

Minimally Invasive Cervical Foraminotomies



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Surgical options to address the symptoms and signs of unilateral cervical radiculopathy include posterior foraminotomies, anterior foraminotomies, anterior cervical discectomy and fusion, and cervical disk arthroplasty. Foraminotomies are often performed in combination with larger surgical procedures such as fusion, disk arthroplasty, and laminectomy. In these cases, the more extensive surgical exposure makes the procedure technically easier to perform. Minimally invasive posterior and anterior cervical foraminotomies for the treatment of cervical radiculopathy is the focus of this chapter. The goal of both approaches is to address the compressive pathology while minimizing tissue disruption and alteration of cervical spine biomechanics. Of these 2 approaches, the posterior cervical foraminotomy is the most common. The classic posterior approach was described by Spurling and Scolville in 1944. Since then, several variations have been described, all having the shared goal of decompressing the nerve root at the cervical neural foramen.¹ Minimally invasive laminoforaminotomy provides access to and visualization of the cervical neural foramen through muscle-sparing techniques in order to decrease the pain and morbidity associated with traditional open surgery while maintaining the same efficacy as the open procedure. The anterior cervical microforaminotomy, often referred to as the Jho procedure, was first described in 1996. It was developed to try to address the known limitations and potential pitfalls of classic anterior and posterior cervical procedures.² The technique involves accessing the compressive pathology through the anterior uncovertebral junction. Once access is achieved, the soft disk and/or bone spurs that compose the compressive pathology are excised. The procedure has evolved over time to include 4 basic variations of the technique and favor the utilization of an endoscope vs the operating microscope for visualization. Oper Tech Orthop 29:100718 © 2019 Published by Elsevier Inc.

Introduction

Cervical radiculopathy is caused by irritation of the nerve roots in the cervical spine. This irritation can involve both mechanical and chemical insults to the nerve from pathologies within the cervical neural foramen or in the lateral recess of the cervical spinal canal.^{1,2} Compression of the nerve root by herniated disks and foraminal bone spurs are the most common mechanical causes. Radiculopathy can also be caused by dynamic neural irritation from

spondylolisthesis, micromotion from degenerating discs and pseudarthrosis, trauma, and other forms of spinal instability. Chemical causes of neural irritation are less common and include inflammatory cytokines released from damaged or degenerating intervertebral disks and infections.³

The prevalence of cervical radiculopathy is 3.5 cases per 1000 population and the incidence is 0.1% worldwide.⁴⁻⁶ The symptoms are often self-limiting. Between 75% and 90% of patients experience symptomatic improvement with non-operative care including immobilization, anti-inflammatory medications, physical therapy, cervical traction, and epidural steroid injections. The small subset of patients that do not experience significant improvement of pain and function after 6 weeks to 3 months of conservative management are candidates for surgical management. In addition, patients who demonstrate significant functional loss or progressive functional loss due to pain, weakness, or both are also candidates for surgery.

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Minimally Invasive Posterior Cervical Foraminotomy

Equipment

The minimally invasive (MIS) technique for posterior cervical foraminotomies using a tubular retractor and glass endoscope was first described by Richard Fessler MD in 2002.⁷ The technique was adapted from MIS techniques using a tubular retractor developed in the late 1990s for lumbar surgery. The tubular retractors come in 16 mm and 18 mm diameters and standard and long lengths. Standard and long 30-degree glass endoscopes are connected to a standard HD arthroscopy camera unit using a custom C-mount. A flexible mechanical arm attached to the operating room table is used to hold the tubular retractor in position during the surgery.

Patient Positioning

The patient is placed in Mayfield tongs secured to a Mayfield head holder in the semisitting position with the neck in a slightly flexed position (Fig. 1). This flexed position decreases the overall amount of bony resection necessary to decompress the cervical foramen, decreases the amount of posterior occipital protuberance that may get in the way of tools and cameras especially when decompressing the upper cervical levels (C2-3 and C3-4), and prevents potentially injurious hyperextension of the cervical spine during sequential dilation of the muscular interval. In addition, the flexed position also increases the amount of space in cervical spinal canal minimizing the chance of inadvertent injury to the spinal cord in patients who have mild to moderate amounts of clinically asymptomatic central cervical stenosis. The degree of reverse Trendelenburg can then be adjusted to place the cervical spine into an optimal ergonomic position for the surgeon. Lateral fluoroscopic imaging is used to determine the level of the skin incision.

Surgical Approach and Technique of Decompression

A 16-18 mm incision is placed approximately 5-7 mm lateral to the midline on the affected side, in line with the disk space

of the affected level. The ligamentum nuchae is then incised in line with the skin incision to expose underlying paraspinous muscle fibers. A small straight Kelly clamp is then used to carefully separate the muscle fibers in line with the disk space under fluoroscopic visualization down to level of the lateral mass of the cephalad level of the level to be decompressed (ie, the lateral mass of C5 when we are performing a C5-6 foraminotomy). The use of a guide-wire, although part of the originally described technique, is contraindicated as it can inadvertently penetrate through the interlaminar space and cause a neurologic injury. Once the muscle split has been developed using the straight clamp, sequential dilation is performed using straight dilators docked at the junction of the lateral mass and lamina over the area to be decompressed. At all times, dissection in the direction of the interlaminar space is avoided. The 16 mm or 18 mm tubular retractor is then placed over the final dilator and docked at the lamina facet junction, initially facing the ipsilateral lamina (Fig. 2). This allows a better angle to start the laminotomy portion of the laminoforaminotomy. A 2.2 mm bur is used to remove the lateral lamina bone at the lamina facet junction down to ligamentum flavum (Fig. 3). Since the exiting nerve root will always be ventral to the dorsal dura, identifying the dorsal dura and the ligamentum flavum decompresses the proximal portion of the exiting nerve root and provides a reference for the depth of further bony removal. This is especially important when using the endoscope since depth perception is limited when using the video. After the laminotomy is completed, the tubular retractor is then turned laterally to allow decompression of the middle and exit zones of the neural foramen. The bur is then used to remove the inferior medial-third to the inferior medial-half of the inferior facet of the cephalad vertebra (Fig. 4). This exposes the superior medial-third to superomedial-half of the superior facet of the caudal vertebra (Fig. 5). This area of exposed superior articular process is then burred down to very thin shell and then removed with a combination of 1.5 mm and 2 mm Kerrison punches from the medial border of the pedicle of caudal vertebra to the lateral border pedicle to caudal vertebra, decompressing the middle zone of the neural foramen. The exit zone neural foramen lateral to the pedicle can be further

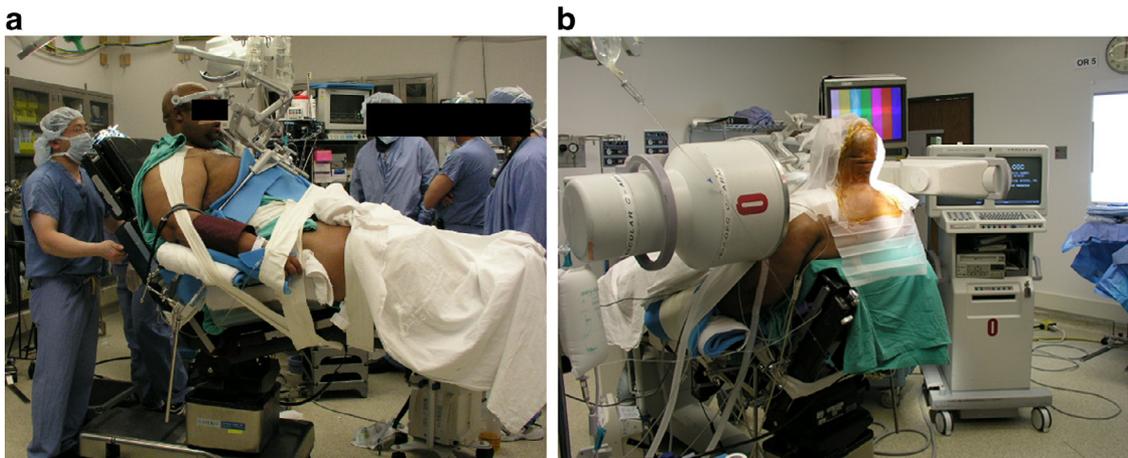


Figure 1 (a and b) The patient is positioned in the sitting position in Mayfield Tongs.

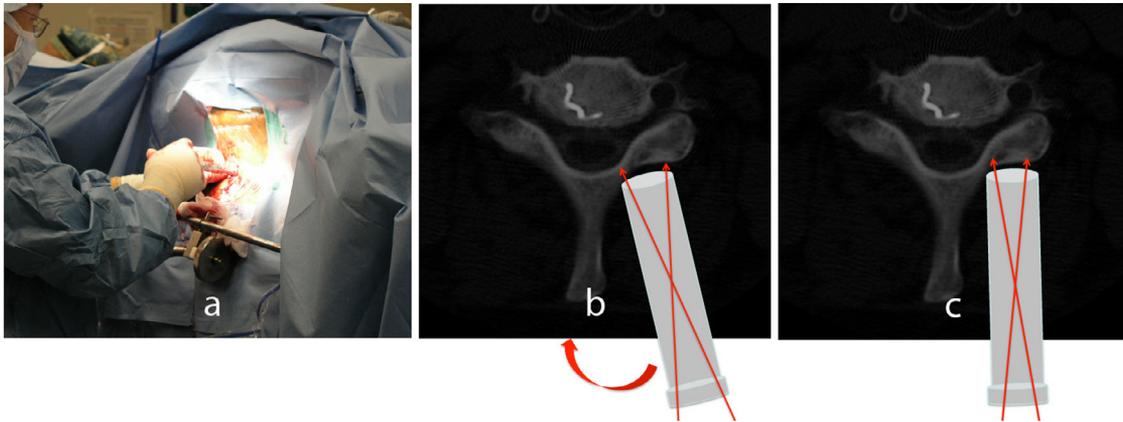


Figure 2 Tube positioning. (a) After sequential dilation of the muscular interval over the facet, the tube is secured to the mechanical arm. (b) The tube is initially angled medially to face the lateral lamina and lamina-facet junction to allow decompression of the entrance zone of the foramen. After the laminotomy is completed, the tube is angled laterally to allow decompression of the middle and exit zones of the foramen (c).

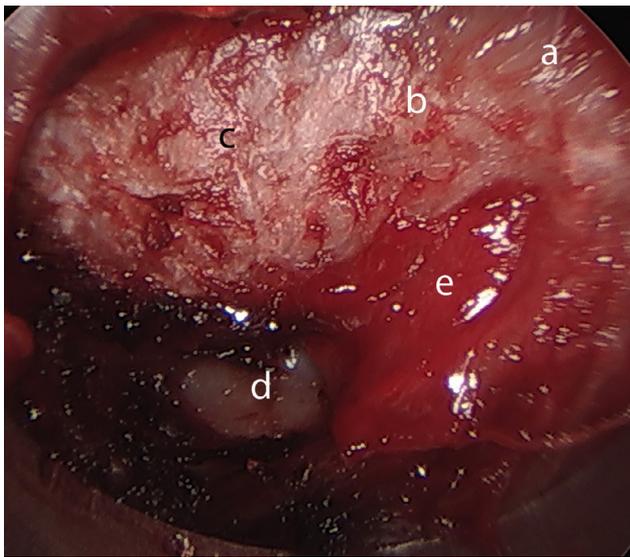


Figure 3 The 3.5-mm endoscope allows visualization of the lamina (a), lamina-facet junction (b), the medial two-thirds of the lateral mass (c), the base of the superior articular process of the caudal vertebra (d), and the interlaminar space (e).

decompressed, if necessary, with a 2-0 angled microcurette. The tubular retractor is then slowly withdrawn under direct vision. At this time, any active bleeding within the muscular sleeve can be controlled with bipolar electrocautery. The wound is then closed in standard fashion (Fig. 6).

MIS Anterior Cervical Foraminotomy

Microscopic visualization through the small bony opening used to perform the anterior foraminotomy is limited because of the straight tubular viewing access and an inwardly coning field of view. Even if the operating microscope is tilted to visualize the medial inner aspect of the spinal canal, the view at the surgical target is limited despite providing a 3-dimensional image. Because of these limitations, the operating microscope has been subsequently replaced by the glass endoscope (*endoscopic anterior cervical foraminotomy*). An endoscope provides an outwardly coning viewing configuration with a flask-shaped view. A wide and enhanced visualization at the surgical target region is achieved although the image is 2-dimensional.

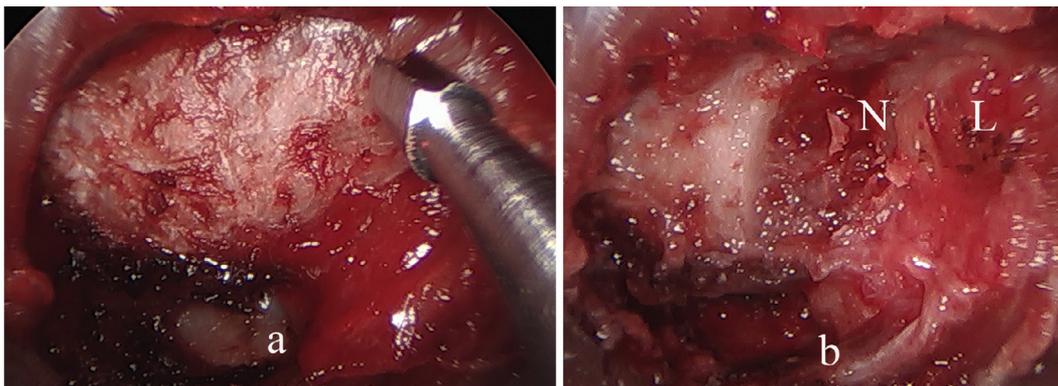


Figure 4 The lateral 5-6 mm of lamina is removed using a 2.2-mm matchstick burr. Burr is pointed at the lateral lamina (a). After laminotomy is completed (b), the ligamentum is exposed (L) and the exiting nerve root (N) is visible before it enters the middle zone of the foramen.

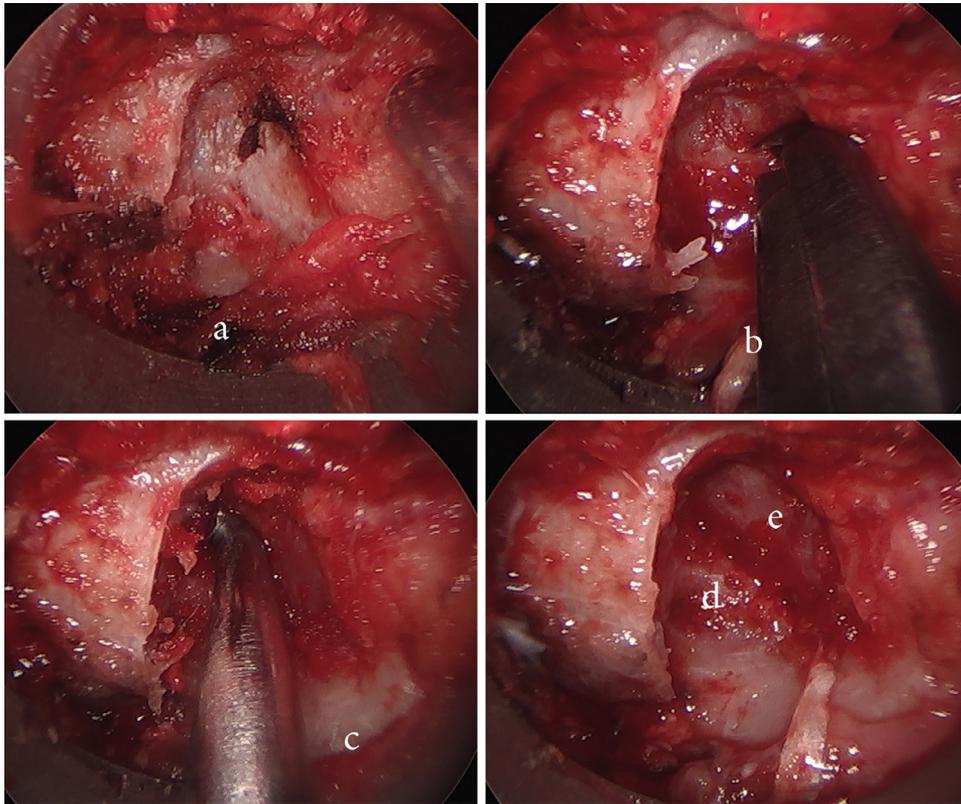


Figure 5 (a) The medial 5 mm of the inferior facet is burred down to expose the medial 5 mm of the superior facet. (b) The exposed superior facet is removed to decompress the underlying nerve root. The nerve is further decompressed to the lateral border of the caudal pedicle. (c) The exit zone of the neural foramen can be decompressed, if necessary, with microcurettes. The top of the pedicle of the caudal vertebra (d) can be seen and palpated and the exiting nerve root (e) is well decompressed.

Equipment

The endoscopes that are currently used for this technique are rod-lens endoscopes that are 4 mm in diameter and 18 cm in length. One set consists for five endoscopes: a 0-degree lens endoscope, 30-degree lens angled toward the light source, 30-degree lens angled away from the light source, 70-degree lens angled toward the light source, and 70-degree lens angled away from the light source (Fig. 7). The 0-degree lens endoscope is the basic working configuration used for most applications. Because the endoscope provides a wide-angle view, the 0-degree lens endoscope usually provides adequate views for exposure at the nerve root as well as the spinal cord. However, the 30-degree lens endoscope angled toward the light source can be used when a more-angled view toward the spinal cord is desired, and a 30-degree lens endoscope angled away from the light source can be used when a more-angled view toward the nerve root at the neural foramen is desired.

An endoscopic lens-cleaning device is invaluable to keep the lens clear so that the surgeon can continually operate without interruption (Karl Storz CLEARVISIONII system, Fig. 8). The device consists of a disposable irrigation tube that passes through an electric motor. The endoscope is placed through the rigid tubular irrigating sheath, which is connected to the irrigating tube. The irrigation tube is connected to a saline bag, which is hung on a pole. This motor-

powered irrigation device is controlled by a foot pedal to flush saline forward. When the foot pedal is released, the motor reverses its rotary direction and draws the saline back from the tip of the endoscope for 1-2 seconds. The forward flow of irrigating saline cleans the lens, and the reverse flow clears away water bubbles at the tip of the endoscope.

An endoscope holder (Aesculap Unitrac) is mounted to the operating table (Fig. 9). It provides steady video imaging while allowing the surgeon to use both hands freely. A telescoping tubular drill with a 2-mm diamond bit is used to perform the bony resection. The drill bit tip can be progressively extended as the depth of drilling advances. Bipolar forceps are shaped to accommodate the endoscopic surgical environment, and the blades of the bipolar forceps are parallel to each other, similar to a single-bladed instrument, once the blades are approximated. Various surgical curettes and other endoscopic instruments have been customized and developed in order to function efficiently within the uniquely curved endoscopic surgical trajectory.

Patient Positioning

Patient positioning is similar to that for conventional anterior discectomy with the neck in neutral rotation and flexion and extension. Gentle neck extension with a small bolster under the shoulder may only be done if sufficient spinal canal

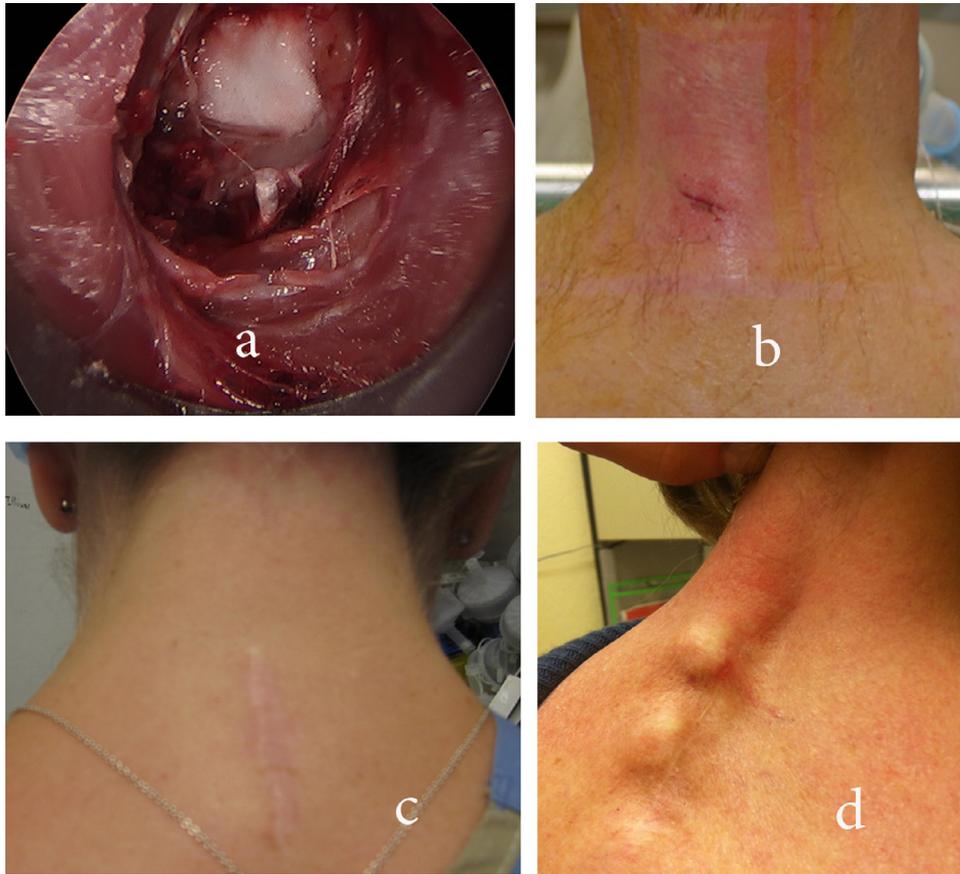


Figure 6 (a) The tubular retractor is withdrawn and the muscular sleeve is inspected for any bleeding that is controlled by bipolar electrocautery. (b) The incision is closed with absorbable stitches and sealed with skin glue. In comparison, the incision for an open foraminotomy can be significantly larger (c) and can potentially cause local paraspinal muscle atrophy (d).



Figure 7 One set of the rod-lens endoscopes that are 4 mm in diameter and 18 cm in length consists of 5 endoscopes: a 0-degree lens, a 30-degree lens angled toward the light source, a 30-degree lens angled away from the light source, a 70-degree lens angled toward the light source, and a 70-degree lens angled away from the light source. The 0-degree lens endoscope is the basic working configuration used for most applications.

clearance is demonstrated on MRI to provide room for the spinal cord. Neck extension during positioning should not exceed what the patient can achieve comfortable while awake. Cervical traction devices are not used. Obese patients

with short, thick necks might require 2-inch adhesive tape for application of gentle skin traction at the chin superiorly and at the anterior chest wall inferiorly. Intraoperative neural monitoring is used only for severe cases of myelopathy.



Figure 8 Karl Storz CLEARVISION II system for intraoperative cleaning of the lens. The device consists of a disposable irrigation tube that passes through an electric-powered motor. The endoscope is placed through a rigid tubular irrigating sheath, which is connected to the irrigating tube. The irrigation tube is connected to a saline bag, which is hung on a pole. This motor-powered irrigation device is controlled by a foot pedal to flush saline forward. When the foot pedal is released, the motor reverses its rotary direction and draws the saline back from the tip of an endoscope for 1-2 seconds. The forward flow of irrigating saline cleans the lens, and the reverse flow clears away water bubbles at the tip of the endoscope.



Figure 9 Aesculap Unitrac holder for spine applications. The Aesculap holder has a longer, more flexible arm compared to other products, but its holding terminal has a limited range of motion, even with custom modifications.

Surgical Approach and Technique of Decompression

The skin incision site is assessed by finger palpation of the C6 transverse tubercle, which is typically palpable just medial to the sternocleidomastoid (SCM) muscle. Surgical target area related to the jaw and larynx is reviewed in reference to MRI scans of the cervical spine, along with the location of the vertebral arteries (being mindful of anatomic variants). The skin incision starts 1-2 cm lateral from the midline and extends laterally across the medial margin of the SCM muscle for approximately 3-5 cm in total length. Although the center of surgical exposure is usually 3-4 cm lateral from the midline,

it must be adjusted to the size of the neck. A patient with a large neck requires a longer skin incision to maintain a 20-degree lateral-to-medial trajectory angle toward the surgical target.

At the anterior portion of the cervical spine column, the surgical target anatomy is the uncovertebral juncture that is covered by the longus colli muscle. Picturing in axial view, the surgical trajectory angle is determined by an extension line from the very medial margin of the inlet neural foramen to that of the outlet. When this line is extended toward the skin, it is the key exposure point of the skin. The platysma may be split longitudinally or transversely per surgeon

preference. The medial border of the SCM must then be defined allowing dissection down to the prevertebral fascia just medial to the SCM.

The carotid artery on the working side is identified with finger palpation, and a Meyerding retractor is placed just medial to the carotid artery. The trachea and esophagus are gently displaced medially and retracted with a Meyerding retractor. The perimeter of exposure at the lateral portion of the cervical column is just over the longus colli muscle. An intraoperative X-ray is obtained to confirm the correct level of surgery.

The extent of the longus colli is identified by palpating the transverse tubercle. The longus colli is split just medial to the transverse tubercles rostral and caudal to the intervertebral disk level, being careful to avoid injury to the sympathetic trunk and fibers located laterally along the longus colli. A self-retaining, tapered cervical retractor system is applied between the split longus colli muscle fibers to maintain exposure of the uncovertebral juncture.

An endoscope is then brought into the surgical field and the vertebral artery is identified just lateral to the uncinete process under endoscopic visualization. The vertebral artery pulsation is easily visible lateral to the uncinete process. The vertebral artery entry into the transverse foramen should be traced and confirmed preoperatively in MR scans in order to avoid incidental injury. Usually, the vertebral artery enters into the C6 transverse foramen; however, it can enter C5 or less often C4. The proximal transverse processes of the rostral and caudal vertebrae are then defined.

Pathology-Targeted Approaches in Endoscopic Anterior Cervical Foraminotomy

Transuncal Approach (Jho Procedure Type 1)

When the surgical trajectory from the skin incision to target pathology is perpendicular to the sagittal plane of the cervical spine, a bone opening at the anterolateral spine should be made along this trajectory line. Particularly for C4-5 or C5-6 operations, a routine skin incision at the upper or mid portion of the neck produces such a perpendicular surgical trajectory. In this case, the uncinete process lies directly along the perpendicular surgical trajectory (Fig. 10a). The skin incision to the point of bone exposure is similar to the general description of the anterior cervical foraminotomy approach. The vertebral artery is readily identified lateral to the uncinete process.

The vertebral artery is dissected off laterally from the lateral portion of the uncinete process. Often the uncinete process protrudes laterally far beyond the line drawn between the medial margin of the upper and lower transverse foramina. Thus, the most lateral 2-3 mm portion of the uncinete is drilled just medial to the vertebral artery toward the PLL (Fig. 10b).

The compressing pathology is exposed rostrally from the normal margin of the rostral vertebra and caudally to the normal margin of the caudal vertebra. The caudal-to-rostral exposure must be performed in reference to the endplates of the caudal and rostral vertebrae along with the intervertebral

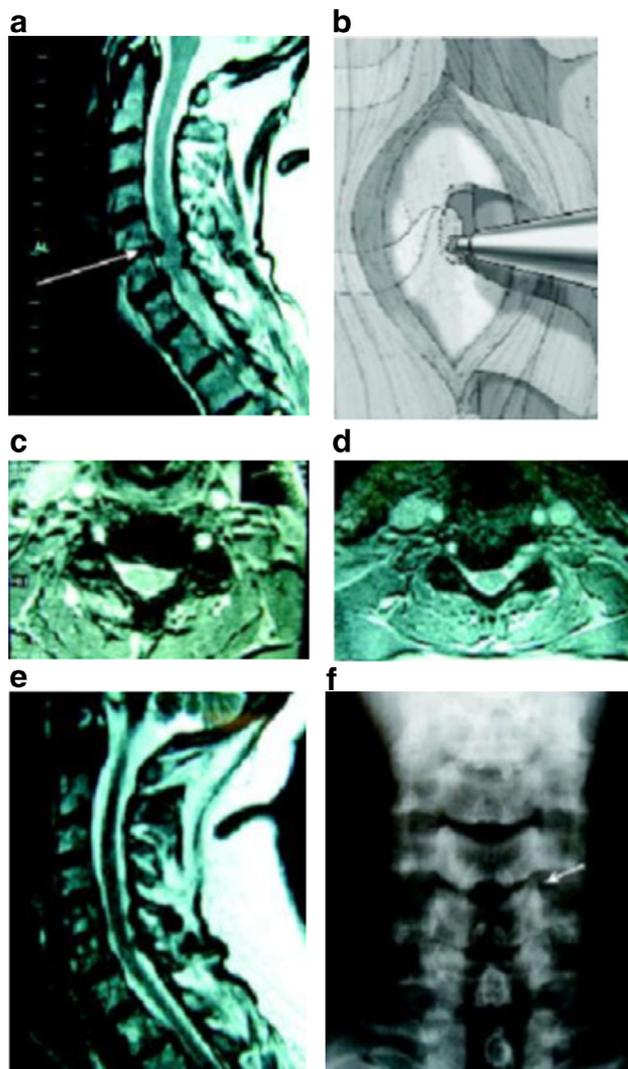


Figure 10 The schematic drawing illustrates the transuncal approach (Jho procedure type 1) from the left side. (a) The surgical trajectory from the skin incision to the target pathology must be perpendicular to the longitudinal axis of the spine for this technique. The vertebral artery is defined just lateral to the uncinete process. (b) The lateral uncinete process is dissected from the vertebral artery, and the lateral 2- to 3-mm portion of the uncinete process (dotted area) is drilled toward the posterior longitudinal ligament. The medial uncinete process has to be preserved to maintain the integrity of the intervertebral disc. (c) Preoperative T2-weighted axial magnetic resonance imaging (MRI) scan showing left greater than right spondylotic stenosis at the C5-6 level. (d and e) Postoperative T2-weighted axial (d) and sagittal (e) MRI scan taken 6 weeks postoperatively confirm good decompression from the left at C5-6. (f) Postoperative X-ray in an anteroposterior view shows the left-sided preserved C6 uncinete process (arrow).

disk space posteriorly. The vertical extent of bone removal is usually about 5 mm in length. Because of the natural lateral-to-medial incline of a surgical trajectory demanded by surgeon's standing at the side of the patient, the surgical trajectory slightly inclines medially when bone drilling advances toward the spinal canal. Drilling must therefore be maintained laterally, initially leaving a very thin rim of cortical bone on the nerve root and vertebral artery.

Once the PLL is exposed posteriorly, the thin layer of uncinete cortical bone that was left attached at the nerve root is dissected and removed. Additional compressing pathologies such as herniated soft disk and/or bone spurs are then removed off the nerve root and lateral portion of the spinal cord (Fig. 10c-e). Often the PLL is opened to expose the dura mater at the most lateral portion of the spinal cord and proximal nerve root to detect any hidden migrated disk fragments. When the PLL is opened, the ligament should be opened medially in front of the spinal cord because the epidural vein is located at the junction between the nerve root and the spinal cord. Copious epidural bleeding can occur when the PLL is opened laterally. Herniated disk fragments or bone spurs are removed with variously curved curettes. Awareness is necessary to avoid damaging the bony wall of the medial uncinete to maintain the integrity of the intervertebral disk (Fig. 10f). When spinal cord decompression is required, a specially designed curette system is used to achieve further medial decompression by undercutting the compressive pathology posterior to the rostral and caudal vertebral bodies.

Upper-Vertebral Transcorporeal Approach (Jho Procedure Type 2)

The term *upper-vertebral transcorporeal approach* refers to the location of the bone opening at the lateral portion of the upper vertebra to the intervertebral disc. This technique involves creating a bone opening at the inferolateral portion of the upper vertebra when the anteroposterior surgical trajectory inclines caudally (Fig. 11a). This approach is most often used in C6-7 or C7-T1 surgery but is also commonly used with other levels when the skin incision is made purposefully cephalad. When the vertebral artery is shown to enter at the C6 transverse foramen on preoperative MRI scans, an intraoperative X-ray is not absolutely necessary for C6-7 or C7-T1 surgery because the vertebral artery entrance into the C6 transverse foramen is visible at the time of surgery and can be used as anatomic landmark to confirm the surgical level. However, an intraoperative X-ray is still prudent if the patient's body habitus allows visualization of those levels intraoperatively.

The vertebral artery is exposed and a 2-mm medial portion of the transverse process is removed at the upper vertebra. Bone opening is then made at the inferolateral 2- to 3-mm portion of the upper vertebra with drilling toward the PLL (Fig. 11b). The surgical trajectory is directed toward the pathologic target through only the most posterior portion of the intervertebral endplate. Damage to the intervertebral endplate at the anterior two-thirds portion of the intervertebral disk must be avoided. The rest of the procedure is the same as described for other approaches (Fig. 11c-f).

Lower-Vertebral Transcorporeal Approach (Jho Procedure Type 3)

The term *lower-vertebral transcorporeal approach* refers to the location of the bone opening at the lateral portion of the

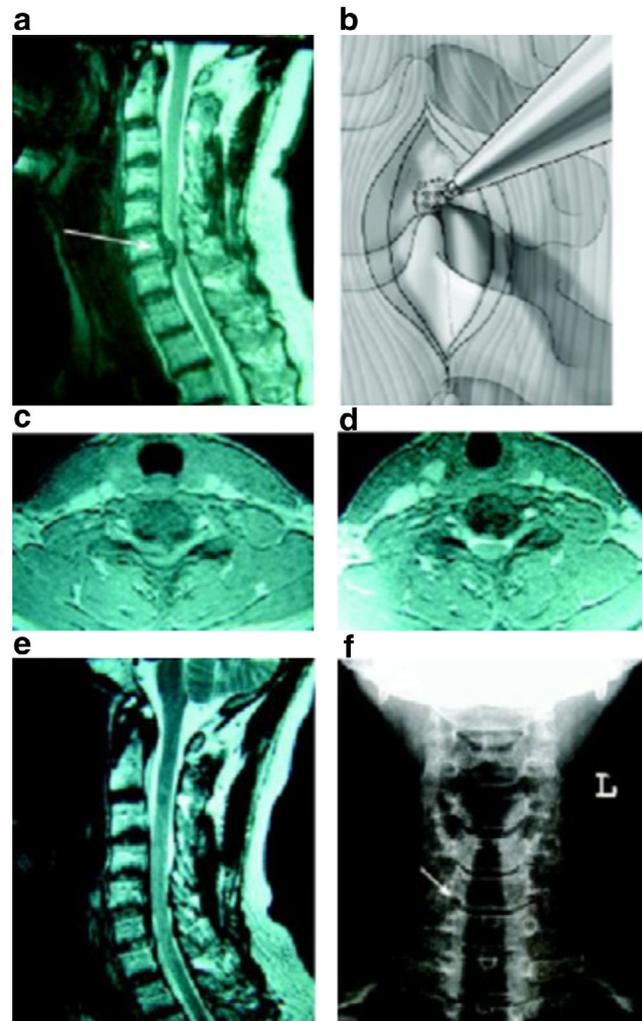


Figure 11 (a and b) Illustrative drawing and a T2-weighted sagittal magnetic resonance imaging (MRI) scan demonstrate the surgical trajectory (a) and bone opening (b) in the upper-vertebral transcorporeal approach (Jho procedure type 2) from the right side. Anteroposterior surgical trajectory from the skin incision to the target pathology inclines caudally in this technique. The medial 2-mm portion of the transverse process at the upper vertebra is removed, and the vertebral artery is defined. The lateral 3-mm portion of the inferolateral upper vertebra is drilled posteriorly (dotted area). (c) Preoperative T2-weighted axial MRI scan demonstrating large right paracentral disk herniation at C6-7. Postoperative T2-weighted axial (d) and sagittal (e) MRI scan taken 6 weeks postoperatively showing a trace of the surgical tract and good decompression. (f) Postoperative radiographs, anteroposterior view, shows a bone opening (arrow) at the right-sided C6-7. The anterior two-thirds of the endplate should be avoided to prevent damage in this technique.

lower vertebra to the intervertebral disc. For a C3-4 operation or when a skin incision is made inadvertently more caudal than it should be at any cervical disk level, this technique is utilized (Fig. 12a).

The medial portions of the transverse processes at the rostral and caudal vertebrae are identified. The superomedial 1- to 2-mm portion of the transverse process at the lower vertebra is removed, and the vertebral artery is identified. Just medial to

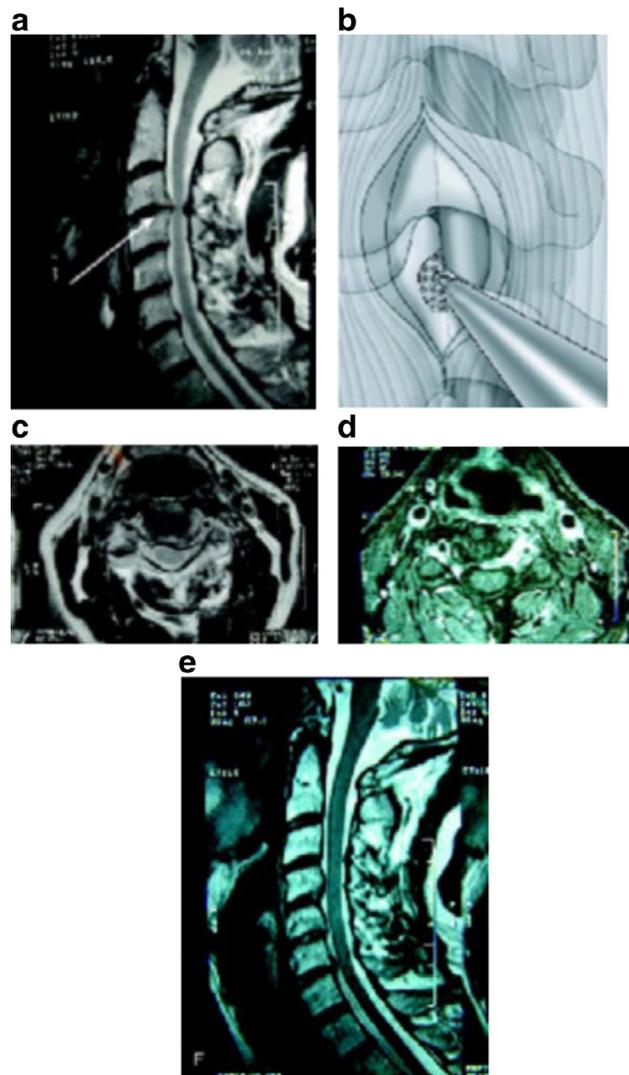


Figure 12 (a) The schematic drawing demonstrates the lower-vertebral transcorporeal approach (Jho procedure type 3) from the left side. This technique is used when a foraminotomy is performed at a high cervical disk such as C3-4. The anteroposterior surgical trajectory from the skin incision to the surgical target pathology makes a cephalad incline (arrow) as demonstrated in preoperative magnetic resonance imaging (MRI) scan, a T2-weighted sagittal view, of a patient with left-sided C3-4 stenosis. (b) A small bone opening is made at the superolateral aspect of the lower vertebra. The most medial 2-mm portion of the transverse process at the lower vertebra is removed, and the vertebral artery is exposed. The lateral 3-mm portion of the superolateral part of the lower vertebra or the base of the uncinat process (dotted area) is drilled toward the posterior longitudinal ligament. Thus, the bone opening has to be made at the lower vertebra to reach the target along the surgical trajectory. Similar techniques can be used if a skin incision is made inadvertently caudal for surgery at other cervical levels. (c) Preoperative T2-weighted axial MRI scan at C3-4 of a patient with C3-4 and C4-5 stenosis. (d and e) Postoperative T2-weighted axial MRI scan at C3-4 (d) and sagittal view (e), taken 6 weeks after left-sided C3-4 and C4-5 Jho procedure type 3 anterior foraminotomy demonstrating good surgical decompression.

the vertebral artery, the superolateral 2- to 3-mm width portion of the lower vertebra is drilled away posteriorly using a 2-mm diamond drill bit (Fig. 12b). The total vertical dimension of bone removal is approximately 5 mm in length. A cephalad-directed surgical trajectory leads the drilling posteriorly toward the target. In other words, a superior-posterior surgical trajectory from a bone opening at the rostral lower-vertebral body leads to the compressing pathology at the intervertebral disk while preserving the uncovertebral juncture at the ventral part of the cervical spine. Microdissectors and various up-curved curettes are used to remove compressing herniated soft disk or bone spurs. The nerve root and the most lateral portion of the spinal cord are released from compression.

The amount of bone removal posteriorly must be tailored depending on the extent of pathology. As drilling is advanced posteriorly, the surgical reference points include the endplate of the lower vertebra, followed by the intervertebral disk space, and the endplate of the upper vertebra at the area of target pathology. The PLL is first exposed at the uncompressed portion just caudal to the compressing pathology; then, it is exposed rostral to the compressing pathology. Drilling must be done with caution at the lateral portion where the nerve root is located. The thin cortical bone covering the nerve root is dissected and removed, followed by lifting the compressing pathology away from the PLL and removing it. The PLL can be opened medially with a microdissector and

excised laterally except when the MRI scans do not suggest soft disk herniation and the PLL fails to show any defect. Removal of the PLL laterally can cause cumbersome epidural bleeding because the epidural veins run between the 2 layers of the PLL at the lateral spinal cord canal. When the PLL is opened longitudinally with a microdissector, the white glistening dura mater is visualized. After the spinal cord dura mater is identified, the PLL can be excised. When spinal cord decompression is required, the compressing pathology is removed farther medially along the posterior margin of the rostral and caudal vertebrae (Fig. 12c-e).

Anterior Cervical Foraminoplasty (Jho Procedure Type 4)

Sometimes the compressive pathology continues along the entire medial wall of the narrowed neural foramen, such as when spondylotic bone spur formation extends from the inlet (where the nerve originates from the spinal cord) to the outlet (where the nerve exits posterior to the vertebral artery). In this case, the nerve foramen must be enlarged along its entire longitudinal axis, and the term foraminoplasty describes this procedure of remodeling the neural foramen to its larger normal shape by eliminating medial bone spurs along the longitudinal axis of the neural foramen. Because the compressive pathology usually exists at the medial wall of the neural foramen, an anterior approach toward the medial wall of the foramen is most suitable for effectively eliminating the compressive pathology.

The 2-mm medial portion of the transverse process at the vertebral artery foramen is removed at both the upper and lower vertebrae. Then the inferolateral portion of the upper vertebra, superolateral portion of the lower vertebra, and lateral 2-mm portion of the uncinete process are drilled toward the PLL (Fig. 13a). Drilling is directed along the nerve passage from pedicle to pedicle in order to have complete decompression in the vertical dimension. After the PLL is exposed, posterior bone spurs are excised in front of the lateral spinal cord. If spinal cord decompression is required, bone spurs anterior to the spinal cord are excised through a foraminoplasty hole (Fig. 13b-e). The PLL is excised, and the dura mater is exposed from pedicle to pedicle. Sometimes it is necessary to shave the superior portion of the pedicle of the caudal vertebra when the vertical dimension of the neural foramen is excessively narrowed, which is relatively common in elderly patients.

Outcomes

Outcomes of MIS Posterior Cervical Foraminotomy

The MIS approach is essentially an open approach that is modified to limit soft tissue injury. The outcomes for this approach have been generally favorable in comparison to an open approach. These good outcomes are expected since the degree of neuroforaminal decompression is similar in both

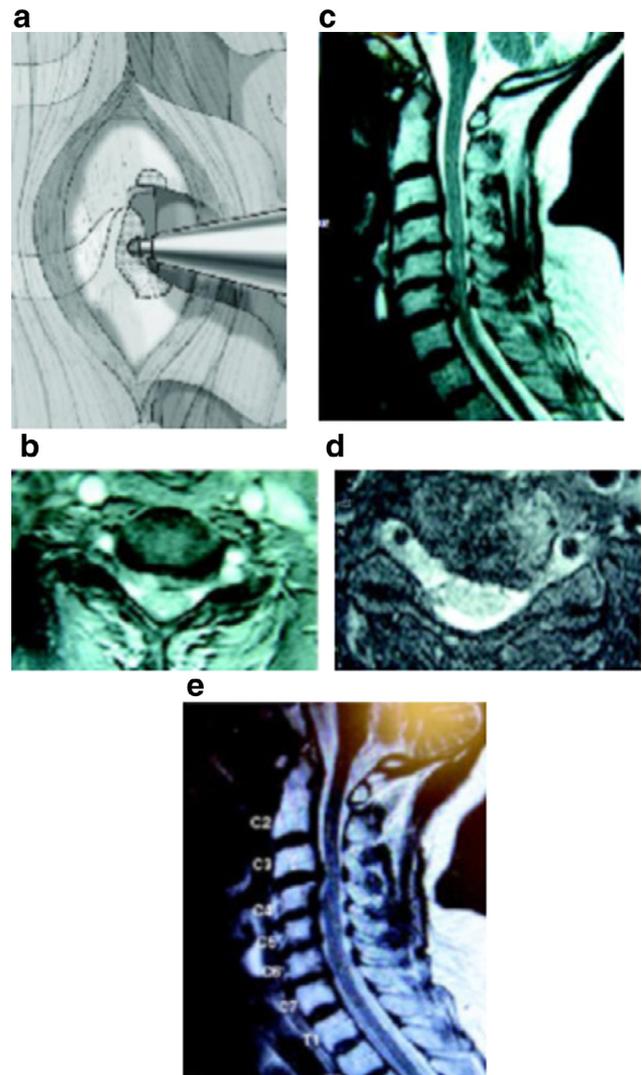


Figure 13 (a) The schematic drawing demonstrates anterior cervical foraminoplasty (Jho procedure type 4). The vertebral artery is defined by removal of a 2-mm portion of the transverse processes at the upper and lower vertebrae. This technique is used for spondylotic foraminal stenosis. The bone spurs along the medial wall of the neural foramen along the longitudinal axis of the neural foramen are trimmed with a high-speed drill. (b and c) Preoperative magnetic resonance imaging (MRI) scans, T2-weighted axial view at C5-6 (b) and sagittal view (c), in a 65-year-old woman with myelopathy reveal multiple-level stenosis with cord compression. She underwent right-sided foraminoplasty and cord decompression at C4-5, C5-6, and C6-7. (d and e) Postoperative MRI scans, T2-weighted axial view at C5-6 (d) and sagittal view (e), demonstrate enlarged right C5-6 neural foramen in axial view and good cord decompression from C4 through C7.

techniques. In 2002, Fessler reported on his first 25 patients treated with the MIS technique in comparison to 26 patients treated with open technique. Symptomatic improvement in cervical radiculopathy was observed in 87%-92% of patients. Although these results were not significantly different from the open technique, patients undergoing the MIS technique had less blood loss, shorter hospitalizations, and much lower postoperative pain medication requirements than patients

who had open foraminotomy.⁷ Skovrj et al reported outcomes for 70 patients who underwent MIS posterior foraminotomy with a mean 32.1 months' follow-up. The mean NDI of the treated group decreased from 35.1 pre-op to 10.9 post-op. The mean neck pain VAS decreased from 4.5 to 1.8. The arm pain VAS decreased from 4.2 to 0.7.⁸ Kwon et al studied 33 patients who underwent MIS posterior cervical foraminotomy with a mean follow-up of 32.7 months. The patients reported a decrease in their mean NDI from 35.6 pre-op to 14.7 post-op. Arm pain VAS also decreased from 5.3 pre-op to 1.6 post-op.⁹

Outcomes of Anterior Cervical Microforaminotomy

Unlike posterior cervical foraminotomies, studies reporting the outcomes of the anterior foraminotomy approach are more limited. Jho reported the largest series, 104 patients suffering from unilateral cervical radiculopathy from foraminal stenosis unresponsive to conservative treatment after at least 6 weeks (or at least 4 weeks if patients exhibited profound motor weakness).¹⁰ Compressive pathology was spondylotic spurs in 44 patients (42.3%), soft disk herniation in 54 patients (51.9%), and a combination of the 2 in 6 patients (5.8%). Follow-up periods ranged from 12 to 86 months (median, 36 months). Eighty-three patients (79.8%) demonstrated excellent results, 20 patients (19.2%) demonstrated good results, and 1 patient (1%) experienced fair outcome. No patient had a poor outcome, and there were no results that were unchanged or worse. One patient developed discitis, which resulted in spontaneous fusion at the operated level following antibiotic treatment, although his radiculopathy resolved well. One patient developed transient position-related hemiparesis, which resolved in 6 weeks. Two patients developed transient Horner's syndrome, which resolved in 6 weeks postoperatively.¹⁰

The clinical improvement after anterior cervical foraminotomies appear to be sustained over time. A recent retrospective review of 94 patients with minimum 10-year follow-up demonstrated that 89.4% of patients maintained good or excellent outcome by Odom's criteria.¹¹ The reoperation rate was 14.5% for symptom recurrence.¹¹

Complications

Complications of Posterior Cervical Foraminotomies

The incidence of complications after posterior cervical foraminotomies is low. In a cohort of 319 patients followed for a mean time of 10 years, the reported complications included a surgical site infection rate of 2%, durotomy rate of 0.5%, and new weakness rate of 0.5%.¹²

When a foraminotomy fails to relieve the radiculopathy or when symptoms recur, salvage options include revision foraminotomy, ACDF, or posterior cervical revision decompression and fusion. Church et al reported a 6.2% reoperation

rate in 338 patients with a mean follow-up of 10 years.¹³ Similarly, Kerry et al reported a 6% reoperation rate for recurrent root symptoms at a median follow-up of 4.8 years in 181 patients.¹⁴ Another study of 162 patients with 5-year follow-up noted a 3.1% conversion rate to fusion.¹⁵ Thus, the revision rate remains low in these patients for up to 10 years from the index surgery.

The rate of adjacent segment disease for foraminotomy appears to be lower than those reported for ACDF. Clarke et al who reported a 3.2% 5-year rate of same segment disease. In the same 303 patients, the 10-year rate of same segment disease and adjacent segment disease was 5.0% and 6.7%, respectively.¹⁶

The rate of development of postoperative instability after posterior cervical foraminotomy has been reported to be 4.9%. Loss of lordosis (segmental Cobb angle <10 degrees) was seen in 20% of a cohort of 162 patients. The loss of lordosis was correlated with clinical symptoms in 30%. Worsening sagittal alignment was associated with age >60, patients with prior posterior surgery, and patients with less than 10 degrees of cervical lordosis preoperatively.¹⁵ Postoperative neck pain has been reported in up to 22% of patients 40 months following posterior laminoforaminotomy.¹⁷

Complications of MIS foraminotomy are reported to be about 4.3% and include CSF leak, wound hematoma, and radiculitis. The rate of index level reoperation was 5.3% and adjacent level reoperation was 2.1% at an average 44.4 months post-op.⁸

Complications of Anterior Cervical Microforaminotomies

Although the surgical risks of anterior cervical foraminotomy have been minimal in the hands of surgeons experienced in this technique, permanent and serious complications theoretically exist as in any type of anterior cervical spine surgery. This MIS form of surgery is not recommended to be performed by inexperienced surgeons because of the potential devastating complications.

Major potential complications are approach-related and include vertebral artery injury, Horner's syndrome, recurrent disk herniation, infection, spinal cord injury, and spinal instability. The cervical sympathetic nerve and chain pass along the lateral margin of the longus colli. Horner's syndrome can occur if sympathetic nerves are damaged by traction injury or complete section while dissecting the longus colli.

The vertebral artery injury is a risk especially in anatomic variations where the artery enters the transverse foramen though C4 or C5 instead of the common location at C6. When the lateral aspect of the cervical spine is exposed by splitting or dissecting the longus colli, one must be mindful if there is a vertebral artery course that passes through the muscle at the level of dissection. The level of vertebral artery entry into the transverse foramen should be foreseen on preoperative MRI scan to help avoid this injury. Because vertebral artery injury (especially for dominant or codominant vertebral arteries) can result in brain stem stroke immediately or in a delayed fashion, significant damage might need to be

surgically repaired with the aid of extended proximal and distal exposure.

Recurrent disk herniation through the surgical defect in the annulus is a delayed complication that can occur when the intervertebral disk is violated substantially. To prevent recurrent disk herniation, the foraminotomy hole has to be minimal in size but large enough to provide adequate decompression. This recurrent disk herniation is extremely rare in our practice.

Spinal instability can occur if bone removal is substantial.¹⁶ When patients complain of significant neck pain postoperatively, spinal instability has to be considered. If significant spinal instability is found, fusion may be necessary.

Summary

MIS anterior and posterior approaches to foraminal decompression in the cervical spine provide consistently good and sustainable outcomes in the treatment of unilateral cervical radiculopathy. Although the anterior uncovertebral approach is more adaptable in its ability to manage a larger breadth of cervical pathologies, it also requires a greater amount of experience and training to avoid complications. In the current health care environment, health care value is becoming increasingly important for patients, physicians, and the entire health care industry. The ability to obtain good and excellent outcomes with the least amount cost is a shared goal. Given the low cost associated with a cervical foraminotomy and comparable outcomes to costlier procedures as ACDF, MIS foraminotomy performs well in regards to value per unit cost.

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