Evolving Transforaminal Endoscopic Microdecompression for Herniated Lumbar Discs and Spinal Stenosis

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ABSTRACT

The objective of this chapter was to demonstrate evolving transforaminal endoscopic microdecompression for herniated lumbar discs and spinal stenosis, and to become accomplished with endoscopic micro spinal instruments and laser application. Since 1993, 2000 patients with 3421 herniated lumbar discs were diagnosed with symptomatic lumbar single and multiple herniated intervertebral discs. Progressive series of different diameters endoscopic-assisted tubular retractors, with appropriate-sized dilators and more aggressive saw-toothed trephines, and laser were used to perform transforaminal endoscopic microdecompression, in addition to the posterior-lateral foraminoscope and endoscopic-assisted spinal operating systems. No postoperative mortalities occurred, and the morbidity rate was less than 1%, in the 2000 patients. For a single level, 94% of the patients had good or excellent results; 6% had some residual symptoms although improved overall. Transforaminal endoscopic laser microdecompression can effectively decompress herniated lumbar discs and spinal stenosis, when foraminoplasty is performed, which provides a safe and effective modality to achieve results in effective spinal decompression, preserves spinal motion, and creates a channel for spinal arthroplasty.
INTRODUCTION

Lumbar stenosis is one of the most common diseases of the spine for patients over the age of 65. Although the pathophysiology of lumbar stenosis is multifactorial with compression of neuro elements, it generally occurs from a combination of degenerative changes, including bulging discs, ligamentum flavum hypertrophy, facet thickening, and arthropathy. The classic wide posterior decompresive laminectomy with foraminotomy involves extensive muscle and soft-tissue dissection for exposure, decompression, and resection of the posterior spinal elements. Despite varying degrees of success, it is associated with significant iatrogenic trauma and failed back syndrome. As a result, the search for a minimally invasive spinal surgery (MISS) began.

With accumulated experience with endoscopically assisted mechanical and laser lumbar discectomy, the need for a method to more effectively decompress the lateral recess and intervertebral neural foramen from very large or extruded disc protrusions, recurrent discs, scar tissue, and spondylitic spurs became evident. The most frequently seen lumbar spinal disc disease in the elderly is spinal and lateral foraminal stenosis. Lateral stenosis may be congenital or degenerative when secondary to acute disc disease and spinal trauma. This article describes the surgical techniques of evolving transformal endoscopic microdecompression for herniated lumbar discs and spinal stenosis, and a minimally invasive transformal microdecompressive endoscopic-assisted discectomy and foraminoplasty (TF-MEAD), a new system of more aggressive mechanical instruments and laser application, developed at the California Center for Minimally Invasive Spine Surgery (C-MISS).


Currently, attention is being directed toward treatment of epidural scarring, lateral recess, foraminal stenosis, and advanced degenerative changes often bilateral and occur at multiple levels. The author has developed a more aggressive TF-MEAD system to address endoscopic transformal mechanical and laser microdecompressive discectomy and foraminoplasty in a fast and effective manner for both unilateral single and bilateral multiple levels. These MISS procedures should now be added to the choice of interventions of the spinal surgeon in treating advanced degenerative spinal stenosis and lateral foraminal stenosis.

Such procedures require the surgeon to be knowledgeable and competent in MISS, with thorough knowledge of the procedure of endoscopic lumbar discectomy and foraminoplasty, patho-anatomy of the neuro-foramen and spine, relationships of the lumbar exiting and traversing nerve roots, dorsal root ganglion, the facet joint, disc, and vertebrae.

INDICATIONS

Endoscopic lumbar foraminoplasty is indicated in the following clinical situations.
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Figure 2. Steerable Spinoscope system, C-MISS TF-MEAD system, and foraminoScope for treatment of disc herniation and foraminal stenosis. (A) Spinoscope surgical application for TF-MEAD. (B) Steerable Spinoscope and cannula set for laser application and with flexible tip (Karl Storz Endoscopy America, Inc., Culver City, CA). (C) Posterolateral foraminoScope with wide angle 6-degree 3-mm w.c. operating foraminoScope (Karl Storz Endoscopy America, Inc., Culver City, CA). (D) C-MISS TF-MEAD system with a working channel 9.9 mm assisted by endoscopes (0 and 30 degrees, 4-mm OD). (E) Lumbar foraminoPlasty with C-MISS TF-MEAD system in surgical application.

- Intractable low back pain with radiation down the leg (radicular pain).
- Symptoms of spinal neurogenic claudication.
- Compressive and irritative radiculopathy with sensorimotor impairment.
- Disc extrusion or sequestration with predominantly back or leg pain.
- Degeneration and settlement of the spine with predominantly back, buttock, or leg pain.
- Non-radicular low back pain persisting despite facet joint injection.
- Lateral recess stenosis with dynamic compressive or non-compressive radiculopathy.
- Prior failed conventional surgery with perineural scarring and failed back syndrome.
- No improvement of symptoms after a minimum of 12 weeks of conservative therapy.
- Spondylolytic spondylolisthesis.
- Diagnostic imaging, MRI, CT, CT 3D, CT Myelogram, that demonstrate disc herniation, extrusion, or both, or lateral recess stenosis.
- Positive pre- or intraoperative discogram and pain provocation test.
- Positive electromyography is considered helpful.
- Multiple lumbar discs/levels can be treated at one sitting with TF-MEAD.

CONTRAINDICATIONS

The endoscopic lumbar foraminoPlasty procedure is contraindicated in the following clinical situations:

- Cauda equina syndrome.
- Painless motor deficit.
- Tumors.
- Clinical findings that suggest pathology other than degenerative discogenic disease.

INSTRUMENTS AND PREPARATIONS

These surgical instruments are necessary to perform endoscopic laser, lumbar foraminoPlasty, or both:

- Digital fluoroscopic equipment (C-arm) and monitor.
- Radiolucent C-arm/fluoroscopic carbon-fiber surgical table.
- Endoscopic tower equipped with digital video monitor, DVT/VHS recorder, light source, tri-chip digital camera, and photo printer system.
- Percutaneous fiber optic foraminoScope 0-degree 6-mm OD, 3.9-mm working channel (Karl Storz Endoscopy America, Inc., Culver City, CA) (Fig. 1).
- Wide-angle percutaneous posterolateral foraminoScope 6-degree, operating sheath 6-mm OD, 3-mm working channel (Karl Storz Endoscopy America, Inc., Culver City, CA; see Fig. 1).
- C-MISS TF-MEAD system-instruments (see Fig. 1).
- Set of serial/progressive dilators, and cannula in graduated sizes (3.5-5.8 mm); a set of progressive cannulae with duck bill extensions (with various lengths 5-10 mm on one side) (see Fig. 1).
Anesthesia

The patients are treated in an operating room under local anesthesia and monitored conscious sedation. The Anesthesiologist maintains mild sedation, but the patient is able to respond. Two grams Cefazolin and 8 mg dexamethasone are given intravenously at the start of anesthesia. Surface EEG (SNAP™, Nicolet Biomedical, Madison, WI, USA) monitoring provides added precision of anesthesia.

Localisation

C-arm fluoroscopy is used to identify the lumbar levels relative to the sacrum. The midline, operative levels, and point of entry (operating portal) (Figs. 3 & 4) for surgery are marked on the skin with a marking pen. The distance of the point of entry from the midline varies with the height and weight of the patient, but for an average-size patient is approximately 12 cm at the affected disc level. Positioning of the instruments is checked throughout the procedure by fluoroscopy in two planes (Figs. 5-8) as often as needed. At the involved nerve root distribution, sterile needle electrodes are placed for continuous intraoperative neurophysiological electromyogram (EMG) monitoring.

Patient positioning

For this procedure, if surgery is unilateral the patient is placed in a lateral decubitus position (Fig. 3) with the painful leg up and both hips and knees in moderate flexion. If the patient has an increased medical risk (i.e., pulmonary, cardiac, morbid obesity, and other high-risk medical conditions, but requires a bilateral procedure), the decubitus position may be used first on one side, and then, turning the patient over, on the other side, to perform the bilateral procedure in one sitting. Otherwise, bilateral operations are performed in the prone position on a radiolucent support similar to the Wilson frame. The arms are supported on arm boards over the head. When local anesthesia and mild sedation are used, the extremities, buttocks, and shoulders are secured and restrained from sudden motion with adhesive tape.
If a pain provocation test and discogram were not done preoperatively, they are done at the outset. If the discogram and pain provocation tests are confirmatory, surgery is performed (see Figs. 2, 4, 5, & 7). An 18-gauge stylet is inserted and advanced incrementally under C-arm fluoroscopic guidance in two planes, at a 55- to 60-degree angle from the sagittal plane, targeting toward the center of the disc, through the safety zone, into the desired interspace. All instrumentation is performed under C-arm fluoroscopic control and endoscopy. The usual procedure for MISS is followed. The appropriate size cannula and dilator are passed over the stylet to the annulus.

Under fluoroscopy, the extended side of this cannula is turned to face the nerve root so as to retract and protect it. The cannula retractors have variously shaped extensions like a duck's bill (with various lengths 5-10 mm on one side; see Figs. 1 & 5) to retract and protect the nerve root after the cannula is inserted through the foramen into the epidural space and the extension is oriented properly toward the root. The larger, more aggressively toothed trephines (see Fig. 5) are then inserted and rotated to cut through annulus, disc protrusion, spur, or spondylitic bar. The cannula is large enough to admit a slim punch (rongeur), spinal disc forceps, or pituitary forceps and full-size curettes to aid decompression of the foramen and lateral recess (see Fig. 5). An endoscope can be passed through it instead of the endoscope's sheath to facilitate mechanical and laser decompression, foraminoplasty, and discectomy. The endoscope is useful in TF-MEAD surgery for decompression in the lateral recess and peri-foraminal area. Biting forceps, dissector, and Holmium laser with continuous irrigation are used consecutively to perform intradiscal discectomy; lower-energy, non-ablative laser is applied for shrinking and tightening of the disc (laser thermodiskoplasty).17,18

The decompression area can be enlarged with a larger cannula retractor/trephine set. Usually, a small amount of bleeding can be controlled with cold saline irrigation and rarely requires hemostasis by laser or bi-polar coagulation. Holmium: YAG laser with a side-firing probe or 550-µm Holmium laser bare fiber (see Fig. 1) is used to ablate the disc and shrink and contract the disc, reducing the profile of protrusion and hardening the disc tissue (i.e., laser thermodiskoplasty).17,18 Table 1) Disc removal is aided by a rocking excursion of the cannula in a 25-degree arc, a "fan sweep maneuver."17,19 from side to side, that creates an inverted cone-shaped area of removed disc totaling up
to 50 degrees. Laser thermodiskoplasty also can cause sino-vertebral neurolysis or denervation. The discectome is again used to remove charred debris from use of the laser.

The disc space and neural foramen can be directly visualized and examined by endoscopy to confirm adequate disc decompression and perform further decompression if necessary. If the foramen is compromised, the depth of insertion of the endoscope is adjusted, nerve root again protected by the duck bill extension, and spurs removed with curettes, bone punches (rongeurs), and Kerrison rongeurs that can be passed through the large cannula for decompressive foraminoplasty, or with laser application. Recently, an endoscopically assisted larger 9.9-mm tubular retractor system (see Figs. 1, 2, & 5) was added to facilitate foraminoplasty.

The steerable Spinoscope (Karl Storz Endoscopy America, Inc., Culver City, CA) also can be used to perform intradiscal lumbar laser discectomy and laser foraminoplasty (see Figs. 2, 7, & 9). The Spinoscope is fixed in a holding device, which allows the surgeon to guide and steer precisely a flexible fibrescope and working channel for a laser fiber of 0.6-mm diameter to the pathologic part of the disc and intra- and peri-foraminal tissue. The laser fiber can be advanced or retracted mm by mm inside the disc under direct vision with the fiber optic endoscopic system, within a given distance. Also, the tip of the applicator/laser fiber can be navigated and angulated from 0 degrees to 90 degrees, with fine adjustment, and rotated through 360 degrees in all directions.

After removing all instruments, 0.25% Marcaine is injected intradermally and into the incision and paraspinal muscles along the path of the cannulation to prolong analgesia. A band-aid is applied at the incision sites.

### Table I
Laser Setting for Lumbar Disc-Laser Thermodiskoplasty

<table>
<thead>
<tr>
<th>Laser Energy Used—At 10 Hz—5 Seconds On and 5 Seconds Off for TF-MEAD</th>
<th>Stage</th>
<th>Watts</th>
<th>Joules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbar</td>
<td>First Stage</td>
<td>15</td>
<td>1000</td>
</tr>
<tr>
<td>Lumbar</td>
<td>Second Stage</td>
<td>10</td>
<td>500</td>
</tr>
</tbody>
</table>

**POSTOPERATIVE CARE**

Ambulation begins immediately after recovery, and the patient is usually discharged one hour after surgery. They may shower the following day. Applying an ice pack is helpful. Nonsteroidal anti-inflammatory drugs (NSAIDs) are prescribed, and mild analgesics and muscle relaxants as needed. Patients return to usual activities in ten days to three weeks, provided heavy labor and prolonged sitting are not involved.
OUTCOME

Since 1993, 2000 patients with a total of 3421 herniated lumbar discs (males: 1010, females: 990) underwent endoscopic lumbar discectomy. The average age of the patients with symptomatic lumbar single and multiple herniated intervertebral discs was 44.2 (24-92) years. Each failed at least 12 weeks of conservative care. Postoperative follow up was performed at 6 to 72 (average: 42) months. No postoperative mortalities occurred, and the morbidity rate was less than 1% in the 2000 patients. For single level, 94% of patients had good or excellent results, 6% had some residual symptoms although improved overall, and 3% of patients did not improve significantly. A newly devised, larger, and more aggressive decompressive discectomy instrument set (MEAD) safely and efficaciously allowed wider and more complete removal of large discs (single or multi level) or recurrent disc protrusions, scar tissue, and bony spurs that cause nerve root compression, while protecting the adjacent nerve root.

DISCUSSION

The TF-MEAD, with mechanical and laser application, using more aggressive instruments, allows wider and more complete removal of larger discs and decompressive foraminoplasty at bilateral and multiple levels in one sitting. It has proven to be safe and effective. To become competent and avoid complications, the TF-MEAD or surgeon must have a thorough knowledge of the surgical anatomy and procedures, specific surgical training with hands-on experience in a laboratory, and worked closely with an endoscopic surgeon expert at these procedures throughout the steep surgical learning curve.

ADVANTAGES

Decompression of the lateral recess and foramen is accomplished at a single sitting, and can be at multiple levels, bilaterally, or both, by a procedure having all the following advantages:

- Same-day outpatient procedure.
- Less traumatic, physically and psychologically.
- Small incision and less scarring.
- Zero mortality.
- Minimal blood loss and little or no epidural bleeding.
- No dissection of muscle, bone, ligaments, or manipulation of the dural sac or nerve roots.
- Does not promote further instability of spinal segments or adjacent segment recurrent discs.
- Commonly done under local anesthesia, and no general anesthesia necessary.
- Multiple-level discectomy feasible and
well tolerated.\textsuperscript{27} 
- Least challenging to medically high-risk patients and the obese.
- Exercise programs can begin same day as surgery.
- No significant incidence of infection.
- Direct endoscopic visualization and confirmation of the adequacy of decompression.
- Minimal use of analgesics postoperatively.
- Earlier return to usual activities including work.
- Costs less than conventional lumbar surgery.

\section*{COMPlications AND AvoIDANCE}

A thorough knowledge of the endoscopic lumbar foraminoplasty and discectomy procedures and surgical anatomy of the lumbar spine and intervertebral foramen, careful selection of patients and preoperative surgical planning with appropriate diagnostic evaluations, and meticulous intraoperative techniques facilitate the TF-MEAD procedures and prevent potential complications. All potential complications of open lumbar disc surgery are possible, but are much less frequent\textsuperscript{27,30} in endoscopic lumbar foraminoplasty.

- Inadequate decompression of disc material: Minimized by using multiple modalities and instruments such as forceps, dissector, and laser application to both vaporize tissue and perform thermodiskoplasty (shrinking and hardening the disc with laser energy at a lower level).
- Neural injury: Rare with MISS. Nerve root injury, although possible, can be avoided with the warming provided by continuous intraoperative neuromusculoskeletal monitoring (EMG/NCV)\textsuperscript{5} and direct endoscopic visualization. Operating strictly within the safe zone or triangle minimizes the root’s exposure to injury.

Sym pathetic nerve injury is extremely remote, as the procedure is largely intradiscal or in the foramen. Use of local anesthesia with a verbally responsive patient also provides a further warning system.

- Ganglion (dorsal root) injury: One of the more common complications.
Figure 8. Endoscopic view of lumbar mechanical decompressive foraminoplasty and discectomy. (A) Disc removal with cutter forceps. (B) Disc decompression below the nerve. (C) Curette for osteophytic decompression. (D) Rasp for osteophytic decompression. (E) Bone punch/rongeur for foraminal decompression. (F) Disc and foramen appearance, post foraminoplasty and post discectomy.

Figure 9. Endoscopic views of lumbar laser foraminoplasty, disc decompression, and laser Thermodiskoplasty. (A) After disc defect after decompression, and laser thermodiskoplasty with bare laser fiber. (B) Side fire laser probe in action for disc decompression and foraminoplasty. (C) Lumbar nerve root above the disc after disc decompression and foraminoplasty. (D) Disc before laser thermodiskoplasty. (E) Disc shrinkage after laser thermodiskoplasty.
reported in posterolateral lumbar percutaneous approaches to the foramen is dysesthesia (the incidence of transient dysesthesia has been reported to be as high as 25% transient at one center but usually is less than 2%-3%, and permanent <1%) in the leg on the operated side. Careful technique guided by close endoscopic and C-arm fluoroscopic monitoring and knowledge of the surgical anatomy of the lumbar nerve root, dorsal root ganglion, and foramen minimize this complication.

- Operating on wrong level: A major complication of disc surgery at any level of the spine is operating at the wrong level. Proper use of digital C-arm fluoroscopy for correct anatomic localization avoids operating at the wrong disc level. Routine pain provocation test and discogram provides additional verification of the proper level.

- Infection: Avoided by a careful sterile technique, the much smaller incisional area, absence of prolonged retraction of soft tissues, and by using prophylactic antibiotics I-V intraoperatively.

- Discitis: Prophylactic antibiotics, continuous irrigation of the interspace throughout the procedure, and introduction of instruments through a cannula without contact with the skin tissues help minimize the incidence of infectious discitis.

- Aseptic discitis can be prevented by aiming the laser beam in a "bowtie" fashion to avoid damaging the endplates (at 6 and 12 o'clock).

- Hematoma (subcutaneous and deep): May occur with MISS (reported in the early literature), but is minimized by careful technique, not prescribing anticoagulants, aspirin, or NSAIDs within a week before surgery, doing a basic clotting screening preoperatively, application of gentle digital pressure or placing a full I-V bag over the operative site for the first 5 minutes after surgery, and application of an ice bag thereafter.

- Vascular injuries: They are extremely rare when care is taken to remain within the disc space with stylettes and cannulae. The aorta, vena cava, femoral arteries, and veins are best avoided by accurate placement of all instruments. No vascular injury has been reported with lumbar MISS since the early experience with similar procedures.

- Bowel and ureteral injuries: Ureteral injuries have not been reported with MISS. Bowel perforation was reported in the early experience, but was not reported in the recent multicenter study of more than 26,860 cases. 10

- Cerebrospinal fluid leak or dural injury: Dural injury has not occurred in any way other than as evidenced by spinal headache and presumed cerebrospinal fluid leakage. The incidence of only transient leakage in the multicenter study was less than 1%, and none required surgery to repair a dural tear. 10 Spinal headache has responded to simple blood patches.

- Excessive sedation: Avoided by surface electroencephalogram (EEG) monitoring that provides more precise estimation of the depth of anesthesia, reduces the amount of anesthetics, and prevents excessive or insufficient sedation. Operations under local anesthesia with conscious sedation allow patient's responsiveness to be tested directly.

- Soft-tissue injuries due to prolonged forceful retraction as occurs in many open disc operations are not an issue with TF-MEAD.

**CONCLUSIONS**

Evolving transforaminal endoscopic microdecompression for herniated lumbar discs and spinal stenosis has replaced open decompressive lumbar surgery for lateral spinal stenosis and disc herniation (Fig. 10) in this group of treated patients, and has proven to be safe, less traumatic, easier, and efficacious with significant economic savings. TF-MEAD is minimally invasive technique which decreases intraoperative and postoperative complications significantly by using endoscopic surgical techniques.

TF-MEAD combines more aggressive mechanical decompression and laser application to effectively treat spinal pathology at multiple levels and bilaterally. Many elderly patients (even octogenarians and beyond) who suffer symptoms caused by lateral spinal stenosis and disc problems can be treated successfully. The results of this operation can be an extremely gratifying experience for both the patient and the surgeon.

These procedures require a knowledgeable and competent surgeon with a thorough comprehension of the surgical anatomy. A minimally invasive spine surgeon must have specific surgical training with hands-on experience in the laboratory and, most importantly, must spend time working through the steep surgical learning curve with an endoscopic spinal surgeon expert present at this procedure.

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Figure 10. Axial CT images demonstrating severe bilateral lumbar foraminal stenosis secondary to posterior circumferential disc bulge/protrusion and facet osteophytic hypertrophy at L1-2, L3-4, L4-5, and L5-S1.
REFERENCES