



Use of an endoscope for spinal intradural pathology

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Abstract: The endoscope has been increasingly used to treat various spinal diseases. However, the application of spinal endoscopy in an intradural lesion has been less common compared to that of an epidural counterpart. The authors reviewed existing literature describing spinal endoscopy as an aid in surgical treatment for intradural pathologies. Importantly, available literature indicated the safety and feasibility of spinal endoscopy for intradural lesions. Especially, an endoscope was utilized for intradural subarachnoid cystic lesions, tethered cord syndrome, extramedullary tumors, spinal arteriovenous malformations, and cordectomy for intractable pain. The results of this review should enhance further development and broaden application of an endoscope for various intradural pathologies.

Keywords: Arachnoid cyst; cordotomy; endoscope; intradural extramedullary tumors; tethered cord syndrome

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Introduction

The concept of direct spinal cord visualization by intradural endoscopy was introduced in medical practice in the 1930s (1,2). However, until recently, an endoscope had been too large or not reliable enough to be safely inserted into the intradural space (3), so spinal intradural endoscopy was not widely performed. Rather, the spinal endoscopic technique has evolved in the treatment of extradural pathology, including herniated discs and spinal canal stenosis, through minimally invasive methods (4). After recent technical advancements have led to create a small and flexible endoscope (3,5,6), the enthusiasm to apply such a novel device to intradural pathologies was revived. Before using an endoscope in clinical cases, cadaveric studies were conducted to verify the usefulness and safety of manipulation in the intradural space (3,7,8).

In this review, we summarized recent clinical reports describing how spinal intradural endoscopy has provided direct and magnified visions inside the spinal canal from

small and limited exposure. More importantly, to discuss its usefulness, safety, and limitations, we categorized available literature as follows: cystic and inflammatory diseases in the subarachnoid space, tethered cord syndrome, intradural extramedullary tumors, spinal arteriovenous malformations (AVM), and percutaneous cordotomy for intractable pain (Table 1).

Cystic and inflammatory diseases in the subarachnoid space

A flexible fiberscope that is sufficiently small can be passed through the dura into the intradural space with minimum incision. Based on an anatomical study, the sizes of the ventral and dorsal subarachnoid space around the spinal cord were 1–3 mm and 2–6 mm, respectively (3). Thus, an endoscope with an external diameter of <2 mm can safely pass along the spinal cord. Several authors indicated the usefulness of spinal endoscopy in cases of spinal arachnoid cysts (9–11). In surgery, following a few levels

Table 1 Application of spinal endoscopy for intradural lesions

Category	References	Endoscopy	Number of cases	Method
Cystic and inflammatory	Endo <i>et al.</i> , 2010 (9)	Fiberscope, 2.5 mm of its outer diameter	6	Puncture cyst wall, open
	Mauer <i>et al.</i> , 2011 (10)	MurphyScope, 1.4 mm	31	Observation, open
	Tanaka <i>et al.</i> , 1997 (11)	Myelofiberscope, 1.67 mm	1	Puncture cyst wall, percutaneous
	Fukushima <i>et al.</i> , 2006 (12)	Endoscopy, type not mentioned	1	Biopsy, open
	Torres-Corzo <i>et al.</i> , 2019 (13)	Fiberscope, 3.7 mm	3	Remove the cysticerci, open
	Arishima <i>et al.</i> , 2018 (14)	Angioscope, 0.75 mm	2	Observation, percutaneous
	Tani <i>et al.</i> , 2003 (15)	Endoscopy, type not mentioned	2	Observation, open
	Hara <i>et al.</i> , (5)	Angiofiber, 0.5 mm	4	Observation, open
Tethered cord syndrome	Woods <i>et al.</i> , 2010 (16)	MurphyScope, 1.4 mm	68	Observation, open and percutaneous
	Di <i>et al.</i> , 2009 (17)	Rigid endoscope, 4 mm	2	Untethering, open
	Magrassi <i>et al.</i> , 2008 (18)	Rigid endoscope	1	Untethering, open
	Telfeian <i>et al.</i> , 2017 (19)	Rigid endoscope, 6.3 mm	1	Untethering, open
Intradural tumors	Barami <i>et al.</i> , 2007 (20)	Rigid endoscope	2	Assisted use
	Parihar <i>et al.</i> , 2017 (21)	Rigid endoscope	18	Assisted use
	Zhu <i>et al.</i> , 2015 (22)	Rigid endoscope	3	Assisted use
Spinal AVM	Endo <i>et al.</i> , 2014 (23)	Rigid endoscope, 4.2 mm	8	Assisted use
	Mansour <i>et al.</i> , 2019 (24)	ICG Endoscope, 5 mm	1	Assisted use
	Ito <i>et al.</i> , 2019 (25)	ICG Endoscope, 4.2 mm	1	Assisted use
Corpectomy	Fonoff <i>et al.</i> , 2016 (26)	Microendoscope, 0.9 mm	24	Observation, percutaneous

AVM, arteriovenous malformation; ICG, indocyanine green.

of hemilaminectomy, an endoscope was inserted into the cyst cavity through the dura and bone window (9). The endoscope was moved in the cranial and caudal directions to penetrate or remove the cyst wall. Intraoperative fluoroscopy helps surgeons confirm the position of the endoscope relative to the vertebral levels, which would provide important intraoperative feedback (9). Eventually, these maneuvers allowed to establish communications of the cyst cavity and the subarachnoid space, resulting in clinical improvements of neurological symptoms (*Figure 1*) (9). Although long-term follow-up is required to estimate recurrence rates, endoscopic treatment can be an important surgical intervention option.

The same strategy can be applied to subarachnoid inflammatory disease, in which observation and/or biopsy is required. Surgeons can observe a relatively long range along the dorsal and ventral spinal cord surface with an endoscope. In a case of suspected neurosarcoidosis, spinal

endoscopic biopsy of the nodular lesion in the lumbar spinal cord established the diagnosis (12). Torres-Corzo *et al.* reported a rare case of neurocysticercosis, a parasitic disease affecting the human central nervous system, caused by the tapeworm *Taenia solium* (13). In this case, a flexible spinal endoscope was valuable to explore the entire subarachnoid space and remove parasites and cysticerci. Eventually, thickened adhesive arachnoid membranes were cleared, and cerebrospinal fluid (CSF) flow was restored under direct vision through an endoscope. Furthermore, cases of anterior located sacral meningocele and superficial siderosis were successfully treated with less invasive intradural spinal endoscopy (14,15).

These cases indicated that various intraspinal subarachnoid lesions, including arachnoid cysts and arachnoiditis, can benefit from spinal endoscopy. Especially when pathologies were extensive and extending over multiple vertebral levels in the subarachnoid space, open



Figure 1 A case of spinal arachnoid cyst in a 3-year-old girl treated by a 2 mm flexible endoscope. (A) Preoperative T2-weighted MR image revealing an intradural arachnoid cyst extending from the C-7 to the L-3 vertebral level; (B) intraoperative pictures showing how we inserted an endoscope through a 2-levels hemilaminectomy; (C) an endoscopic view showing the caudal cyst wall (single asterisk) and the cauda equina (double asterisk). Figures were obtained and modified with permission (9).

surgical treatment often require large incisions. A better alternative is to use a flexible endoscope that can be inserted and advanced through a small opening, allowing a less invasive approach.

Tethered cord syndrome

Endoscopy has also demonstrated diagnostic and therapeutic potential for tethered cord syndrome. In the lower lumbar vertebral level, an endoscope can be advanced through the cauda equina to observe the filum terminale, since the lumbar spine has a wider space compared to the thoracic or cervical vertebrae (3). Yörükoğlu *et al.* described a percutaneous fully endoscopic interlaminar approach to the filum terminale in cadaveric studies (7). In clinical cases, endoscopic observation was proven useful to visualize the filum terminale in 68 patients with tethered cord syndrome (16). Laminectomy and 2-mm dural incision was adequate to insert a flexible endoscope, which confirmed posterior

displacement of the filum terminale, one of the diagnostic criteria of tethered cord syndrome (27).

Other authors described endoscopic untethering techniques for tethered cord syndrome (17-19). By interlaminar approach and 1-cm durotomy, a ridged endoscope could open the dura, coagulate and cut the filum terminale, and finally close the dura with continuous sutures. Although the number of the cases was small, a percutaneous endoscopic interlaminar approach may become a feasible option for untethering of the filum terminale in the near future.

Intradural extramedullary tumor

Barami *et al.* reported their first experience of assisted use of an endoscope to remove ventrally located intradural extramedullary tumors (20). Spinal endoscopy can effectively provide views of the ventral spinal cord without retraction, which was difficult through a microscope. Parihar *et al.*

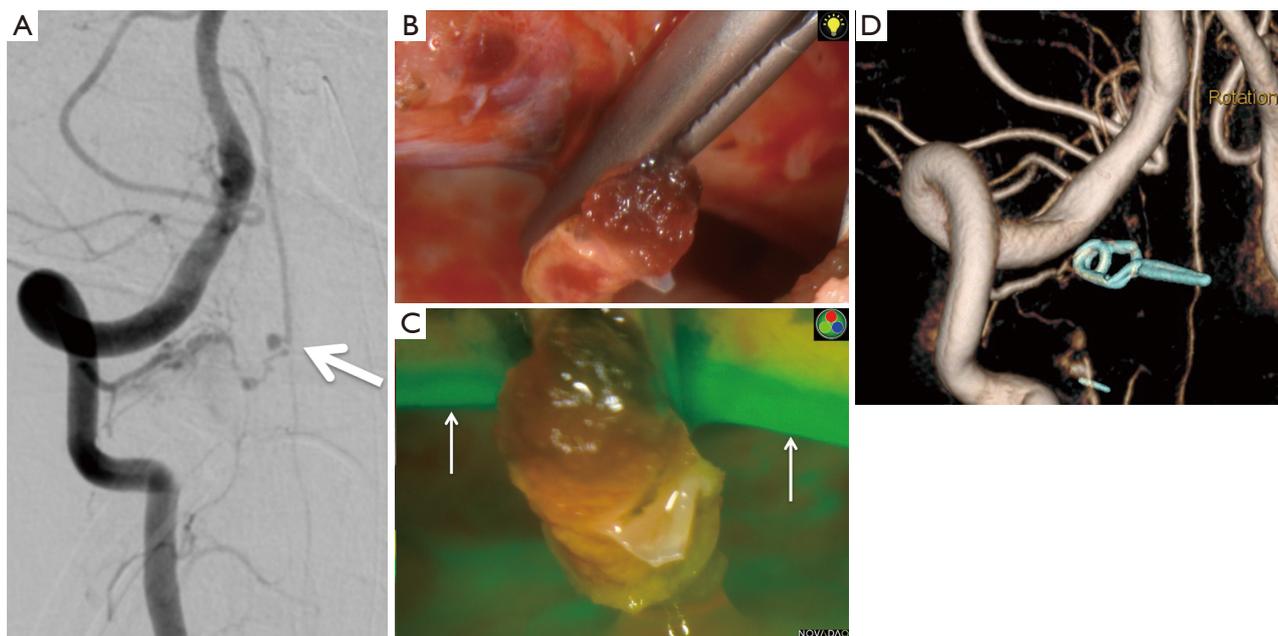


Figure 2 A case of craniocervical junction epidural arteriovenous fistula with a ruptured anterior spinal artery aneurysm. The anterior spinal artery aneurysm was successfully clipped by posterior approach with assisted use of rigid angled indocyanine green endoscopy. (A) Anteroposterior view of the selective right vertebral artery angiogram showing a ruptured aneurysm of the ASA (arrow). (B) Endoscopic view. The aneurysm located next to the ASA was clipped using a Yaşargil titanium clip. (C) Endoscopic image from indocyanine green video-angiography demonstrating obliteration of the aneurysm and preservation of the ASA (arrows). (D) Three-dimensional reconstructed image from a rotational angiogram of the right vertebral artery, confirming complete obliteration of the aneurysm and preservation of the ASA. Figures were obtained and modified with permission (24).

confirmed that endoscopic surgery can be applied to spinal tumors located in any spinal vertebral level (21). They could successfully remove 18 tumors, if maximal sagittal and axial diameters did not exceed 4.1 cm and 1.8 cm, respectively. Zhu *et al.* demonstrated the feasibility of endoscopic removal of intradural extramedullary tumors through an interlaminar approach (22). Vital structures, including an artery and affected spinal nerve roots, were dissected and safely coagulated using a bipolar flexible radiofrequency probe. When an endoscope is used in combination with an interlaminar approach, it would cause minimum bone destruction. Patients can benefit from less postoperative pain, minimal blood loss, and shorter recovery period. In such cases, individualized surgical planning and satisfactory dural closure technique is a key to success. A method to secure watertight CSF leak closure can enhance further application of spinal endoscopy in this type of surgery.

Spinal AVM

Endo *et al.* proposed other examples of utilizing angled

endoscope in direct surgery for spinal AVM. For instance, perimedullary arteriovenous fistulas in the cervical spine are often located on the ventral surface of the spinal cord with close relationship to the anterior spinal artery (23). In such case, it would be difficult to visualize lesions under the microscope through a common posterolateral approach unless the spinal cord is extensively rotated. Instead, a combination of posterolateral exposure and assisted use of endoscopy can provide sufficient views of the ventral spinal cord without rotating it (24). Since the endoscopy was introduced following an open microsurgical procedure, hemilaminectomy and paramedian 2cm dural incision were required. By securing an adequate space to insert the rigid angled endoscope from posterolateral exposures, 360° circumferential views of the spinal cord surface can be appreciated with assisted use of an endoscope (23). When combined with indocyanine green (ICG) fluorescence endoscopy, it can further enhance its ability (24,25). Surgeons can appreciate detailed information regarding vascular anatomy and blood flow through ICG fluorescence endoscopy, which is important for proper management of

spinal cord vascular lesions (*Figure 2*).

Intractable pains

Technical advancements have already resulted in smaller-diameter spinal endoscopes, making percutaneous use of an endoscope practical. Tanaka *et al.* used a percutaneous endoscope to perforate a spinal arachnoid cyst and restore CSF flow (11). The size of the endoscope is similar to that of a needle, therefore it can percutaneously puncture and provide a magnified view of the spinal cord surface. Fonoff *et al.* have contributed to the development of percutaneous endoscopic procedures for intractable pain (26,28). Using percutaneous dual channels, an endoscope could provide clear views of the pial surface of the spinal cord and tip of a radiofrequency cordotomy probe. Since surgeons appreciate real-time views, it became more reliable in determining targets for electrode insertion. Furthermore, trauma or injury of the spinal cord vessels or nerve roots is less likely to occur. As a result, procedures resulted in sufficient pain control with no complications of CSF leak (26). According to a recent review, cordotomy can be an optional method to treat cancer pain (29). As we consider that the increasing number of patients with cancer pain is related to minimal invasiveness and safety of endoscopic procedure, percutaneous endoscopic cordotomy can have wider clinical application.

Limitations

In this review, we focused on the usefulness of intradural spinal endoscopy, highlighting that both flexible and rigid angled endoscopes can provide views that are otherwise difficult to obtain through a microscope. However, limitations still exist regarding the degrees of manipulation that endoscopic instruments can offer. Thus, recent achievements regarding manipulation in endoscopic procedures were relatively confined to basic maneuvers, as pointed out elsewhere (30). The risk of bleeding and difficulty in obtaining hemostasis in endoscopic procedures should also be taken into account (22). Considering that technical difficulties may possibly be encountered during full endoscopic procedures, surgeons should be able to convert to a microsurgical procedure, if necessary. It can work as a backup and safeguard option in spinal intradural endoscopic surgery.

Another important issue is how to avoid postoperative CSF leak. In cases of endoscopic lumbar spinal surgery,

the rate of dural tears was reported as high as 8.6% (31). Although there is no gold standard in managing dural tears or dural closure in endoscopic spine surgery, direct dural suturing techniques in endonasal surgery and in minimally invasive spine surgery could be helpful (32,33). If surgeons felt more comfortable in achieving water-tight dural closure under endoscopy, application of endoscopic spine procedures for both intradural and extradural pathologies would expand.

Conclusions

Existing literature confirmed increased utilization of spinal endoscopy in various intradural pathologies. An endoscope can provide direct views of the spinal cord from a small incision. By moving a fiberscope along the spinal cord, longitudinal lesions extending to multiple vertebral levels can be approached and surgically managed. Moreover, an endoscope can provide magnified views from different angles from a microscope. Using a rigid angled endoscope, even ventral spinal cord tumors or vascular lesions can be surgically managed by posterolateral approach. Technical advancements make percutaneous procedures possible in selected clinical indications. As experiences accumulate with further technical advancements, we believe that intradural endoscopy will be applied in the treatment of other diseases in this region.

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