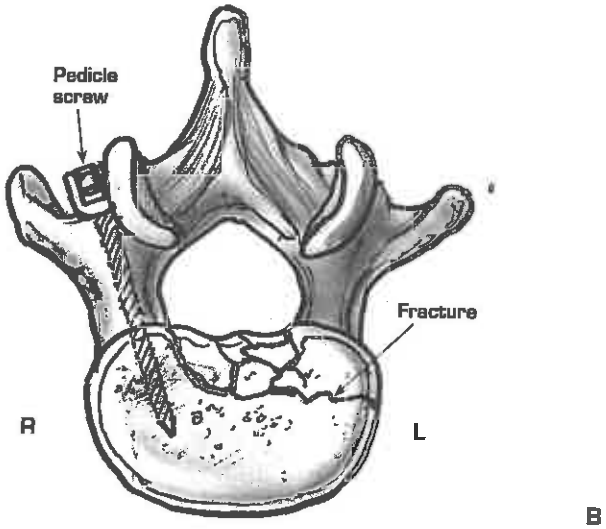


Figure 56–2

(A) The fracture is stabilized on the opposite side of the pedicle to be decompressed. (B) Cross section of the fracture vertebra with pedicle screw in place.

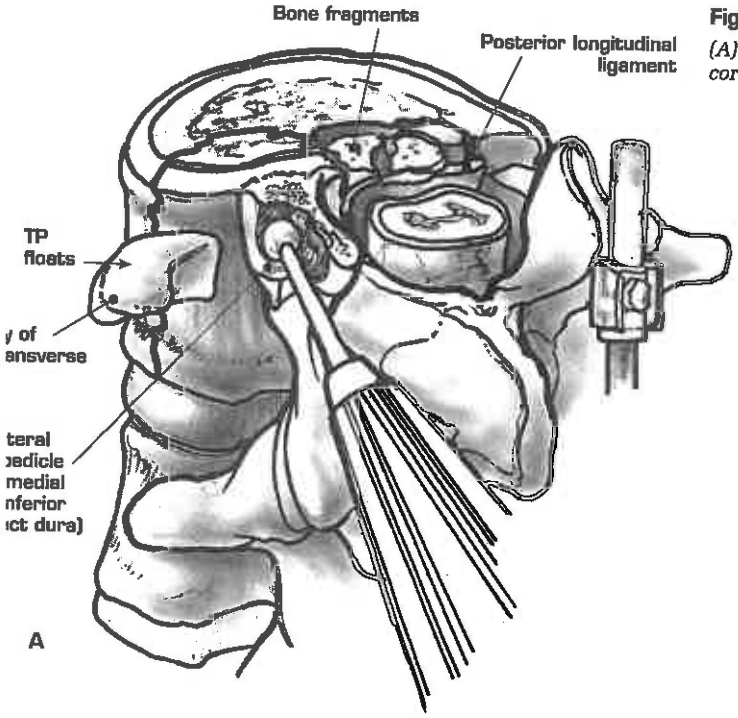
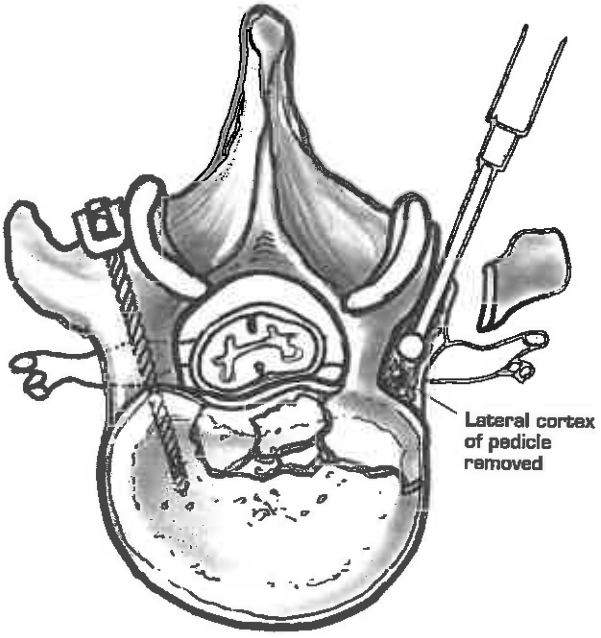
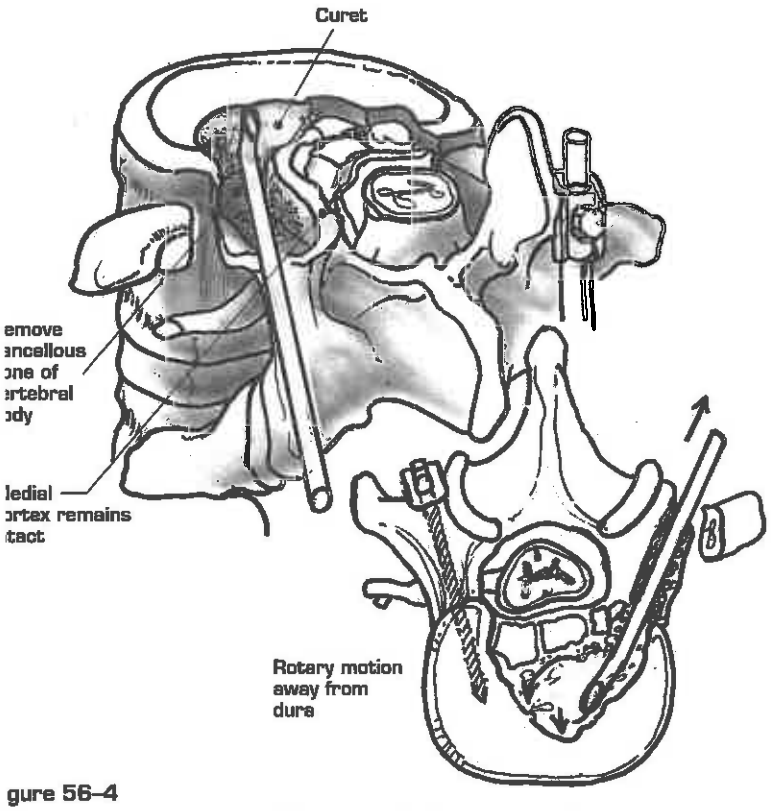


Figure 56–3

(A) Pedicle is being removed using a power bur. (B) Axial view; initially the medial cortex of the pedicle is kept intact.





gure 56–4

emoval of cancellous bone of the vertebral body using special curets.

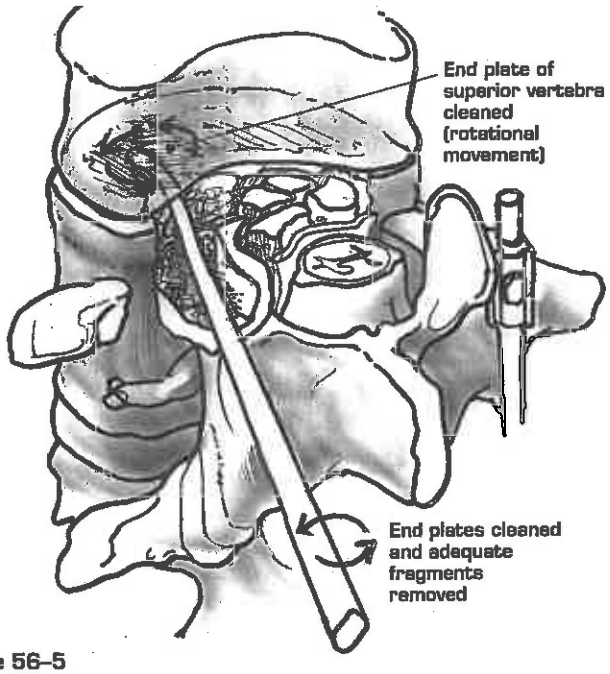
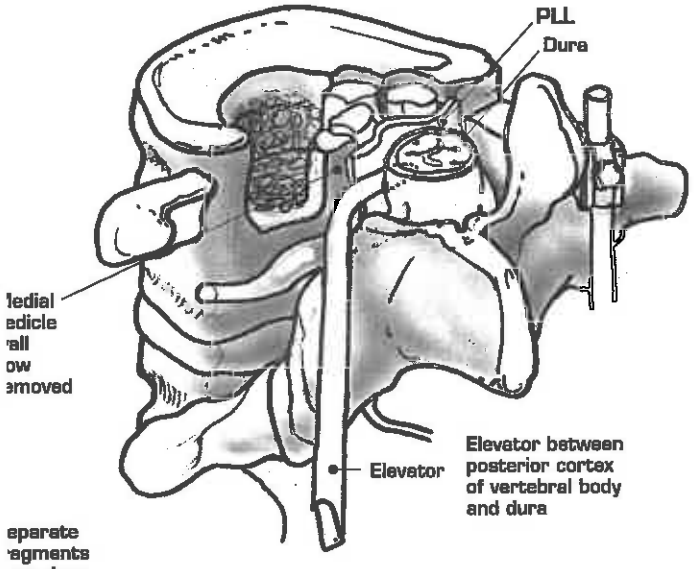


Figure 56–5

The disc is removed, and a disc curet is used to clean the disc space and prepare the end plates for bone grafting.



igure 56–6

pecial elevator is placed between the dura and bone agments to separate the dura.

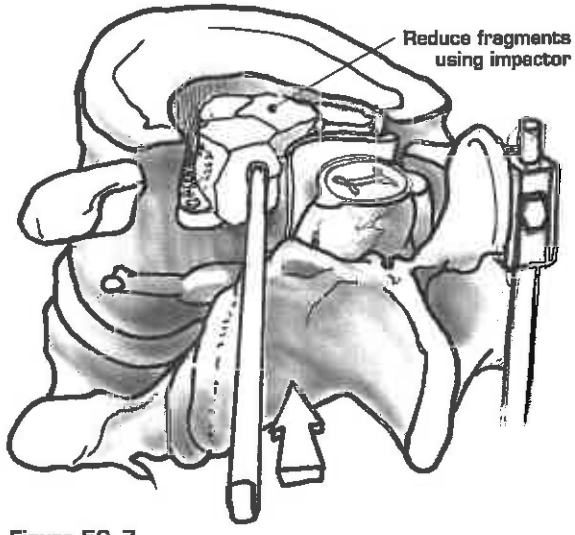
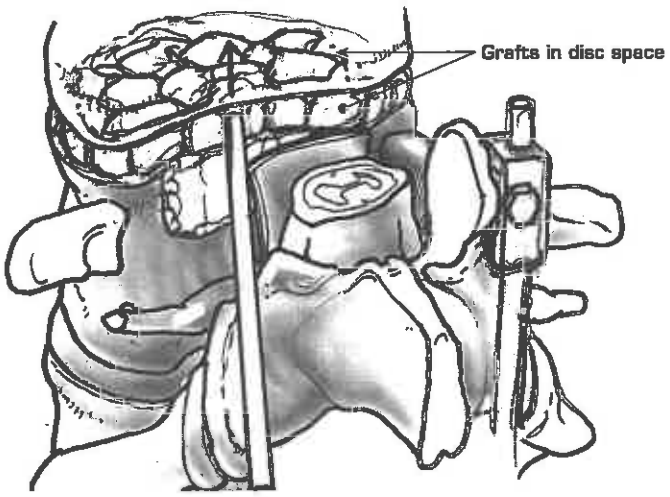


Figure 56–7

Fracture fragments are reduced using the impactor.



igure 56–8

down-pushing curet can also be used to remove the bone when necessary.

4. Removal of the disc and cleaning of the end plates. The disc curet is used to clean the superior disc from the end plates (Fig. 56–5). The disc material is removed by long-handled rongeurs. When adequate space is created in the vertebra and the disc above has been removed, then reduction and bone grafting can be undertaken.
5. Removal of the medial cortex of the pedicle and reduction of fragments. If the medial cortex of the pedicle is not already fractured, it is removed from the superior margin using Kerrison rongeurs. If it is fractured, it is removed through the fracture site. The lower or caudal portion of the pedicle is usually left intact except in more extensive approaches. The dura is exposed and protected. All the sharp edges of the bone are removed to protect the dura. A special curve elevator is passed between fragments and the dura to separate the fragments from the dura before the impactor is inserted (Fig. 56–6). Because the space is already created anterior to the fragments, reduction is usually easy and fragments are pushed anteriorly into the vertebral body using the special impactor (Fig. 56–7).
6. Anterior grafting. The anterior longitudinal ligament and annulus fibrosis are felt with a probe to detect any deficiencies. Small blocks of corticocancellous bone graft are then inserted from the opening of the pedicle to fill the disc space and to support the anterior column (Fig. 56–8). The dura is inspected again for any possible remaining compression. Bone fragments from the vertebral body are also impacted into the body and the disc space away from the dura, which should be inspected to ensure that no loose fragments are present.
7. Completion of instrumentation. The decompression side is instrumented, maintaining desired sagittal contour, and the implant on the opposite side is replaced or adjusted. Slight compression is applied between the two vertebrae to compress the grafts between them. Final tightening of the instrumentation is accomplished, and additional grafting is applied posterolaterally. After completion of instrumentation, the dura and disc space are inspected again and alignment is confirmed by intraoperative radiograph.

During the procedure, the blood loss from the bone or epidural veins is controlled by bone wax, Gelfoam, and thrombin; however, good exposure reduces the chance of uncontrollable blood loss. The small opening, especially on the lamina rather than the pedicle, does not allow access to the anterior bleeders. The adequacy of the decompression could be assessed during the procedure by a special elevator. Other methods such as ultrasonography can also be used for this purpose. In addition to posterior interbody fusion, a posterolateral facet arthrodesis using autogenous iliac bone graft is essential to achieve fusion.

Pitfalls

1. Excessive bleeding
2. Nerve root injury
3. Inadequate decompression (follow the steps)
4. Inadequate structural graft

Complications

Complications such as infection, pseudarthrosis, and instrumentation problems are observed in the procedure, at a similar rate to other spine procedures. The use of posterior interbody fusion and saving of the facets increase the rate of fusion. Operative bleeding is reduced when segmental vessels are avoided as well when dissection is kept next to the cortex and hemostatic agents are used. Neurologic deterioration, both in reported series and in my experience, has not been observed. Occasionally, based on a follow-up CT scan, the decompression is not adequate (less than 5 % in my series). If there is still clinical indication for further decompression, then an anterior approach is more appropriate as a second-stage procedure for additional decompression.

Results

Previous reported series have included a relatively small number of patients undergone this technique. Flesch and coworkers (1977) reported a series of five patients with incomplete neurological deficit. The neurologic condition improved in four patients from Frankel grade C to D, and one patient remained unchanged (grade D). The condition of all three patients with instrumentation improved.

McAfee and colleagues (1982) reported on 16 patients. Twelve patients had incomplete neurologic deficit, nine of whom improved neurologically by one or two Frankel grades. No patient's condition deteriorated as the result of surgery.

Garfin and associates (1985) described their findings for nine patients with incomplete neurologic deficit. They also observed improvement in six of the nine patients and no deterioration of neurological function.

McEvoy and Bradford (1985) reported on 53 patients with spine fracture, 31 of whom underwent a variety of surgical procedures. Seventeen patients had posterolateral decompression and posterior spine fusion and Harrington rod instrumentation. The authors concluded that the results in this group were satisfying and that many of the patients benefited by this procedure. After obtaining postoperative CT scans in some patients, however, the authors were not impressed by the adequacy of decompression following this technique. They recommended a formal anterior decompression and fusion in patients with burst fracture and neurologic deficit. None of the above series described the technique of removal of the pedicle as a part of their surgical procedure.

In my series of 36 patients who underwent the described procedure, there was no deterioration of neurologic function following surgery (Akbarnia, 1997). The condition of 13 of 20 patients with incomplete neurologic deficit improved. The average improvement using American Spinal Injury Association motor point score was 13.4 points. Using the modified Frankel grade, the condition of 65 % of patients improved at least one level. Although not statistically significant, there seemed to be a trend for better recovery in patients who had decompression within the first 48 hours. This trend is consistent with the results of early decompression achieved by anterior approach (Clohisy et al, 1992). The preoperative CT scan showed improvement from a preoperative average of 68 % canal compromise to a postoperative average of 15 %.

In this group, 28 of 29 patients with a minimum of 1-year follow-up had solid fusion. Three patients had increased kyphosis and loss of correction. All patients who had grafting of the anterior column had solid fusion and maintained the correction.

Postoperative Care

Patients are fitted with a bivalve thoracolumbosacral orthosis and ambulate as soon as possible if no other injuries present. The jacket is worn for 4 to 7 months. The progress of fusion is monitored with periodic radiographs.

Suggested Readings

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Clohisy J, Akbarnia BA, Bucholz RD, Burkus JK, Backer RJ. Neurologic recovery associated with anterior decompression of spine fractures at the thoracolumbar junction (T12-L1). Spine 1992;17(suppl 8):S325–S330.

Dendrinos GK, Halikias JG, Krallis PN, Asimakopoulos A. Factors influencing neurological recovery in burst thoracolumbar fractures. Acta Orthop Belg 1995;61:226–234.

Dimar JR, Glassman SD, Raque GH, et al. The influence of spinal canal narrowing and timing of decompression on neurologic recovery after spinal cord contusion in a rat model. Spine 1999;24:1623–1633.

Fidler M. Remodeling of the spinal canal after burst fracture: a prospective study of two cases. J Bone Joint Surg Br 1988;70:730–732.

Flesch J, Leider LL, Erickson DL, Chou SN, Bradford DS. Harrington instrumentation and spine fusion for unstable fractures and fracture-dislocations of the thoracic and lumbar spine. J Bone Joint Surg Am 1977;59:143–153.

Garfin SR, Mowery CA, Guerra J Jr, Marshall LF. Confirmation of the posterolateral technique to decompress and fuse thoracolumbar spine burst fractures. Spine 1985;10:218–223.

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McCormack T, Karaikovic E, Gaines R. The load sharing classification of spine fractures. Spine 1994;19:1741–1744.

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57 Anterior Threaded Cage Revision Surgery

Tae M. Shin and Robert J. Banco

Goals of Surgical Treatment

To revise anterior threaded cages for migration, loss of fixation, and pseudarthrosis.

Diagnosis

Migrated or malaligned cages can be evident by plain x-rays alone (Fig. 57–1). Computed tomography (CT) scan with reconstruction allows for better visualization of the placement of the cage as well as presence of fusion. Radiographic determination of fusion, however, is difficult and somewhat controversial with threaded cages. The most reliable indicator of fusion postoperatively is the presence of bridging bone anterior to the fusion cage. This finding is a late occurrence and may not always be present. Even when using CT scans with reconstructed images, it is difficult to assess visible bone within the hollow titanium cages. Data from our institution showed no difference in opacity of the bone within the hollow cages on Ferguson radiographs at periods immediately postoperative and at 3 months postoperative. The absence of the signs of pseudarthrosis rather than signs of fusion should be used as a criterion for fusion.

Signs of pseudoarthrosis include:

1. Visible motion on flexion and extension radiographs
2. Halo around implant
3. Sclerotic changes at end plate adjacent to the implant
4. Fractures of implant or vertebrae
5. Migration of implant

Indications for Surgery

1. Anterior prominence of cage: If migration of the cage occurs postoperatively, the cage should be revised because of risk of possible vascular impingement.
2. Lateral prominence with neurologic injury. Proper preoperative templating and complete surgical exposure to visualize the lateral extents of the annulus bilaterally should prevent this problem. Postoperative migration of the cages with neurologic injury requires revision of the cages.
3. Posterior migration is rare after anterior interbody fusion because of the intact posterior lip of the end plate and the intact posterior annulus and posterior longitudinal ligament. If the patient is symptomatic, the implant should be revised. If asymptomatic, the cage should be monitored closely. If there is any signs of progression of the migration, early posterior supplemental fixation is recommended.
4. Pseudarthrosis: If implant position is satisfactory, posterior supplemental fusion with instrumentation is recommended. Anterior revision surgery should be performed if there is an unacceptable cage position and the patient is symptomatic.

Contraindications

1. Calcified or aneurysmal anterior vessels
2. Prior vessel injury and repair during initial operation
3. Abundant scar expected because of unexpectedly high amount of adhesions noted at primary surgery

When these conditions exist, the risk of vessel tear is high. In addition, revision surgery is difficult due to less than adequate anterior exposure. Consideration should be given to a retroperitoneal approach through a flank incision to expose the lumbar spine laterally.

Advantages

Anterior approach to the revision directly addresses the area of the problem, but there is additional risk of vessel injury. It is recommended that a vascular surgeon perform the approach and remain in the operating room throughout the procedure.

Disadvantages

Posterior approach to revision of anterior lumbar interbody fusion is contraindicated. The extent of retraction required subjects the nerve roots to injury and arachnoiditis.

Procedure

Positioning

For a paramedian approach to the lumbar spine, the patient should be positioned supine on a radiolucent table with access for a fluoroscope. Proper positioning should be confirmed to ensure that the patient is not rotated, and that the axis of the body is parallel to the table.

Positioning Tips

1. Improved access into the disc space can be achieved by increasing lumbar lordosis using a roll towel under the lumbar spine.
2. Using two pillows under the knees flexes the hips to relax the psoas muscle and the anterior vessels for enhanced exposure of the lateral aspects of the spine.
3. It must be ensured that the patient's position does not change throughout the operation. The Bookwalter retractor, which is commonly used for the anterior approach, has a tendency to pull the torso to the right if a left-sided retroperitoneal approach is used. The eccentric pull to the right necessary to retract the abdominal contents gradually translates and rotates the torso. During surgery, proper positioning must be confirmed and adjustments made as necessary by using fluoroscopy to visualize the bony elements of the spine.

Exposure

1. A paramedian retroperitoneal approach is preferable (Fig. 57–2A). The skin incision is made in a longitudinal fashion approximately 3 cm from the midline. The approach may be made from either side, but the left side is preferable because the more fragile iliac vein lies on the right side. For one-level fusion the length of the incision is about 9 cm. The distal aspect of the skin incision should extend to about two fingerbreadths above the pubic symphysis for the L5-S1 level. For the L3-L4 level, the proximal aspect of the skin incision should be about two fingerbreadths above the umbilicus.
2. If the primary surgery was performed through a left-sided skin incision, a midline skin incision can be made to avoid adhesions between the rectus muscle and the anterior sheath. Necrosis of the skin bridge is rare because of the abundant vascular supply in the abdominal wall.
3. After dissection of the subcutaneous adipose tissue, the anterior rectus sheath is incised in line with the skin incision. The superficial epigastric vessels, which sometimes lie on the surface of the anterior rectus sheath, require ligation especially at the caudal aspect of the incision. The medial border of the left rectus muscle is identified and the muscle reflected laterally. The thin layer of the posterior rectus sheath is incised just medial to midline while being elevated with two forceps to avoid injury to the peritoneum (Fig. 57–2B).
4. Using blunt dissection, the peritoneum is reflected from the right lateral abdominal wall. Then the abdominal contents are retracted to the contralateral side to expose the major vessels. The ureter with the accompanying testicular vessels, which crosses the common iliac vessel at the level of L4, should be retracted with the abdominal contents. Care must be taken to avoid injury to the lumbosacral plexus, which fans out from the aortic bifurcation to the sacral promontory. Injury to this sympathetic chain can cause retrograde ejaculation in males. Minimal electrocautery should be used and if required, only bipolar electrocautery should be employed.
5. For exposure of levels between L2 and L5, the segmental vessels above and below the disc to be fused should be ligated. In addition, the iliolumbar vein, which usually branches off the common iliac vein at the level of the bifurcation of common iliac artery, is ligated especially for exposure of the L4-L5 disc space. Damage to this vessel can cause profuse bleeding due to its larger caliber and deep location. Ligation of this vessel also increases the mobility of the iliac vein.
6. For exposure of the L5-S1 disc level, the approach is made between the common iliac vessels. The iliac vessels are carefully freed from the anterior longitudinal ligament and retracted laterally. The middle sacral artery is ligated. Minimal electrocautery should be used for this exposure.

Exposure Tips

1. If the initial anterior fusion was performed through a retroperitoneal approach and abundant adhesion is expected, a transperitoneal approach can be employed. This can potentially avoid inadvertent tears in the peritoneum where repair can be difficult especially if it occurs through the posterior aspect. This approach is especially useful for exposure of the L5-S1 level. Conversely, if a transperitoneal approach was used initially, a retroperitoneal exposure can avoid some of the adhesions.
2. A large tear of the parietal peritoneum that occurs on the posterior aspect is difficult to repair because of its hidden access. However, the

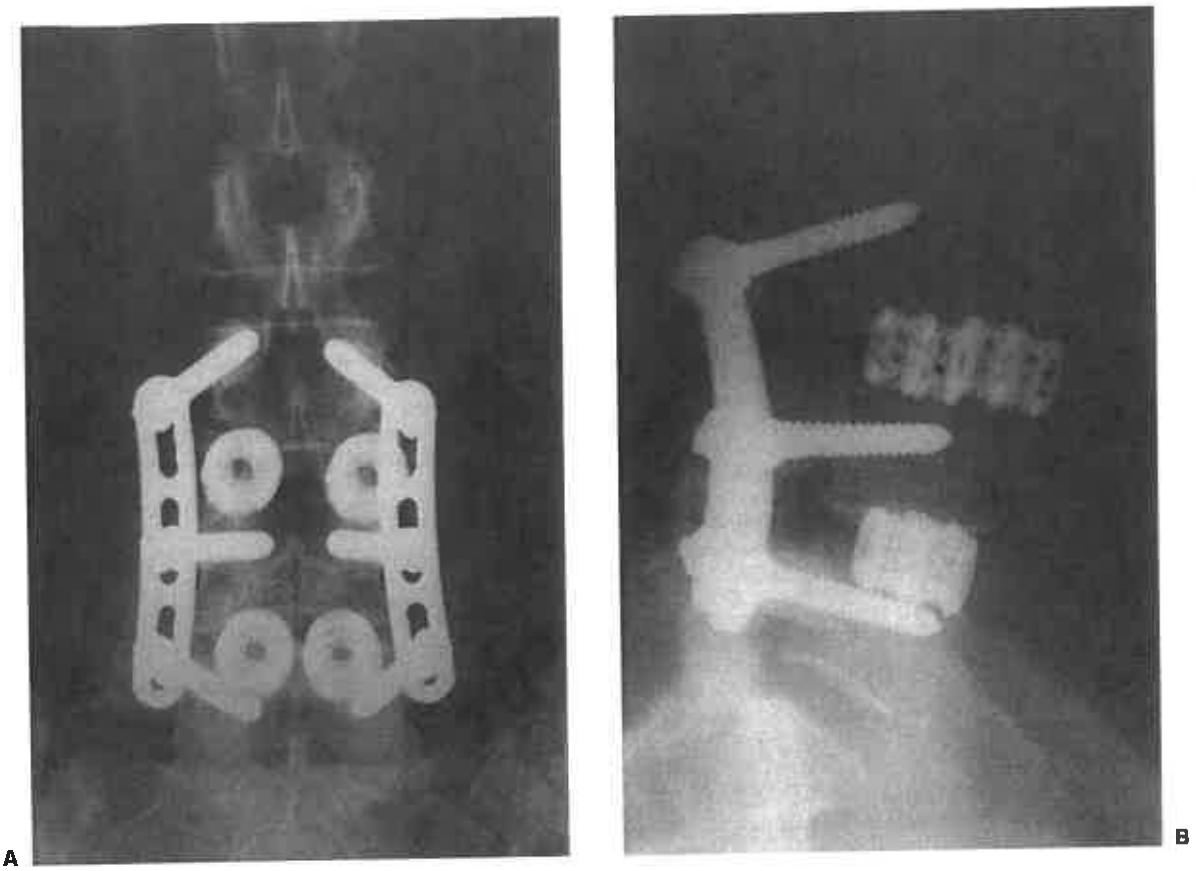
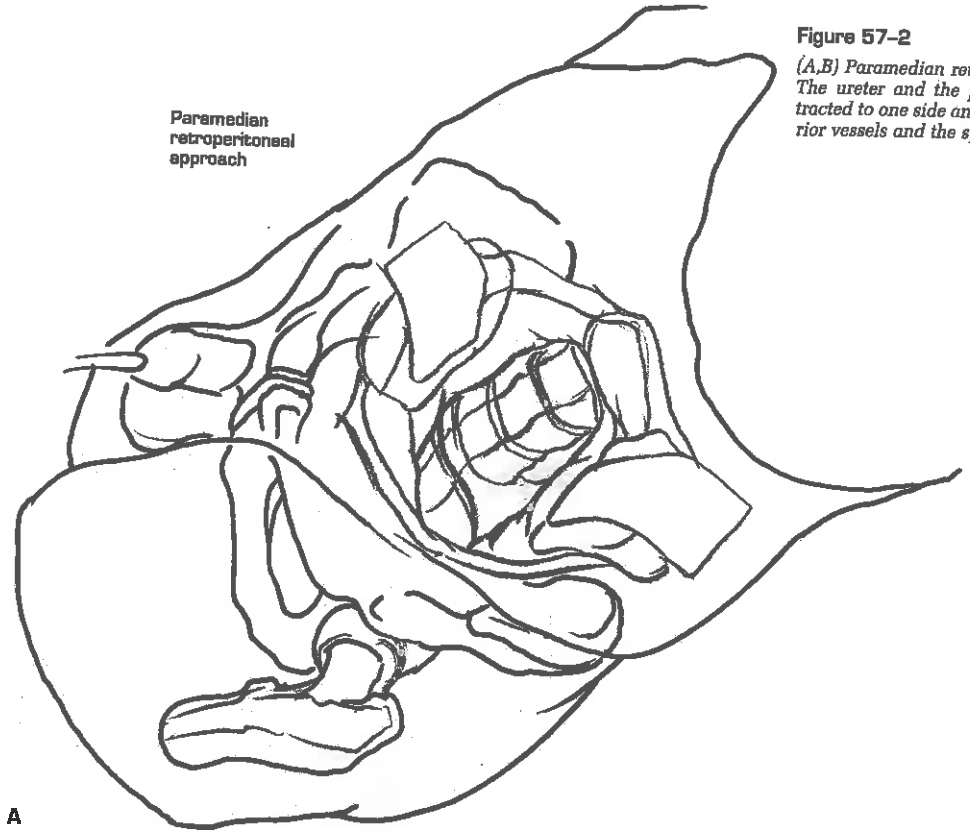
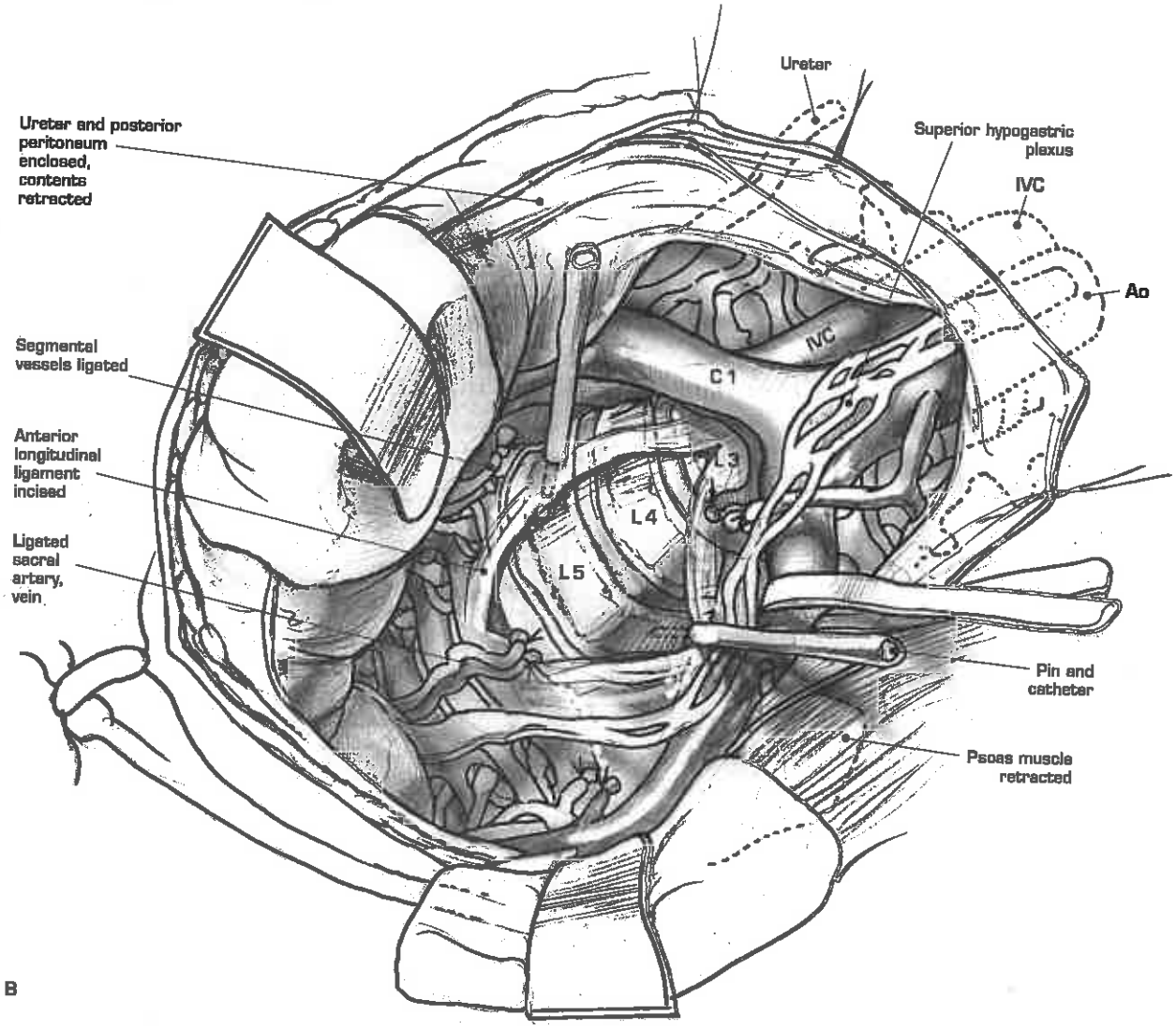


Figure 57–1

Two-months-postoperative anteroposterior (AP) (A) and lateral (B) radiographs of the lumbar spine after a two-level anterior lumbar interbody fusion (ALIF). A 42-year-old woman status post-posterior instrumented fusion with continued low back pain and limited posterolateral fusion mass. Patient underwent ALIF with threaded cages after positive discograms. Two months later, anterior and lateral migration of the right threaded cage at L3-L4 is evident.



A



B

Figure 57–2

(A,B) Paramedian retroperitoneal approach to the lower lumbar spine. The ureter and the peritoneum enclosed abdominal contents are retracted to one side and the psoas muscle to the other to expose the anterior vessels and the spine.

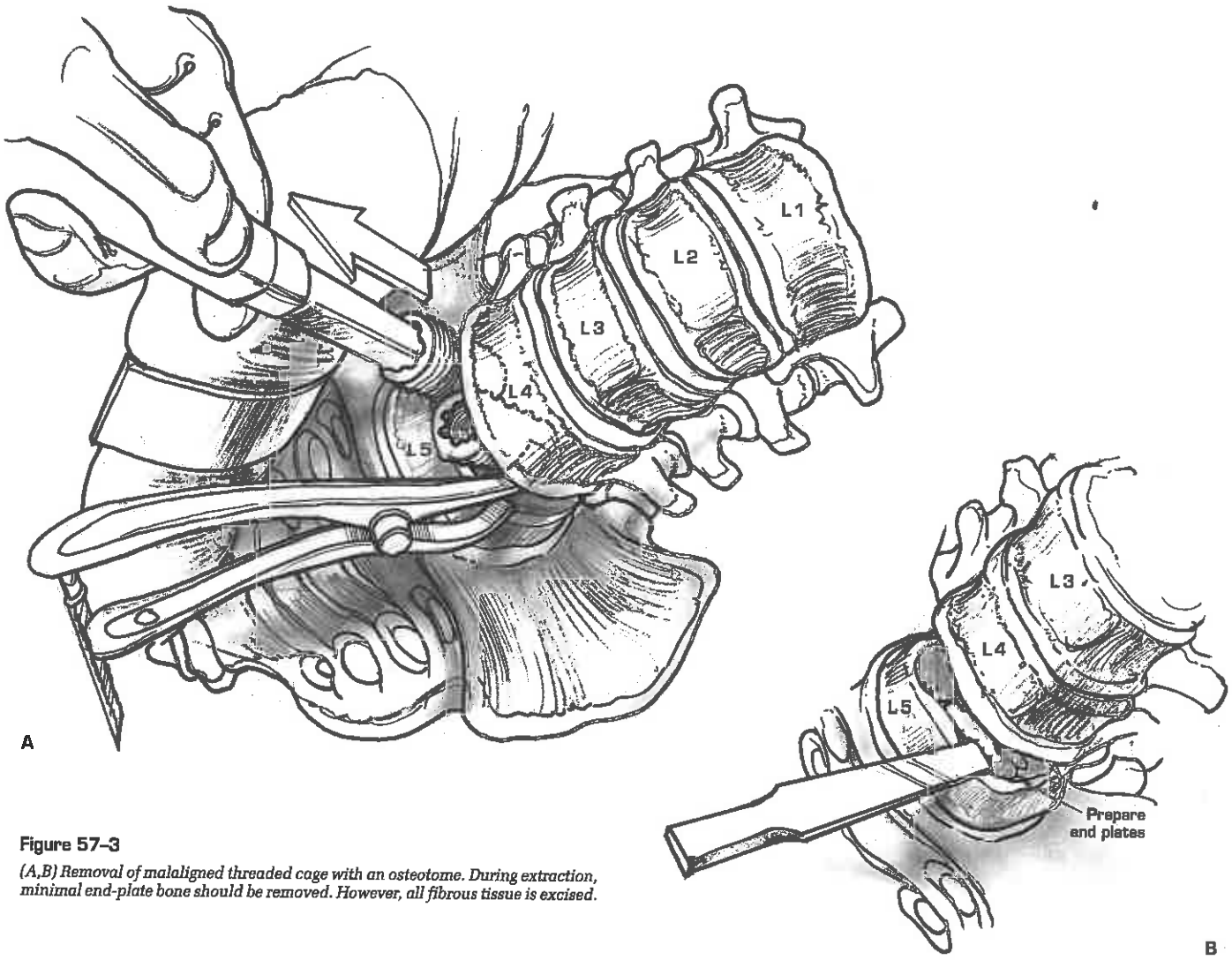


Figure 57–3

(A,B) Removal of malaligned threaded cage with an osteotome. During extraction, minimal end-plate bone should be removed. However, all fibrous tissue is excised.

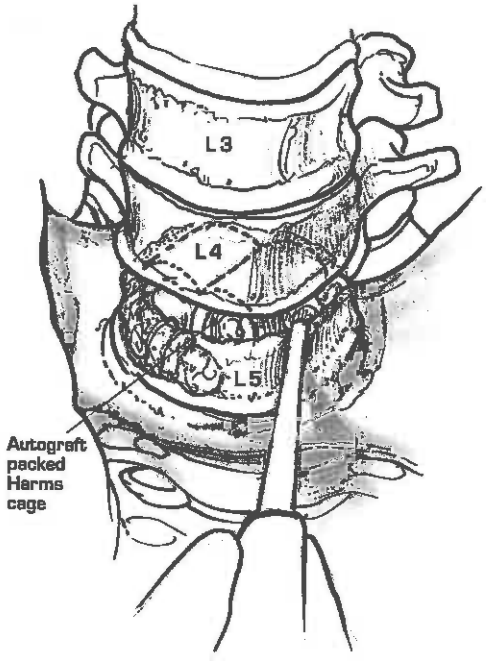


Figure 57–4

Insertion of Harms cage. After preparation of end plates, the Harms cage is inserted to provide firm fixation. However, care must be taken to avoid a scoliotic deformity by unilateral overdistraction.

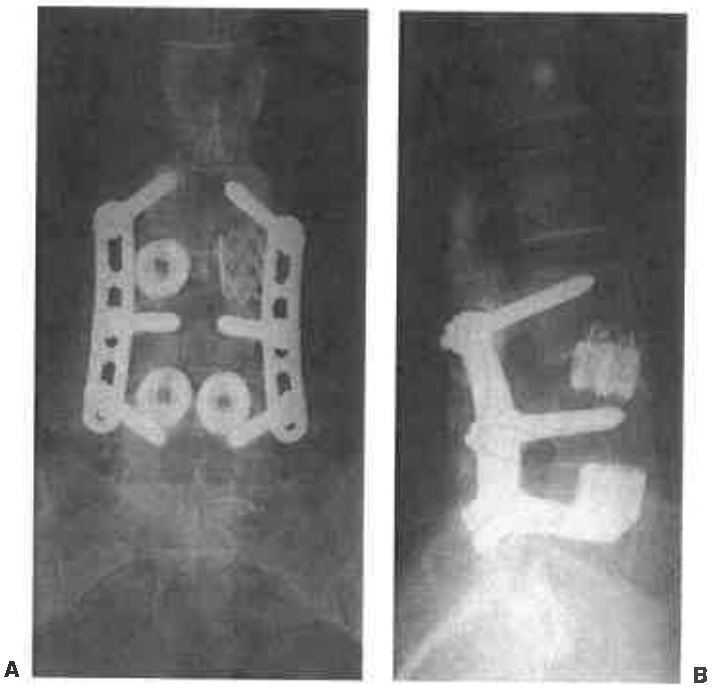


Figure 57–5

Postoperative AP (A) and lateral (B) radiographs. The malaligned right threaded cage has been replaced with a Harms cage.

tear can be revealed for repair by incising the peritoneum anteriorly, and retracting the bowel. The exposed posterior tear is repaired and then the anterior peritoneal incision is sutured.
3. In females, the round ligament is ligated for improved exposure.

Instrumentation

1. Any migration suggests poor fixation; therefore, removal of the malaligned cage should be performed rather than repositioning. An attempt should be made to remove the cage using its associated insertion tool. If firm fixation is encountered, an osteotome can be used. However, minimal bone should be excised to preserve the structural integrity of the end plate. All fibrous tissues are debrided with a curet, but the end plate should be maintained as much as possible (Fig. 57–3).
2. A Harms cage filled with autograft is inserted into the defect (Fig. 57–4). To solidly wedge in the cage, a lamina spreader is used to distract the disc space and released after insertion of the cage. Firm fixation of the Harms cage must be confirmed without causing a scoliotic tilt. Additional bone graft may be pack around the cage (Fig. 57–5).
3. Any remaining annulus fibrosus and longitudinal ligament at the anterior lip of the vertebral bodies are removed with a rongeur to expose cancellous bone. This allows for formation of an anterior bone bridge between the vertebral bodies, which is the best sign radiographically to confirm fusion.
4. Supplementary posterior fixation is performed with instrumentation at the motion segment. Because some destruction of the end plate is inevitable during revision surgery, posterior fixation prevents cage subsidence into the vertebral bodies. Also additional stability is provided.

Instrumentation Tips

1. The open abdominal wound retracted by the Bookwalter retractors causes a density difference, which results in difficult visualization of the spine under fluoroscopy. On the fluoroscopy screen, the spine is too bright and the surrounding soft tissues are dark, obscuring bony details. For improved visualization of the spine, sterile saline can be poured into the abdominal wound to equalize the density with the surrounding tissues.
2. If only one threaded cage is malaligned, the other cage with acceptable position and satisfactory fixation is left intact.

Complications and Pitfalls

1. Injury to the common iliac vein or the inferior vena cava can occur during exposure or instrumentation. Up to a 15 % vascular complication rate has been reported in anterior approaches to the lumbar spine. The risk is higher with revision surgery because of adhesions.
2. Retrograde ejaculation results from injury to the lumbosacral sympathetic plexus. Reported incidence ranges from 0.4 to 2 %. Use of the electrocautery when dissecting between L5 and S1 should be minimal.
3. A postoperative temperature increase of the foot on the same side as the exposure results from aggressive retraction of the sympathetic chain, which courses along the lateral margin of the anterior vertebral bodies. Minimal bipolar electrocautery should be used when reflecting the psoas muscle from the lateral aspect of the vertebral bodies. This temperature difference usually resolves over time.
4. Occasionally, ipsilateral leg swelling is noted a few weeks postoperatively. This is due to injury to the lymphatic system, which also courses along the lateral aspect of the vertebral bodies. Fortunately, this also resolves. However, when a patient presents with this symptom, precautions should be taken to rule out a deep vein thrombosis.
5. Ureteral injury as well as thrombotic occlusion of the left iliac artery have been reported.

Postoperative Care

Early activity is encouraged after surgery. Physical therapy for ambulation training is started on the day following surgery. However, log rolling in and out of bed is maintained. The patient wears an elastic corset for comfort while the abdominal wound heals. Diet is slowly advanced to solid foods when flatus occurs.

Suggested Readings

Bauer R, Kerschbaumer F, Poisel S. Atlas of Spinal Operations. New York: Thieme; 1993.

McAffe P. Current concepts review: interbody fusion cages in reconstructive operations on the spine. J Bone Joint Surg Am 1999;81:859–880.

58 Reduction of Spondylolisthesis with Pedicle Screw Fixation and Transforaminal Lumbar Interbody Fusion

Thomas A. St. John and Todd J. Albert

Goals of Surgical Treatment

To decompress and stabilize the spondylolytic defect; reduce the slippage; restore disc space height; restore sagittal alignment.

Diagnosis

Spondylolisthesis is defined as a forward slippage of a lumbar vertebral body most commonly due to an abnormality of the pars interarticularis from a developmental or acquired condition. Activity related pain localized to the lumbar region may be present, and may occasionally radiate to the buttocks and posterior thighs. True radicular symptoms are rare; however, they may be seen with more severe spondylolistheses, and are typically in an L5 distribution. Physical findings are limited with mild degrees of slippage (increased lumbar lordosis). As the disease progresses, patients may develop the classic knees bent/hips flexed stance and gait (secondary to paravertebral spasm and hamstring tightness). Lateral and oblique radiographs of the lumbar spine should illustrate the diagnosis. In spondylolytic spondylolisthesis, the defect in the pars interarticularis is more clearly seen on the oblique views, as represented by a break through the neck of the "Scotty dog." Computed tomography (CT) scans may be helpful with unilateral defects or to identify sites of neural compression. In the acute stage, single photon emission CT is most sensitive in detecting a stress fracture through the pars before it is apparent radiographically (Fig. 58–1).

Indications for Surgery

Surgical intervention may be necessary when:

1. There is persistent back pain and/or leg pain (usually in an L5 distribution) that interferes with activities of daily living and has not responded to conservative therapy, consisting of activity restriction, physical therapy, and/or bracing.
2. There is significant progression of the slip.
3. The slip is >50 % whether or not the patient is symptomatic.
4. There is progressive postural deformity or gait abnormality

Reduction of the slippage may be considered for:

1. High-grade spondylolistheses (grade III and IV)
2. A significant increase in slippage seen intraoperatively after neural decompression

Contraindications

Reduction should be performed following a complete decompression of the neural elements. Furthermore, reduction techniques that use only posterior distraction systems have been associated with poor results. Posterior distraction/translational systems are preferred. Finally, reduction should not be attempted in patients with spondyloptosis.

Advantages of Reducing a High-Grade Spondylolisthesis

1. Improved cosmesis
2. Restoration of trunk height and sagittal balance
3. Improved buttock and spine contour
4. Nerve root decompression
5. Better milieu for fusion

Procedure

An adequate exposure of the lumbar spine is necessary. A wide release over the lumbar transverse processes and sacral ala is important for the posterior fusion and will aid in the reduction itself. Furthermore, if a reduction and fusion is being performed on an L5-S1 spondylolisthesis, then exposure of L4 is required for placement of a pedicle screw, which will aid in the reduction. This screw may then be removed following reduction or remain if the fusion is to extend to L4 (secondary to a retrolisthesis at L4-L5 or concomitant disc degeneration at this level).

Decompression and Disc Space Preparation

Decompression of the neural elements is performed as necessary. This may include removal of the Gill fragment, as well as foraminotomies as indicated (Fig. 58–2). A wide decompression allows access to the intervening disc space, lateral to the thecal sac. Both the exiting and transversing nerve roots should be well visualized. Gentle retraction of the thecal sac will expose the intervening disc inferior to the exiting nerve root. An annulotomy is performed, followed by a near-total discectomy to allow for a large graft recipient site. Annulotomies may be done bilaterally to facilitate removal of disc material. Often, removal of the sacral dome with an osteotome is necessary to gain access to the disc space and aid in reduction. Progressively larger dilators are then introduced into the disc space through the annulotomy to provide distraction, allowing for the insertion of the interbody cage or allograft (Fig. 58–3). Retained disc fragments may become apparent at this time. Partial decortication of the end plates is then performed to expose the graft site to marrow elements while leaving some cortical bone to provide for load sharing. Interbody fusion cage trials can then be used to size the prosthesis. A dilator is left in place to maintain distraction of the disc space during reduction. A variety of specialized instruments can be utilized during the disc space preparation, including right-angled curets, mortising chisels, and dilators.

Pedicle Screw Placement and Reduction

Pedicle screws are introduced at the level of the spondylolisthesis, as well as one level above the slip. The cephalad level is a temporary screw used during the reduction, unless the fusion is to extend to this level. The middle screw is a specialized screw with a long threaded barrel, which will provide for a gradual instrumented reduction as the locking cap is tightened down onto the rod (Fig. 58–4A). Distraction is applied across L4-S1, providing a combined cranial and dorsal movement of L5, contributing to the reduction effect (Fig. 58–4B). Under continued distraction the inner locking caps are advanced against the rod reducing the listhesis (Fig. 58–4C). Distraction may be applied earlier to assist in removal of the disc material and dilation of the disc space. Upon completion of the reduction and transforaminal lumbar interbody fusion (TLIF), the cephalad screw is removed as indicated, to preserve motion through that segment. The reduction tabs are then broken off the reduction screw using a specialized instrument.

Transforaminal Lumbar Interbody Fusion

After the reduction has been completed, the dilator is removed. Cancellous autograft is maximally impacted into the disc space using a depth limiting impactor. Depending on the surgeon's preference, one or two fusion cages or a structural allograft is then inserted into the disc space and countersunk below the level of the posterior vertebral body (Fig. 58–5). A standard posterolateral intertransverse process fusion (with decortication of the posterior elements and placement of autograft) is then performed (Fig. 58–6).

Exposure Secrets

1. A wide muscle dissection and release of foraminal ligaments facilitates reduction of the slip.
2. Be certain to fully seat the "reduction" pedicle screw. Failure to do so prevents the slipped vertebral body from adequately translating posteriorly, resulting in an incomplete reduction.
3. Do not overcontour the rods. A properly contoured rod will not fully engage the reduction screw; it will sit proud in the reduction barrel. The screw will then reduce to the rod as the locking caps are tightened.
4. Perform the reduction with the dilator in place. Removing this device allows the disc space to collapse during reduction, preventing placement of an adequate size cage/graft and possibly causing compression of the nerve roots.
5. While performing the reduction, alternate the sides while tightening the locking caps. This facilitates a gradual reduction.
6. Be certain to countersink the interbody fusion device to avoid graft extrusion or impingement on the neural elements.
7. After completion of the reduction, the pedicle screws should be used to compress the vertebral bodies against the fusion cage or structural allograft. This ensures maximal contact with the end plates, facilitat-

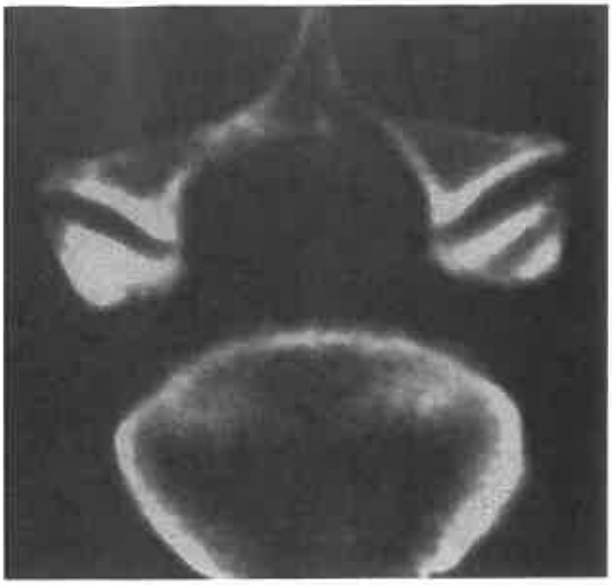


Figure 58–1
Computed tomography (CT) of spondylolytic spondylolisthesis.

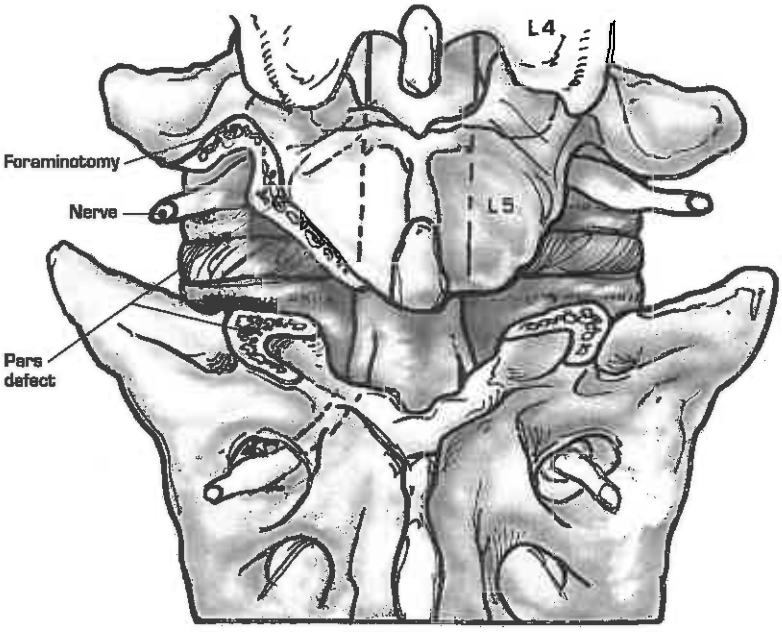


Figure 58–2
Intraoperative diagram illustrating a wide decompression of L5 (removal of Gill fragment). The exiting and traversing nerve roots are visualized.

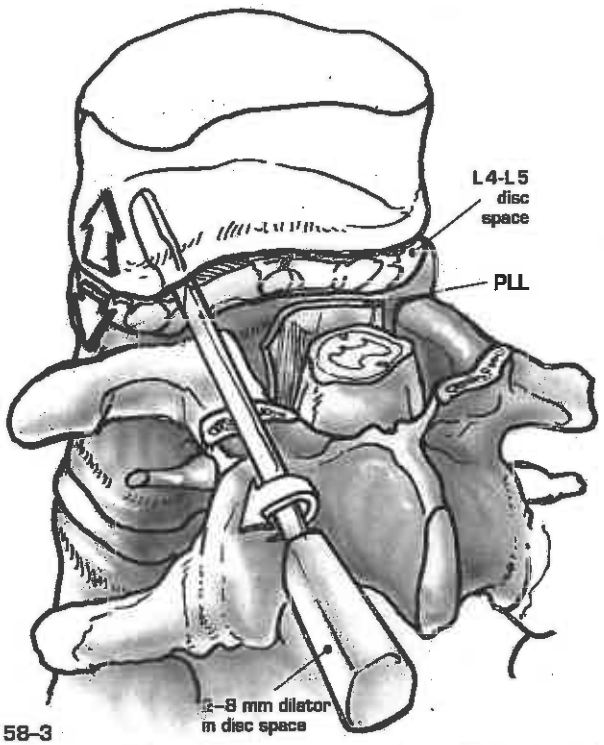


Figure 58–3
Drawing illustrating dilation of disc space, with a 2–8 mm dilator inserted through the annulotomy.

ing an adequate surface area for fusion as well as restoration of lordosis.

Pitfalls

1. L5 nerve root symptoms may occur postoperatively if an adequate decompression is not performed prior to reduction. Bilateral foraminotomies and maximal restoration of disc height help protect the nerve roots from compression following reduction.
2. Postoperative sagittal decompensation may occur with unrecognized adjacent segment instability and/or with overdistraction. Care must be taken to identify all unstable segments and plan fusion levels accordingly.
3. Inability to achieve a reduction may result from inadequate exposure or by attempting to use a posterior reduction-fixation system without a concomitant lumbar interbody fusion.
4. Be certain to remove any loose fragments of bone in the canal. Check anterior to the thecal sac and exiting nerve root.

Postoperative Care

1. The patient is kept NPO for 36 hours postoperative to allow for adequate return of bowel function.
2. A morphine patient-controlled anesthesia (PCA) pump is used for pain control for the first 24 to 48 hours as indicated.
3. The patient may be out of bed on postoperative day 1. Ambulation is allowed, as tolerated.
4. A lumbosacral orthosis (LSO) with leg extension is prescribed for 6 weeks postoperatively.

Suggested Readings

Bridwell KH, DeWald RL. The Textbook of Spinal Surgery. 2nd ed. Philadelphia: Lippincott-Raven; 1997.

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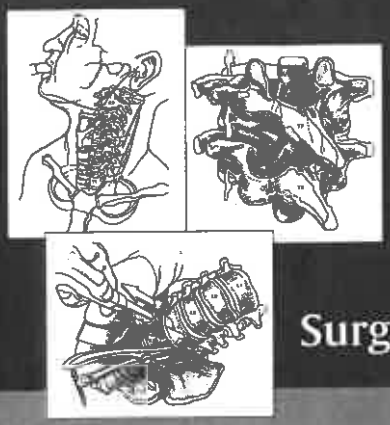

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