



Full endoscopic cervical spine surgery

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Background: The authors present 4 techniques for fully-endoscopic cervical spine surgery with accompanying case series: (I) posterior cervical unilateral laminectomy and bilateral decompression, (II) posterior cervical foraminotomy (PCF), (III) anterior cervical discectomy, and (IV) anterior transcorporeal discectomy.

Methods: We retrospectively reviewed fully endoscopic cervical spine surgery cases at one high-volume endoscopic center in the United States and present clinical data extracted from endoscopic spine surgery performed over a 6-year period with a minimum clinical follow up of 1 year.

Results: A series of 114 patients who underwent fully endoscopic cervical spine surgery between 2012 and 2018 is presented. Clinical results and technical data are presented.

Conclusions: Fully endoscopic cervical spine surgery is an emerging surgical technique for addressing cervical radiculopathy and myelopathy through a minimally invasive approach.

Keywords: Endoscopic spine surgery; minimally-invasive; cervical radiculopathy; myelopathy

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Introduction

Cervical disc herniation is common and can affect patients of different ages (1). It can present as a radiculopathy or myelopathy, depending on the pattern of herniation. Cervical radiculopathy commonly presents with pain, paresthesia, and motor weakness (2). Cervical myelopathy can typically present with gait disturbance, motor weakness, loss of hand dexterity, bowel or bladder dysfunction, and paresthesia (3). Traditional surgical management includes anterior cervical discectomy and fusion (ACDF) and posterior cervical foraminotomy (PCF). These approaches have been exhaustively studied and validated (4-7). ACDF has long been considered the gold standard of cervical disc replacement techniques, but does pose some disadvantages, mainly the need for fusion and the risk of developed adjacent disc disease requiring future additional surgical

intervention (8). With advances in endoscopic techniques and technologies, opportunities for development of minimally invasive and less disruptive surgical approaches presented itself.

Fully-endoscopic cervical spine surgery is different from micro-endoscopic cervical spine surgery in the sense that the tubular retractor is so small that even with loupes or microscope the operative field is not visible. Fully-endoscopic spine surgery is typically cervical spine surgery performed through a working-channel endoscope. Bi-portal fully endoscopic spine surgery, as the name implies, utilizes 2 ports: a port for surgical instruments and a port for an endoscopic camera. Endoscopic approaches to the cervical spine have been reported and found to be safe and effective in the literature (9).

Here we present 4 distinct fully endoscopic cervical spine surgery approaches for the treatment of cervical

radiculopathy and myelopathy (with case series) that utilize a working channel endoscope, are truly minimally invasive, and do not require a fusion: (I) posterior cervical unilateral laminectomy and bilateral decompression, (II) PCF, (III) anterior cervical discectomy, and (IV) anterior transcorporeal discectomy.

Methods

Patient selection

A retrospective patient review was performed on 114 patients who underwent fully endoscopic cervical spine surgery procedures between 2012 and 2018. Minimum patient follow-up was 1 year.

Statistical analysis

Statistical calculations were carried out using IBM SPSS version 24 for Mac (IBM Corp.).

Posterior cervical unilateral laminectomy for bilateral decompression operative technique

The procedure was performed under general anesthesia; the patient was positioned prone on hip and chest bolsters with the head secured in the Mayfield head holder. Somatosensory evoked potential monitoring was used. The Joimax iLESSYS[®] Delta endoscopic system was used for the procedure. A 1 cm incision was made through the skin 1 cm lateral to the midline. Using intermittent fluoroscopic guidance, alternating between lateral and anterior-posterior (AP) view, a sequential dilators, then the final 10-mm beveled tubular retractor, were placed on the junction of the spinous process and the lamina. The 10-mm outer diameter working channel endoscope with 6 mm working channel was placed and a high speed Shrill[®] drill was used to complete the sub-spinous process laminectomy. An endoscopic micro Kerrison rongeur was used to remove the ligamentum flavum and to finish the laminectomy/laminotomy. *Figure 1* demonstrates preoperative and postoperative MR images, intraoperative fluoroscopic images, and endoscopic camera views of a multi-level posterior cervical unilateral laminectomy for bilateral decompression.

PCF operative technique

The procedure was performed under general anesthesia;

patients were positioned prone on hip and chest bolsters with their heads secured in a Mayfield head holder. The Joimax iLESSYS[®] Pro endoscopic system with a 7.3 mm outer diameter was used for the procedure. Percutaneous entry was established entering through the skin 1 cm lateral to the midline. Using intermittent fluoroscopic guidance, alternating between lateral and AP view, a 3.5-inch 18-gauge needle was advanced, and the tip placed on junction of the inferior lamina and facet complex. A Kirschner wire (K-wire) was placed, then the needle removed, and sequential dilators and then the 7-mm beveled tubular retractor were placed on the junction of the superior part of the inferior lamina at the facet junction. The Shrill[®] diamond drill was used to perform the foraminotomy which was completed with the endoscopic micro Kerrison punch. The foraminotomy was completed when the exiting nerve root could be visualized, and the decompression was carried lateral to the inferior pedicle. *Figure 2* demonstrates the preoperative images, intraoperative fluoroscopic images, and endoscopic camera views from an endoscopic PCF.

Anterior cervical discectomy operative technique

The procedure was performed under general anesthesia; patients were positioned supine. The Wolf Vertebri Cervical scope was used for the procedure. Lateral fluoroscopy was used to determine the level of the incision. A 5 mm incision was made just medial to the sternocleidomastoid muscle. Blunt dissection was done medial to the carotid and jugular and blunt dissection was used to mobilize the esophagus off the prevertebral space. The 1st blunt dilator was subsequently placed through the disc space under bi-planar fluoroscopy monitoring. After sequential dilation, the final tubular retractor was advanced through the disc space under fluoroscopic control. The working channel endoscope was advanced and the Shrill[®] drill was used to drill down the uncinate joint to allow access for the endoscopic graspers to remove the disc herniation. *Figure 3* demonstrates the preoperative images, intraoperative fluoroscopic images, and endoscopic camera views from an endoscopic anterior cervical discectomy.

Anterior cervical transcorporeal discectomy operative technique

The procedure was performed under general anesthesia; patients were positioned supine. The approach was similar to the anterior cervical discectomy technique. A 1.5 cm incision

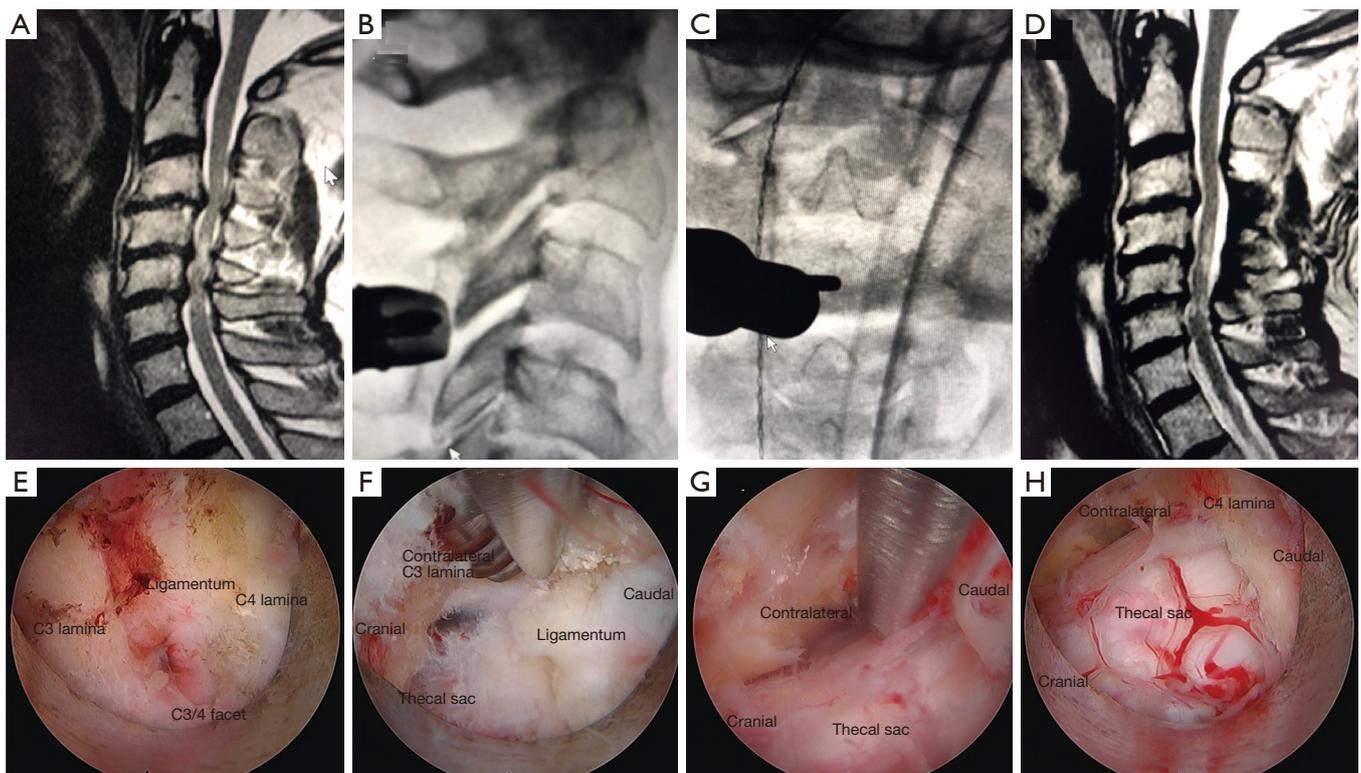


Figure 1 Posterior cervical unilateral laminectomy and bilateral decompression. (A) Pre-operative T2-weighted sagittal MRI demonstrates severe spinal cord stenosis from C3–6 and cord myelomalacia; (B) lateral and (C) AP fluoroscopic images depicting the cannulated beveled tubular retractor with the Delta® working channel endoscope and Shrill® at the spinolaminar junction of C3–4; (D) post-operative T2 weighted sagittal MR image demonstrating the resolution of the cervical stenosis after the C3–6 endoscopic laminectomy; (E) endoscopic camera view at the C3–4 spinolaminar junction. The C3 and C4 lamina, facet, and ligamentum flavum are demonstrated; (F) endoscopic camera view of the Shrill® drill performing the laminectomy; (G) endoscopic camera view of the Kerrison rongeur removing the contralateral ligamentum flavum; (H) endoscopic camera view of the bilaterally decompressed thecal sac. AP, anterior-posterior.

was made just medial to the sternocleidomastoid muscle, blunt finger dissection was done with a standard Smith-Robinson approach. A 13-mm Matrix tubular retractor was placed first over the upper vertebral body, a guide pin was placed into the upper vertebral body with planned trajectory toward the disc herniation. Next, a 6.5-mm cannulated power drill was used to drill over the guide pin, and a Shrill® drill was used to finish drilling a channel through the superior vertebra to allow placement of the tubular retractor with its distal opening at the junction of the inferior endplate of the superior vertebral body and the posterior longitudinal ligament (PLL). The TESSYS® (6.3 mm outer diameter) was used, and instead of entering the disc with the tubular retractor, drilling was performed using intermittent fluoroscopic guidance, alternating

between lateral and AP view, through the superior vertebral body to safely target the disc pathology. The channel created allowed access to the herniated ventral disc fragment without violating the anterior portion of the disc. *Figure 4* demonstrates a preoperative image, intraoperative fluoroscopic image, and endoscopic camera views from an endoscopic anterior cervical transcorporeal discectomy procedure.

Results

Posterior cervical unilateral laminectomy for bilateral decompression operative technique

Twenty-one patients were in this case series with a mean age of 68 (range, 57–86) years. Mean preoperative modified

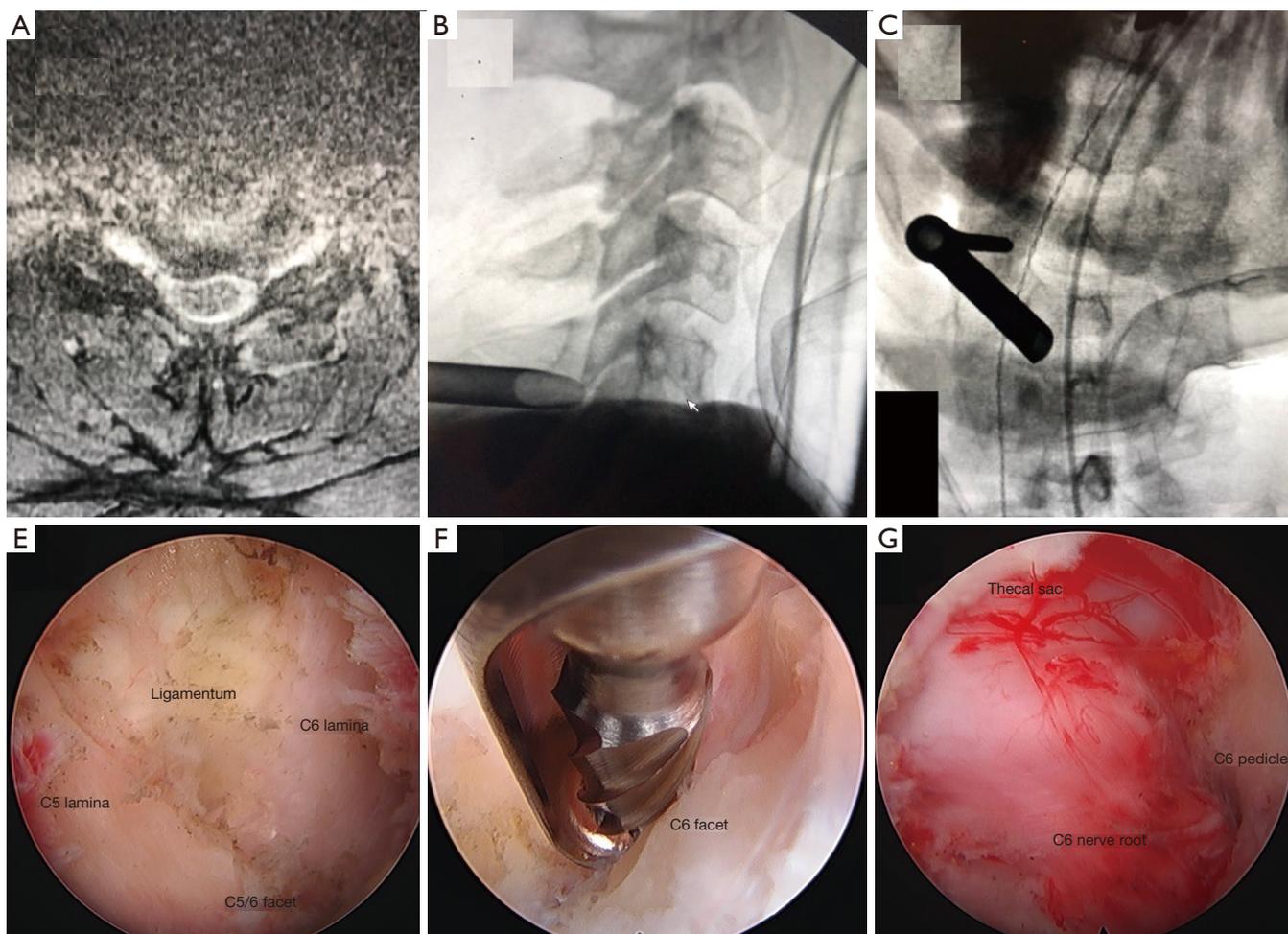


Figure 2 PCF. (A) Preoperative T2 axial MRI illustrating the right C5–6 foraminal stenosis; (B) lateral and (C) AP fluoroscopic views demonstrating the position of the beveled tubular retractor on the lamina-facet junction at C5–6; (D,E) endoscopic camera views of (D) the lamina-facet junction at C5–6, (E) the Shrill[®] drill removing the superior lateral edge of the C6 lamina, and (F) the decompressed C6 nerve root. PCF, posterior cervical foraminotomy; AP, anterior-posterior.

Japanese Orthopaedic Association (mJOA) score was 10.2. The mean operation time was 58 minutes/level, and blood loss was minimal. There was no intraoperative or postoperative complication, including cord or nerve root injury, C5 nerve palsy, dural tear/cerebrospinal fluid (CSF) leak, hematoma, or infection. Mean hospital stay was 0.6 (range, 0–1) day.

The mean 1-year postoperative mJOA score was 15.6, recovery rates 52.9%, showing statistically significant improvement ($P < 0.001$). Clinically, muscle weakness and sensory deficit significantly improved in all patients. Gait improved in 16 patients. No patient showed neurologic deterioration or increased kyphosis after surgery.

PCF operative technique

Sixty-eight patients were in this case series with a mean age of 56 (range, 32–86) years.

The mean operation time was 42 minutes/level and blood loss was minimal. There were no intraoperative complications, no postop hematoma or infection, and none of the patients required a revisional operation in the early post-operative period. Mean baseline visual analog scores (VAS) scores of neck (nVAS), VAS scores of arm (aVAS), and neck disability index (NDI) were 6.3 (4.0–10.0), 5.6 (3.0–8.0), and 41.6 (22.9–49.6), respectively. The 1-year follow-up values were: nVAS 1.6 (0.0–4.0), aVAS 1.2 (0.0–3.0), NDI 14.7 (4.6–16.8) ($P < 0.001$, respectively).

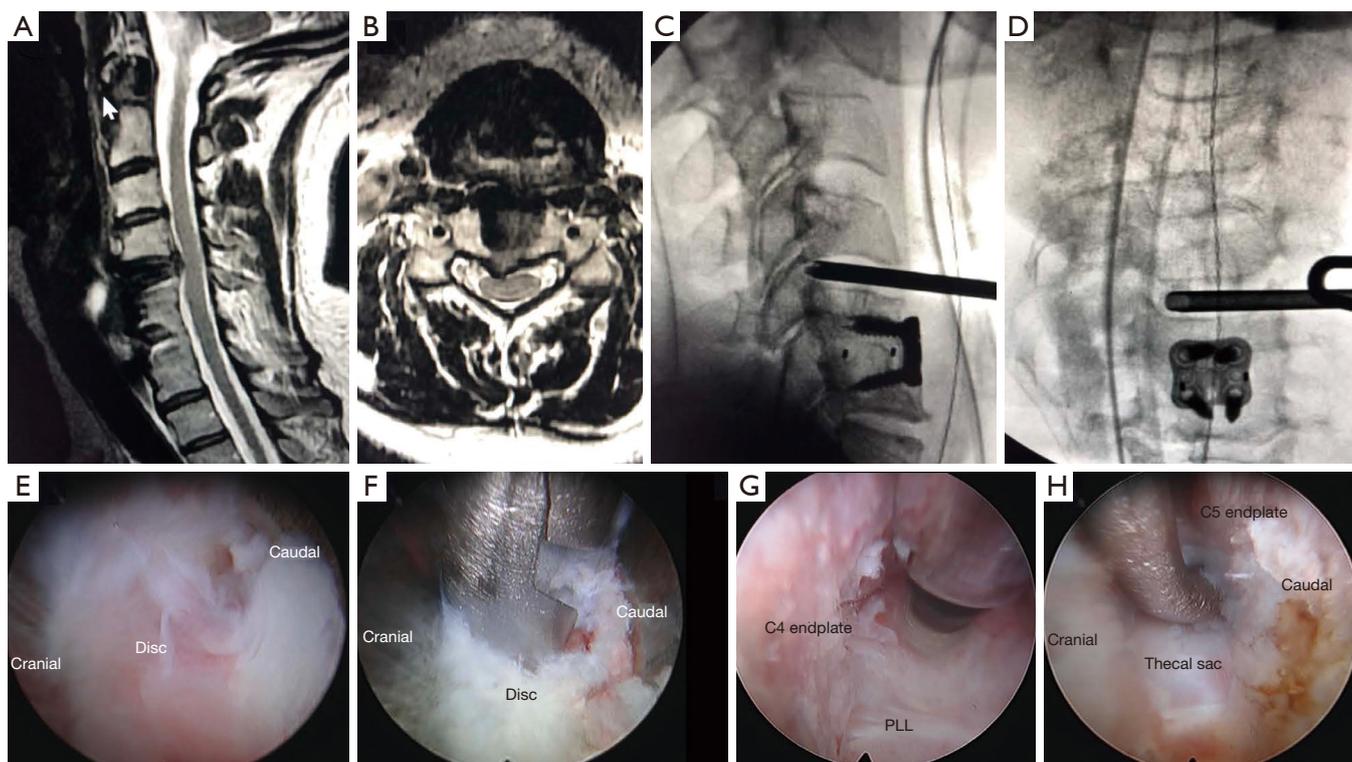


Figure 3 Anterior cervical discectomy. (A) Preoperative T2 sagittal and (B) T2 axial MR images demonstrating the C4–5 herniated disc superior to a previous C5–6 fusion; (C) lateral and (D) AP fluoroscopic images of the CESSYS® Cervical Hybrid endoscope and working channel in the C4–5-disc space; (E,F,G,H) endoscopic camera views of (E) the C4–5-disc herniation, (F) the endoscopic grasper removing the herniation, (G) the Shrill® drill drilling down the uncinate joint, and (H) the bendable grasper removing disc from the foramen. AP, anterior-posterior; PLL, posterior longitudinal ligament.

Anterior cervical discectomy operative technique

Nineteen patients were in this case series with a mean age of 38 (range, 30–56) years. There were no intraoperative or postoperative complications. One patient developed recurrent herniation and underwent ACDF surgery within 3 months of index surgery. For the remaining 18 patients: nVAS for neck pain reduced from average 7.2 (range, 6–10) to 1.6 (range, 0–3); aVAS for arm pain reduced from 5.6 (range 3 to 9) to 1.2 (range 0 to 3) at 1-year follow up. NDI reduced from 58.7 (range 32.8 to 68.2) to 12.8 (range 8.2 to 16.9) at 1-year follow up, all statistically significant ($P < 0.02$).

Anterior cervical transcorporeal discectomy operative technique

Six patients were in this case series with a mean age of 32 (range, 28–42) years. Estimated blood loss was minimal, no intraoperative or postoperative complication, no recurrent

disc herniation (no patient required a subsequent ACDF). nVAS for neck pain reduced from average 7.6 (range, 6–10) to 0.8 (range, 0–2) at 1-year follow up. NDI reduced from 49.8 (range 36.8 to 72.6) to 10.6 (range 7.2 to 16.7) at 1-year follow up, all statistically significant ($P < 0.01$).

Discussion

Our experiences with four distinct fully endoscopic cervical spine approaches reveal highly successful outcomes with effective reduction in symptoms, no significant complications, minimal blood loss, and short hospital stays. Our results are aligned with other author's experiences with such techniques.

Indications for cervical endoscopic spine surgery were the same as those for traditional anterior and posterior techniques. Most patients in this study sought out care by the senior surgeon because they were interested in the most

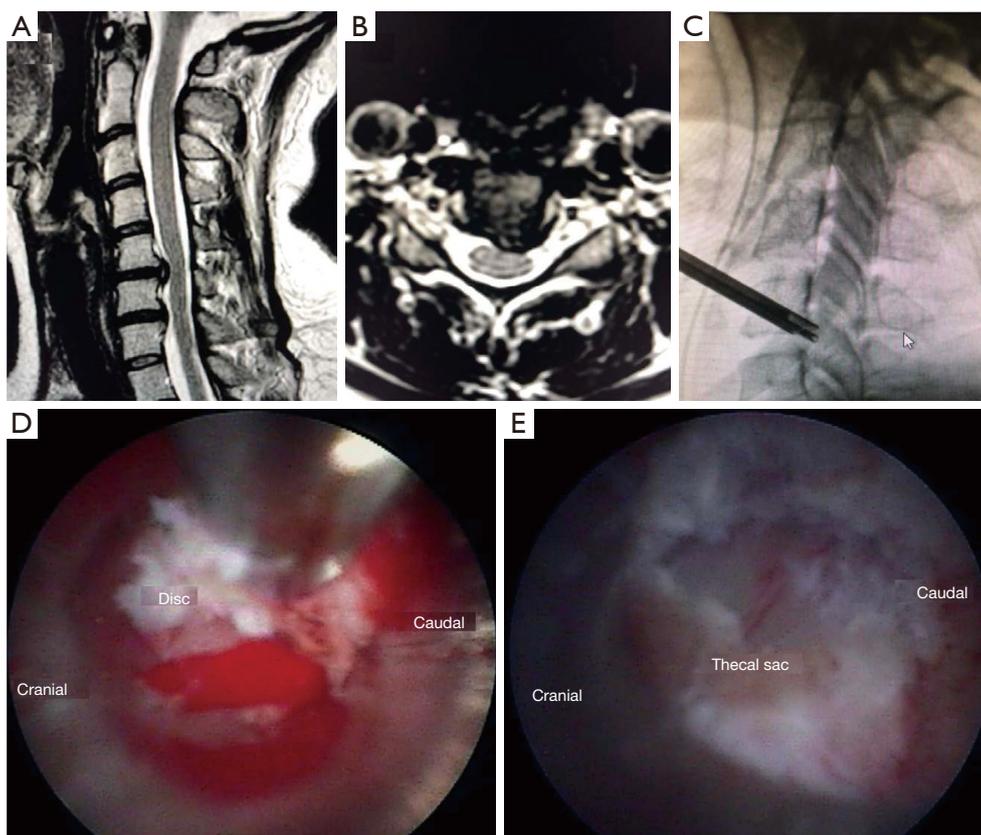


Figure 4 Anterior transcorporel discectomy. (A) Preoperative T2 sagittal and (B) axial MR images of a C5–6 herniated disc; (C) lateral fluoroscopic image of the TESSYS® endoscope and tubular retractor placed through the body of C5; (D) endoscopic image of the disc herniation; (E) endoscopic image of the decompressed thecal sac after removal of the disc herniation. AP, anterior-posterior.

minimally invasive procedure possible.

When compared to other reports of anterior endoscopic approaches, our study cohort experienced similar rates of decrease in nVAS and aVAS scores and improvement in NDI scores. For instance, in a retrospective study of 187 patients undergoing anterior endoscopic cervical discectomy, Parihar *et al.* show decrease in VAS scores for arm and neck pain, 6.7 to 1.7 and 3.2 to 1.1, respectively, with only 2 patients requiring a second procedure with mean follow up of 29 months (10). This same series showed that despite lack of fusion and placement of an intervertebral spacer, cervical lordosis improved. However, reports in the literature have varied when it pertains to cervical lordosis, some suggesting that ACDF is superior in maintaining proper cervical alignment. Results have ranged from improved, unchanged, and worsened lordosis (11,12). However, these reports also show that clinical outcomes were improved despite the different cervical alignments

seen on imaging (11,12). Similarly, Lee and Lee found that despite loss of disc height after fully anterior endoscopic cervical discectomy, their patients report improved nVAS and aVAS as well as NDI scores (13). Yet, with ACDF patients are at risk for injuries during dissection, may develop pseudarthroses, and may develop adjacent segment disease. All of these complications are mitigated with the use of endoscopic techniques (8,14,15). Long term data, however, remains scarce. Our experiences with anterior endoscopic discectomy techniques show similar resolution of symptoms and improvement in NDI and VAS scores as has been reported in the literature.

Similarly, successful results have been reported in posterior endoscopic techniques as well. A recent study by Wan *et al.*, reports on their experience with posterior percutaneous full endoscopic cervical discectomy under local anesthesia (16). Twenty-five patients underwent the procedure with 24 achieving resolution of symptoms,

and no major complications were reported (16). Another study looked at strength recovery after fully-endoscopic posterior cervical discectomy (FEPCD) and reported a 95% rate of strength recovery with 86% of full resolution of weakness at 1 year follow up (17). Similar rates of favorable outcomes (>85%) have been reported in the literature (18). Proponents of endoscopic posterior approaches have argued that post-operative pain is minimized due to the lack of muscle stripping, blood loss is avoided, operative time is reduced, and hospital stays are shortened. Our results are consistent with these beliefs and add to a growing body of favorable research into endoscopic approaches. However, a prospective large volume trial comparing ACDF or PCF with FEPCD has not been undertaken yet. Such a trial will help better delineate the role of endoscopic approaches as compared with traditional cervical approaches in the treatment of cervical radiculopathies and myelopathies.

Fully endoscopic cervical spine surgery is an emerging minimally invasive surgical option for the treatment of symptomatic cervical radiculopathy and myelopathy. Advantages include the high definition visualization of the surgical pathology, the reduction of tissue trauma, and taking advantage of familiar anatomical approaches. Anterior cervical endoscopic discectomy techniques offer additional advantages including preservation of movement at that level and avoiding fusion and minimal to no manipulation of nerve roots. Main disadvantages include the steep learning curve of endoscopic techniques for surgeons accustomed to traditional open approaches, the limited direct field of view, and the narrow working channel. However, multiple strategies can be used to mitigate these downsides. First, surgeons may take advantage of multiple cadaver course to accelerate their progress on the learning curve. Moreover, surgeons may start with more simple endoscopic procedures to familiarize themselves with the approach. Flexible instruments have helped overcome the limitations of a narrow channel, and device development has been rapid.

In brief, we present 4 illustrative case series from a high-volume endoscopic spine surgery center in the United States that highlight the similar outcomes of endoscopic cervical spine surgery to those of traditional cervical spine surgery. The results reported regarding the effectiveness and success of these techniques are similar to what has already been reported in the literature and add to the growing cases of successfully fully endoscopic cervical spine surgery. Endoscopic cervical approaches offer a novel and

promising treatment option for cervical radiculopathy and myelopathy. However, our experience remains limited by its retrospective nature, the lack of a direct comparison arm, limited follow-up data, and a relatively small patient population. Larger long-term prospective trials with a control arm are still needed to tease out the true potential and shortcomings of endoscopic approaches to the cervical spine as compared to traditional techniques.

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Footnote

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