Technique of Minimally Invasive Cervical Foraminotomy

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BACKGROUND: Posterior cervical foraminotomy is a long utilized and commonly performed procedure, but has been supplanted in many cases by anterior procedures. With the advent of minimally invasive techniques, posterior foraminotomy may again deserve a prominent place in the treatment of cervical foraminal stenosis.

OBJECTIVE: To report in detail a successfully utilized minimally invasive technique and the results in a large series of patients, by a single author.

METHODS: The technique is described and illustrated in detail. A retrospective review of the use of this technique in a large series is reported.

RESULTS: Precise details of the technique are described with specific attention to complication avoidance. In over 360 cases, there have been no nerve root injuries other than idiopathic C5 palsies, no wound infections, and a single durotomy that required no specific treatment.

CONCLUSION: Minimally invasive posterior cervical foraminotomy is a well-tolerated and effective procedure which can be performed with minimal complications when attention to detail is maintained.

KEY WORDS: Cervical foraminotomy, Posterior approach, Posterior foraminotomy, Cervical foraminal stenosis

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Posterior cervical foraminotomy (PCF) has been part of the neurosurgical armamentarium for decades. Minimally invasive (MIS) techniques have improved the procedure. By minimizing muscle dissection, shortening surgical times, reducing pain, and decreasing infection risk, this procedure became a mainstay of the senior author's treatment of cervical foraminal stenosis, lateral soft disc protrusion, and some instances of stenosis of the cervical canal.[1] We describe the operative technique used in over 360 cases from 2001 to 2015. Unlike prior reports, we describe, in detail, specific techniques required for a safe MIS approach, thus countering arguments favoring open approaches.[2] A review of the literature is also provided. (see **Video**, **Abstract**, **Screenshot**, and **Annotations, Supplemental Digital Content 1-4**, which discusses the advantages of an MIS approach for decompression of the cervical nerve roots).

ABBREVIATIONS: AP, anterior–posterior; **CT,** computed tomography; **MIS,** minimally invasive; **PCF,** posterior cervical foraminotomy

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TECHNIQUE

Given the brevity of the surgery, the bladder is not catheterized, even for 2-level procedures. A tubular retractor (METRx; Medtronic, Inc, Dublin, Ireland) table mount is placed at the head of the table contralateral to the intended surgery. A Jackson OSI table (Mizuho OSI, Union City, California) is used. A clear plastic head rest with a thick foam pad is preferred over a ProneView device (Mizuho OSI), as its metal feet may obscure radiograph visualization. The cervical spine should be in slight flexion. The chest pad should be distal enough to not impact the chin nor interfere with radiographs. The upper extremities are secured at the patient's sides with a sheet after padding the ulnar nerves. Reverse Trendelenburg is used to bring the cervical spine parallel to the floor (Figure 1). Skin folds over the posterior cervical region should be straightened by gently taping the shoulders.

FIGURE 1. *Photograph of a patient positioned for surgery (patient consent obtained).*

FIGURE 2. *Intraoperative photograph of large monofilament sutures used to straighten the skin folds on the posterior cervical region of a very obese patient. The retractor is already in place.*

In morbidly obese patients, after draping, large sutures have been used to put traction on the skin and open up intertriginous folds (Figure 2). The eyes are protected to avoid ocular chemical injuries from preparation solutions. The field is sterilely draped, including an Ioban drape (3M, Minneapolis, Minnesota).

Anterior–posterior (AP) fluoroscopy is used to localize the skin incision, (Figure 3) usually directly over the facet at the disc space of the intended level. For 2-level procedures, the incision is placed midway between the 2 levels. It is often necessary to tilt the fluoroscope in a rostral-to-caudal direction to remove the mandible from imaging. If this is done, the incision should be moved slightly distally from the proposed entry point to account for this angle. The intended incision is infiltrated with a mixture of bupivacaine and epinephrine.

A 2-cm paramedian vertical skin and fascial incision is made. It is necessary to incise deeply through several layers of fascia. Otherwise, dilators will not pass without undue force, resulting in undesired neck extension. Occasionally, the incision will result in hemorrhage from the wound, but this will usually stop with retractor placement or with packing a cottonoid outside the retractor tube. The bleeding point can be coagulated under direct vision during closure.

The blunt guide pin is avoided. Rather, the smallest dilator is passed, avoiding forcible extension of the neck. Fluoroscopic

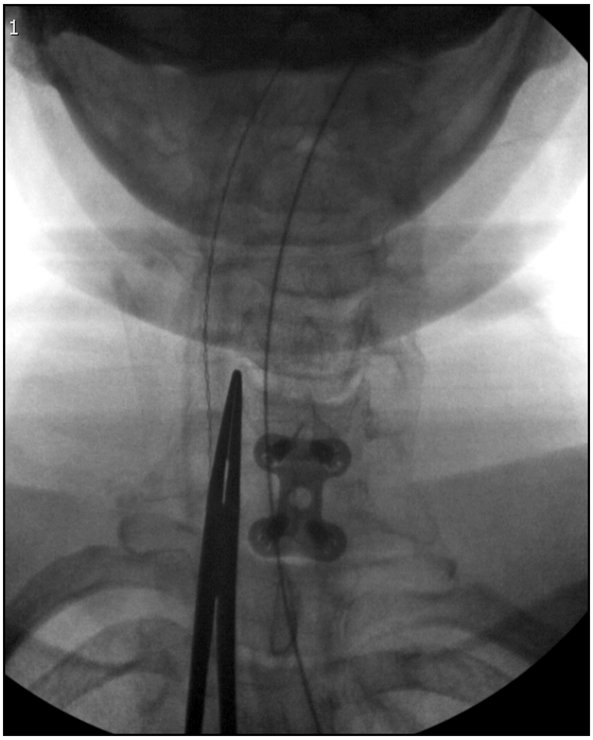

FIGURE 3. *AP view of the cervical spine showing the localization of the skin incision for a C5-6 foraminotomy.*

AP images ensure that the device trajectory is neither too medial (penetrating the canal) nor too lateral (hitting a root or the brachial plexus; Figure 4). In a slender adult, a 4-cm tube may reach the cervical spine; in an average adult a 6-cm tube, and in obese adults, up to an 8 or 9-cm tube. Tubular access surgery beyond this depth is not recommended, as the drill and other instruments are awkward to control at great depth. If the dilator has not contacted bone by the expected depth, fluoroscopy should be checked to re-verify the trajectory. Ideally, the dilator will be docked on bone at the medial half of the facet at the intended level (Figure 4). If bone is not contacted, but the trajectory is correct, it is better to dilate at this shallower depth, then reposition the retractor under direct vision rather than endeavor to force the retractor deeper. In the upper cervical spine, the lamina and facets slope laterally, and the dilators can slip off the side of the spine laterally if not carefully controlled.

Serial dilators are used to reach the appropriate retractor diameter. We use an 18-mm tube up to 7 cm in length, but increase to 20 mm for longer tubes to maintain some degree of freedom of movement. Dilators should be manually screwed in, rather than forced. The tube is attached to the table mount and fluoroscopy used to again verify the correct position (Figure 5). For foraminotomies at C6 or rostrally, a lateral or lateral oblique X-ray is taken to verify that the retractor is docked on bone and the joint line of the intended facet is centered in the tube. If the tube is docked obliquely on the spine, as is often the case with 2-level procedures, then one must be cautious not to overshoot the intended level. The lateral view will also show if the retractor has not contacted bone, and thus needs to be deepened. A useful lateral view distal to C6 is rare; therefore, in these cases, the authors rely only on the AP view.

The microscope is brought into the field. If the tube has not been docked on bone, the last muscle layer is linearly incised. The smallest dilator is replaced in this opening, and the dilation process repeated. Fluoroscopy is checked to ensure the tube did not migrate from the intended target.

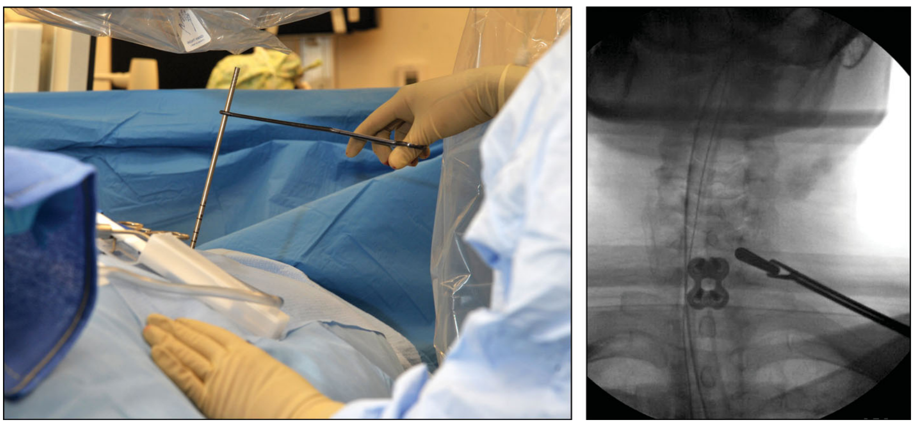

FIGURE 4. **Left:** *The smallest dilator is passed, and fluoroscopic images in the AP view are utilized to ensure the trajectory is neither too medial nor lateral. The dilator is held with a pituitary rongeur to keep the surgeon's hand out of the beam.* **Right:** *AP view of the cervical spine showing the smallest dilator docked on the medial facet in preparation for dilation.*

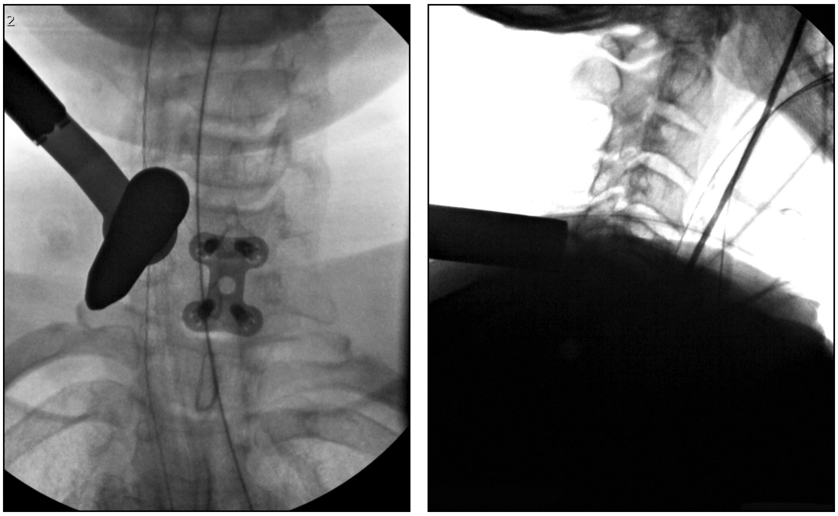

FIGURE 5. *AP and lateral oblique fluoroscopy images showing an 18-mm retractor properly positioned at C5-6 with the joint line centered in the retractor tube.*

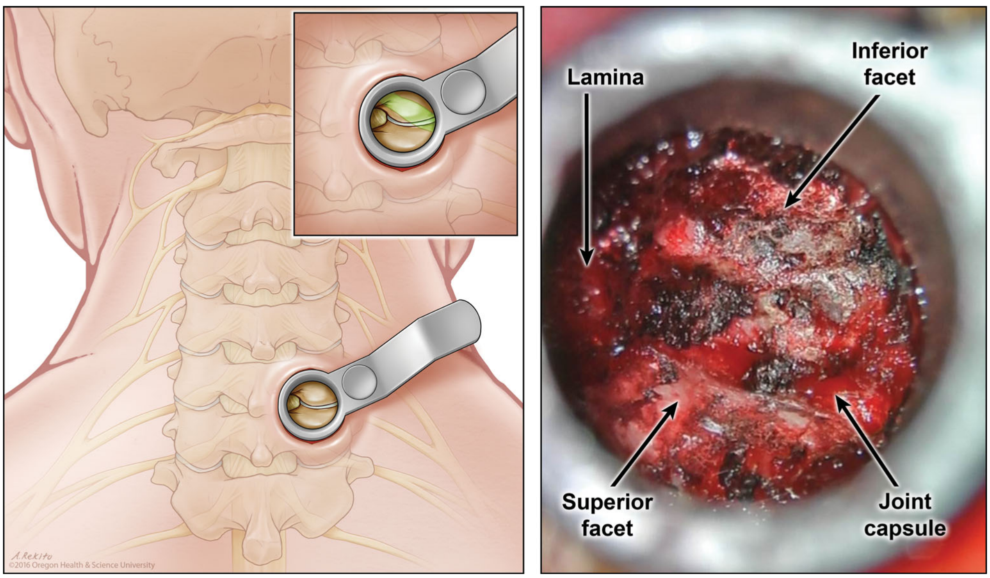

FIGURE 6. **Left:** *figure demonstrating the location of the retractor in relationship to the lamina and medial fascet. © 2016 Oregon Health & Science University* **Right:** *surgical view looking down the retractor prior to drilling showing the facet joint line centered in the field with a few mm of lateral lamina exposed. The lateral facet is outside the retractor and remains covered by paraspinal muscles.*

The last remaining soft tissue is removed with pituitary rongeurs to expose the bone. Bipolar electrocautery is used for hemostasis, and monopolar devices are avoided to reduce pain and minimize risk of infection.[1]

The field should expose the medial two-thirds of the facet joint and a few millimeters of the lateral lamina (Figure 6). The anesthesiologist is queried at this point to confirm that any paralytic agents have worn off.

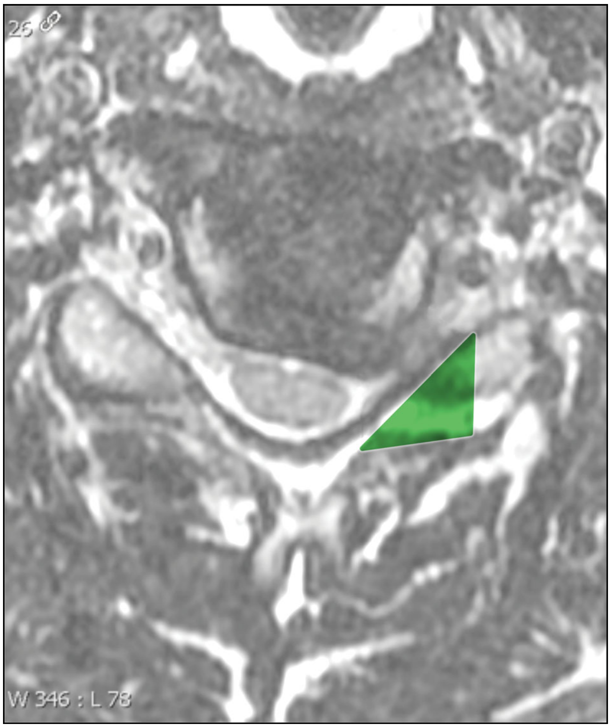

FIGURE 7. *Preoperative MRI showing left C6 foraminal stenosis. The extent of intended decompression is marked by the green triangle, requiring approximately half of the facet be removed.*

Reference to imaging is made to ascertain the expected thickness of the bone and how much of the facet must be removed to reach the lateral portion of the foramina where the stenosis is no longer present (Figure 7). In some patients, constriction is only at the entrance to the foramen, while others may require more extensive exposure. A 5-mm smooth diamond drill under continuous irrigation is preferred. Although a cutting drill or coarse diamond can be utilized to hasten bony removal, these bits are more aggressive, increasing risk of durotomy and neurological injury. The medial two-thirds of the facet and a few millimeters of the lateral lamina are removed. Drilling should proceed in a circular fashion, maintaining the same depth throughout the opening. The lamina medially may be the thinnest bone, and the epidural space may first be entered there. Drilling starts over the joint line of the facet, but as the joint angles rostrally, drilling will ultimately be directed distal to the joint line as the foramen is approached. Drilling along the trajectory of the facet should be avoided as this will lead to an unintended rostral endpoint. Under irrigation, the thin bone over the nerve root often appears pink or purple as the dura is approached, sometimes with linear striations visible through the bone (Figure 8). Drilling is paused frequently for inspection and palpation with a nerve hook. The intraforaminal cervical root is not covered by ligamentum flavum and will be injured if the foramen is entered forcefully. Bone bleeding is controlled with bone wax prior to entering the foramen to avoid displacing bone wax into the epidural space.

A 1-mm Kerrison rongeur is used to further unroof the nerve root. Its thin footplate is unlikely to impinge upon the nerve root even in a stenotic foramen. The opening should expose the lateral dura of the canal so that the shoulder of the nerve root is decompressed. It should extend laterally until a nerve hook can pass laterally without obstruction, and extend rostrally and caudally until the pedicles flanking the foramen can be palpated. A fluoroscopic image is made and saved with the nerve hook under the rostral pedicle to confirm the correct root was operated upon (Figure 9). An AP view can be used to confirm the laterality of the decompression. The wound is copiously irrigated. A

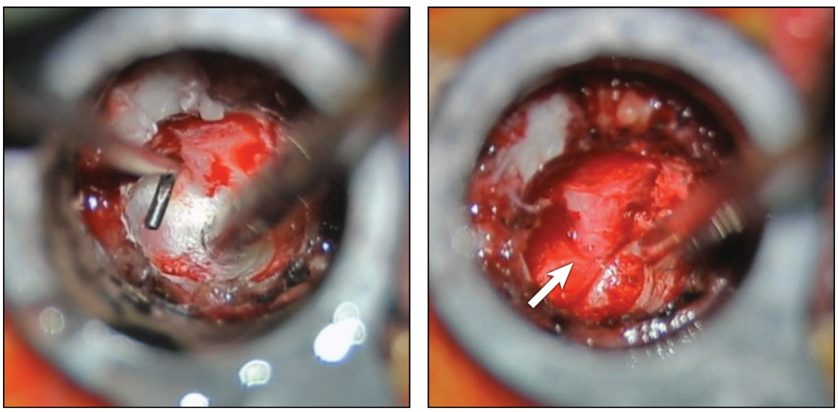

FIGURE 8. **Left:** *intraoperative microscope image down the tube as the drilling approaches the epidural space and the thinned bone appears purple or pink in color. This is pointed out by the nerve hook in this image.* **Right:** *intraoperative view of the decompressed nerve root.*

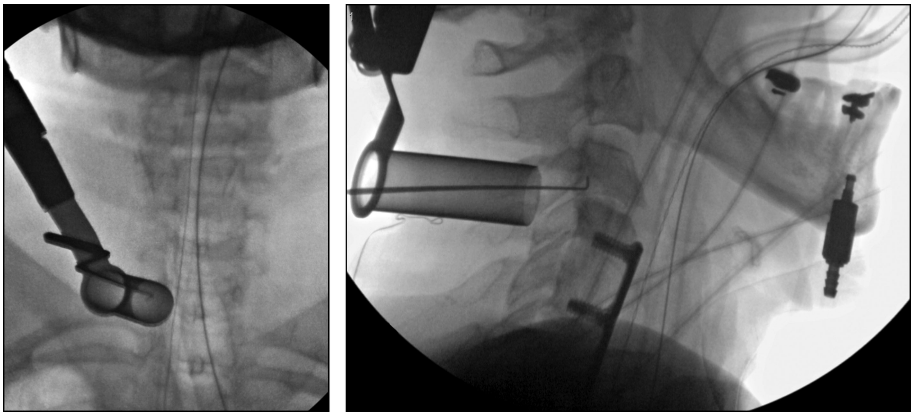

FIGURE 9. Left: *an AP image showing a nerve hook in the foramen at C8 lateral to the pedicle to show the lateral extent of the decompression.* **Right:** *a separate case demonstrating a lateral fluoroscopic image of the nerve hook in the foramen at C4.*

simple hemostatic agent such as Nu-Knit (Ethicon, Somerville, New Jersey) is placed over the nerve root.

If a second level is to be decompressed, the retractor is wanded to the adjacent level, and the process repeated. It is critical to use fluoroscopy to avoid skipping a level, especially in diminutive patients. A bridge of bone approximately 5 mm across is usually left between the 2 foraminotomies. If a posterior discectomy is to be attempted, the rostral portion of the inferior pedicle may require removal to improve access to the axilla without nerve root retraction.

The wound is copiously irrigated. A cottonoid is positioned over the exposed dura. Under the microscope, the retractor is slowly withdrawn, and any muscle bleeding points are meticulously coagulated to prevent an epidural hematoma. Rarely, a 3/32 tubular drain can be placed. The deep fascia is closed with an 0 absorbable suture on a urology needle, which is highly curved and can be passed in the small incision. The pattie is removed. In obese patients, it may not be possible to reach the fascia. Scarpa's layer and the dermis are each reapproximated with interrupted inverted 3-0 absorbable sutures. Mastisol and a single Steri-Strip (3M) are placed lengthwise on the wound. No orthosis is used. If there is bleeding from the wound postoperatively, this can be controlled by lying on a rolled towel for 30 to 60 min, applying pressure to the surgical site. The average duration of a single-level foraminotomy is 75 min. A postoperative computed tomography (CT) of successful foraminotomies decompressing the C7 and C8 nerve roots is shown in Figures 10 and 11.

The vast majority of patients are discharged on the day of the procedure. The patient may shower 48 h after surgery. No restrictions on neck motion are advocated, but avoiding heavy lifting for 2 weeks is advised.

The senior author has not performed bilateral simultaneous foraminotomies at the same level unless there is a pre-existing anterior fusion at that level. In cases of contralateral symptoms, a contralateral foraminotomy performed more than 6 mo after the ipsilateral procedure, and with flexion extension films showing no overt instability, has not resulted in any overt instability requiring

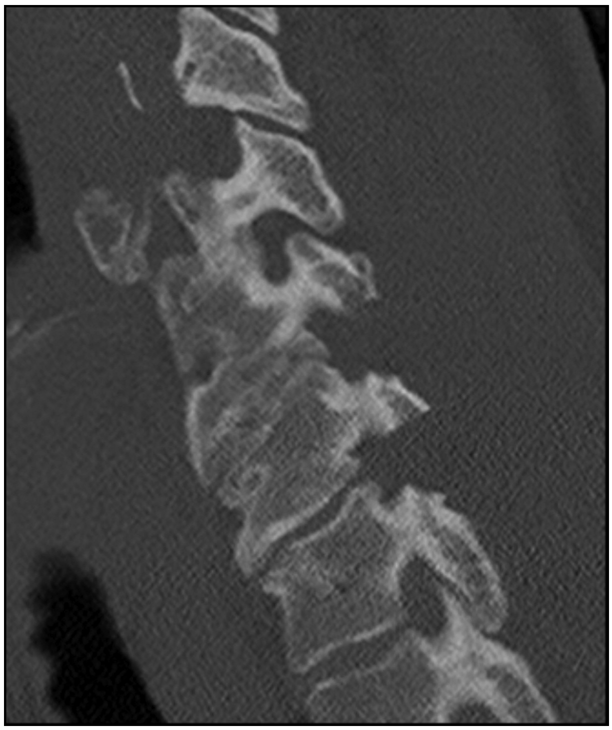

FIGURE 10. *Parasagittal CT of the cervical spine after 2-level foraminotomies showing the unroofing of the foramina with the bone removal reaching the pedicles rostral and caudal to the exiting root.*

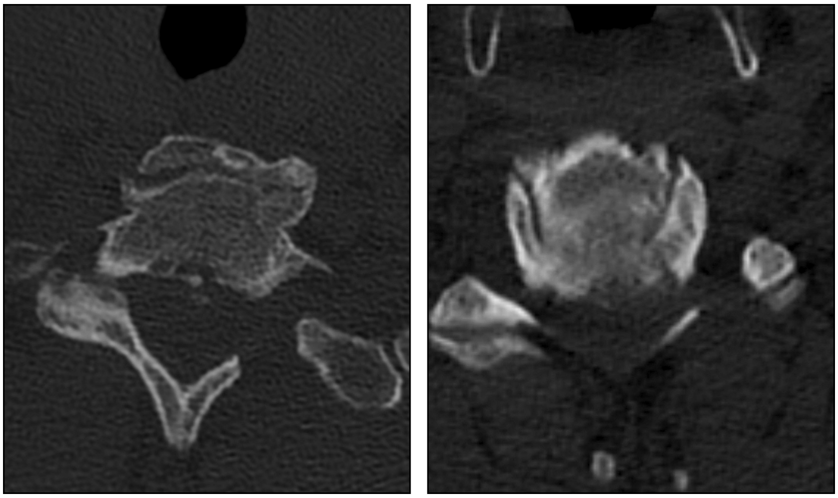

FIGURE 11. *Axial CT after left foraminotomy showing the extent of bone drilling at C7/T1 (C8 root; left figure) and at C3/4 (C4 root; right figure).*

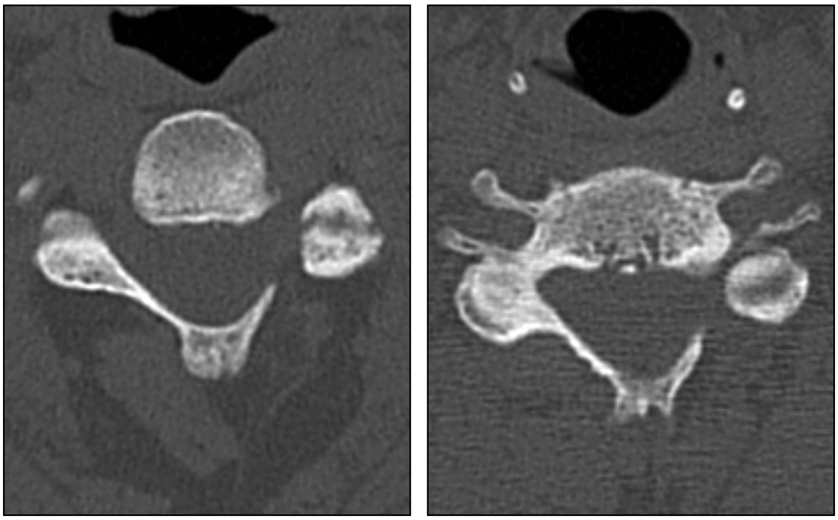

FIGURE 12. *Noncontrast axial CT images showing inadequate foraminotomies which required reoperation by the authors. Left shows a C4 root foraminotomy and right a C6 root procedure, both of which are too medial, leaving persisting foraminal stenosis laterally.*

fusion. We have seen a number of patients inadequately treated by cervical foraminotomy performed at other centers (Figure 12). Postoperative MRI is difficult to interpret, and CT is very useful. Frequently, bone removal is too medial (Figure 12), and repeat posterior surgery usually relieves the patient's symptoms without need for an anterior approach.

DISCUSSION

Anterior cervical discectomy and fusion has been a mainstay of treating cervical spondylosis for decades;[3,4] however, adjacent segment disease,[5] injury to the viscera,[6] dysphagia,[7] recurrent laryngeal nerve palsy, and visible surgical scar are potential risks.

Adjacent segment disease may occur at a lower rate after foraminotomy than after anterior fusion. Clarke et al[8] calculated an annual adjacent segment disease rate of 0.7% and a 10-yr rate of 6.7%. Skovrlj et al (97 patients)[9] reported a 1.1% per year rate of index level fusion and a 0.9% per year rate of adjacent level disease requiring surgery. This compares favorably to anterior fusion rates of adjacent segment disease of 12.2% over 20 yr requiring surgery[4] and 25.6% at 10 yr for symptoms.[10] Jagannathan et al[11] reported on 162 open foraminotomies and noted no significant trend toward kyphosis. Postoperative dynamic instability was identified in 4.9% of patients (only 1 required a fusion).

In 2015, Ahn et al[2] outlined the key steps of an MIS PCF, with utilization of a sitting position. Some surgeons may prefer this technique, feeling it decreases blood loss and improves fluoroscopic images. However, in our experience, there have been no bleeding problems with the head slightly elevated, and AP fluoroscopic views have been adequate for the lower cervical spine. In addition, the sitting position is more arduous to accomplish, increases risk of air embolus, and requires cranial fixation.

Following Ahn et al's publication,[2] Epstein[12] argued in favor of open posterior cervical laminoforaminotomies over an MIS approach. The report referenced 6 separate papers citing complications such as dural tears, infection, and neurological deficit following MIS PCF. Epstein[12] posited a steep learning curve, and noted that complications outweighed the benefits when compared to open foraminotomy. The statement that greater morbidity is associated with MIS foraminotomy than that of open surgery[12] has not been substantiated in our experience nor that of others.[9,13-18]

Branch et al[19] retrospectively reviewed a single surgeon's experience of MIS PCF of 463 patients. There were 10 complications (2.2%), preoperative conditions improved in 98.2% of patients, and complete symptom relief was achieved in 92.2%. Authors found the results comparable, "if not superior" to the open approach. McAnany et al[20] found no significant difference in outcomes between the open and MIS groups.

Kwon[17] reported no complications (33 patients), Fessler and Khoo[15] reported 2 durotomies (25 patients), and Lawton et al[18] reported 1 uncomplicated durotomy (38 patients). In a series of 97 patients, Skovrlj et al[9] reported 1 cerebrospinal fluid leak, 1 wound hematoma, and 1 radiculitis, none of which required reoperation; 5 patients required an anterior approach an average of 44 mo after surgery. Fessler and Khoo[15] reported on 25 MIS procedures compared to 26 open surgeries. Long-term clinical results were equivalent; however, the MIS group had overall shorter hospitalizations, less blood loss, and less postoperative pain medication requirements when compared to the open cohort. Winder and Thomas[21] retrospectively reviewed 107 patients, and their results echoed Fessler's and Khoo's findings.[15] Clark et al[14] reviewed 19 reported series and had similar findings. Holly et al[22] looked at 21 consecutive patients undergoing MIS 2-level PCF. Results were comparable to conventional foraminotomy with complete resolution of symptoms in 90% of patients, and no perioperative complications.

The complication rate in our 360 cases is low in comparison to its open counterpart. Three patients (<1%) developed delayed C5 root palsies, 2 of whom recovered completely (1 permanent neurologic deficit). There have been no wound infections and no direct neural injuries. There was 1 durotomy, which required only a drop of fibrin glue and no other treatment. Seven patients (2%) subsequently required an anterior approach for persistant anterior impingement. Fourteen patients (4%) required reoperation at the index level by redo foraminotomy; 6 were at C8 in the setting of continuing decline of hand function, and surgery was performed to ensure that all possible relief had been provided.

CONCLUSION

In sum, a posterior approach obviates the risks associated with anterior cervical approaches, and there is high likelihood of relief of unilateral cervical radicular pain due to foraminal stenosis. With meticulous technique, MIS PCF can be performed with very low complication rates and markedly reduced postoperative pain compared with open procedures.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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