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Endoscopic Posterior Cervical Foraminotomy and Discectomy

John E. O'Toole, MD[a], Hormoz Sheikh, MD[b], Kurt M. Eichholz, MD[c], Richard G. Fessler, MD, PhD[d], Mick J. Perez-Cruet, MD, MS[b,*]

[a]*Department of Neurosurgery, Rush University Medical Center, 1725 West Harrison Street, Suite 970, Chicago, IL 60612, USA*

[b]*Michigan Head and Spine Institute, 22250 Providence Drive, Suite 300, Southfield, MI 48075, USA*

[c]*Department of Neurological Surgery, Vanderbilt University, T-4224 Medical Center North, Nashville, TN 37232–2380, USA*

[d]*Section of Neurosurgery, The University of Chicago, 5841 South Maryland Avenue, MC-3026, Chicago, IL 60637, USA*

Conceived by Spurling and Scoville [1] in 1944, posterior cervical foraminotomy has been historically proven as an effective and safe method for treating foraminal stenosis resulting from lateral disc herniation or osteophytes (Fig. 1). One can achieve excellent decompression of the lateral recess and neural foramen while directly visualizing the exiting nerve root [2–5]. Indeed, in properly selected patients with isolated cervical radiculopathy, posterior laminoforaminotomy results in symptomatic improvement in 93% to 97% of patients [3,4]. Open posterior approaches to the cervical spine require extensive subperiosteal stripping of the paraspinal musculature, however, which leads to postoperative pain, spasm, and dysfunction and can be persistently disabling in 18% to 60% of patients [6–9].

Since the description of anterior cervical discectomy by Cloward [10] in 1958, popularity of the anterior approach has grown as the technique has gradually been made safe and easy to perform [11,12]. Because of the smaller incision and reduced muscle trauma, patients undergoing anterior approaches typically demonstrate less postoperative pain and muscle spasm and have shorter hospital stays than those undergoing open posterior approaches. In prospectively comparing anterior versus posterior approaches for cervical disc disease, Herkowitz and colleagues [13] reported good to excellent results in 90% of anteriorly operated patients and in 75% of posteriorly operated patients. Almost 90% of posteriorly operated patients enjoyed relief specifically of radicular symptoms, however [13]. In 2000, Wirth and coworkers [14] randomized 72 patients with cervical radiculopathy from single-level spondylotic disease to posterior foraminotomy, anterior cervical discectomy, or anterior discectomy with fusion. Nearly 100% of patients in all groups enjoyed relief of their symptoms, and no statistically significant difference between the procedures was observed with regard to outcomes [14]. From the overall data available, it seems that the principal difference between anterior and posterior approaches relates to the postoperative pain produced by soft tissue injury from the open posterior surgical technique.

Nevertheless, the anterior approach is associated with risk of injury to the esophagus, trachea, carotid artery, jugular vein, recurrent laryngeal nerve, superior laryngeal nerve, and thoracic duct. Moreover, the sacrifice of motion with anterior cervical fusion predisposes patients to accelerated degeneration of adjacent motion segments [6,15–19]. These risks are clearly avoided with the posterior approach.

In 1997, Foley and colleagues [20] first introduced the microendoscopic technique for

* Corresponding author.
E-mail address: perezcruet@yahoo.com (M.J. Perez-Cruet).

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Fig. 1. The laminofacet junction is targeted for the cervical microendoscopic discectomy or MEF procedure. (*From* Sandhu FA, Perez-Cruet MJ, Fessler RG. Microendoscopic cervical foraminotomy and discectomy. In: Perez-Cruet MJ, Khoo LT, Fessler RG, editors. An anatomical approach to minimally invasive spinal surgery. St. Louis (MO): Quality Medical Publishing; 2006. p. 338; with permission.)

lumbar disc disease. This minimally invasive muscle-splitting approach helps to reduce paraspinal muscle denervation as compared with the muscle stripping approach used in typical open procedures. The posterior cervical microendoscopic foraminotomy (MEF) was developed to address cervical nerve root compression by direct visualization of pathologic findings while minimizing tissue destruction on exposure. Muscle and ligamentous attachments to the spine are preserved, thus decreasing postoperative pain and spasm and helping to maintain long-term stability. Initial cadaveric studies using this technique demonstrated that the average vertical and transverse diameters of the laminotomy defect were identical for the MEF or open techniques [21,22]. In fact, the average amount of facet removed and length of neural decompression was greater with MEF than with the open approach. Initial clinical results have been quite favorable for the MEF procedure [6,9,23]. Operative times, blood loss, lengths of hospitalization, and need for postoperative pain medications have all generally been reduced when MEF is compared with the open procedure [24]. Using the sitting position within the MEF cohorts further improved these operative measures. Compared with the open technique, MEF in the sitting position shows reductions in average operative time from 171 to 90 minutes, in average blood loss from 246 to 28 mL, and in average hospital stay from 68 to 8 hours [24].

Despite these many benefits, there is a steep learning curve in mastering this endoscopic technique that may require additional training or practice within a cadaver laboratory. Once mastered, however, the results of this technique can be satisfying for the clinician and patient. This article focuses on the technical considerations in performing cervical MEF effectively and safely.

Preoperative evaluation

Patients routinely undergo anteroposterior (AP), lateral, oblique, and dynamic radiographic views to determine spine alignment, disc space height, foraminal encroachment, and instability. Additional radiographic evaluation includes MRI or myelogram with computed tomography (CTM) to visualize the area of neural compression. CTM is particularly helpful in multilevel degenerative cervical disc disease to determine the level of maximal neural compression because this study clearly shows bony pathologic findings as well as foraminal stenosis and nerve root compression. The radiographic evaluation determines the operative level in conjunction with a thorough clinical history and physical examination. Further assessments may include diagnostic selective nerve root blocks or electromyography (EMG) and nerve conduction studies. It is obviously critical to identify correctly the anatomic level from which the patient's radiculopathy originates to achieve surgical success.

Indications

Endoscopic posterior cervical foraminotomy is indicated for cases of lateralized disc herniation (Fig. 2), osteophyte compression, and foraminal stenosis. Ideally, patients should present with painful cervical radiculopathy with correlative neural compression seen on MRI or CTM. Contraindications include pure axial neck pain without neurologic symptoms, gross cervical instability, symptomatic central disc herniation, excessive burden of ventral disease (eg, diffuse ossification of the posterior longitudinal ligament [OPLL] or a kyphotic deformity that would make

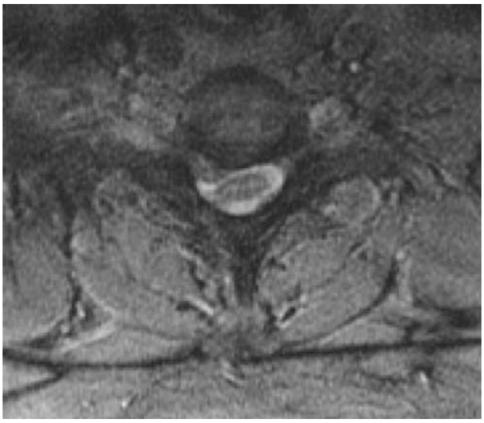

Fig. 2. Lateralized right C6-C7 disc herniation, which is ideal for treatment using the cervical microendoscopic discectomy approach.

posterior decompression ineffective, or an inability to tolerate general anesthesia.

Even with a concordant clinical history of radiculopathy and appropriate radiographic findings, a potential for misdiagnosis can exist. The differential diagnosis for nerve root–like pain includes spinal canal tumors, trauma, inflammatory diseases, demyelinating conditions, toxic and allergic conditions, hemorrhage, congenital defects, metabolic diseases, neuropathies, thoracic outlet syndrome, rotator cuff pathologic condition, impingement syndromes, bursitis, arthritis of the shoulder, and bicipital tendonitis. EMG and nerve conduction studies performed by an experienced neurophysiologist may be particularly helpful in this regard. Finally, in some cases, psychologic screening of patients may be warranted to rule out secondary gain or psychologic issues that may result in a poor surgical outcome.

Anesthesia and operative setup

After the induction of general endotracheal anesthesia, adequate intravenous access is secured. Somatosensory evoked potentials (SSEPs) and myotomal EMG are monitored throughout the case. An arterial line is often helpful to maintain normotension, with the patient in a sitting position to avoid spinal cord hypoperfusion. A precordial Doppler scan is used to monitor for air embolism, although this has not presented a problem to date. Foley catheterization is generally not needed. Use of neuromuscular paralytic agents is minimized to allow assessment of intraoperative nerve root irritation. A single dose of antibiotics (cephazolin or vancomycin) is routinely administered before skin incision. Intravenous steroids are not typically used for cervical MEF cases.

Initially, cervical MEF was performed with patients in the prone position. This led to bleeding that often obscured the endoscopic image during the operative procedure and resulted in increased operative blood loss and operative times, however (Fig. 3). By decreasing epidural venous congestion, the semisitting position (Fig. 4) has resulted in significantly improved operative visualization and decreased operative times and blood loss (see Fig. 3). To accomplish this the table is turned 180° relative to the anesthesia station. The patient is placed in Mayfield three-point head fixation, and the table is progressively flexed and put into a Trendelenburg position to bring the patient into a semisitting position so that head is flexed but not rotated and the posterior neck is perpendicular to the floor. The Mayfield headholder is secured to a table-mounted crossbar, and the patient's arms are folded across the lap or chest depending on body habitus. The legs, hands, and arms are well padded, particularly over the cubital

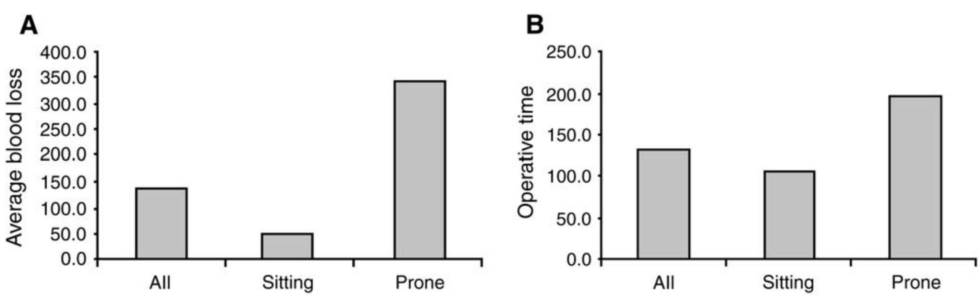

Fig. 3. Operative blood loss (*A*) and time (*B*) for the cervical microendoscopic discectomy procedure in all patients combined, in the semisitting position, and in the prone position. (*From* Perez-Cruet MJ, Fessler RG. Endoscopic posterior cervical foraminotomy and microdiscectomy. Prog Neurol Surg 2003;16:255; with permission from S. Krager AG, Basel.)

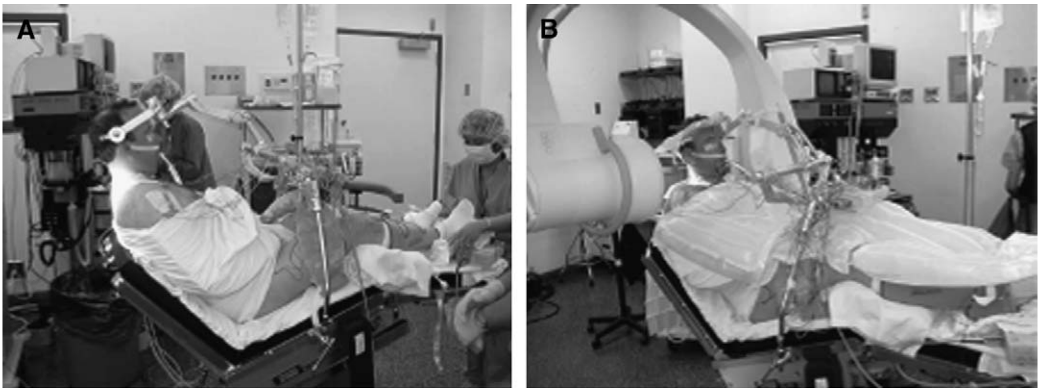

Fig. 4. Patient positioned in a semisitting position with the head in Mayfield head fixation (*A*) with the C-arm in place (*B*).

tunnel, to prevent positional ulnar neuropathy. The base of the fluoroscopic C-arm is placed on the same side as the surgical approach. The fluoroscopic and endoscopic monitors are placed next to the head of the patient opposite the side of approach so that the surgeon can look directly at the monitors while standing behind the patient and operating through the tubular retractor at a comfortable height (Fig. 5). The C-arm may be arranged beneath, in front of, or above (see Fig. 4B) the patient depending on the design specifics of the C-arm and operating table and whether or not AP images are needed during the case. The neck is checked a final time to ensure safe positioning, which allows adequate jugular venous drainage and airway patency.

Approach

Before draping, an initial fluoroscopic image is acquired to confirm adequate visualization and to plan the initial entry point. The posterior neck is sterilely prepared and draped. If an adhesive layer, such as Ioban (3M Health Care, St. Paul, Minnesota), is used to maintain the drape position during the procedure, a small area should be excised around the planned incision to prevent introduction of plastic sequestra during placement of the percutaneous soft tissue dilators. Suction tubing, cautery lines, and an endoscope light source and camera cables are typically draped over the top or side of the field and secured against the drapes. The operative level(s) is once again confirmed on lateral fluoroscopy while a long Kirschner wire (K-wire) or Steinmann pin is held over the lateral side of the patient's neck. A 1.8-cm longitudinal incision is marked out approximately 1.5 cm off the midline on the operative side, and this is injected with local anesthesia. For two-level procedures, the incision should be placed midway between the targeted levels (Fig. 6). For bilateral procedures, a midline skin incision can be used and the skin can be retracted to each side for independent dilations. After an initial stab incision, the K-wire is advanced slowly though the musculature under fluoroscopic guidance and docked at the inferomedial edge of the rostral lateral mass of the level of interest (Fig. 7A). It is critical to engage bone and not to penetrate the interlaminar space, where the laterally thinned ligamentum flavum may not protect against iatrogenic dural or spinal cord injury. At this point, the incision is completed approximately 1 cm above and below the K-wire entry point and the wire is removed. The

Fig. 5. The position of the surgeon, standing behind the patient, viewing the endoscopic image on the operative monitor. Note the ergonomically favorable position.

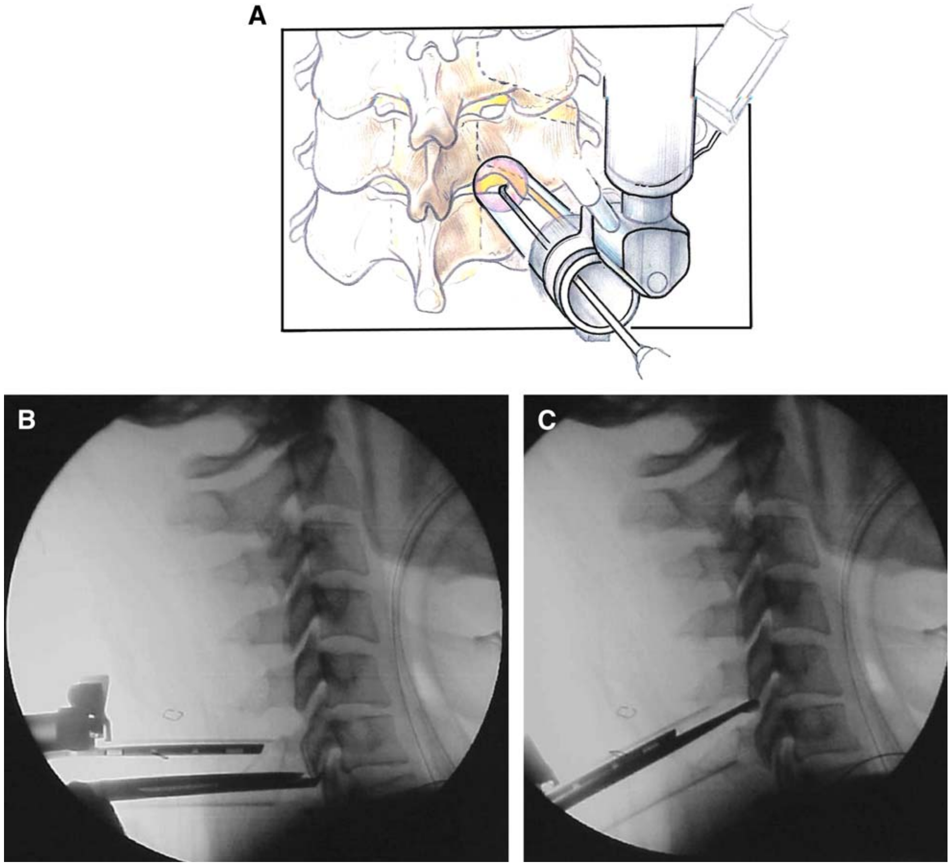

Fig. 6. (*A*) Tubular retractor and endoscopic setup in place for performing cervical microendoscopic discectomy or MEF. (*From* Sandhu FA, Perez-Cruet MJ, Fessler RG. Microendoscopic cervical foraminotomy and discectomy. In: Perez-Cruet MJ, Khoo LT, Fessler RG, editors. An anatomical approach to minimally invasive spinal surgery. St. Louis (MO): Quality Medical Publishing; 2006. p. 340; with permission.) Intraoperative lateral fluoroscopic images during two-level MEF show the procedure preformed through a tubular retractor at the first level (*B*) and wanding of the tube to approach the adjacent level (*C*).

axial forces that are applied during muscle dilation in the lumbar spine are more hazardous in the cervical spine. Therefore, the cervical fascia is incised equal to the length of the incision using monopolar cautery or scissors so that muscle dilation can proceed in a safe and controlled fashion. The K-wire is replaced under fluoroscopy again, and the tubular muscle dilators are serially inserted. The final 16- or 18-mm tubular METRx retractor (Medtronic Sofamor Danek, Memphis, Tennessee) is placed over the dilators and fixed into place over the laminofacet junction with a table-mounted flexible retractor arm, and the dilators are removed (Fig. 7B–F). Alternatively, in heavy muscular individuals, docking on bone can be difficult and may require significant force because of the large muscular attachments to the spine. To avoid excessive force while approaching the spine with the muscle dilators, it is safer to dock the tubular retractor above the spine. Under direct visualization, a straight curette can then be used to separate the muscle fibers and palpate the underlying facet complex. Once identified and confirmed with lateral fluoroscopy, the muscles can be dilated down to the facet complex and the tubular retractor can be advanced in a safe manner without undue force. The 25°-angled glass rod endoscope is attached to the camera, white-balanced, and treated with an anti-fog solution before insertion and attachment to the tube via a cylindric plastic friction-couple (see Fig. 6A).

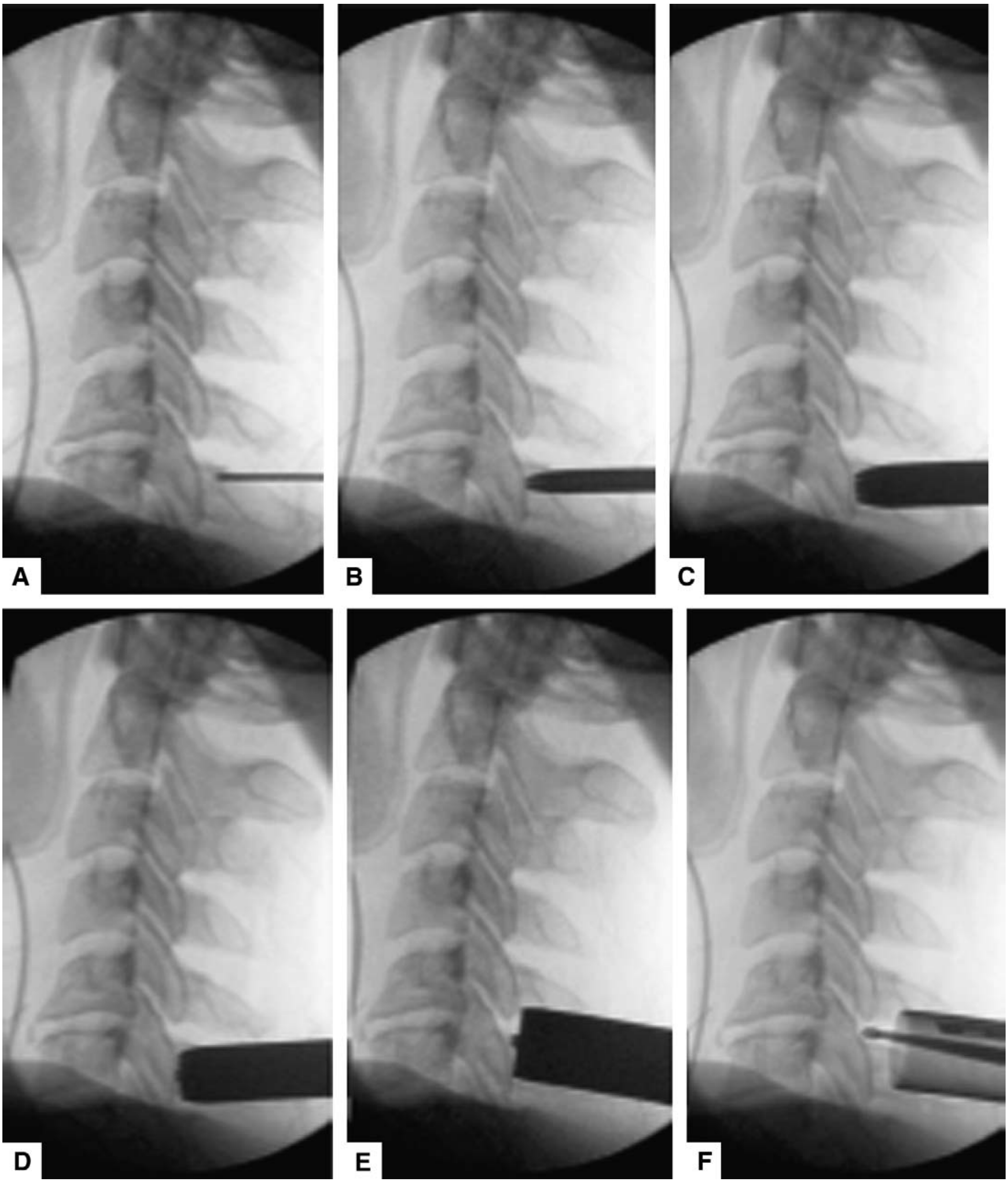

Fig. 7. Lateral fluoroscopic images show the K-wire docked on the facet complex (*A*), first dilator (*B*), second dilator after the K-wire is removed (*C*), third dilator (*D*), fourth dilator (*E*), and the tubular retractor in place with a curette on the facet (*F*).

Surgical technique

Monopolar cautery and a pituitary rongeur are used to clear the remaining soft tissue off of the lateral mass and lamina of interest, taking care to start the dissection over solid bone laterally (see Fig. 4). A small up-angled curette is used to detach the ligamentum flavum gently from the undersurface of the inferior edge of the lamina (Fig. 8). Bleeding from epidural veins is controlled using a long-tipped endoscopic bipolar cautery. For bleeding underneath the edge of the lamina,

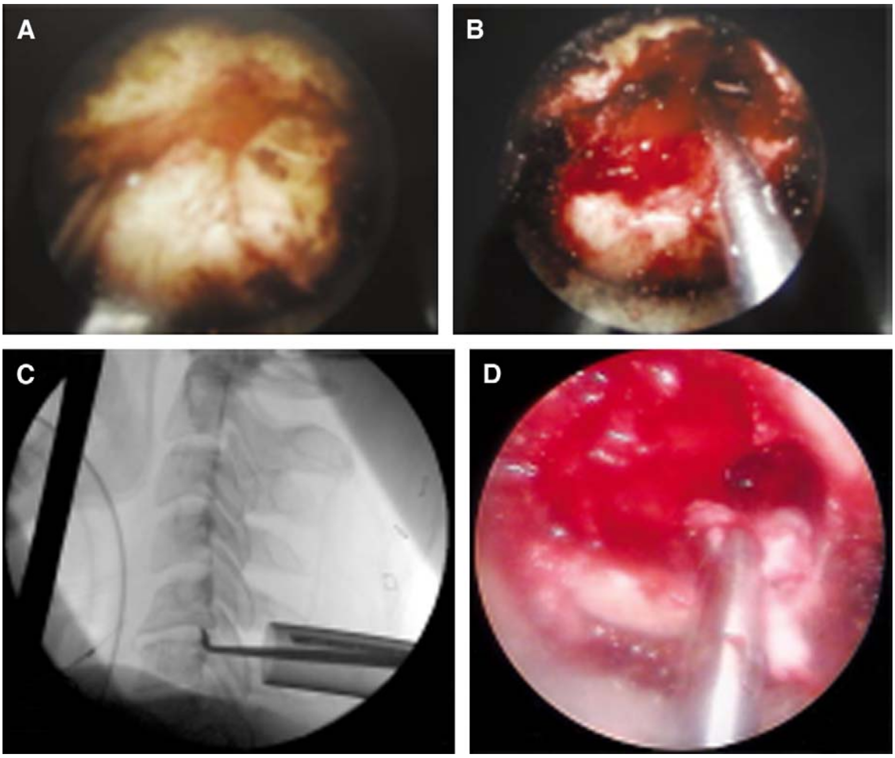

Fig. 8. Intraoperative images show a Kerrison punch initiating medial facet removal (*A*), the probe passing out of the foramen once the foraminotomy is performed with the underlying nerve root exposed (*B*), a lateral fluoroscopic image with a down-going curette on the disc under the nerve root (*C*), and endoscopic imaging of removal of a disc fragment (*D*).

bipolar forceps with a 45° angle are often useful. A Kerrison punch with a small footplate is used to begin the laminotomy (Fig. 9A). Depending on the degree of facet hypertrophy, the Kerrison punch may be used to complete most of the laminotomy and early foraminotomy or a high-speed drill with a long endoscopic bit may be required early in the course of bone removal.

In this fashion, the decompression is carefully continued inferiorly and laterally along the course of the neural foramen. The ligamentum flavum can be removed medially after the laminotomy to identify the lateral edge of the dura and proximal portion of the nerve root. The venous plexus overlying the nerve root should be carefully coagulated with bipolar cautery and incised. The bony decompression is complete when the nerve root has been well exposed along its proximal foraminal course. Particular caution must be taken to avoid resecting too much of the medial facet complex during the decompression. Up to 50% of the facet complex can be resected unilaterally without inducing iatrogenic instability [25]. The view through the 25°-angled endoscope can lead to more extensive facet resection, however, so deliberate care must be taken to avoid excessive bony removal [22]. The adequacy of the decompression should be confirmed by palpating the root along its course with a small nerve hook (Fig. 9B). In cases with a herniated disc fragment or ventral uncovertebral osteophyte, drilling approximately 2 mm of the superomedial pedicle creates a safe working space around the nerve root (Fig. 9C). In this way, disc fragments (Fig. 9D) may be removed or a down-angled curette may be used to tamp calcified material into the disc space or to fragment it for further removal. Before closure, the nerve root should be palpated along its anterior surface to ensure that no residual compression exists along its course. Radiographic and tactile confirmation of the extent of discectomy or foraminotomy can be obtained. Fig. 8 illustrates the intraoperative endoscopic visualization of the procedure.

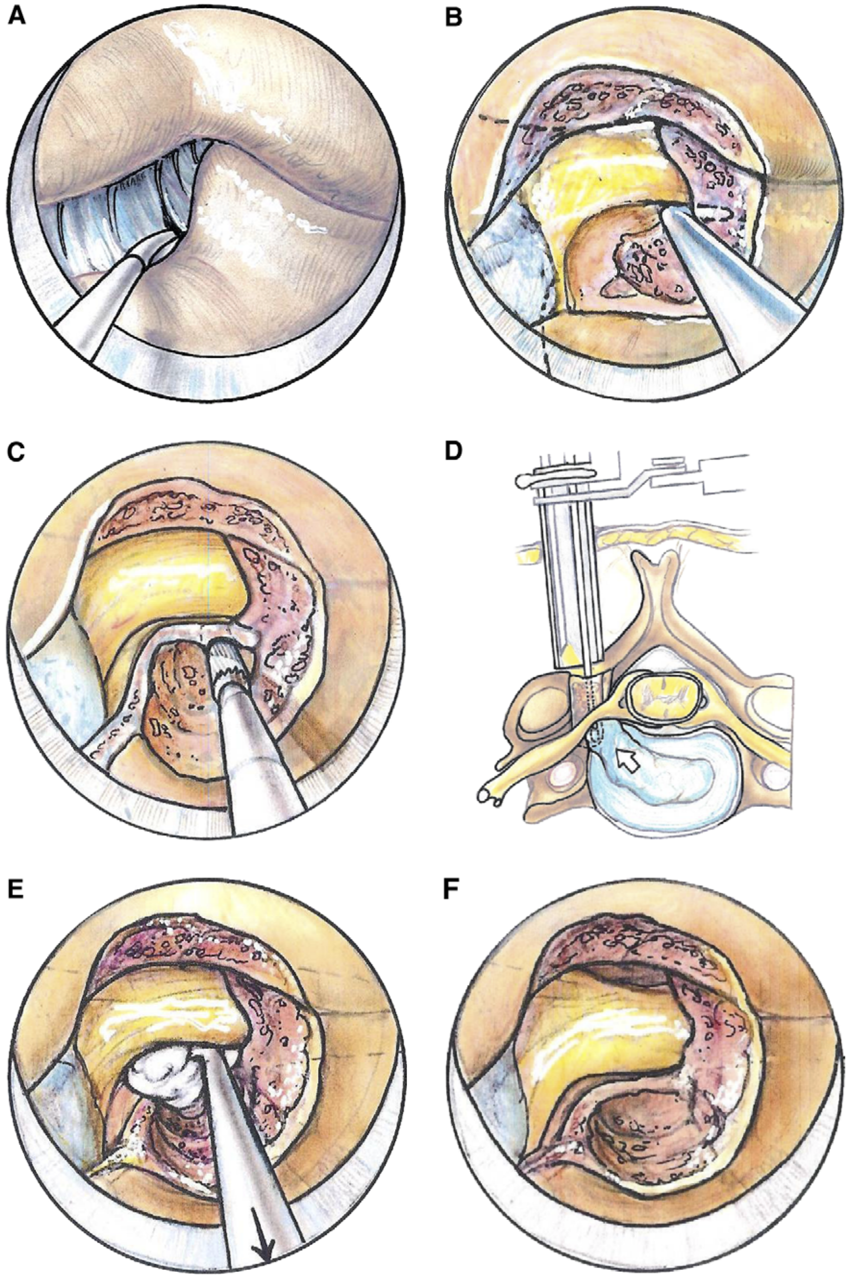

Fig. 9. Illustration shows the steps of the cervical microendoscopic discectomy or MEF procedure. (*A*) Laminofacet complex is identified by removing the overlying soft tissue with a Bovie cautery and curette. (*B*) Foraminotomy is then performed in a standard fashion. (*C, D*) Drilling with a long tapered drill on the medial superior aspect of the facet of the caudal pedicle allows access to the disc while minimizing nerve root manipulation. Leaving a thin rim of bone between the pedicle and the nerve root during drilling avoids injury to the nerve root. This piece of bone is then removed with a pituitary rongeur. (*E, F*) Removal of a disc fragment and final image of the decompressed nerve root. (*From* Sandhu FA, Perez-Cruet MJ, Fessler RG. Microendoscopic cervical foraminotomy and discectomy. In: Perez-Cruet MJ, Khoo LT, Fessler RG, editors. An anatomical approach to minimally invasive spinal surgery. St. Louis (MO): Quality Medical Publishing; 2006. p. 343; with permission.)

Another advantage with this technique is that far lateral foraminal stenosis or disc herniation can be decompressed through this approach. Because the nerve root often passes in close proximity to the vertebral artery laterally, particular attention should be paid during decompression in this area. Inadvertent passage of instruments beyond the bone defining the posterior margin of the foramen transversarium should be avoided. The rich venous plexus, which typically surrounds the vertebral artery, can produce brisk dark bleeding. When encountered, such bleeding should serve as a useful warning to limit further dissection and thus prevent inadvertent arterial injury.

Closure

Meticulous hemostasis is obtained by a combination of bipolar cautery and gentle tamponade with thrombin-soaked gel-foam or another hemostatic agent. Bone bleeding is controlled with bone wax. The wound is then copiously irrigated with an antibiotic-saline solution. A methylprednisolone-soaked pledget may be placed over the root to reduce postoperative inflammation. The tubular retractor and endoscope are removed, and local anesthetic, such as bupivacaine, is injected around the incision to reduce postoperative pain and allow for more rapid recovery and mobilization. The wound is closed using one or two absorbable stitches for the fascia, two or three inverted stitches for the subcutaneous layer, and a running subcuticular stitch and Dermabond (Ethicon, Inc., Summerville, New Jersey) for the skin. The advantage of Dermabond is that it keeps the skin edges closely approximated for 7 to 10 days and provides a waterproof barrier. The patient can thus shower almost immediately after surgery. Fig. 10 shows the surgical incision, which is much smaller than for the open procedure.

Postoperative care

The patient is awoken from anesthesia and taken to the postanesthesia recovery unit. Long-acting inhalational and intravenous agents should be avoided to allow for rapid awakening of the patient after surgery. Thorough preoperative patient education is required for this procedure to be performed on an outpatient basis [26].

Once in the recovery area, patients are allowed to mobilize rapidly and ambulate as tolerated. Arterial and intravenous lines are removed early.

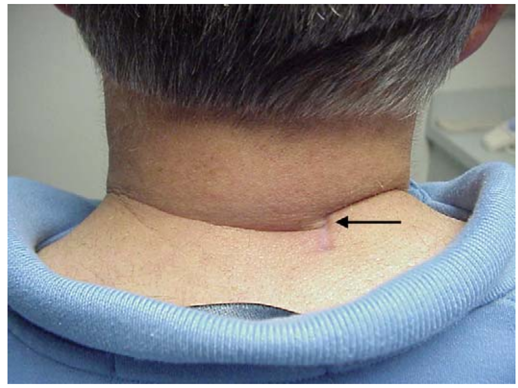

Fig. 10. Typical postoperative incision (*arrow*) after cervical microendoscopic discectomy or MEF.

This procedure does not result in instability or fusion of the operated cervical motion segment; therefore, no cervical collar is required. Patients are typically discharged on a combination of muscle relaxants, nonsteroidal anti-inflammatory drugs, and an oral opioid for breakthrough pain. When compared with patients treated via open cervical foraminotomy, we have found that patients undergoing MEF require significantly less pain medication after surgery [24]. Patients are generally discharged after a few hours.

Complications

Complications from this procedure are unusual. Adamson [23] retrospectively reviewed 100 patients undergoing MEF and reported complications in 3 patients: two cases of dural puncture requiring no intervention and one case of superficial wound infection. Fessler and Khoo [6] reported three complications in a series of 25 patients undergoing MEF, including two small durotomies and one case of partial-thickness dural violation. No direct dural repair was performed, but the patients underwent 2 to 3 days of lumbar drainage. None of the patients experienced long-term clinical sequelae of cerebrospinal fluid (CSF) leak or pseudomeningocele. Although large defects should likely undergo lumbar drainage, small durotomies may also be treated simply with local adjuncts, such as synthetic dural substitutes, fat or muscle grafts, fibrin glue, or synthetic sealants, all followed by overnight bedrest. To date, the senior authors (R.G. Fessler and M.J. Perez-Cruet) have not had any cases of delayed pseudomeningoceles or persistent CSF leaks. The risk of dural injury is reduced with surgical experience, because most durotomies occur during a surgeon's initial attempts at performing this endoscopic procedure.

Potential neurologic complications include radicular injury from manipulation within the tight foramen or direct mechanical spinal cord injury during dilation or decompression. Additionally, lateral displacement of the K-wire or dilators can result in vertebral artery injury, the harbinger of which is brisk venous bleeding. This bleeding is generally controlled with gentle gel-foam packing or bipolar cautery. As mentioned previously, despite the use of the semisitting position, air embolism has not presented a problem to date. Delayed complications, such as recurrent disease or postoperative instability, also have not been observed in our use of this technique thus far.

Clinical case

A 43-year-old college professor experienced the acute onset of radiating left arm pain 1 day after digging holes in his backyard. The pain began in his neck; radiated to his left scapula; and traveled down the medial aspect of his arm and into the third, fourth, and fifth digits of his left hand. The pain was intense, graded 10 of 10 on a visual analog scale without medication and 2 of 10 with narcotic pain medication. He denied any bowel,

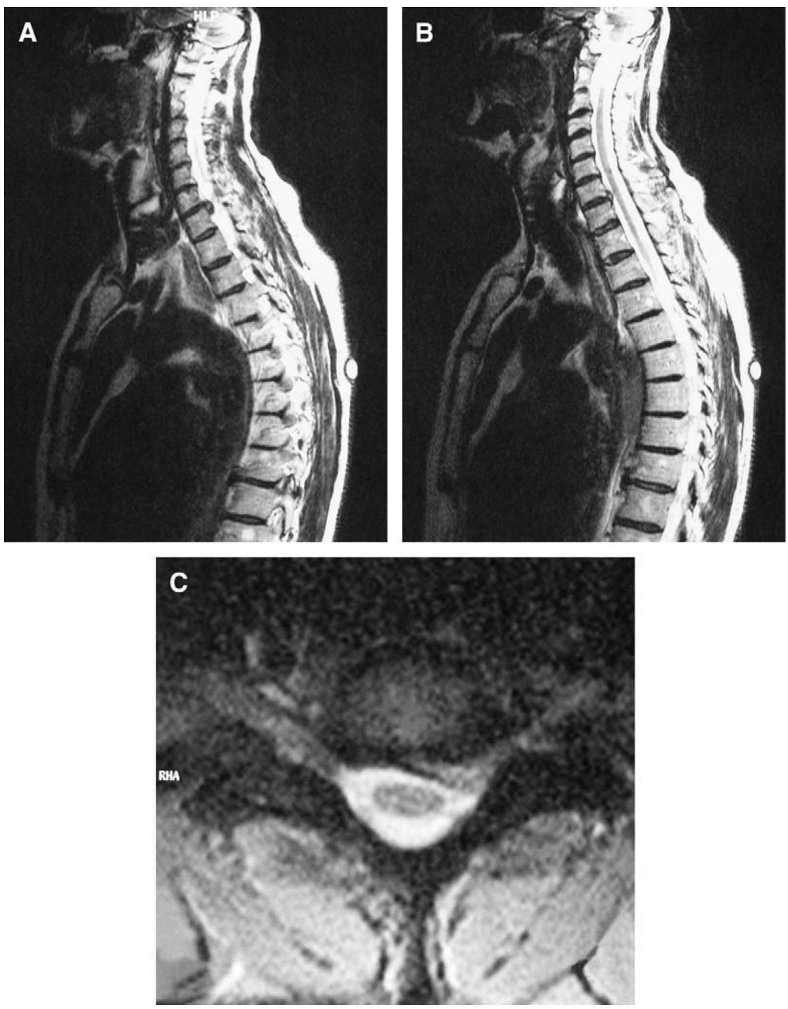

Fig. 11. T2-weighted MRI showing C7-to-T1 disc herniation on sagittal (*A, B*) and axial (*C*) views demonstrates lateral disc herniation compressing the left C7 root.

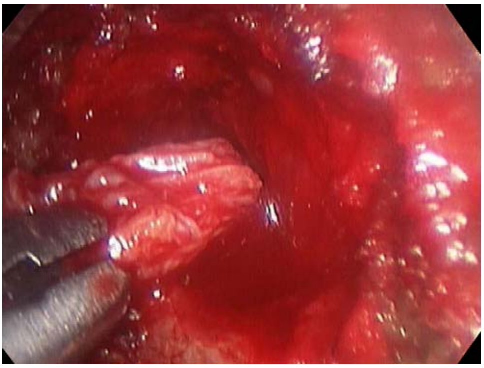

Fig. 12. Endoscopic view of a large disc fragment being removed.

bladder, balance, or sexual dysfunction. On examination, he had weakness (4/5) in finger flexion and finger abduction of his left hand and decreased sensation to pinprick in a left C7 and C8 distribution. Cervical spine MRI demonstrated a left lateral disc herniation at C7-T1 (Fig. 11).

The patient underwent a left posterior microendoscopic discectomy performed in the semisitting position as described previously. A large disc fragment was removed (Fig. 12). The operative time was 75 minutes, and the estimated blood loss was 10 mL. The patient was discharged 3 hours after surgery. He returned to work full-time 4 weeks after surgery. By 6 weeks after surgery, his radicular pain had completely resolved, his hand strength was normal, he was completely off narcotic pain medications, and the muscular pain from surgery had resolved after initiation of physical therapy.

Summary

Posterior cervical foraminotomy for lateral cervical spondylotic disease is safe and efficacious. The advent of tubular retractor systems has made it possible to treat cervical radiculopathy effectively in a minimally invasive fashion. These approaches have several advantages over more invasive open procedures: (1) reduced operative time, (2) decreased hospital stay, (3) decreased postoperative pain and muscle spasm, (4) decreased postoperative need for narcotic pain medications, and (5) earlier return to work and normal activity. The decision to use a minimally invasive posterior approach partly depends on surgeon's familiarity with the technique. We believe that posterior cervical MEF is associated with fewer operative risks than anterior cervical foraminotomy or discectomy and that, with proper patient selection, it achieves excellent surgical results.

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