Neuroendoscopy for spinal disorders: a brief review

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Neuroendoscopy has grown rapidly in the last 20 years as a therapeutic modality for treating a variety of spinal disorders. Spinal endoscopy has been widely used to treat patients with cervical, thoracic, and lumbosacral disorders safely and effectively. Although it is most commonly used with minimally invasive lumbar spine surgery, endoscopy has gained widespread acceptance for the treatment of thoracic disc herniations and for anterior release and rod implantation in the correction of thoracic spinal deformity. The authors review the use of endoscopy in spine surgery and in the treatment of spinal disorders as well as in the treatment of intrathoracic nonspinal lesions. Endoscopy has some significant advantages over open or other minimally invasive techniques in that it can allow for better visualization of the lesion, smaller incision sizes with reduced morbidity and mortality, reduced hospital stays, and ultimately lower cost. In addition, spinal endoscopy allows observers and operating room staff to be more involved in each case and fosters education. Spinal endoscopy, like any novel modality, carries with it additional risks and the surgeon must always be prepared to convert to an open procedure. The learning curve for spinal endoscopy is steep and the procedure should not be attempted alone by a novice surgeon. Nevertheless, with training and experience, the spine surgeon can achieve better outcomes, reduced morbidity, and better cosmesis with spinal endoscopy, and the operating times are comparable to open procedures. As technology evolves and more experience is obtained, neuroendoscopy will likely achieve further roles as a mainstay in spine surgery.

KEY WORDS • endoscopy • spinal disorder • lumbosacral spine

BACKGROUND

Neuroendoscopy has grown rapidly in the last 20 years as a therapeutic modality for treatment of a variety of spinal disorders. After Dubois, et al.,²⁰ reported their initial laparoscopic cholecystectomy in 1990, endoscopy grew rapidly as a familiar technology in most operating rooms. Obenchain⁶⁹ reported the first laparoscopically performed lumbar discectomy. Since then, endoscopy has been widely used for numerous disorders of the cervical, thoracic, and lumbosacral spine. Although most commonly used in minimally invasive lumbar spine surgery,^{19,23,31,37,41,58,85,92,96} endoscopy has gained widespread use for the treatment of thoracic disc herniations^{5,12,17,18,22,27,30,34,36,48,49,60,68,72,74,76–78,81} and for anterior release and rod placement in the correction of thoracic spinal deformity.^{4,6,21,50,55,60,66–68,70,88,90} We review the use of endoscopy in spine surgery and in the treatment of spinal disorders.

Lumbosacral Spine

In 1997, the field of minimally invasive spine surgery was revolutionized by the introduction of the MED retractor system,⁸⁹ followed shortly by its successor, METRx (Medtronic Sofamor Danek, Minneapolis, MN). The sys-

tem allowed for access to the lumbar spine by splitting of muscle fascicles with a series of dilators, allowing for a minimally invasive muscle splitting approach with minimal subsequent muscle dysfunction and pain. The use of such a tubular retractor allows the surgeon the choice of using loupes, the operating microscope, or endoscopy.⁹² Subsequently, excellent results have been reported for minimally invasive endoscopic lumbar discectomy and/or foraminotomy by using variants of this approach and similar retractor systems.^{13,14,35,37,61,62} Additionally, decompressive surgery for lumbar stenosis has been performed using this approach.^{26,46,73} Sairyo, et al.,⁸³ described a way to use similar techniques to perform endoscopically a modified Gill decompression of nerve roots in patients with spondylolysis. Although the procedure is less popular, good results have also been described for arthroscopic techniques for endoscopic discectomy.^{44,58}

Anterior lumbar spinal fusion is also now becoming more commonly performed using laparoscopy.^{57,59,79,97} In a trial involving eight spine centers, 240 patients undergoing laparoscopic spinal fusion were compared with 591 patients undergoing fusion with the same device.⁷⁹ The laparoscopic group had shorter hospital stays and decreased blood loss but also had increased operating time. Surgical complications were similar in both groups, with an occur-

rence of 4.2% in the open approach and 4.9% in the laparoscopic approach. The authors concluded that laparoscopic fusion is associated with a higher learning curve, but with experience it is a safe and effective approach when compared with traditional surgery. Others have also reported good results.^{29,53} Nevertheless, the enthusiasm for laparoscopic lumbar spinal fusion is not universally shared. Numerous series have detailed minimal benefit for this approach compared with others such as the open minilaparotomy, despite the increased operating times and increased technical difficulty.^{15,43,54} Additionally, poor results with multilevel fusions have been described by some.⁴⁵ The variability in vascular anatomy at the L4–5 segment may also make the procedure more difficult at this level.⁴⁷

Several other endoscopic lumbar spinal fusion approaches have been described, including the retroperitoneal approach,¹⁰ balloon-assisted endoscopic retroperitoneal gasless approach,⁹⁴ the lateral transpsoas approach,⁹ and percutaneous endoscopic endplate preparation with percutaneous pedicle screw insertion.^{51,52} The feasibility of performing lumbar endoscopic posterolateral fusion by using recombinant growth factors and an osteoconductive matrix has recently been demonstrated in a sheep model.³⁸ Additionally, the feasibility of inserting endoscopic lumbar pedicle screws has been demonstrated.³⁹

Endoscopy has been used successfully for the treatment of lumbar spinal fractures. Olinger, et al.,⁷¹ described an endoscopic retroperitoneal approach for the treatment of fractures from the T12–L5 segments, in which disc and bone fragments were removed endoscopically, followed by bone grafting and plate placement. Schultheiss and colleagues^{86,87} demonstrated good outcomes in the ventral treatment of thoracolumbar spinal fractures with endoscopically placed instrumentation. More recently, Beisse, et al.,⁸ described good results when using anterior endoscopy in the thoracolumbar spine for decompression of the spinal canal and interbody fusion/spinal fixation for disorders arising from a variety of causes, including fractures, degenerative disc disease, tumor, and infection.

Endoscopy has also been used to treat anterior sacral meningoceles.^{75,91} Both laparoscopy and endoscopy may be used to place a suture around the communication between the thecal sac and cyst. Additionally, endoscopic obliteration of the connection between meningocele and spinal subarachnoid space by entering the meningocele and placing numerous fat grafts intradurally has been described.⁴⁰

Lumbar spinal canal epidural endoscopy (myeloscopy) has been used by anesthesiologists and other pain management physicians for the amelioration of lumbago, radiculopathy, and other pain syndromes. Richardson, et al.,⁸⁰ described using a spinal endoscope introduced through the sacral canal to target nerve roots with application of local anesthetic and steroid agents. Additionally, adhesions in contact with affected roots were mobilized. In their series of 38 patients who underwent this procedure, in which 50% had received a diagnosis of failed-back surgery syndrome, significant improvements were seen in pain severity scores and functional abilities at 1 year. Myeloscopy potentially provides the pain specialist with another diagnostic and therapeutic tool beyond conventional imaging and surgical techniques with regard to treatment of arachnoiditis and similar conditions.^{56,93}

Thoracic Spine

Diseases of the anterior thoracic spine require creative approaches for the spine surgeon. Prior to the 1980s,⁸² endoscopic anterior approaches were not available and open thoracotomy was the routine. By the 1990s, however, improved endoscopic technology (for example, improved optics and video technology) had become widely available and was refined within the fields of general, urological, and thoracic surgery. It was only a matter of time before spine surgeons adopted and refined endoscopic techniques for their own use.

Endoscopic approaches have been described and are commonly used for numerous thoracic spine disorders.^{2,3,7,8,16,17,25,27,32,63,64,66,67,81,82} These include but are not limited to kyphosis surgery (that is, anterior release for deformity), scoliosis surgery, thoracic corpectomy (for trauma, tumor, degenerative change/stenosis, instability, or infection), discectomy, or biopsy sampling. Video-assisted thoracoscopic surgery has also revolutionized other procedures commonly performed within the thoracic cavity by neurosurgeons, such as sympathectomies for hyperhidrosis and shunting of cerebrospinal fluid for hydrocephalus, and has made approaches for extraaxial tumors (for example, schwannomas) safer.^{16,27}

There are many advantages to using an endoscopic anterior approach to the thoracic spine. Thoracic ports are much smaller and are better tolerated than open thoracotomy incisions. They allow the surgeon to avoid rib resection, with consequently less potential for disruption of the underlying neurovascular bundle. Small portals also avoid excessive muscle injury, further reducing patient morbidity. This not only reduces perioperative pain but also leads to fewer pulmonary complications. The smaller wound (4-cm incision compared with a 20-cm one in the traditional open approach)³ allows for much faster recovery times and thus fewer days in the intensive care unit, shorter hospital stays, and therefore reduced cost.^{3,7,8,27,81,82}

The use of thoracic endoscopy provides many additional benefits to the surgical team and operating room staff. The video documentation of a procedure can easily be shared with other medical professionals and students, allowing review and study of the steps involved in complex spine surgery cases. Inevitably, robotic assistance during video-assisted thoracoscopic spine surgery will allow the field of remote surgery to grow. The ability to have a highly skilled spine surgeon assist in operations would be quite valuable.

Just as in any novel surgical procedure, thoracoscopic spine surgery creates additional risks. The ability to visualize the working field broadly is limited by the view of the endoscope, and it is possible to damage the critical structures that lie close by. The surgeon must always be prepared to convert rapidly to an open thoracotomy, should the need arise. Just as with any anterior approach to the spine, one must be prepared to deal with pulmonary complications such as pneumothorax, hemothorax, chylothorax, and chest tube-related complications as well as potentially catastrophic conditions caused by damage to the nearby pericardium and great vessels. For procedures requiring image-guided navigation, there may be an increased risk of exposure to radiation for patients and all operating room personnel.⁷

Thoracoscopic approaches to the spine require that the

surgeon receive additional training, and initially the help of a good cardiothoracic surgeon. The learning curve in thoracic spinal endoscopy can be steep. Over the last few decades there have been numerous reports from surgeons of their experiences with spinal endoscopic surgery. Adulkasem and Surangsriat³ reported their experience with nine patients undergoing anterior spine surgery for Pott disease, vertebral compression, instability, fracture, infection, and metastatic disease. The duration of surgery ranged from 1.5 to 3 hours, with blood loss ranging from 100 to 700 ml. Of the nine patients described, seven were ambulatory by 2 to 3 days postoperatively. Several complications arose, including an adjacent segmental vertebral vessel injury in one patient, and neurapraxia as a result of traction or electrocautery injury in another.

In their landmark paper on thoracoscopic spine surgery, Newton, et al.,⁶⁵ reported a series of 38 patients in whom endoscopic thoracic spine surgery was performed to correct idiopathic scoliosis. Approximately 5.5 hours were required to fuse an average of seven levels. The incision length was approximately 10.5 cm, which was estimated to be one third the length of an incision required for an open procedure. These patients were compared with 68 individuals in whom an open procedure had been performed. The scoliosis correction achieved was found to be comparable in both groups. The morbidity, however, was found to be considerably reduced by endoscopic techniques. In addition, the cosmetic result afforded by endoscopy is much more appealing to the patient. Although the surgery lasted longer when the thoracoscopic approach was used, it was assumed that as surgeons become more comfortable with endoscopy and progress along the learning curve, operating times may become comparable.

Han, et al.,²⁷ reported their experience with 241 thoracoscopic procedures, including 164 thoracic sympathectomies, 60 discectomies, five neurogenic tumor resections, eight corpectomies and spinal reconstructions, two anterior releases, and two biopsy sampling procedures. Of the patients undergoing thoracic discectomies, 98% demonstrated complete decompression on follow-up imaging. Although sympathectomies and resection of paraspinal neurogenic tumors do not directly involve bone, the benefits afforded by this minimally invasive technique are comparable. Han's group concluded that the thoracoscopic approaches to these cases compared favorably with the alternative open approaches. Endoscopy provides better visualization of the ventral spine and spinal cord, lower morbidity rates, increased patient comfort, and superior cosmesis. In their series, open procedures could be performed faster with less blood loss; however, this again may be because of the steep learning curve associated with video-assisted thoracoscopic spine surgery. Currently, open procedures remain the operation of choice for en bloc resection of malignant tumors because of the possibility of seeding cancer cells through the less invasive technique. Perhaps in the future a combined approach, such as mini-thoracotomies with thoracic endoscopy, can reduce the risks associated with removing tumors in a piecemeal fashion. The personal experience of the surgeon strongly influences the choice of approach.

Image guidance for spine surgery is a relatively new technology designed to make the operation safer. Assaker⁷ reported on two patients for whom endoscopic spine sur-

gery was supplemented by image guidance. The first patient presented with a T8–9 calcified disc and myelopathy, and the second one presented with lumbosacral disease. Although both patients did well postoperatively, the significant amount of time needed for positioning and preparation detracted greatly from the potential benefits of the technique. The authors postulate that in a specialized operating suite equipped with mobile computerized tomography or magnetic resonance imaging capabilities the preparatory time could be significantly reduced.

Endoscopic approaches to the anterior thoracic spine have also been described. Beisse, et al.,⁸ reviewed a series consisting of 30 patients who underwent endoscopic anterior spinal canal decompression and fusion. The majority of these procedures were for thoracolumbar fractures (27 cases). The spinal canal fracture clearance was significantly increased on postoperative computerized tomography scans obtained for evaluation in the patients treated using the endoscopic technique. Ninety percent of the patients in their study improved neurologically.

Thoracoscopy can also be used safely in surgery involving the upper thoracic spine. Huang, et al.,³² reported on eight patients undergoing video-assisted approaches to the upper thoracic spine (T1–4). They reported a mean surgical time of 3.1 hours, which is similar to their experience with traditional open approaches. Their patients' diseases included metastases and infectious spondylitis.

The most extensively studied as well as the most common procedure performed using video-assisted thoracic spine surgery is thoracic discectomy. In their key article, Rosenthal and Dickman⁸¹ report on their experience with herniated thoracic discs. Fifty-five patients underwent thoracoscopy, for which the mean surgical time was 3 hours and 25 minutes, and the mean blood loss was 327 ml. The approach was compared with costotransversectomy and was found to provide better resection of midline thoracic discs. Thoracoscopy afforded better visualization of the anterior dura mater, thus allowing the authors to proceed both quickly and safely. Clinical outcomes were reported as excellent, with 22 of 36 patients with myelopathy attaining complete recoveries. None of the patients in the series had worsening radicular pain or any further neurological decline.

Huntington, et al.,³⁴ used an ovine model to address the question of the ability of thoracoscopic discectomy compared with open thoracic discectomy to decompress the disc space adequately. They used 60 sheep in their study, in which the animals were killed and dissected after surgical intervention. Photographs of the vertebral end plates and remaining discs were analyzed using computer imaging. The results revealed no significant difference in the amount of disc resected, further supporting the use of an endoscopic technique.

Perez-Cruet, et al.,⁷⁴ described a minimally invasive posterior approach to thoracic microendoscopic discectomy. They studied seven patients with nine disc herniations. Using fluoroscopy and a visualization tube, the minimally invasive thoracic microendoscope can be placed over the facet complex of interest. Muscle dissection is minimized and visualization is aided by fiberoptic light sources. Five of seven patients had excellent results, one had good, and the other had fair results when measured on the Prolo scale.

Endoscopy has also been used in the thoracic spine to treat intradural disorders. Guest, et al.,²⁵ described a tech-

nique in which endoscopic thoracic guidance was used to place the distal end of a shunt in the pleural space. The presenting diseases included five patients with syringomyelia, one with a perineurial cyst, and one with an arachnoid cyst. All seven patients underwent successful catheter placement. Although the surgery does not directly involve the osseous spine, the endoscopic technique is directly applicable to thoracoscopic spine surgery.

Huang, et al.,³³ reported specifically on complications in thoracoscopic spine surgery. Their paper is notable and commendable for bringing to light the complications of this relatively new technique. They reported on 90 consecutive patients with multiple disorders. These included 41 spinal metastases, 13 cases of scoliosis, 12 burst fractures, 10 cases of Pott disease, eight cases of pyogenic spondylitis, two thoracic disc herniations, two cases of ankylosing spondylitis with discitis, one osteoporotic compression fracture, and one case of thoracolumbar kyphosis. Thirty complications in 22 patients were noted (24.4%). Two deaths were recorded (hemorrhage, postoperative pneumonia). Other complications included intercostal neuralgia, wound infections, pharyngeal pain, atelectasis, pneumothorax, subcutaneous emphysema, pericardial penetration, screw malposition, and graft dislodgment. Four patients required conversion to open procedures.

Cervical Spine

Endoscopy has been less widely used in the cervical than in the thoracic or lumbosacral spine, perhaps because of the relatively easy access to spinal anatomy in this region, given the relative ease of the anterior cervical approach and the smaller dissection of the posterior approach when compared with thoracolumbar anatomy. Nevertheless, an endoscopic approach may facilitate a quicker recovery with less muscle spasm, and it may promote minimal tissue disruption. Thus, endoscopic techniques, which are most commonly used for cervical disc herniations and spondylosis causing cervical radiculopathy, have been developed.

Posterior cervical endoscopic laminoforaminotomy has been advocated as an alternative to microscopic posterior laminoforaminotomy.^{1,11} This technique uses a modification of the microendoscopic discectomy instrumentation introduced by Smith and Foley.⁸⁹ Postoperatively, this may result in a marked reduction of pain and a quicker return to preoperative levels of activity. Additionally, Adamson² reported good to excellent results in 97 of 100 patients undergoing the procedure for unilateral cervical radiculopathy. Posterior endoscopic partial cervical laminectomy was recently described by Yabuki and Kikuchi⁹⁵ as a novel technique for the treatment of cervical spondylotic myelopathy. The decompression is performed one side at a time, through two 20-mm incisions. Patients rated their postoperative neck pain as slight, and at a mean of 14.9 months their Japanese Orthopaedic Association scores had improved significantly, with no evidence of spinal instability.

Anterior endoscopic cervical foraminotomy for cervical radiculopathy has also been described.⁸⁴ Saringer, et al.,⁸⁴ used the microendoscopic discectomy system in conjunction with a modification of Jho's⁴² technique of resection of the uncovertebral joint to allow for anterior endoscopic cervical nerve root decompression. Advantages of this technique include a very small surgical exposure, improved in-

traoperative visualization, direct decompression and visualization of the nerve root, and avoidance of graft-related complications/preservation of the motion segment (a bone graft is not required).

Endoscopy may also be useful for diseases involving the odontoid process. Hashizume, et al.,²⁸ described using endoscopic assistance for the placement of odontoid screws in Type II odontoid fractures. An endoscopic tube was custom made for the approach based on the preoperative x-ray films. The tube, cut obliquely at 40°, was used as a retractor and the endoscope was used to visualize screw insertion. Frempong-Boadu, et al.,²⁴ described an endoscopic technique to assist a transoral-transpharyngeal approach to the craniovertebral junction and to facilitate subsequent decompression. Seven patients with upper cervical and clival abnormalities were treated. The pathological entities encountered included basilar invagination, craniovertebral junction malformations, migration of odontoid fracture, pseudogout granulation mass, and a clivus chordoma. All seven patients attained adequate decompression with improved or stable neurological outcomes. One patient died of a perioperative myocardial infarction. When used with intraoperative fluoroscopy, the endoscopic approach allows broader visualization as well as minimization of soft-palate splitting.

CONCLUSIONS

Use of neuroendoscopy has become widespread in spine surgery for indications ranging from degenerative disease to deformity correction. Although at present it is most widely used in minimally invasive spine and thoracoscopic surgery, novel uses continue to emerge in the literature. As technology evolves and more experience is obtained, neuroendoscopy will likely achieve additional roles as a mainstay in spine surgery.

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