

Original Article

Minimally invasive tubular access for posterior cervical foraminotomy

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Abstract

Background: Minimally invasive tubular access for posterior cervical foraminotomy can be an effective and safe technique for decompression of the nerve root utilizing minimally invasive muscle splitting with routine outpatient discharge. This technique has come under scrutiny calling into question the associated learning curve, a subjective limited exposure provided, and an argument that the risks and complications are largely unknown. In response to previously published critiques, this study aims to describe the outcomes and complications associated with this technique in a large patient series.

Methods: A retrospective chart review was performed from 1999 to 2013 capturing a single surgeon's experience with the minimally invasive tubular access for posterior cervical foraminotomy technique from a single institution, encompassing 463 patients. Surgical outcome documented at follow-up and complications were obtained from this patient series. Additional variables analyzed include: Hospital length of stay, number of levels operated, targeted root for decompression, side operated, length of surgery, and estimated blood loss.

Results: Outpatient discharge was achieved in 91.6% of cases. There were 10 complications (2.2%) among the 463 patients undergoing this technique from 1999 to 2013. Patients were followed for an average of 1 year and 2 months postoperatively. Improvement from the preoperative condition was observed in 98.2% of patients and excellent outcomes with patients reporting complete relief of symptoms with no or mild residual discomfort was seen in 92.2%.

Conclusions: Compared with open techniques, minimally invasive tubular access for posterior cervical foraminotomy demonstrates comparable, if not superior, complication rates, and patient outcomes.

Key Words: Cervical, complications, foraminotomy, minimally invasive surgery, outcomes, tubular retractor

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INTRODUCTION

Cervical radicular root syndromes were first described in 1943 by Semmes and Murphey.^[15] The subsequently

developed posterior cervical foraminotomy technique became an established method of addressing radicular pain and weakness arising from compression of the cervical nerve root in the foramen, from either bony

stenosis or soft disc herniation.^[5,7,13,14,16] Such open techniques have since been the routine posterior approach to address these radicular symptoms arising from foraminal pathology for almost 50 years. With the advent of microendoscopic discectomy (MED) in 1997 as a lumbar application by Foley and Smith, alternatives to the traditional open posterior cervical foraminotomy technique began to emerge.^[6] In 2001, Adamson presented 100 cases using MED for cervical laminotomy and root decompression.^[1] These cases were performed in the sitting position with lateral fluoroscopic guidance to localize the level. A new approach was described in 2007 by Hilton, which utilized the tubular retractor, bayonnetted instruments, and direct surgical microscope, thus allowing three-dimensional visualization as opposed to the two-dimensional option provided by the endoscope.^[10] This technique also advocated the use of AP fluoroscopy for intraoperative localization.

As with any innovation, some have questioned the technique's utility, arguing that a limited exposure is provided, and raising concerns that the risks and complications are largely unknown.^[4] This study examines a large series of patients who have undergone minimally invasive tubular access for posterior cervical foraminotomy.* A thorough analysis of the complications and general outcomes associated with this technique is provided. Additionally, several secondary variables are presented to characterize this technique. These variables include: Recurrent disk herniation at the level of surgery, reoperation rate, hospital length of stay, operative time, and blood loss.

MATERIALS AND METHODS

A retrospective chart review was performed from 1999 to 2013 capturing a single surgeon's experience with the MITAC technique (DLH). All patients in this series underwent this technique as previously described [Video 1]; patients were positioned prone and AP fluoroscopy was used for level localization and placement of the tubular retractor.^[10] A total of 463 patients were identified having undergone MITAC during this time frame. Patient demographics, number of levels operated, targeted root for decompression, hospital length of stay, side operated, length of surgery, estimated blood loss, diagnosis, last follow up date, patient outcome

*The title of the procedure, minimally invasive tubular access for posterior cervical foraminotomy, is too long and complex for routine use in the text. Therefore, it will be replaced by the acronym MITAC, when the general procedure is referred to. When the specific target is identified, the acronym will be altered by the addition of letters as appropriate: D – discectomy, F – foraminotomy, L – laminotomy. The popular name for this procedure when a case is booked in the operating room (OR) is cervical MITR (minimally invasive tubular retractor).]

at last follow up date, and complications were recorded from the chart review [Table 1]. Due to a change in our electronic medical record system, some of the secondary outcomes could not be obtained for patients undergoing this technique prior to 2008.

CLINICAL EXPERIENCE/RESULTS

Demographics

The average age of these 463 patients at time of surgery was 49.6 years. There were 272 (58.7%) males and 191 (41.3%) females. Average length of surgery was 59.7 min and mean estimated blood loss was 59.5 cc. Only 37 patients (8.6%) required overnight hospital admission, and the remaining 395 patients (91.6%) were treated as outpatients [Table 1].

Complications

There were 10 complications (2.2%) among the 463 patients undergoing this technique from 1999 to 2013. Durotomy was the most frequent complication and occurred in four patients (0.8%). The durotomy was repaired by placing a small piece of DuraGen Plus™ *Integra LifeSciences Corp.* over the defect prior to closure. None of the four durotomies went on to develop a persistent cerebrospinal fluid (CSF) leak, wound break-down, or required additional surgery. There was one surgical wound infection (0.2%), which required incision and drainage followed by a course of antibiotics. There was one case of meningitis (0.2%) and after a thorough review of the patient record, we are unable to identify the cause, there was no durotomy during surgery, and no known preexisting infection. This patient was readmitted to the hospital and placed on a course of IV antibiotics and ultimately did well. While the CSF profile was suggestive of meningitis CSF cultures never

Table 1: Demographic data on 463 subjects undergoing minimally invasive tubular access for posterior cervical foraminotomy

Demographic	
Number of subjects	n=463
Gender (%)	
Males	58.7
Females	41.3
Mean age	49.6 years
Diagnosis (%)	
Disk herniation	58.3
Foraminal Stenosis	41.5
Hospital length of stay (%)	
Outpatient	91.6
Admitted overnight	8.6
Mean length of surgery	59.7 minutes
Mean estimated blood loss	59.5 mL

mL: Milliliters

grew an organism; however, the specimens were sent after the initiation of antibiotics. There was one case of unilateral vertebral artery occlusion (0.2%) early in the series; no obvious cause was identified upon review of the patient's record. One patient was extubated in the prone position during surgery; this was thought to be secondary to a poorly secured endotracheal tube. The tubular retractor was quickly removed and tegaderm was stapled over the incision allowing for the patient to quickly be positioned supine and reintubated while keeping the surgical field sterile. After the patient was reintubated the surgery was completed and the patient had no further complications. Two patients (0.4%) undergoing a two level ipsilateral decompression awoke with marked biceps weakness, which ultimately resolved completely within 2 months. Immediate postoperative imaging was performed on these two patients and did not identify an etiology for this weakness. Patients were treated with steroids and eventually had complete resolution of these symptoms. Both of these patients had ipsilateral two level decompressions of the C7 and C8 roots. There were no surgical site hematomas, wound dehiscence, death, and no instances of entering the cervical canal with the tubular retractor. None of the durotomies occurred as result of the dilating process, but rather were related to dural dissection during microdisectomy with very tight neural components.

Clinical outcome/follow-up period

Follow-up data was available on 450 patients. Average follow up was 1 year and 2 months. A total of 415 (92.2%) patients were pleased with their result reporting complete relief of symptoms with no or mild residual discomfort. Twenty-seven (6.1%) said they had some degree of residual pain and/or numbness but were improved from the preoperative state. Eight patients (1.7%) reported unchanged or worse symptoms and seven of these patients eventually underwent anterior cervical fusion with satisfactory outcomes.

Secondary outcomes

Secondary outcomes were obtained on all patients undergoing this technique from 2008 to 2013, ($n = 241$). Of these 241 patients, 21 (8.7%) had two ipsilateral levels decompressed at the time of surgery, and 220 patients (91.3%) had a single level decompressed. There were no patients in which a bilateral decompression was attempted or performed. One hundred and forty patients (58.1%) underwent a left sided decompression while 101 patients (41.9%) underwent decompression on the right. The distribution of the cervical roots targeted for decompression in these 241 patients is presented in [Table 2]. The mean age of patients undergoing a single level decompression was 49.7 years. A diagnosis of disk herniation was present in 128 patients (58.2%) and foraminal stenosis in 92 patients (41.8%). The average length of surgery

was 56.5 min and the mean estimated blood loss was 45.7 cc. Decompression was performed on the left side in 132 patients (60%) and on the right in 87 patients (40%). The C7 root was the most frequent targeted root for decompression in 55% of patients.

An ipsilateral two level decompression was performed in 21 of the 241 patients (8.7%). The mean age of patients undergoing a two level decompression was 54.2 years. A diagnosis of disk herniation was present in 2 patients (9.5%) and foraminal stenosis in 19 patients (90.5%). The average length of surgery was 82.1 min and the mean estimated blood loss was 81.4 cc. Decompression was performed on the left side in 8 patients (38.1%) and on the right in 14 patients (66.7%). The C6 and C7 roots were the most frequent roots targeted for decompression in 66.7% of patients.

Recurrent disk herniation at the same level of prior surgery occurred in 9 of the 241 patients (3.7%) with available electronic medical records from 2008 to 2013. Recurrent disk herniations were diagnosed and additional surgery was performed from 7 to 32 months after the initial decompression. Five recurrences (3.5%) occurred at C7, three (3.8%) at C6, and one (4.5%) at C8. In all nine patients with recurrent disk herniation at the same level of prior surgery, an anterior cervical disectomy and fusion (ACDF) was the technique used upon revision. Two of the 241 patients (0.8%) went on to develop a *de novo* adjacent level disk herniation within 12–18 months after the initial surgery. These two patients underwent a minimally invasive tubular posterior cervical foraminotomy to address their adjacent level disk herniation.

DISCUSSION

The MITAC procedure was developed as an alternative to the minimally invasive endoscopic approach to the spine, permitting direct 3-D microscopic visualization of the operative field through a tube, several millimeters in diameter, which is used both as a dissector and a retractor. The patient is placed in the prone position, and intraoperative imaging for localization is carried out in the A-P plane of the spine. The A-P view for localization is one of the major advantages of the MITAC. It is carried out in the plane of the surgical procedure, which intuitively improves accuracy. The tubular retractor

Table 2: Distribution of affected level and side operated in 241 patients

Anatomic level %	Side %
C4 (3.3)	Right (12.5), Left (87.5)
C5 (5.4)	Right (53.8), Left (46.2)
C6 (32.4)	Right (50.0), Left (50.0)
C7 (58.1)	Right (39.3), Left (60.7)
C8 (9.1)	Right (50.0), Left (50.0)

provides a path of light to enhance visualization. Although the tube is primarily a retractor, it can be used as a dissector, allowing the surgeon to visualize the entire operative field during dissection and retraction.

The approach is through a muscle splitting incision, which results in less blood loss during the opening phases of the surgery, and less pain during the postoperative period. When the procedure is over, the tube retractor is removed and the muscles return to their usual positions, avoiding the need for deep layered closure.

Some have raised a question about the learning curve in the acquisition of the skills necessary to perform this procedure. There are few relevant papers in the literature concerning morbidity and mortality and learning curves. It is for this reason we report our cases, to establish a large data base, perhaps the largest in the literature on this subject, which can be used by others as they seek various ways of presenting their outcomes.

The learning curve for this procedure is unique for each surgeon, considering the knowledge base each surgeon brings to each learning process. Neurosurgery residents and fellows leave training with an understanding of the gross and microscopic anatomy of the cervical spine and its nerves. Additionally, each has experience with the microscope intraoperatively, and with intraoperative imaging for localization. They have had experience with operating at depths, including through a “tube” in the transphenoidal approach to the pituitary gland. Some have used muscle splitting procedures in harvesting iliac bone. These and other skills can be honed in the surgical laboratory. General principles to a MITAC can be observed while assisting and, then, finally conducting the lumbar variant of this procedure before performing this technique on the cervical spine.

Although a purpose of this paper was not to provide a tutorial for the procedure, some of the key elements of the procedure will be stressed to provide the reader with a frame of reference for a discussion of complications.

A tubular exposure viewed under the microscope gives the surgeon a high resolution 3-D and magnified view of the medial facet and foramen targeted for decompression. This exposure provides a focus on the area of pathology negating the need for extraneous dissection for the purposes of maintaining an open exposure on a small area of pathology [Video 1]. Furthermore the tubular retractor is able to be angled in any direction during the surgery, which we advocate, such that the surgeon can constantly make adjustments to optimally visualize and instrument a targeted area of stenosis or disk herniation. With the advent of bayoneted instruments for the tubular retractor surgeons gain an even less restricted view of the targeted pathology. The tubular retractor can and should be used as an instrument (not just as a retractor set down in a fixed position) mobilized to view different perspectives. This principle in conjunction with bayoneted tubular

instruments will provide the surgeon with an adequate degree of maneuvering free of restrictions.

To evaluate the complication rates of MITAC we first review the published complication rates in open posterior cervical laminoforaminotomy. Reports on open cervical laminoforaminotomy describe complication rates ranging from 0% to 5.3%, and reoperation rates ranging from 1% to 14% [Table 3].^[3,8,9,12,13,17] One of the largest series published on the open posterior cervical laminoforaminotomy technique is that of Henderson *et al.*, in which they report on the results of 846 procedures performed on 736 patients from 1963 to 1980.^[9] They did not report on durotomy as a complication. Thirteen of the 846 procedures (1.5%) had complication related to wound infection ($n = 10$) or wound dehiscence ($n = 3$). One hundred and three patients (14%) required an additional posterior surgery, 32 patients (3.8%) required ACDF, and they state a 3.3% disk recurrence rate. Three patients (0.4%) had a postoperative motor deficit, which is not stated whether these were transient or permanent. Patients were admitted postoperatively and remained inpatients for an average of 5 days postoperatively.

Much of the data on the outcomes of the open technique were published in the 1980–1990s, with only small case series being published more recently. The few larger case series published more recently in the 1990s cite complication rates of 2.2–3.8% among series with 89–183 patients.^[12,17,18] Furthermore these authors do not make mention of durotomies, and only one reports on recurrence rate of 6.7%.^[12] Of the complications reported by these authors, there was an infection rate of 0–2.2%,^[12,17,18] poor outcome of 3–4.5%,^[12,17,18] asymptomatic air embolism of 2.3%,^[18] and one case of central cord syndrome.^[18] Two authors report on hospital length of stay, which ranges from 100% outpatient

Table 3: Comparison of complication and reoperation rates among MIS and open cervical foraminotomy techniques

Complication	Present study	Open techniques*	Former MIS techniques ⁺
Durotomy	4 (0.8%)	Not reported	2.0%
Postoperative weakness	2 (0.4%)	0-5.0%	Not reported
Wound Infection	1 (0.2%)	0-2.2%	1.0%
Meningitis	1 (0.2%)	Not reported	Not reported
Unilateral vertebral artery occlusion	1 (0.2%)	Not reported	Not reported
Extubated intraoperatively	1 (0.2%)	Not reported	Not reported
Hematoma/seroma	0	0-0.4%	0
Canal dilated	0	n/a	Not reported
Poor outcome	8 (1.7%)	0-4.5%	1%
Reoperation rate	3.7%	1.0-14.0%	3.0-4.2%
Overall complication rate	2.2%	0-5.3%	1.0-3.0%

*Aldrich F. *J Neurosurg* 72:370-377, 1990; Harrop JS, *et al.* *J Neurosurg (Spine)* 98:131-36, 2003; Henderson C, *et al.* *Neurosurgery* 13:504-512, 1983; Kumar GR, *et al.* *Br J Neurosurg (England)* 12:563-568, 1998; Murphey J, *et al.* *J Neurosurg* 38:679-83, 1973; Tomaras CR, *et al.* *J Neurosurg* 87:41-43, 1997; Adamson TE. *J Neurosurg (Spine)* 95:51-57, 2001; Adamson TE. *J Neurosurg (Spine)* 1:43-46, 2004.

procedures among 183 patients to an average inpatient length of stay of 7 days among 89 patients.^[12,18]

There were 10 complications in our series of 463 patients undergoing this technique from 1999 to 2013 for an overall complication rate of 2.2%. This is well within the published complication rate ranges of the open techniques of 1.5–3.8% among the larger series.^[9,12,17,18] Furthermore we include durotomies within our complications, whereas in the open technique publications there is no mention of durotomy. Without inclusion of durotomy our complication rate falls to 1.3% among 463 cases. Complications are of a similar scale to those seen in a related technique as described by Adamson in which a complication rate of 1–3% was reported from two large series of patients.^[1,2] There was one surgical wound infection in our series (0.2% vs. 0–2.2% reported in open technique), one case of meningitis (0.2% vs. 0% reported in the open technique), one case of unilateral vertebral artery occlusion (0.2% vs. 0% reported in the open technique), and one patient was extubated in the prone position during surgery (not necessarily a surgeon-related complication but included nonetheless). Two patients (0.4% vs. 0 to 0.6% reported in the open technique) in our series undergoing a two level ipsilateral decompression awoke with marked bilateral biceps weakness, which ultimately resolved completely over a matter of weeks. In our series of 463 patients, there were no surgical site hematomas, wound dehiscence (0% vs. 0–0.4% reported in the open technique), death, and no instances of entering the cervical canal with the tubular retractor.

The four cases of durotomy reported in our series all occurred after the foraminotomy had been performed and during microdissection around the nerve root. Interestingly all the durotomies were located in the root axilla; no cases of central canal durotomy occurred. Frequently seen in these situations was an adherent piece of ligamentous or scar tissue in the root axilla, which we attempted to dissect free. Also of note, each durotomy was characterized by a small pin hole sized defect in the dura of the root axilla when viewed under the high powered surgical microscope. There were no situations in which we observed a contused thecal sac or large dural defect at any point during the procedure, and specifically upon completion of the foraminotomy exposure.

In our series of patients, 91.6% were performed on an outpatient basis and only 8.6% required inpatient admission. This compared with a majority of the open technique patients requiring inpatient admission and only one series of the open technique publishing the technique performed on an outpatient basis [Table 4].^[9,12,17]

Extended data were available on 450 patients who were followed for an average of 1 year and 2 months. Eight patients (1.7%) had postoperative dysesthesias or radiculopathy where persistence or exacerbation of symptoms postoperatively is reported at 1.5–8.5%.^[9,12,13,17,18]

Improvement from the preoperative condition was observed in 98.2% of patients. Excellent outcomes with patients reporting complete relief of symptoms with no or mild residual discomfort was seen in 92.2%.

Of interest, one small prospective randomized study comparing open cervical foraminotomy with minimally invasive tubular cervical foraminotomy has been reported in the literature.^[11] Forty-one patients with cervical radicular symptoms were randomized to either open or tubular cervical foraminotomy. Surgical outcomes and postoperative pain was compared between the two groups. Significant differences found between the groups include: (i) significantly greater postsurgical neck pain in those undergoing the open technique, as assessed by visual analog scale (VAS), up to 4 weeks postoperatively, (ii) significantly longer hospital stay in those undergoing the open technique, (iii) significantly longer duration of postoperative prescription pain medication use in those undergoing the open technique, and (iv) a significantly larger incision size among those undergoing the open technique. No complications were reported in this study. There was no significant difference observed between the groups in the average surgical time (76–78 min) or surgical success rate (84–86%). This study describes a similar technique for minimally invasive foraminotomy as we report here except for one important difference, which being the use of AP fluoroscopy for localization and placement of the tubular retractor.

Of the secondary outcomes reported, a disk recurrence requiring additional surgery occurred in 9 of 241 patients (3.7%) in our series. Recurrent disk herniations requiring additional surgery have been reported at rates of 1.0–6.7% in the larger open technique series.^[8,9,12,13] Of the nine patients with recurrent disk herniation in the present series, an ACDF was the technique used upon revision. Two of 241 patients (0.8%

Table 4: Comparison of surgical outcome and hospital length of stay among MIS and open techniques

Outcome	Present study %	Open techniques* %	Former MIS techniques+ %
Surgical outcome			
Complete relief of symptoms	92.2	90.0-98.0	91.0-95.0
Residual pain/numbness but overall improved	6.0	4.2	6.0
Unchanged or worse symptoms	1.7	1.5-8.5	3.0
Admission status			
Outpatient	91.6	0-100	90
Inpatient	8.6	0-100	10

*Aldrich F. J Neurosurg 72:370-377, 1990; Harrop JS, et al. J Neurosurg (Spine 2) 98:131-36, 2003; Henderson C, et al. Neurosurgery 13:504-512, 1983; Kumar GR, et al. Br J Neurosurg (England) 12:563-568, 1998; Murphey J, et al. J Neurosurg 38:679-83, 1973; Tomaras CR, et al. J Neurosurg 87:41-43, 1997. +Adamson TE. J Neurosurg (Spine) 95:51-57, 2001; Adamson TE. J Neurosurg (Spine) 1:43-46, 2004.

vs. unknown in open technique) in our series went on to develop an adjacent level disk herniation within 12–18 months after the initial surgery. These two patients successfully underwent a MITAC to address their adjacent level disk herniation.

Based on this comparison we would postulate that the minimally invasive tubular posterior cervical laminoforaminotomy technique has a risk/complication profile similar to the open technique when performed by surgeons experienced in tubular spine surgery and utilizing AP fluoroscopy for localization.

LIMITATION

This study, as with any of retrospective design, suffers primarily in that data are acquired before the appropriate study questions may be asked. This is also the principal limitation created by the change that occurred in the institutions electronic medical recordkeeping. However, this problem did not materially affect our goals of identifying complications and addressing the “learning curve.” Most neurosurgeons who have finished a program of neurosurgical education and training have the basic skills to be trained in this procedure.

Some might say the single surgeon experience is also limiting, if so, the limitation was minor. At the worst it created a constant and homogeneous data base.

CONCLUSIONS

We hope to raise awareness on the outcomes and complications of the minimally invasive tubular access for posterior cervical foraminotomy technique by presenting the largest published series to date on this technique. When compared with the complications and outcomes of the open techniques, we find surprisingly that the complication rates are within the range of those published for the open technique, and that a majority of cases are able to be performed on an outpatient basis with good patient outcomes. Our series and discussion highlight the MITAC technique providing evidence that this minimally invasive technique serves as an excellent tool for foraminal pathology. As previously stated, this technique should be reserved for surgeons experienced in tubular spine surgery who have already developed competency in the lumbar spine. We strongly advocate the utilization of AP fluoroscopy for localization in order to safely and successfully perform this technique.

The advantage of the minimally invasive tubular posterior cervical foraminotomy over traditional techniques is found in several facets. Foraminotomy as explained here does not destabilize the facet joint. Muscle splitting access provided by the tubular dilation system may reduce intraoperative bleeding, and postoperative pain. The tube, of course, is continuously curved. The retracted tissues are constantly

subjected to the local forces of the curve. Even when used as a dissector there are no sharp edges along the shaft of the tube over which tissues can be left draped over sharp edges, common with standard retractors. Upon removal of the tube from the wound, there is immediate closure of the wound and reconstitution of fascial layers, leaving no space for the accumulation of fluid. Using the surgical microscope and a tubular retractor, the surgeon is provided a high resolution exposure and working corridor. AP fluoroscopy is performed in the same plane as that of the surgery facilitating a simple yet safe and reliable means of localization and retractor insertion. As result of these characteristics this technique can adequately address the pathology, has a reasonable complication profile, and can be performed on an outpatient basis in a majority of patients.

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