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REVIEW ARTICLE

Endoscopic spine discectomy: indications and outcomes

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Abstract

Purpose Percutaneous endoscopic discectomy is an effective minimally invasive spine surgery (MISS) for soft disc herniations. The objective of this review was to describe the current indications, surgical techniques, and clinical outcomes of endoscopic spine surgery.

Methods A narrative review was performed with a focus on surgical indication of percutaneous endoscopic discectomy and the clinical outcomes in lumbar and cervical spine. Percutaneous endoscopic or full-endoscopic discectomy using a working channel endoscope was described.

Results The basic principles, surgical techniques, and clinical outcomes in lumbar and cervical disc herniations were demonstrated. For the lumbar disc herniation (LDH), transforaminal and interlaminar approaches were reviewed, whereas for the cervical disc herniation (CDH), anterior and posterior approaches were reviewed.

Conclusions Endoscopic spine surgery for soft disc herniation can be effective with benefits of minimal tissue trauma in properly selected cases. Given the recent technical advancements, the surgical indications for endoscopic spine surgery are still expanding and the clinical results have become more practical and reliable.

Keywords Discectomy · Endoscopic · Indication · Interlaminar · Transforaminal

Introduction

Radiculopathy which stemmed from lumbar, cervical, or thoracic disc herniations is the most common reason why patients require extensive and special treatment. The conventional surgical technique for disc herniations is open discectomy with or without fusion surgery. However, considerable sequelae related to the surgical trauma and long recovery time have been the major problems of spinal surgery. For that reason, the need for minimally invasive spine surgery (MISS) is growing as the aging population in many countries is dramatically increasing and the quality of life is given more importance nowadays [1, 2].

Since Hijikata [3] and Kambin [4] independently introduced the posterolateral percutaneous lumbar nucleotomy technique, a group of endoscopic spine surgery has been a significant minimally invasive surgical alternative for spinal disc herniations.

The advantages of endoscopic spine surgery are as follows: a stab skin incision, do not require muscular retraction, avoidance of excessive bone removal, minimal neural manipulation, feasibility under local anaesthesia, minimal blood loss, shorter operative time, and early return to normal activities of daily living [5–7].

Given the technical development of endoscopic spine surgery, including optics design, surgical instruments, and specific surgical approach, its clinical application became practical and standardized [8, 9].

This review article presents a discussion of the proper indications of endoscopic spine discectomies and to demonstrate their outcomes. Furthermore, we describe the technical considerations for endoscopic spine surgery to achieve a clinical success.

Basic concepts and history

The basic concept of endoscopic spine discectomy is to provide a direct access to the disc pathology with minimal tissue trauma and to remove the herniated disc under endoscopic

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visualization (Fig. 1). A safe working zone is typically required to achieve the direct, percutaneous endoscopic access in the lumbar, cervical, and thoracic areas. This safe working zone should provide the following characteristics, which are typical for endoscopic spine surgery: direct access, selective discectomy, and feasibility of local anaesthesia. It can be determined according to the disc level and approach type.

Percutaneous posterolateral lumbar discectomy was first developed by Hijikata [3] and Kambin [4] in the mid-1970s. Onik [10, 11] and Maroon [12, 13] used a motorized aspiration shaver for the percutaneous discectomy technique (automated percutaneous discectomy) in the mid-1980s. At the same time, a new endoscopic discectomy technique was developed with an assisted endoscope (discoscope or nucleoscope) for direct endoscopic visualization [14, 15]. The term "percutaneous endoscopic lumbar discectomy (PELD)" was coined by Mayer and Brock [16] who used angled optics for viewing the dorsal aspect of the annular tear of the contained lumbar disc herniation (LDH). A real transforaminal approach in which a working channel endoscope passes completely through the intervertebral foramen into the spinal canal was described by Mathews [17] and Ditsworth [18]. Since then, surgeons can explore the epidural space and can treat the non-contained LDH. Since 2000, a variety of endoscopic techniques have been developed. A selective endoscopic discectomy for extruded LDH was developed by Kambin [8] and Yeung [9] independently. In the mid-2000, an interlaminar approach for the L5-S1 level was described, but the transforaminal approach is not available [19]. In fact, modern-concept endoscopic lumbar discectomy techniques were established at this time.

Regarding the cervical spine, Tajima and colleagues [20] reported the first anterior percutaneous cervical discectomy procedure. Since then, varying similar techniques have been developed for soft cervical disc herniation (CDH), such as percutaneous cervical automated nucleotomy [21, 22], percutaneous cervical disc decompression with chemonucleolysis [23], percutaneous cervical laser decompression [24], and percutaneous cervical manual and laser discectomy [25, 26]. Since 2000, owing to the technical advancement of a working channel endoscope and a concurrent development of surgical instruments and side-firing laser technology, the percutaneous endoscopic cervical discectomy (PECD) technique has become more practical [27–29]. In the mid-2000s, minimally invasive posterior endoscopic cervical foraminotomy techniques have been published [30–33].

Nomenclatures

According to the categories of the applied endoscopes

There are currently several categories of endoscopic spine surgery based on the characteristics of endoscopes: percutaneous endoscopic (or full-endoscopic), microendoscopic, epiduroscopic, and biportal endoscopic surgeries [16, 34–36]. Among them, percutaneous endoscopic or full-endoscopic spine surgery is the most commonly used technique for real and practical endoscopic discectomy. This technique usually meets the following criteria [35]: the use of a working channel endoscope which contains the optical system and a working channel, a complete percutaneous approach through a stab skin incision, and a monoportal technique performed under constant saline irrigation (Fig. 2). This article mainly reviewed about the percutaneous endoscopic or full-endoscopic spine disc surgery in lumbar and cervical spine.

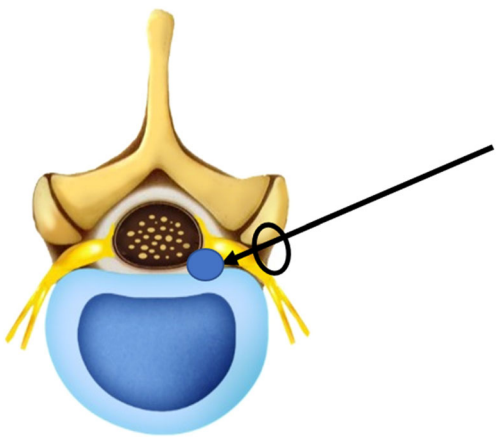

Fig. 1 The basic concept of endoscopic spine surgery. The original idea of endoscopic spine discectomy is a direct, posterolateral access (arrow) to the herniated disc through a safety working zone (circled line)

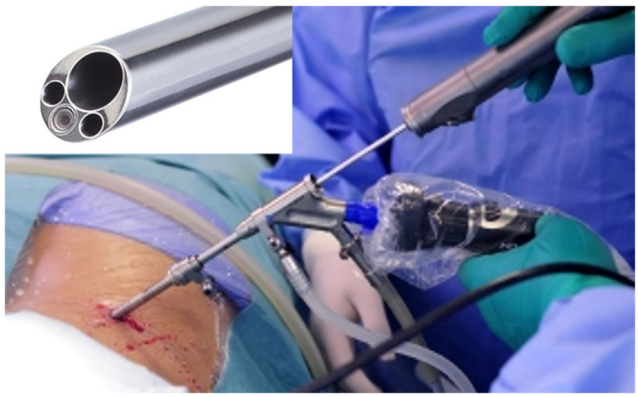

Fig. 2 Percutaneous endoscopic or full-endoscopic spine surgery. The technique usually meets the following criteria: the use of a working channel endoscope which contains the optical system and a working channel (upper left), a complete percutaneous approach through a stab skin incision, and a monoportal technique performed under constant saline irrigation

According to the surgical approach

Percutaneous endoscopic spine surgeries for lumbar and cervical spine categorized according to the surgical approach and disc level, which are as follows: transforaminal lumbar, interlaminar lumbar, anterior cervical, and posterior cervical [5, 6, 37].

Surgical techniques

Transforaminal PELD

The standard transforaminal percutaneous endoscopic lumbar discectomy can be performed under local anaesthesia (Fig. 3) [7, 9, 38]. The two most important principles of the transforaminal approach are to provide an access as close as possible to the disc pathology and to avoid irritating the exiting nerve root at the same time. A proper access angle and a landing point are essential for the clinical success. They can be adjusted according to the patient's body size, disc level, and zone of disc herniation. After a posterolateral, transforaminal insertion of the guiding needle, a gentle serial dilation from the smaller dilator to the final working sheath is conducted. A rigid, rod-lens endoscope with a working channel was then introduced. The ideal working sheath placement is when both the epidural and intradiscal spaces are visualized simultaneously close to the herniated fragment. Then, a selective endoscopic discectomy was performed at the periannular and epidural spaces. The surgical instruments used for decompression include grasping forceps, micropunches, flexible curved dissector, and a bipolar radiofrequency (RF) system. Finally, the end point was confirmed by the adequate exposure of neural tissue and complete mobilization or pulsation of the neural tissues.

Interlaminar PELD

Interlaminar PELD can be performed under conscious sedation or general anaesthesia, according to a previously described technique (Fig. 4) [19]. The target point is the lateral edge of the interlaminar window under fluoroscopic guidance. A blunt dilator was introduced to the target point, and a bevel-ended working sheath was positioned toward the surface of the ligamentum flavum (LF). Then, a rigid, rod-lens endoscope with a working channel was then introduced and the LF can be observed. The exposed LF can be removed using micropunches and forceps, and then the epidural space with the epidural fat and dural sac can be seen. Soft tissue removal and preparation can be aided by the dissector, RF probe, or supplementary lasers. Before selective discectomy, the dural sac and compressed nerve root should be defined and dissected to avoid neural injury. The herniated disc fragment can be removed by the endoscopic instruments with gentle retraction of the dural sac by the beveled tip of the working sheath. At the final step of the procedure, the decompressed dural sac and nerve root can be confirmed with a dissector under endoscopic visualization.

Anterior PECD

The PECD was performed using the standard technique described in previous studies (Fig. 5) [28, 29]. An anterior cervical percutaneous approach under fluoroscopic guidance was performed with conscious sedation anesthesia. The patient was placed in a supine position on a radiolucent table. A

Fig. 3 Transforaminal percutaneous endoscopic lumbar discectomy (PELD). The ideal transforaminal approach is a posterolateral percutaneous access to the herniated disc as near as possible, avoiding irritation to the exiting nerve root. Then, a safe epidural exploration and selective discectomy can be feasible under endoscopic visualization

Fig. 4 Interlaminar percutaneous endoscopic lumbar discectomy (PELD). A posterior endoscopic approach can be performed through the interlaminar space. After removing the hypertrophied ligamentum flavum, the herniated fragment can be removed protecting the nerve root using a bevel-ended working sheath

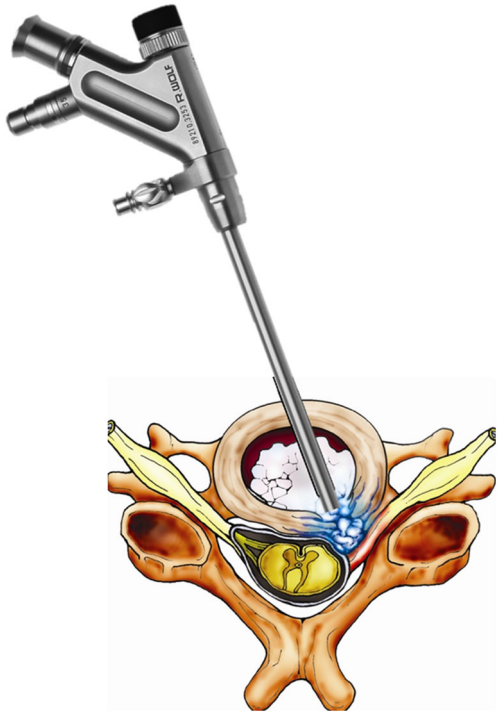

Fig. 5 Anterior percutaneous endoscopic cervical discectomy (PECD). A contralateral percutaneous anterior approach can be performed through the safety working zone between the carotid artery and tracheoesophagus. A selective removal of herniated disc fragment at the posterior margin of the disc while preserving central nucleus is essential

contralateral approach is usually recommended, because it can provide a better visual field for the herniated disc fragment. The approach needle was introduced intradiscally through a safety working zone between the carotid artery and the tracheoesophagus. Intra-operative discography was then performed with a mixture of contrast media and indigo carmine to demonstrate the herniation type and annular fissure. After a stepwise serial dilation process, the final working sheath was placed intradiscally with the tip of the working sheath on the posterior vertebral line. A working channel endoscope was inserted, and the intradiscal structures were inspected including annular fissure, posterior longitudinal ligament, endplate, and herniated disc. Then, a selective discectomy was performed using endoscopic forceps, RF, and supplementary side-firing holmium yttrium–aluminum–garnet (Ho:YAG) laser. The anterior part of the disc should be preserved to avoid post-operative disc collapse or segmental kyphosis, while the herniated disc fragment was removed at the posterior part of the disc. The end point of the procedure is free mobilization or pulsation of the epidural space, thecal sac, and the nerve root.

Posterior PECD

The surgical procedure was performed stage by stage: first, a percutaneous endoscopic landing to the laminofacet junction; second, a foraminal unroofing using endoscopic burrs and punches (endoscopic foraminotomy), and finally, a selective discectomy under endoscopic visualization (Fig. 6) [39]. The patient was placed in a prone position under general or local anaesthesia. An approach needle was inserted into the laminofacet joint under fluoroscopic guidance. A blunt obturator was placed overlying the facet joint and laminae of the target disc, performed carefully to avoid entering the spinal canal. Then, a bevel-ended working sheath was placed over the obturator down to the facet joint with the beveled opening facing the midline, and the obturator was removed. A working channel endoscope was then introduced and inspected the surfaces of the bony structures. The second stage of the procedure was endoscopic foraminal unroofing. The "Y-point," which consists of cranial laminae, caudal laminae, and the facet joint, could be seen after dissecting the bony structures. Starting with the parts of the cranial laminae at the Y-point, a diamond ball-tipped or side-cutting burr was used to remove the lower edge of the laminae and exposed the LF, then moved laterally toward the medial half of the inferior facet, cartilaginous facet joint, and superior facet, caudally toward the cervical pedicle, and then medially toward the intersection of the superior facet with the caudal laminae. Biomechanical studies have reported that cervical facet stability can be preserved as long as facetectomy was limited to 50% [40]. The third stage

Fig. 6 Posterior percutaneous endoscopic cervical discectomy (PECD). Endoscopic posterior foraminotomy and discectomy can be performed simultaneously using burr and punches under endoscopic visualization

of the procedure was selective endoscopic discectomy. After adequate exposure of the exiting nerve root, exploration of disc space was performed. The extruded disc fragment can be removed using a dissector and forceps. The remaining part of the disc herniation, or contained disc herniations, can be removed after the nerve root is protected by rotating the bevel-ended working cannula to retract it away from the disc annulus. After adequate disc decompression, the end point of the procedure can be achieved by free pulsation or mobilization of the nerve root from the proximal part to the distal exiting zone.

Indications and clinical outcomes

The basic surgical indication for percutaneous endoscopic discectomy is soft disc herniation. The feasibility of endoscopic surgery and its approach can be determined according to the various anatomical and clinical conditions of the cases.

Transforaminal PELD

The surgical criteria for the transforaminal PELD were (1) soft LDH as demonstrated on both magnetic resonance imaging (MRI) and computed tomography (CT) scan, (2) intractable lumbar radiculopathy consistent with the radiographic findings, and (3) failed non-operative treatment of at least six weeks. The exclusion criteria were spinal stenosis, segmental instability, painless weakness, cauda equina syndrome, and other pathologic conditions such as tumour and infection.

Throughout the history of endoscopic spine surgery, the transforaminal PELD techniques have been proven by randomized trials, meta-analyses, and systematic reviews. Some authors have published randomized trials on the effectiveness of transforaminal PELD [41–44]. Mayer and Brock [41] were the first to demonstrate the clinical comparison between transforaminal PELD and open microdiscectomy in their randomized trial. They concluded that transforaminal PELD can be a good alternative to microdiscectomy for patients with contained LDH. Hermantin et al. [42] reported an equal satisfaction rate with a shorter period of post-operative disability or narcotic use in the endoscopy group. Ruetten et al. [44] described a full-endoscopic transforaminal discectomy and compared the clinical results with those of open surgery. Although there are still some criticisms that the level of evidence in the published data related to this technique is relatively low with a high risk of bias [45], recent meta-analyses and systematic reviews have reported that the transforaminal PELD is comparable or superior to the conventional open discectomy in terms of the effectiveness and minimal invasiveness for soft LDH [46–48].

Interlaminar PELD

Soft LDHs that were technically inaccessible in the transforaminal approach due to the following conditions: (1) L5-S1 level with high iliac crest level beyond the middle of the L5 pedicle on simple lateral radiography, (2) high-grade migrated disc herniation, either cranial or caudal direction, (3) sufficient interlaminar window between the cranial and caudal lamina and between the midline and mediodorsal borders of the inferior articular process (IAP) measuring at least 6 mm, and (4) no limitations regarding the extent of dorsal or lateral disc herniations.

The interlaminar approach can be used in cases in which adequate access to the disc is difficult through a transforaminal approach owing to anatomical and technical reasons. This technique can now produce favourable results comparable to the conventional open surgery with benefits of MISS [19, 49].

Anterior PECD

The general indications for anterior PECD were (1) soft CDH demonstrated on MRI and CT scan, (2) neck pain and/or radicular symptoms consistent with the radiographic pathology, (3) cervical myelopathy caused by soft disc herniation in patients with a high risk of general anaesthesia complications, and (4) failed conservative therapy of at least six weeks. The contraindications were (1) hard disc herniation, (2) definite segmental instability, (3) severe cervical spondylotic myelopathy, (4) advanced spondylosis with disc space narrowing, and (5) neurological or vascular pathology mimicking disc disease.

The reported overall success rate of the anterior PECD varies from 51 to 94.5% [37, 50]. According to a previous study [26], the clinical outcome was better in patients with radiating arm pain (52.9%) than in those with neck pain (14.3%). In terms of the zone of disc herniation, the lateral herniation group (foraminal and posterolateral herniations) showed better outcomes than the central herniation group.

Posterior PECD

The inclusion criteria for posterior PECD were as follows: (1) foraminal or lateral CDH in which the main part of the disc is located lateral to the lateral edge of the spinal cord on MRI and CT scan; (2) unilateral cervical radiculopathy with arm pain; (3) craniocaudal disc migration, as long as the lateral localization was maintained; (4) concurrent foraminal stenosis; and (5) failed conservative therapy for at least six weeks. The contraindications were (1) definitive segmental instability, (2) cervical myelopathy or intracanal stenosis, (3) medial localization of the disc herniation medial to the lateral margin of the myelon, and (4) neurological or vascular pathologies mimicking disc disease.

Previous studies on endoscopic posterior cervical laminoforaminotomy have reported good or excellent relief of cervical radiculopathy, comparable to ACDF or open cervical foraminotomy techniques [30, 39, 51]. Ruetten et al. [39] published a randomized controlled trial of full-endoscopic posterior cervical foraminotomy versus standard ACDF for soft CDHs. They concluded that posterior PECD can be an effective alternative to conventional surgery in properly selected patients.

Discussion

The two most important keys to success of endoscopic spine surgery are proper patient selection and precise surgical technique. A variety of training courses including hands-on and cadaver workshop have provided opportunities to enhance the proficiency in the technical aspect. In contrast, in terms of patient selection, the importance of surgical indications has been relatively underestimated.

Patient selection

The most common causes of failed minimally invasive or endoscopic spine surgery are either incomplete decompression or intra-operative complications [52, 53]. In fact, most surgical failure cases can be evaluated with pre-operative neurological status and preoperative imaging studies. For example, a painless motor weakness is usually contraindication for endoscopic spine surgery. Instead, open conventional discectomy with thorough decompression is more adequate for this case. Surgeons can be informed not only of the disc herniation type but also of the feasibility of the endoscopic approach by performing imaging studies including X-ray, CT scan, and MRI. The extent of disc herniation, degree of migration, severity of adhesion, risk of dural tear, softness of the herniated disc, and concurrent spinal stenosis should be evaluated. For example, if any neural abnormality such as a conjoined nerve root was detected from preoperative CT scan and MRI, a transforaminal approach should be avoided because of a likelihood of a serious neural injury during the approach. To achieve a proper patient selection, the surgeon should always recognize his technical limitation in comparison with the patient's clinical and radiological conditions.

Technical considerations

The surgical indications can be adjusted according to the surgeons' skill or proficiency [54, 55]. In case of migrated disc herniation, high canal compromised disc herniation, partially calcified disc herniation, and disc herniation at L5-S1 level or C6-7, C7-T1 levels, specialized techniques may be required for adequate decompression to avoid complications.

In the transforaminal lumbar approach, the landing on the disc should be as near as possible to the target and as far as possible from the exiting nerve root. This is the first key to surgical success. Second, the anatomical layers should be confirmed during the procedure. Finally, herniated fragment should be completely removed after adequate releasing process, and the surgeon should not be in a hurry when directly removing the herniated fragment. The tenacious annular anchorage should be released before excision of the disc fragment.

In interlaminar lumbar approach, the most common complication of this approach is dural tear. To prevent this complication, the surgeon should determine whether the approach is toward the shoulder point or axillar point. In other words, the surgeon should differentiate the dural sac and traversing nerve root during the dissection process. The herniation type and deviation of the nerve root can be estimated from the preoperative CT scan and MRI. It is safer to access the space between the dural sac and deviated nerve root. Once the dural sac, deviated nerve root, and herniated fragment are well defined, the discectomy and decompression process can be performed safely and easily. In the anterior cervical approach, a safe and precise targeting is the most essential factor for effective discectomy. The surgeon should identify the carotid pulse and push down his fingertips into the space between the carotid artery and trachea until his fingertips touch the anterior surface of the vertebral body [37]. The tracheal air shadow is a good indicator for correct positioning in the tracheoesophagus. In patient with short and thick neck, the shadow of the shoulder may interfere with the recognition of C6–7 level under lateral fluoroscopic view. Additional oblique fluoroscopic views can be useful to approach the C6–7 level in addition to the A–P and lateral views.

In the posterior cervical approach, identification of the laminofacet junction (Y-point) is very important for adequate foraminotomy. The extent of bone resection should be limited to not more than 50% of the facet joint to avoid post-operative instability. The surgeon should be cautious of dural laceration during foraminotomy because the foraminal pressure is considerably high with disc herniation. After exposure of the dural sac and exiting nerve root, a sophisticated blunt dissection should be performed for safe discectomy. Epidural bleeding from flourishing venous plexus may happen; hence, a gentle tamponade with haemostatic agents can be more effective than direct electrocautery.

Evolution of indications and techniques

At the early endoscopic spine surgery era, the main indications for endoscopic spine surgery were contained disc herniation with mild canal compromise and limited migration. After the year 2000, the development of the working channel endoscope and associated surgical instrument enabled the epidural

exploration, and subsequently, the surgical indications were expanded to extruded disc herniation and related conditions, such as migrated or sequestered disc herniation, recurrent disc herniation, foraminal disc herniation, and high-canal compromised disc herniation [56–59]. For the last decade, advancement in endoscopic technologies has been remarkable. Given the larger working channel endoscope and advanced instruments, such as endoscopic burr, punches, and flexible forceps, the surgical indications have even expanded to spinal stenosis. Today, most of the soft disc herniation and some of the spinal stenosis can be treated with endoscopic spine surgery [4, 60]. Given the further development of articulating or navigating instruments, endoscopic spine surgeries will be more practical in decompressing spinal stenosis and may become feasible even for fusion surgeries under endoscopic control in the near future.

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Compliance with ethical standards

Conflict of interest The author declares that there is no conflict of interest.

Financial disclosure The author has no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

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