The usefulness of endoscopy is well established in peripheral joints, general, urological, thoracic, and gynecological surgery. The successful implementation of endoscopic techniques has resulted in significant reductions in cost, length of hospital stay, patient suffering, and cosmesis. The main advantages of minimally invasive techniques include the following:

1. Avoidance of epidural bleeding and perineural fibrosis.
2. Elimination of rehemiation in spinal canal through surgically induced annular fenestration.
3. Preservation of spinal stability due to lack of bony resection.
4. Establishment of a portal away from neural elements for future herniations.
5. Cost effectiveness.
6. Does not compromise future surgery should it be necessary.
7. Cosmesis.
8. Diminished postoperative discomfort.

ENDOSCOPIC ANTERIOR LUMBAR SPINE SURGERY

Rationale and Historical Perspective

Relief of both back and leg pain through anterior fenestration of the annulus was first described by Hult in 1951. He postulated that pressure of a damaged disc could be diverted anteriorly rather than transmitted posteriorly by anterolateral annulotomy via an open retroperitoneal approach. In 1991, Obenchain reported the first laparoscopic lumbar discectomy. Together with Cloyd, he subsequently reported the first series of 21 laparoscopic lumbar disectomies in 1994. Slotman and Stein described a midline laparoscopic approach for discectomy in 1994. The same year, at the ninth annual North American Spine Society meeting, Matthews and others reported on laparoscopic lumbar fusions using anteriorly placed fusion cages.

Anatomy and Technique

Following routine mechanical large bowel preparation to evacuate the sigmoid colon and aid in the exposure of the lumbosacral spine, the patient is placed in the supine position and general anesthesia is induced. A nasogastric tube and Foley catheter are then placed, as well as any additional cardiovascular monitors. The lumbar spine is extended over a roll placed under the lumbar region. The entire abdomen is then prepped and draped in the usual fashion (Fig. 17-1). The insufflator needle is inserted through a 2-mm incision at the umbilicus. The abdominal cavity is insufflated to a pressure of approximately 15 mm of Hg. The endoscope portal is then established 5 to 10 cm cephalad to the umbilicus in the midline and the abdomen is inspected. The patient is placed in Trendelenburg to allow the bowel to fall out of the pelvis and lower abdomen (Fig. 17-2). Two 10-mm working portals are then established under direct visualization just lateral to the epigastric vessels, opposite the level or levels to be removed (and/or fused). Retractors are inserted and employed to sweep the small bowel cephalad out of the pelvis. The sigmoid colon is swept laterally and held with a fan-type retractor.

At L5-S1, the promontory is readily visualized and the posterior peritoneum overlying the disc space is longitudinally incised with endoshears. The anterior annulus is exposed by blunt dissection of the soft tissue underlying the posterior peritoneum. Fan retractors and the Kimer dissector are used (Fig. 17-3). The sacral artery and vein course directly over the mid-portion of the field. They are hemoclipped and transected. The left fan retractor remains in place holding back the colon, while the right one is replaced by a suction irrigator. Throughout, the lumbar sympathetics are protected by avoidance of dissection anterior to the left common iliac vein and artery and minimization of cauterezation (Fig. 17-4).

At L4-5, the parietal peritoneum is longitudinally incised approximately 4 cm cephalad to the sacral
promontory; at this level the iliac vessel bifurcation is exposed by gentle blunt dissection on its anterior aspect. This usually marks the level of the L4–L5 disc. The left common iliac vein and artery are gently retracted to the right after left lateral dissection. Next, the left ascending segmental vein branch at L5 is identified and ligated to mobilize the vessels over the L4–5 disc space to the right (Figs. 17–4, 17–5, 17–6, 17–7).

With the disc space exposed, a skin incision is placed so the operating trocar will be parallel to the end plates. This is performed with the aid of the lateral fluoroscope and a Steinmann pin. With the operating trocar in the proper position, one may use either a 12 or 18 mm trocar (Ethicon), curettes and pituitary rongeurs, or a Nucleo-tome® (Surgical Dynamics) to remove the central disk material (Figs. 17–8, 17–9). The interspace is then prepared for fusion by cutting of the end plates with Crock-type circular gouges (available from Shelton-Thompson). The interspace should be hyperextended at this point to help lock in the bone plugs or fusion cages (Fig. 17–10). The Crock cookiecutter gouge is placed on the anterior surface of the vertebral bodies and the alignment is verified with the fluoroscope to assure equal cuts in the adjacent end plates.

We carry out instrumented laparoscopic anterior interbody fusions with the BAK fusion cage by Spinetech. Preoperative X rays are used to estimate implant size. The BAK system has a starting point localizer with unipolar cautery to assure proper spacing of the cages (Fig. 17–11). The Spinetech trocars are made to fit the implant system. These are then used for final preparation of the interspace. The Spinetech reamer is then employed to fashion two circular holes of the proper depth, parallel to each other, and separated by approximately 4 mm of space between them. A temporary spacer is used to stabilize the interspace while the BAK cage is inserted under direct endoscopic visualization, with fluoroscopic verification of depth (Figs. 17–12, 17–13, 17–14, 17–15). The spacer is then removed and the second cage is placed in similar fashion. The bone impactor tube is filled with bone graft and each anterior cage chamber with morselized graft (Figs. 17–16, 17–17). The ideal position of the cages is demonstrated in Figures 17–18a,b.
Following completion of the discectomy and fusion, the Trendelenburg position is then reduced, and the abdominal cavity is thoroughly inspected for bleeding under lower abdominal pressure. Finally, the retroperitoneum and skin incisions are closed (Figs. 17–19, 17–20). Ambulation in a body jacket is begun when tolerated. Plain AP and lateral and lateral flexion-extension X rays are performed at follow-up visits to evaluate fusion status.\(^{28,47}\) (Figs. 17–21a,b).

**Applied Physiology and Complications**

The two most important areas of applied physiology that can potentially lead to laparoscopic complications are cardiovascular and pulmonary. The cardiovascular complications include tension pneumoperitoneum, cardiac dysrhythmia, venous stasis/thrombosis, hypothermia, and cerebral ischemia or edema. Additionally, the pulmonary complications are usually insufflation related and include hypercapnia, acute respiratory insufficiency, hypoxia, acidosis, extraperitoneal gas, gas embolism, and explosion.\(^{20}\) The urologic and gynecologic literature is replete with reviews and surveys reporting the rates of laparoscopic complications of 0.6 to 2.4%, with mortality rates in the range of 0.004 to 0.18%.\(^{22–24}\) Some one-third of these complications are physiological in nature.

The cardiovascular system must deal with the mechanical effects of pneumoperitoneum, the hemodynamic stimulation of absorbed carbon dioxide, and the volume shifts brought about by positioning. Increases in central
venous pressure and venous resistance are counteracted by a stimulatory effect of carbon dioxide resulting in a net minimally altered cardiac preload at, or below, the recommended intra-abdominal pressure limit of 15 to 20 mm Hg. Analysis of cardiac performance shows an increased heart rate offsetting a slightly decreased stroke volume yielding a minimally altered cardiac output. Finally, arterial pressure and arterial resistance are increased during laparoscopy, resulting in an increased afterload.

Although healthy individuals easily tolerate the somewhat hyperdynamic state induced by laparoscopy, one must exercise caution when performing surgery on those with cardiac disease. In particular, some have considered cardiomyopathy, untreated congestive heart failure, and moderate to severe ischemic heart disease as contraindications to laparoscopic procedures. Once the intra-abdominal pressure exceeds 40 mm Hg, the compensatory mechanisms begin to fail. Blood flow becomes much more severely restricted and positional influences much more significant. "Tension pneumoperitoneum" results in precipitous drops in venous return, cardiac output, and blood pressure. Cardiac dysrhythmias have been linked to hypercapnia and vagal stimulation secondary to peritoneal irritation. Increased intra-abdominal pressures can also lead to venous stasis through restriction of venous return.

Carbon dioxide is the most commonly used insufflant in laparoscopy. It is, however, also absorbed by the tis-
sues of the peritoneum. The absorption of carbon dioxide causes a mild respiratory acidosis. Additionally, increased intra-abdominal pressure restricts diaphragmatic motion and respiratory capacity. In healthy individuals, the increased levels of arterial carbon dioxide are easily managed by increased ventilation. This may not be possible in patients with underlying pulmonary disease.

Mild hypercapnia has a stimulatory effect; however, once arterial levels exceed 60 mm Hg, direct cardiac depression results. Further, extraperitoneal gas may dissect along tissue planes and blood vessels into the pleural space, mediastinum, pericardium, or retroperitoneum.

Venous gas embolism results from direct injection of gas into the venous system during insufflation and can be
fatal. Intra-abdominal explosion has rarely been reported during the use of both oxygen and nitrous oxide for insufflation.

In a recent prospective, multicenter study, McAfee et al. reported two bone-graft donor site infections and one left common iliac vein injury as the only complications in a series of 22 laparoscopic-instrumented fusion procedures. There were no reported complications from pneumoperitoneum or CO insufflation. The senior author's experience has included one patient who required a subsequent posterior decompression for a displaced end plate fracture behind the cage. It should be noted that each of these complications occurred very early in the clinical series, when our technique was still being refined. We have not experienced any of these, or other problems recently.

Finally, although the application of laparoscopic surgical techniques is exciting, it is not without its own physiological burdens. Knowledge and awareness of the underlying pathophysiology of laparoscopy aid in the prevention, diagnosis, and treatment of its complications. The procedure is extremely demanding and requires reliance on elaborate, sophisticated equipment. Familiarity with
Figure 17-13. Interbody cage placement.

Figure 17-14. Reaming carried out with distraction spacer in place.
the open counterpart of this procedure, ability to manage vascular injuries, and thorough facility with the retroperitoneal and visceral anatomy are absolute prerequisites.  

**Pitfalls**

Although the technique seems straightforward, subtleties can cause more problems than open disectomies and fusions. We hope our adventures will minimize yours.

There is no good reason to place the implants or grafts flush with the posterior vertebral border. In some cases, this may lead to posterior disc material being disclosed through the annulus into the spinal canal, fracture of the posterior vertebral cortex and/or end plate, or reaming the spinal canal. At the L5-S1 level with a large lordosis, the safety mechanisms to keep the implants and reamers from reaching the spinal canal can be overcome by the operating trocar overhanging the sacral
promontory and approximating the spinal canal. All such mishaps can be avoided by insisting on clear, nonoblique c-arm images and frequent checking during reaming (Figure 17-22). Preoperative planning for expected implant length will also be helpful. The height of the implant required may vary from your preoperative X-ray assessment depending on disc elasticity, but the length usually will not.

The trajectory of approach of the operating trocar to the interspace should be perfectly aligned—both centered to the two end plates and parallel to them. Mark your incision sites on the skin with the c-arm prior to draping. When reaming, hold the operating trocar steadily after checking the trajectory with the c-arm; wobbling will cause too big a hole and encourage implant migration. Make sure to hold the operating trocar by the inner sleeve, which is above the outer sleeve. Make sure the trocar hasn’t migrated off the original site by observing it frequently with the laparoscope during reaming.

If you are using the Spinetech instrumentation, remember that the centering system presumes that the anterior threshold to the disc is in line with the posterior disc, as is usually the case. However, in cases with anterior osteophytes or marked end plate irregularities, the anterior disc may not be ideally in line with most of the posterior disc. In these cases, be prepared to free-hand the placement of the operating trocar, letting the c-arm lateral guide you. At present, this is very difficult because the teeth are not long enough to securely engage the anterior vertebra and the trocar tends to slip off its position during the torque produced from the initial
reaming. The soon-to-be-released improved version will make this somewhat easier because of longer tooth design. If you run into this situation, watch the trocar closely with the laparoscope to make sure it does not slip when starting your reaming. If your implant went too deep and lateral stenosis resulted, decompress posteriorly and use a flathead screwdriver to drive the implant anteriorly. The CT scan was better, in our experience, than MRI in judging implant encroachment on the spinal canal. Thoroughly evacuate the nucleus prior to reaming to prevent tissue being driven posteriorly to the spinal canal. For the laparoscopic fusions, position the spine in the amount of lordosis you want the spine to end up in. If trocar sites leak, identify them by water test and use Vaseline gauze to improve the seal. Fortunately, we have only had one retrograde ejaculation in the 15 males we have done fusions on so far. This was the first one, an L5-S1 level case, and it resolved in a couple of weeks. We soon switched to bipolar coagulation in males and try to use little or no coagulation at all in the region of the sympathetics. The exposure over the disc for a discectomy is very small—a square centimeter—and we were very attentive not to disturb the sympathetics. On the other hand, the anterior and retroperitoneal dissection is extensive for fusions, yet we have only seen the case mentioned. It appears to us that there must be great individual differences in susceptibility to retrograde ejaculation. Consequently, all males must be fully informed of this potential outcome because it may not be preventable by surgical technique.

Thrombophlebitis is always a potential occurrence in anterior spinal surgery. We have had one case in thirty-two at this time. TED hose and dynamic compression boots should be used during this procedure and continued until ambulation is frequent. Intraoperatively at the levels above L5-S1, retraction of the vena cava and hypogastric vein should be attended to and periodic release performed. Close the abdominal wall fascia to prevent hernias.

ENDOSCOPIC POSTERIOR LUMBAR SPINE SURGERY

Historical Perspective

In 1951, Hult demonstrated the indirect reduction of intradiscal pressure by anterior annular fenestration via a retroperitoneal approach. A decade later, Smith introduced percutaneous enzymatic dissolution of intervertebral discs with chymopapain. These two seminal events led to the development by such pioneers as
Hijikata, Kambin, and Onik of percutaneous and endoscopic posterior approach techniques for lumbar disc removal.

Hijikata et al. reported on percutaneous nucleotomy and decompression of disc herniation in 1975. Kambin et al. followed with development of the posterolateral approach and instrumentation allowing removal of disc material with the aid of high negative pressure. These approaches led to the development of the nucleotome and automated disc removal. Subsequently, Kambin's group reported a

Figure 17-21. Example of cage placement pitfall secondary to slightly oblique X-ray beam.
Endoscopy of the Central and Peripheral Nervous System

Figure 17-22. The “triangular safe zone.”

reliable, safe, and effective endoscopic posterolateral approach.5

**Rationale**

Success of these techniques hinges on three principles: evacuation, reduction and decompression.6 Removal of the nuclear fragments with the manual instruments accomplishes evacuation. Reduction is carried out by the addition of suction that establishes a negative pressure in the center of the disc capable of drawing some loose fragments into the path of the instruments. This is also aided by the introduction of flexible pituitary rongeurs capable of grasping a wider area within the nucleus. Decompression is accomplished by annular fenestration away from the spinal canal. Rapid decline in in vivo intradiscal pressure has been demonstrated with this technique.6

When the criteria in Tables 17-1 and 17-2 are considered and adhered to, one can reasonably expect good to excellent results in approximately 90% at L3-4, approximately 90% at L4-5, and approximately 50% at L5-S1.

**Anatomy and Technique**

Anatomically, the sympathetic fibers in the lumbar spine run ventral to the vertebral bodies and thus out of the path of the posterolaterally introduced instruments. The iliac vessels are also anterior to the bodies. The annulus at the site of fenestration is covered only by fibers of the psoas. The spinal nerve is separated from the annulus by a thin layer of fat and fibers of the psoas. The nerve courses anteriorly and caudally after leaving the foramen. It sits anterior to the transverse processes.

The so-called “triangular working zone” is defined as the extrapedicular space allowing safe passage of instruments with the spinal nerve as the anterior boundary, the proximal end plate of the caudal lumbar segment as the inferior boundary, and the superior articular process of the caudal vertebrae as the posterior boundary (Figure 17-23).

If one follows the course of posterolaterally introduced instruments, inserted approximately 9 to 10 cm lateral of midline, parallel with the disc space, the nerve is largely covered (and thus protected) by the zygoaphyseal joints, pedicles, and transverse processes.6

A small portion between the foramen and the superior border of the transverse process is vulnerable to penetration; however, this is generally avoided by three techniques. First, through the use of a blunt end trocar, which tends to push the root aside rather than piercing it. Second, through insertion parallel to the disc space. Kambin and Brager6 have shown increased chance of entrance into the neuroforamen when the instruments are angled caudally. Lastly, the endoscope allows direct inspection of the annular fibers immediately prior to use of the fenestrator.

Prophylactic antibiotics are recommended. The patient may be positioned either in the prone or lateral decubitus positions on a radiolucent table. A fluoroscope is positioned perpendicular to the long axis of the spine, allowing perfect anterior-posterior and lateral projections of the disc space under investigation. Anesthesia consists of local skin infiltration superficial to the lumbodorsal fascia, occasionally supplemented by small amounts of short-acting narcotics. It is vitally important that the patient not be overly narcotized, as

**Table 17-1. Inclusion Criteria for Endoscopic Posterolateral Disectomy**

<table>
<thead>
<tr>
<th>Criteria</th>
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<tr>
<td>Unremitting persistent radiculopathy at L3-4, L4-5, or L5-S1</td>
</tr>
<tr>
<td>Failure of appropriate conservative therapy</td>
</tr>
<tr>
<td>Neurologic impairment such as: sensory deficits, deep tendon reflex abnormalities, and motor weakness</td>
</tr>
<tr>
<td>Correlative EMG in absence of correlative neuro deficits</td>
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<tr>
<td>Positive tension signs</td>
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<tr>
<td>Correlative imaging studies (i.e., CT/myelogram/MRI)</td>
</tr>
<tr>
<td>Subligamentous herniated nucleus pulposes</td>
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</tbody>
</table>

Source: Kambin6-19

**Table 17-2. Exclusion Criteria for Endoscopic Posterolateral Disectomy**

<table>
<thead>
<tr>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequestered discs</td>
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<tr>
<td>Bony lateral recess stenosis</td>
</tr>
<tr>
<td>Spinal stenosis</td>
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<tr>
<td>Pedicle induced nerve root kinking</td>
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<tr>
<td>Developmental anomalies or tumors</td>
</tr>
<tr>
<td>Rehemiations following open procedures or chemonucleolysis</td>
</tr>
<tr>
<td>Spondylolisthesis</td>
</tr>
<tr>
<td>Cauda equina syndrome</td>
</tr>
</tbody>
</table>

Source: Kambin10
patient–surgeon communication during the procedure is absolutely essential.

Under fluoroscopic guidance, an 18-gauge needle is introduced into the center of the disc space obliquely, in a posterolateral to anteromedial direction beginning approximately 10 cm lateral to the midline. Preoperative abdominal CT scan through the disc space allows more precise judgment of angle of the approach and avoidance of intraperitoneal puncture (Figure 17-24). Discograms are then carried out at the symptomatic level(s) and at least one asymptomatic level (internal control) to confirm the concordant nature of the pain.

The next steps vary somewhat depending on which endoscopic system one is using, but basically consist of enlarging the needlestick to a puncture large enough to accommodate the trocar. This is accomplished by passing dilators over the guide wire under careful fluoroscopic control. Next, the endoscope is inserted, verifying the position of the trocar within the triangular working zone, as well as visualization of the outer annulus (Figure 17-25 and
Figure 17–25. Endoscopic visualization of annular fenestration.

17–26). The working channel of the scope is then used to gain entrance to the nucleus through annular fenestration⁶–¹⁰ (Figure 17–27).

Alternatively, if a working channel scope is not being employed, the endoscope can be carefully exchanged for manual or automated instruments (i.e., the Nucleotome®, Surgical Dynamics or the intradiscal shaver, Sofamor-Danek), which then carry out the removal of disc material under fluoroscopic guidance with intermittent endoscopic visualization. Surgical Dynamics has recently introduced a flexible probe (the Endoflex) that provides visualization, aspiration, and cutting capabilities through a single portal (Figure 17–28).

Posterior endoscopic lumbar discectomy is efficient, cost effective, and safe. Hospitalization and recovery time seem to be decreased. The surgeon must be always cognizant of the strict indications and contraindications, as well as exacting surgical technique so that they can experience favorable surgical outcomes and minimize potential complications.

Figure 17–26. Endoscopic visualization of Nucleotome.
REFERENCES