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Minimally invasive techniques in spinal surgery: current practice

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Minimally invasive spinal surgery under arthroscopic or endoscopic magnification and illumination is emerging as an alternative, reliable method of treatment in a variety of spinal disorders. The operative techniques being used for discectomy and retrieval of herniated disc fragments or stabilization of unstable spinal motion segments are being utilized for visual diagnosis and debridement of infectious discitis and osteomyelitis transpedicular and transforaminal vertebral body biopsy, temporary diagnostic fixation of unstable lumbar motion segments, and transforaminal epidural steroid therapy.

Key Words * spine surgery * endoscopy * discectomy

HERNIATED LUMBAR DISC

Mixter and Barr[38 and Dandy[5] are credited with the diagnosis and treatment of herniated lumbar discs via laminectomy and exposure of the spinal canal. In the last 40 years many investigators have attempted to find alternatives to laminectomy and discectomy, including evacuation of nuclear tissue via an anterior retroperitoneal approach,[9] chemonucleolysis,[52] or laser nuclear ablation.[2,4,14]

As early as 1973, mechanical nucleotomy using Craig Instrumentation was attempted at the Graduate Hospital in Philadelphia.[21] Hijikata[7] in the mid-1970s reported satisfactory outcome in 75% of their patients who underwent nuclear resection via a cannula inserted dorsolaterally. The principle of mechanical nucleotomy was subsequently pursued by other investigators.[41,49]

In the early 1980s,[21,26] in an attempt to reach the herniated fragments that were dislodged under the posterior longitudinal ligamentum, the Craig instruments were modified and with the diameter of the cannula enlarged (5 mm inside diameter [ID], 6.9 mm outside diameter [OD]). This allowed the passage of upbiting and deflecting instruments. Following cadaveric studies, atmospheric negative pressure was used to dislodge the herniated fragments into the path of the inserted cannula.

Increased understanding of the arthroscopic anatomy of the foraminal and extraforaminal region,[12,19,21] and the description of radiographic landmarks of the working zone on the dorsolateral annulus,[20,24,37,42] combined with the availability of small-caliber glass rod fiberoptics, have permitted further lateralization of the skin entry point and posterior positioning of the open end of the cannula adjacent to the neural structures.[27,30] This has opened a window of opportunity that permits retrieval of herniated disc fragments under arthroscopic illumination and magnification.

ANATOMICAL AND RADIOGRAPHIC CONSIDERATIONS

Arthroscopic disc surgery is performed through the triangular working zone on the posterolateral corner of the intervertebral disc (Fig. 1 left). The exiting root forms the anterolateral boundary of the working zone whereas the traversing root and the dural sac limit its medial extension. Although the height of the working zone is limited by the height of the intervertebral disc, its width in the transverse plane accommodates the insertion of instruments up to 12 to 14 mm in width.[20,37] When the instruments are properly positioned in anteroposterior fluoroscopic examination, the tip of the inserted instrument is observed at the mid pedicular line, (Fig. 1 center) whereas in the lateral projection the tip of the instrument is seen in alignment with the posterior boundary of adjacent vertebrae (Fig. 1 right).

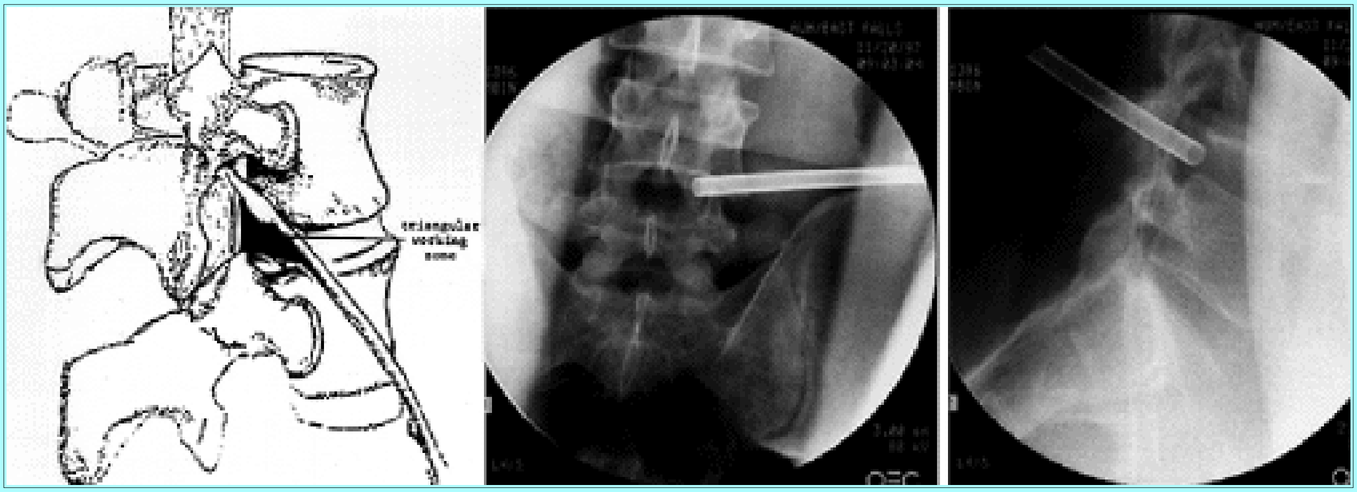

Fig. 1. Left: Schematic drawing of the triangular working zone. The exiting root is seen anterolaterally, the traversing root and dura medially. The proximal plate of the distal segment limits its inferior boundary. Center: Intraoperative anteroposterior fluoroscopic examination demonstrating proper positioning of the working cannular adjacent to the spinal canal at mid-pedicular region. Right: Lateral fluoroscopic examination showing the tip of the cannula in alignment with the posterior border of the adjacent vertebral bodies.

When an extraforaminal herniation is being retrieved at the onset of the procedure, the inserted needle may be positioned at the lateral pedicular line. The triangular working zone voids the neural structures. However, the expansion of the posterior longitudinal ligament into the triangular working zone and the superficial layers of the posterolateral annulus are extremely sensitive and are innervated from the branches of sinuvertebral nerve.[27,42]

In the triangular working zone, the exiting root is located in the pedicular notch under the pedicle. Therefore, when the instruments are being held firmly against the annular surface (at the midpedicular line), the chance of causing neural injury becomes extremely remote. The annular surface in the triangular working zone is covered by loosely woven adipose tissue. For identification and visualization of the annular surface, this fatty tissue may have to be removed with a forceps inserted through the working channel discoscope.

Currently, the majority of arthroscopic discectomies and fragmentectomies are being performed via a subligamentous approach to the intervertebral disc. Therefore, the operating surgeons must familiarize themselves with the visual diagnosis and be able to differentiate between epidural fat and periannular adipose tissue. Generally the globs of epidural adipose tissue are larger than the periannular fat; in addition, whereas the periannular fatty tissue is stationary, the epidural adipose tissue has a tendency to move in and out of the working cannula as the patient inhales and exhales.

INCLUSION AND EXCLUSION CRITERIA

The success or arthroscopic microdiscectomy hinges on the proper patient selection, appropriate choice of surgical access, posterior positioning of the instrumentation, and adequate visualization.

Inclusion Criteria

The inclusion criteria for arthroscopic disc surgery are similar to the well-known indications for open laminotomy and discectomy. Failure to respond to nonoperative conservative measures, presence of positive tension signs, correlative dermatomal distribution of sciatic pain, and correlative positive imaging studies are prerequisites for arthroscopic microdiscectomy. However, the majority of patients who have undergone arthroscopic microdiscectomy at our institution also have demonstrated one or two neurological abnormalities.[28,48]

Exclusion Criteria

Arthroscopic disc surgery should not be used to treat low back pain due to degenerative disc process. The cauda equina syndrome is usually associated with some degree of bony and ligamentous abnormality. Disc herniation in this group of patients should be treated by traditional laminotomy and discectomy with adequate decompression. Individuals with a global bulging disc and sciatica are usually suffering from spinal stenosis; they are best treated by open procedures. A sequestered herniated disc, which has migrated in a cephalad or caudal direction in the spinal canal, will require laminotomy for the retrieval of herniated fragments. The extraction of a central or sequestered disc at the L5-S1 level accompanied by an elevated iliac crest will require an open decompressive procedure.

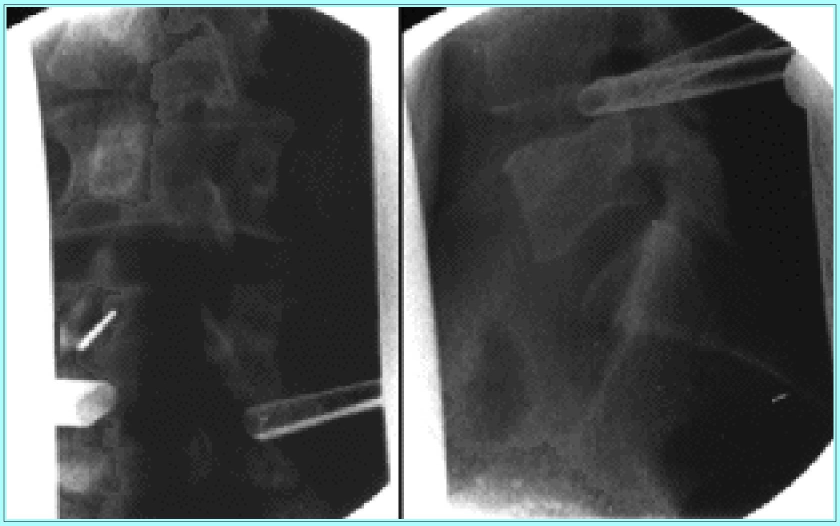

Fig. 2. Left: Intraoperative anteroposterior fluoroscopic examination demonstrating biportal access to the L4-5 intervertebral disc. Note that an oval cannula is used on the left and a 5-mm ID cannula on the right. A guide pin is inserted into the pedicle of L-4 in preparation for insertion of pedicular bolt. Right: Lateral fluoroscopic view shown of the biportal access shown above.

SURGICAL APPROACHES

The herniation site may be reached via a uniportal (Fig. 1 center and right) or biportal approach (Fig. 2). For a uniportal approach, a 5-mm ID cannula or an oval-shaped cannula (8 mm ID by 10 mm OD) (Fig. 3) may be used. However, the availability of the oval cannula has reduced the need for a biportal approach in disc surgery; biportal access is generally reserved for retrieval of a large central or extraligamentous sequestered herniation. The migrated sequestered disc fragments are not accessible by arthroscopic microdiscectomy. We believe that arthroscopic microdiscectomy is the procedure of choice for treatment of foraminal and extraforaminal herniations.

Fig. 3. Instrumentation. From right to left: A guide wire that fits into the lumen of the 18-gauge needle; 18-gauge needle, 6 inches in length; 4.9-mm OD cannulated obturator; 5-mm ID working cannula; 5 X 8-mm ID oval cannula; and 5 X 10-mm ID oval cannula.

The biportal access to L5-S1 intervertebral discs, particularly in individuals with a high iliac crest, remains difficult. However, in a majority of patients, a uniportal approach may be used to treat paramedial, foraminal, or extraforaminal herniations.

UNIPORTAL SUBLIGAMENTOUS APPROACH

The uniportal subligamentous approach is suitable for removal of central and paramedial herniations and is also used for the treatment of foraminal and extraforaminal disc herniations. Proper needle positioning in the triangular working zone is achieved under C-arm fluoroscopic guidance. Prior to insertion of the needle, the C arm should be maneuvered until the vertebral plates adjacent to the herniation site are seen as two parallel lines. Depending on the size of the patient and the level of herniation, the skin entry point may vary from 9 to 12 mm from the midline. Because the facets and articular process of the lower lumbar segments are larger in males than females, a further lateralization of the skin entry point may be necessary in male patients.

The local delivery of a mixture of 1 ml fentanyl (Elkins-Sinn Inc., Cherry Hill, NJ) with 3 ml of normal saline solution in the periannular region via the previously positioned needle may reduce the incidence of postoperative pseudocausalgic-type pain involving the lower extremities. At this time, the stylet of the needle is replaced by a guide wire, and a blunt-end soft-tissue dilator (cannulated obturator) is passed over the guide wire and directed toward the triangular working zone. While holding the obturator firmly against the annular surface, the universal access cannula (5 mm ID, 7 mm OD) is passed over the cannulated obturator and directed toward the annular surface. The cannulated obturator is withdrawn, and the annular surface is inspected with a 0š arthroscope or a working channel scope. The annulatomy site is injected with 1% lidocaine solution (Abbott Laboratories, North Chicago, IL) through an 18-gauge needle inserted into the working cannula.

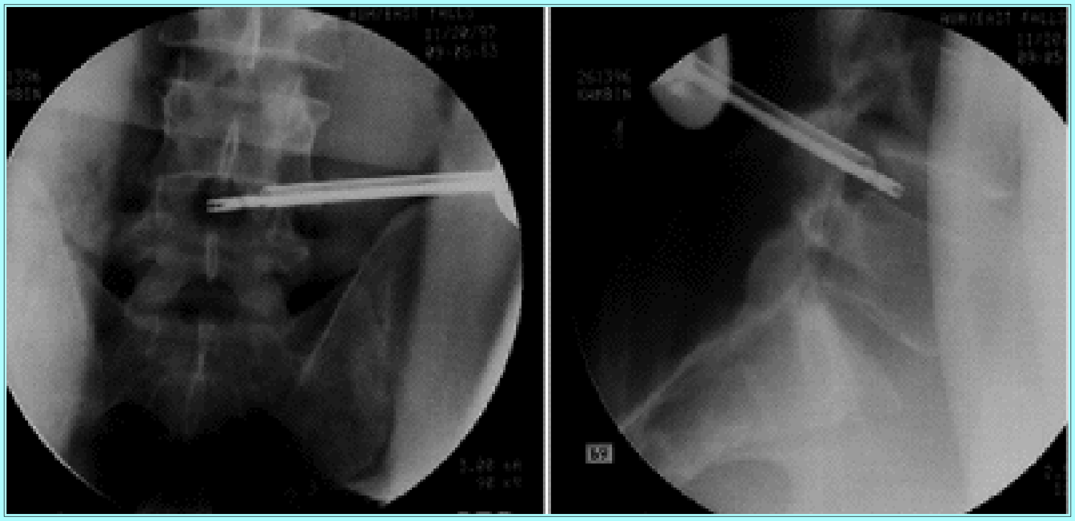

Fig. 4. Left: Intraoperative fluoroscopic examination following full insertion of forceps (extending 2 cm behind the tip of the cannula) demonstrating the posterior positioning of the instrument adjacent to the spinal canal. (In the anteroposterior projection, the tip of the inserted forceps is at the level of the spinal processes of the adjacent segments.) Right: Lateral fluoroscopic examination showing the tip of the instrument seen in the posterior one-fourth of the anteroposterior diameter of the intervertebral disc.

The posterior positioning of the instruments (Fig. 4) in the intervertebral disc is essential for subligamentous removal of herniated disc fragments. Prior to the annulatomy, the fatty tissue (Fig. 5) covering the posterolateral surface of the annulus is removed with a forceps inserted through the working channel scope.

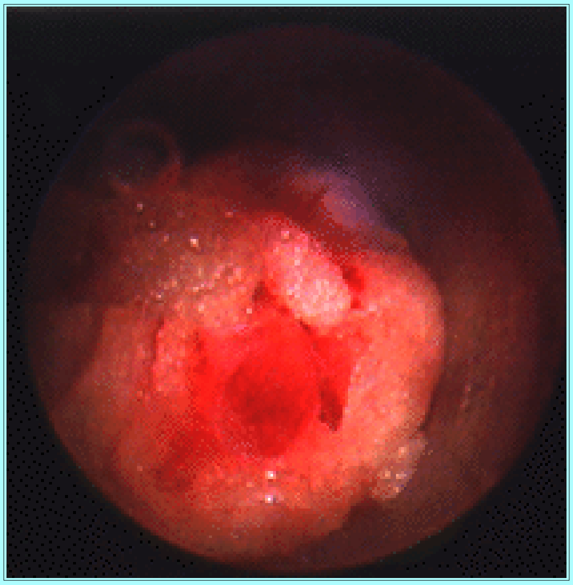

Fig. 5. Arthroscopic appearance of adipose tissue covering the annulotomy site.

The operating surgeon may tilt the inner end of the inserted cannula posteriorly. This maneuver permits arthroscopic visualization of the epidural fat and vessels or the dural sac (Fig. 6 left). The annulatomy is then performed lateral to the above structures (Fig. 6 right).

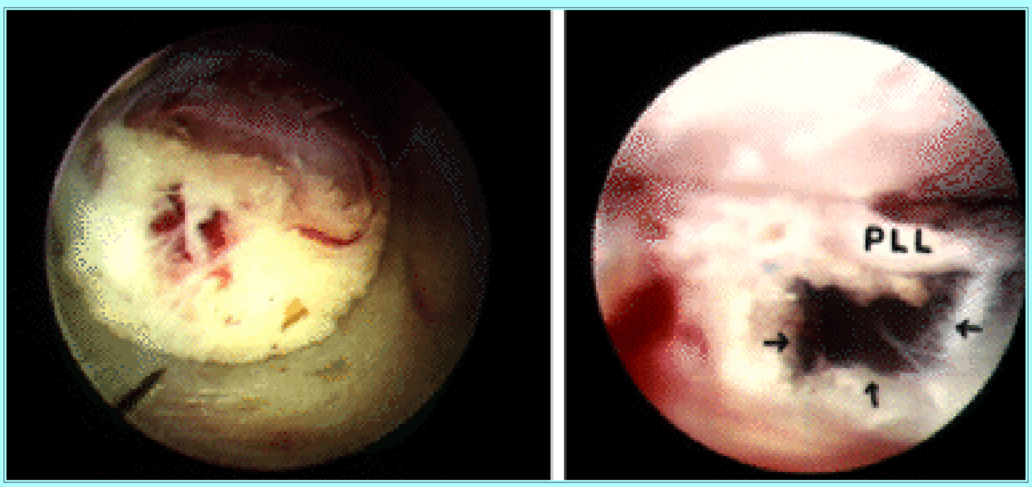

Fig. 6. Left: The annular surface is shown following extraction of fatty tissue. Note that the medial end of the inserted cannula is tilted slightly dorsally toward the spinal canal. The dura and epidural veins are seen on the top of the photograph extending from 10 to 2 o'clock. Right: With the aid of a working channel scope, annulatomy is performed (arrows) adjacent to the neural structures for subligamentous access to the herniation site.

When the instruments are posteriorly positioned, the inserted triphen or forceps will have a tendency to sweep under the intracanalicular segment of the posterior longitudinal ligament, traversing the root and lateral dura and thus evacuating the herniated tissue.

The annulatomy may be performed under direct visualization using a working channel scope (Fig. 7 upper) which fits inside the 5-mm ID working cannula or with the aid of a triphen inserted through the working cannula.

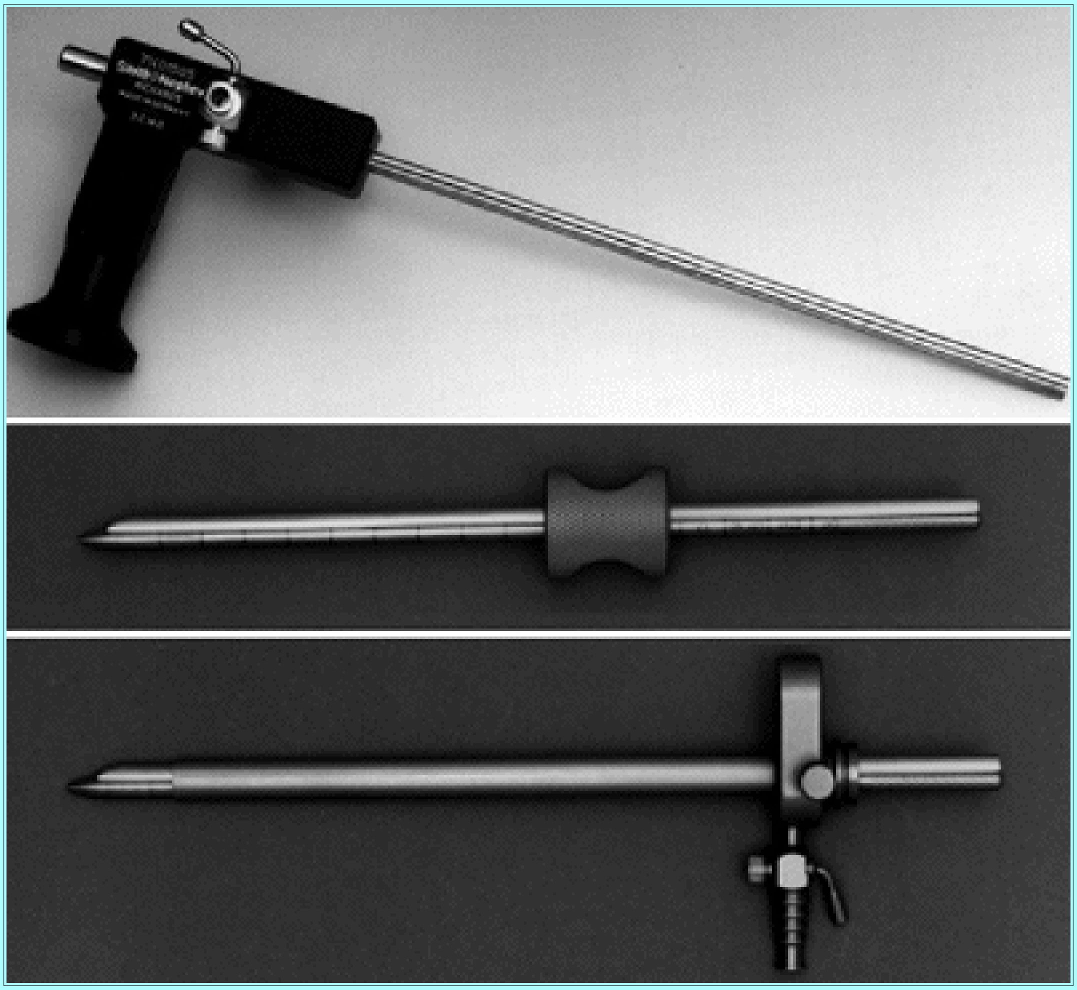

Fig. 7. Upper: Photograph showing the working channel scope that is used in conjunction with 5-mm ID access cannula. Center: A cannulated obturator and auxiliary obturator are passed through the oval bore of the jig. Note the beveled distal end of the auxiliary obturator that has a tendency to push the exiting root aside as it enters the annular fenestration. Lower: The jig is removed and the oval cannula is introduced over the two obturators.

Insertion of Oval Cannula

The universal access cannula may be replaced by an oval cannula (Fig. 3) which provides broader access to the intervertebral disc and allows further dorsal angulation of inserted forceps. In addition, it permits simultaneous introduction of an arthroscope and forceps for direct visualization and extraction of herniated fragments. For the positioning of the oval cannula, the cannulated obturator is reintroduced into the access cannula and passed through the annular fenestration into the intervertebral disc. The access cannula is then withdrawn. A specially designed jig containing an oval-shaped bore (Fig. 7 center) is used and attached to the proximal extremity of the inserted obturator. The oval bore of the jig permits the insertion of an auxiliary obturator that will dilate the annular fenestration as it enters the intervertebral disc. The jig is then removed, and the oval cannula (Fig. 7 lower) is passed over the obturators and directed toward the intervertebral disc and the herniation site.

BILATERAL BIPORTAL APPROACH

The bilateral biportal approach requires the insertion of two working cannulas into the intervertebral discs from the right and left paramedial approaches (Fig. 2).

The ipsilateral placement of an oval cannula provides adequate space for freely maneuvering the inserted instruments and arthroscope, permitting rapid development of communication between the right and left portal.

In bilateral biportal arthroscopic disc surgery, the 30 or 70š arthroscope with its accompanying irrigation sheath is introduced from one portal while the deflecting instruments (Fig. 8 left) are inserted from the opposite cannula. Under direct arthroscopic magnification and illumination, the posterior longitudinal ligament is identified, and the dural sac is exposed (Fig. 8 right). This will allow for the retrieval of intracanalicular herniated disc fragments.

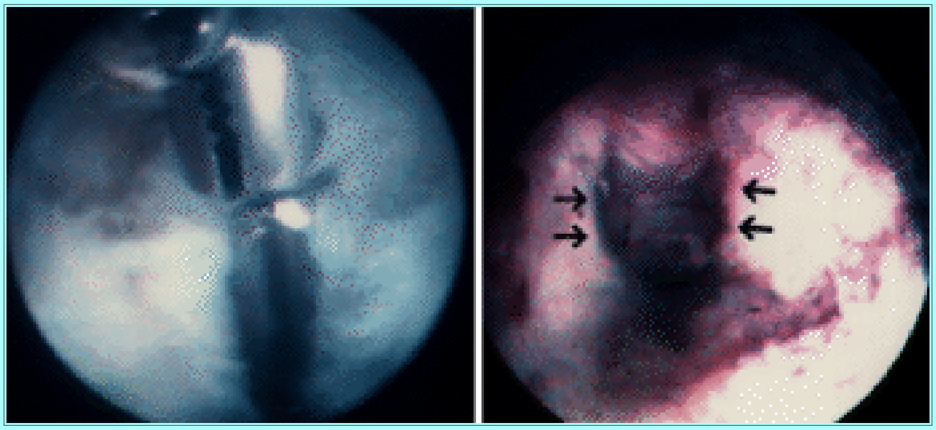

Fig. 8. Left: Intradiscal view of a deflecting forceps reaching the posterior longitudinal ligament and the dural sac for retrieval of a sequestered fragment. Right: Intradiscal view showing the ventral surface of the dural sac following the extraction of a sequestered disc fragment.

OUTCOME DATA

The results of arthroscopic disc surgery performed in our center have been previously published.[12,28,48] In a prospective study of 100 consecutively treated patients with clinical and imaging evidence of disc herniation who underwent arthroscopic microdiscectomy, the authors reported an 85% satisfactory outcome rate in a 2-year follow-up period.

In a recent prospective study of 169 consecutive patients who required disc extraction and treatment via posterolateral arthroscopic fragmentectomy,[28] reviewed by an independent examiner, a satisfactory outcome rate ranging from 86 to 92% was realized. The average length of preoperative conservative treatment in this group of patients was 3.5 months. Postoperatively, these patients were followed for a minimum of 24 months and a maximum of 78 months. Fifty-nine patients with a large central herniation or nonmigrated sequestered fragments underwent biportal surgery for the retrieval of disc fragments, whereas 116 patients with paramedial, foraminal, and extraforaminal herniation were treated using uniportal arthroscopic microdiscectomy.

Complications resulting from the procedures included one female patient who developed transient peroneal nerve palsy that was attributed to tight straps placed behind her knee during the surgery. She responded to therapy modalities and subsequently recovered. Another patient developed postoperative infection that required supportive treatment. Four additional patient reported having skin hypersensitivity and pseudocausalgic-type pain in the involved extremity that subsequently resolved. No neurovascular complications were encountered.

DISCUSSION

Arthroscopic microdiscectomy is a minimally invasive spinal surgery procedure; it provides direct decompression of the neural elements through a paramedial approach and protects the contents of the spinal canal. Efficacy of the procedure has been objectively demonstrated by intraoperative visualization and retrieval of herniated fragments,[13,15-17,23-25] intraoperative neurophysiological testing, (unpublished data) postoperative imaging evaluation,[1] and numerous outcome studies.[8,12,25,28,29,35,45,46,48]

On termination of the arthroscopic decompression of the nerve root, the cannula may be directed toward the spinal canal for visualization of the nerve root and confirmation of adequacy of the decompressive procedure (Fig. 9); however, we discourage the routine invasion of the spinal canal via the foraminal approach. In a majority of patients, the epidural adipose tissue and venous bleeding not only interfere with clear visualization of the neural structures but, furthermore, the manipulation of the content of the spinal canal and compression of the exiting root and ganglia by horizontally positioned access cannula may cause neural injury, as well as postoperative pseudocausalgic pain of the index extremity.

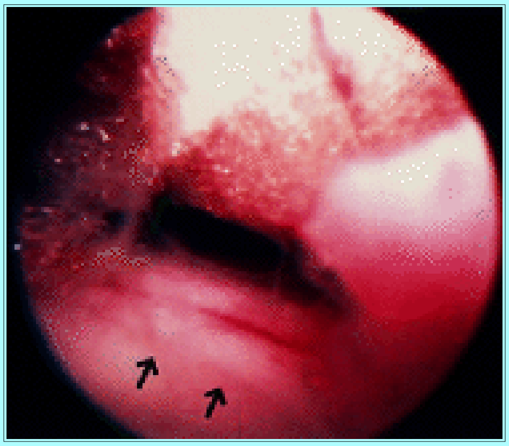

Fig. 9. Transforaminal view of the spinal canal. The traversing root is seen on the bottom (arrows) whereas the epidural adipose tissue is seen on the top.

Concern resulting from the inability to attain direct visualization of the nerve root during the arthroscopic decompression may be unfounded, because most spine surgeons successfully perform anterior cervical discectomy and decompression without being able to observe the nerve roots.

The techniques required to perform arthroscopic microdiscectomy are within the reach of any trained orthopedic or neurological surgeon. With proper patient selection, a satisfactory outcome rate equivalent to that attained in open laminotomy may be achieved following arthroscopic disc surgery.

Unstable Lumbar Motion Segments

The practice of percutaneously inserting pedicular screws for stabilization of the spinal segments is not new. In the 1980s, Magerl[33,34] described the use of pedicular screws and external fixators for reduction and temporary stabilization of fractures of the thoracic and lumbar spine. The same principle was subsequently used for arthroscopic interbody fusion by Leu and Schreiber.[32]

The practical difficulties experienced by patients while sitting or lying down, as well as the occurrence of pin-tract infection with the use of external fixators, led to the development of instrumentation for inserting pedicular bolts, extension bars of various lengths, and subcutaneous placement of the plates.[10,11,47] These instruments may be used in treating and stabilizing unstable motion segments following both open or arthroscopic interbody fusion. In addition, temporary fixators have been used to assess pain relief in selection of the site and level of arthrodesis.[18,34]

Controversy remains unresolved regarding the indications for stabilizing lumbar motion segments and whether posterolateral intertransverse fusion alone provides pain relief or adequate stabilization.[3,31,50-54] Certainly the broad surface of the vertebral plates, adequacy of the blood supply, and natural exposure of the fusion site to compression forces provide a sound basis that favors vertebral interbody arthrodesis. In addition to this, when an internal disc disruption is the primary cause of symptoms, discectomy and stabilization of the anterior column appear to be the treatment of choice.[51]

Anterior column arthrodesis may be performed using a posterior approach following ample laminotomy, partial facetectomy, and discectomy.[3,53] Although the L4-5 and L5-S1 intervertebral discs are readily accessible to this approach, the anatomical position of the exiting root and the content of the spinal canal preclude the use of a posterior approach for insertion of interbody grafts in the mid or upper lumbar region.

Open anterior retroperitoneal, transperitoneal, and laparoscopic approaches provide direct access to the vertebral bodies and the intervertebral disc at L5-S1.[36,39] The anatomical position of vascular structures limits access to the adjacent segments. However, a lateral open retroperitoneal approach has been used to access the mid-lumbar segments.

Posterolateral arthroscopic access for stabilization of the anterior column developed naturally from earlier experience with posterolateral percutaneous arthroscopic disc surgery.[12,15,25,26,48] In situ and uninstrumented interbody fusion was attempted as early as 1983 with a suboptimum outcome.[10,17,22,23,32,51] Failures were attributed to an inability to reach and then decorticate the concave surface of the vertebral plates as well as a high incidence of resorption. Recent technological developments such as the oval cannula and eccentric decorticator have added a new dimension to the field of arthroscopic posterolateral lumbar arthrodesis.

Patient Selection

Individuals who require arthroscopic anterior column stabilization are a subset of those patients generally selected for open arthrodesis of the spinal units. Degenerative spondylolisthesis or retrograde spondylolisthesis demonstrated by abnormal translation of the vertebral bodies in lateral flexion and extension roentgenograms are the most common indications for arthroscopic arthrodesis. Patients with spondylolisthesis associated with an isthmus defect of developmental origin are another subgroup of the patient population who may be included. Individuals with single-level degenerative spondylosis that has been demonstrated to produce symptoms by provocative and analgesic testing and who present with disabling pain may be treated with an arthroscopic technique augmented by removable pedicular bolts and subcutaneous plates.

One limitation to the use of posterolateral approach for arthroscopic arthrodesis is the inability to access the L5-S1 intervertebral disc via a biportal approach in patients with elevated iliac crests. In addition, it may be difficult to insert a cannula into a degenerated and narrowed intervertebral disc. However, the disc height may be increased by the introduction of a blunt-end cannulated obturator into the intervertebral disc; disc height is then temporarily maintained by insertion of an oval cannula into the disc space.

Because nucleotomy and decortication of the vertebral plates are time-consuming procedures, arthroscopic interbody fusion should not be attempted when a multilevel arthrodesis is required. In addition, when reduction and maintenance of spondylolisthesis greater than Grade 1 is desired, the deep positioning of the plates against the bony structures following an open procedure may be advantageous.

Advantages of Arthroscopic Anterior Column Stabilization

In contrast to posterior lumbar interbody fusion, the posterolateral approach does not require entry into the spinal canal. This approach avoids epidural bleeding and subsequent scar formation which, in turn, may contribute to further venous stasis, neural edema, and ischemic radicular symptoms.[6,40,43,44] In addition, tethering of the nerve root and nerve root sleeves, commonly associated with epidural fibrosis, may become symptomatic when postoperative activities are resumed and exercise programs are initiated.

Several studies have asserted the importance of maintaining patency of the epidural venous system to prevent neurogenic claudication, which is seen in association with spinal stenosis.[6,40] Extensive intraoperative electrocoagulation of the epidural veins and retraction of the nerve roots may interfere with venous drainage of the neural tissue and cause postoperative radicular symptoms. The incidence of retrograde ejaculation and the anatomical position of vascular structures limit the use of an anterior transperitoneal approach for either discectomy or segmental stabilization.

Surgical Technique

Positioning of the Patient and C-Arm. Surgery must be performed with the patient prone. A biportal approach (Fig. 2) to the intervertebral disc is necessary to achieve ample nucleotomy, decortication of vertebral plates, and insertion of bone graft. Familiarity with the biportal approach for discectomy and triangulation within the intervertebral disc is a prerequisite for the satisfactory completion of arthroscopic interbody fusion. An adjustable radiolucent frame should be used to provide adequate support under the anterosuperior iliac spine of the patient as well as ample space for expansion of the chest and abdomen. In contrast to the Wilson frame, the radiolucent frame bolsters are converged in order to elevate the patient's pelvis, thus reducing preoperative anterior or posterior translation of the vertebral bodies.

In order to widen the posterior height of the intervertebral disc, the radiolucent top of the operating table may also be flexed at the beginning of the procedure. However, in order to maintain lumbar lordosis, the operating table may have to be straightened prior to insertion of the subcutaneous plates and final closure. The C-arm must be properly covered with sterile drapes and positioned for lateral fluoroscopic visualization during the surgery. Prior to insertion of the needle, the C-arm should be maneuvered until the vertebral plates of the segments adjacent to the fusion site are seen as two parallel lines. The same principle should be exercised when the guide pins are inserted into the pedicles in preparation for insertion of the pedicular bolts. The proximal and distal boundaries of the pedicles must be seen as a single line in the lateral x-ray film projection.

Insertion of the Instruments

The steps taken for positioning of the cannulas into the intervertebral disc at the index level are similar to those previously described for arthroscopic microdiscectomy. Generally it is advantageous to use a 5 X 5-mm ID cannula on one side and a 5 X 8-mm or 5 X 10-mm ID oval cannula on the opposite side. The skin entry point is selected approximately 10 cm from the midline. In obese individuals with abundant subcutaneous adipose tissue, further lateralization of the skin entry site may be necessary. In contrast to arthroscopic fragmentectomy, the tip of the inserted instruments may be placed at the mid or lateral pedicular line, as is observed in anteroposterior fluoroscopic studies.

Annular fenestration is achieved either with a 5-mm trephine or with the aid of a working channel scope. While the 5-mm trephine is fully inserted into the intervertebral disc, the universal access cannula is forced into the annular fenestration for a distance of 5 to 10 mm (Fig. 2) and secured in this position by the cannula stopper on the skin surface. At this time, manual arthroscopic discectomy forceps, trimmer blades, and suction-punch forceps are used, and the nuclear tissue is evacuated.

Nucleotomy and Decortication of the Vertebral Plates

Prior to decortication of the vertebral plates, a meticulous nucleotomy is performed with the aid of large cup forceps and trimmer blades (Fig. 10A). Although in the past a laser (Fig. 10B) was used for nucleotomy under arthroscopic visualization, in recent years a radiofrequency coagulator (Fig. 10C) has been used for removal of fine nuclear debris because it is more cost effective and easier to use. The oval cannula permits the insertion of an angled tip curette (Fig. 10D) and specially designed reamers for access and decortication of the concave surface of the vertebral plates (Fig. 10E). When the decorticator is inserted into the oval cannula and turned to a vertical position, the blades extend behind the boundary of the oval cannula.

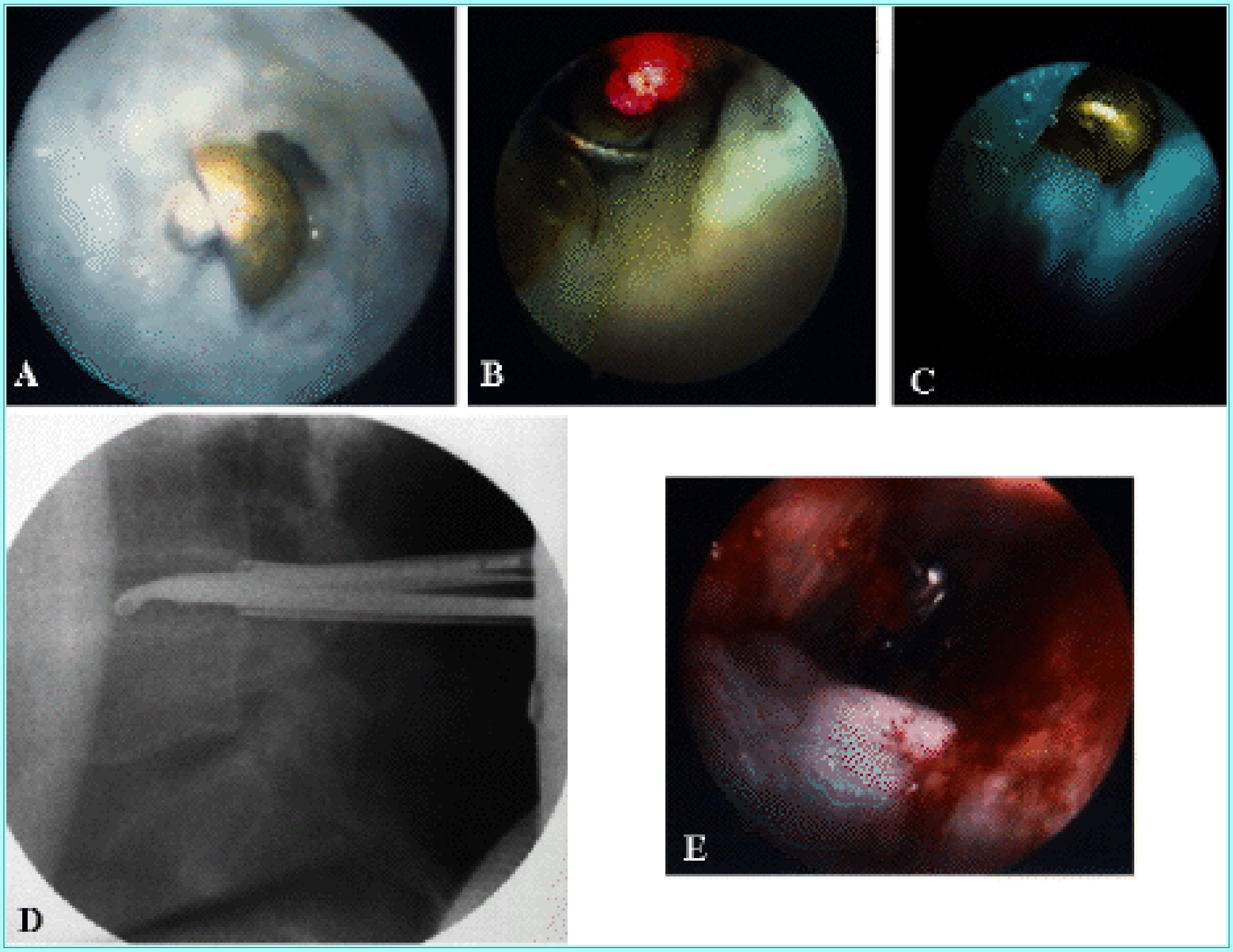

Fig. 10. A: Intradiscal view of a trimmer blade which is being used for nucleotomy. B: Under arthroscopic visualization, the laser is being used for nuclear ablation in preparation for arthrodesis. C: A radio-frequency probe is being used for removal of soft nuclear tissue.

D: Intraoperative lateral fluoroscopy showing a curved tip curette inserted into the intervertebral disc via an oval cannula at L4-5 for decortication of the vertebral plate. E: Arthroscopic view of partially decorticated vertebral plates. Part of the nuclear and annular tissue is seen in the left.

Nucleotomy and decortication must be performed under arthroscopic control by using a biportal approach. Usually the arthroscope is inserted through the 5 X 5-mm ID cannula while the decorticators are introduced through the oval cannula that has been positioned on the patient's opposite side. Bleeding from the partially decorticated plates may obscure ample arthroscopic visualization, but this may be controlled by increasing the inflow pressure of the saline solution while closing the outflow valve.

Bone Grafting

An ample amount of corticocancellous bone is removed from the ileum and the posterior superior iliac spine of the patient through a separate, 3-cm skin incision. The removal of autogenous bone from the external table of the ileum reduces postoperative morbidity at the donor site. Bone grafts are inserted through the cannulas and packed between the vertebral plates of the adjacent segments.

Insertion of the Guide Pins

The proper positioning of pedicular bolts in the pedicle is best accomplished by insertion of a guide pin in the medullary canal of the pedicle under fluoroscopic control.

When a bull's-eye technique for the insertion of a guide pin is being used, the guide pin is held with a specially designed jig, or a long instrument, and is moved about until the entire length of the pin is visualized as a dot (bull's eye) at the center of the pedicle. The guide pin is the hammered into the medullary canal of the pedicle. In our opinion, however, the bull's-eye technique is not always accurate or reliable for proper positioning of the guide pin in the center of the pedicle. The appropriate angle for the insertion of the guide pin and the distance of the skin entry point from the midline may be predetermined by examination of preoperative axial computerized tomography studies of the vertebrae adjacent to the surgical site (Fig. 11).

Fig. 11. Preoperative actual measurement of the axial computerized tomography (CT) scan in preparation of percutaneous pedicular fixation. (Note that the skin surface was included in the CT scan.) The proper angle for insertion of guide pin measured 26š. The skin entry point was 5 cm from the midline.

In anteroposterior intraoperative fluoroscopy, the tip of the guide pin should be seen adjacent to the lateral pedicular line. While in the lateral projection, the pin is observed in the middle of the pedicle and parallel to the proximal plate of the vertebrae (unpublished data) (Fig. 12).

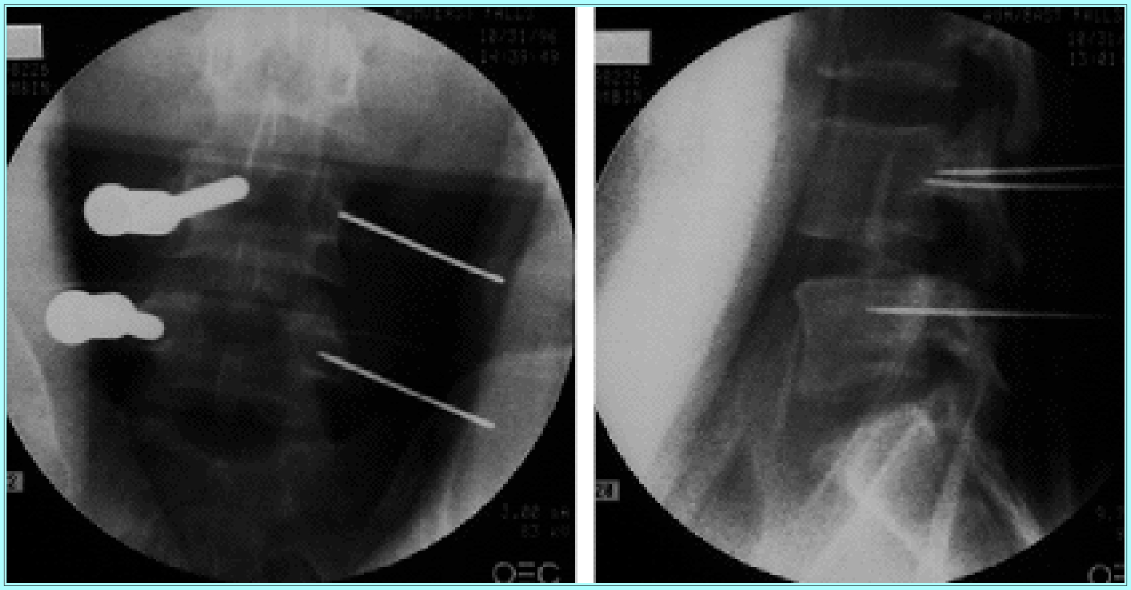

Fig. 12. Left: Intraoperative anteroposterior fluoroscopic examination. Note a satisfactory positioning of the guide pin adjacent to the lateral boundary of the pedicle of L-4 on the right side. The pedicular bolts on the left side are passed through the pedicular cannulas and fully inserted into the pedicle and body of L-4 while it is partially inserted at the L-5 level. Right: Lateral intraoperative fluoroscopy demonstrating satisfactory positioning of the guide pin in the pedicle of L-5 and unsatisfactory positioning of a distal guide pin in the pedicle of L-4.

Positioning of the Pedicular Cannulas

A longitudinal skin incision is made between the guide pins that have been inserted into the pedicles above and below the fusion site. Two small separate incisions are then made in the thoracolumbar fascia to permit the passage of a 9.8-mm OD cannulated obturator, which is then placed over the guide pin and passed through the paravertebral muscles until it reaches the pedicle. At this time, the pedicular cannula (10 mm ID) is introduced over the cannulated obturator, and the obturator is then withdrawn (Fig. 13).

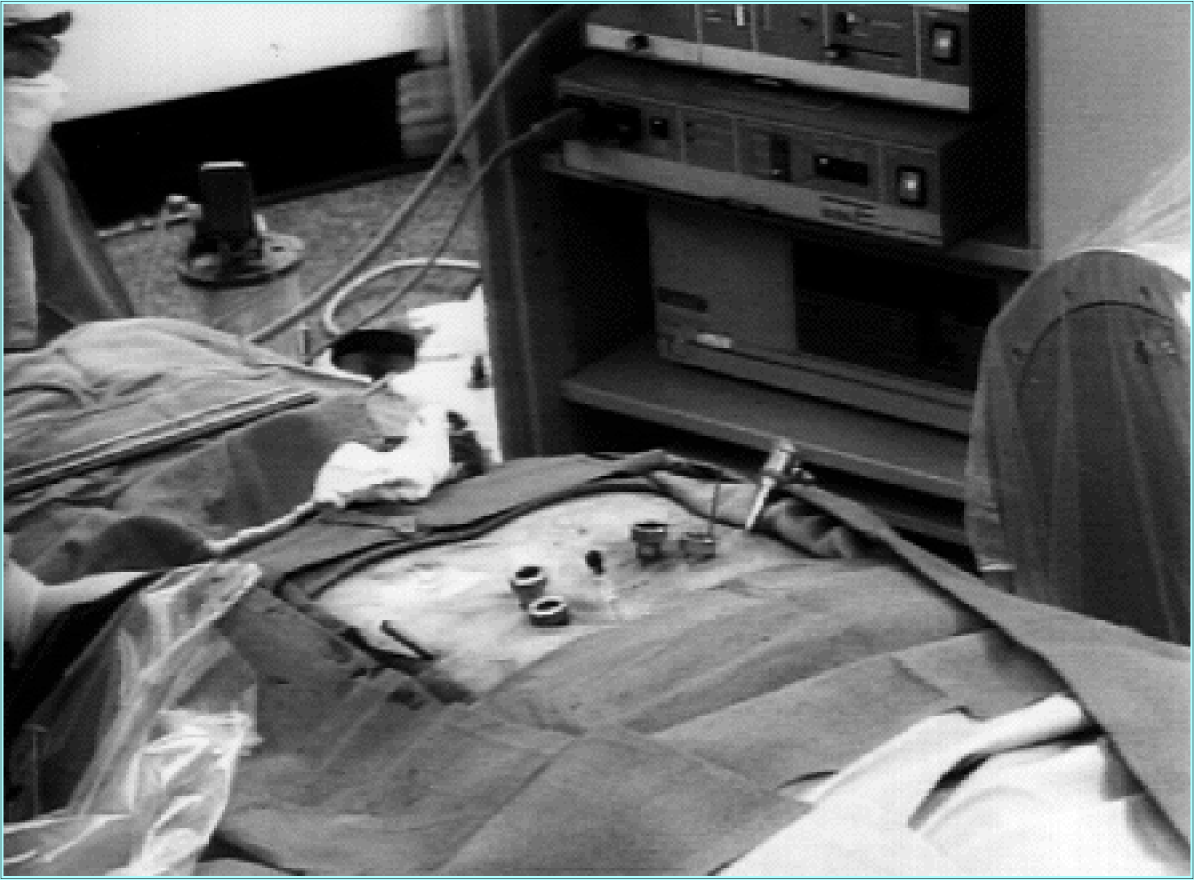

Fig. 13. Photograph showing positioning of four pedicular cannulas on L4-5 pedicles. Two cannulas are inserted lateral to the pedicular cannulas for discectomy and decortication of vertebral plates in preparation of introduction of bone grafts.

Insertion of the Pedicular Bolts

Prior to the insertion of pedicular bolts, the medullary canals of the pedicles are tapped with a cannulated bone tap that is placed over the previously inserted guide pin. Withdrawal of the bone tap and guide pin permits examination of the medullary canal of the pedicle with a flexible sound to ensure the integrity of the pedicular cortex. At this time, a pedicular bolt appropriate in length and diameter is selected and inserted into the pedicles and vertebral bodies adjacent to the fusion site. Most of the pedicles of the L4-5 segments are capable of accepting a 7-mm OD pedicular bolt.

Insertion of Extension Bars and Subcutaneous Plates

Extension bars appropriate in length are selected and screwed clockwise into the proximal end of the previously inserted pedicular bolts. A specially designed wrench is used to stabilize the pedicular bolts while the extension bars are being tightened. This step is then followed by positioning of a prebent plate over the thoracolumbar fascia and its attachment to the extension bars via appropriate washers and nuts (Fig. 14).

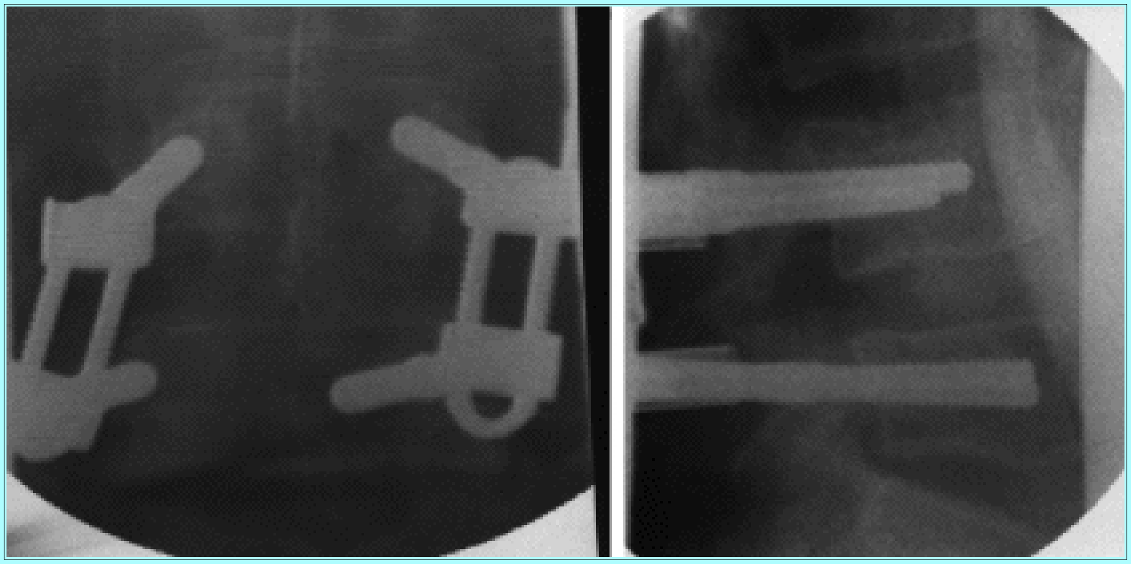

Fig. 14. Postoperative x-ray film, anteroposterior view (upper), demonstrating the satisfactory positioning of the pedicular bolts and subcutaneous plates and lateral view (lower) showing interbody bone grafts.

Perioperative Management

Before surgery the patient should be informed in detail about the nature of the operative procedure, potential complications, expected length of hospital stay, and plans for postoperative rehabilitation. All of our patients received pre- and postoperative prophylactic antibiotic therapy. They are permitted to become ambulatory on the day of their surgical procedure. A lumbosacral corset is used for approximately 8 weeks postoperatively to provide abdominal support and comfort. Swimming exercises and aquatherapy are usually initiated 6 to 8 weeks postoperatively. This regimen is then followed by a more structured isokinetic exercise program.

CONCLUSIONS

Arthroscopic stabilization of lumbar motion segments via interbody arthrodesis offers an alternative method for fusing spinal units. Among the accepted methods of lumbar fusion, posterolateral arthroscopic interbody fusion stands alone by minimizing injury to myoligamentous structures and by excluding entry into the spinal canal or the abdominal cavity. At the present time, posterolateral arthroscopic interbody fusion is undergoing a feasibility study by the Food and Drug Administration and the Internal Review Board of Allegheny University Hospitals, MCP Hahnemann School of Medicine.

Twenty-two patients have undergone arthroscopic interbody fusion and percutaneous insertion of the hardware in our institution. Fracture of the pedicle and dislodgment of one of the pedicular bolts took place in one patient 2 weeks postoperatively. The pedicular bolt was subsequently extracted with no sequelae.

We have been able to demonstrate clinical, radiographic, and computerized tomography evidence of stabilization in the remainder of our patients (Fig. 15). The inserted pedicular bolts and subcutaneous plates were extracted an average of seven months following the initial surgical procedure. Patients tolerated the subcutaneous plates well, and we have not encountered skin breakage, infection, instrument failure, or neurovascular complications.

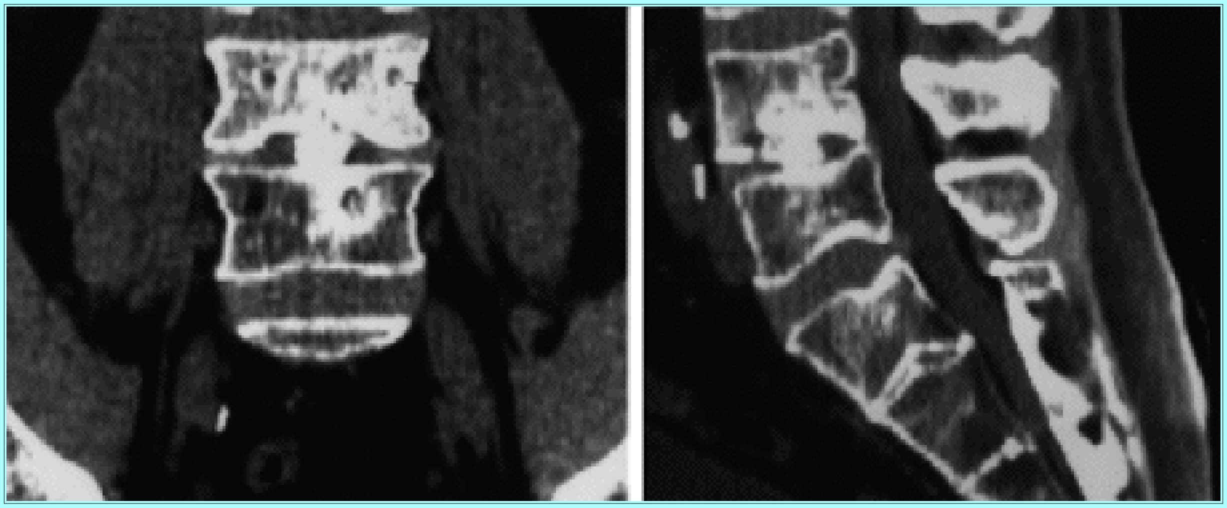

Fig. 15. Left: One-year postoperative anteroposterior computerized tomography reconstruction showing the extension of the bony trabeculae of the graft into the vertebral bodies of the adjacent segments. Right: Sagittal computerized tomography reconstruction showing a similar finding.

Future availability of osteoinductive bone proteins and current experiences with application of frameless stereotaxy in spinal surgery will improve the current rate of development of arthrodesis and will simplify our present practice of percutaneous positioning of instruments. Although the preliminary data on minimally invasive arthroscopic stabilization of the anterior column appear to be encouraging, a multicenter study with a larger patient population will provide us with more information on this interesting subject.

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