

**Techniques and Applications of Endoscopic Spine Surgery. Part II: Safety and
Effectiveness of Endoscopic Spine Surgery in Treating Spinal Conditions**

Kai-Xuan Liu, MD, PhD

Atlantic Spine Center

West Orange, New Jersey 07052

Corresponding author: Kai-Xuan Liu

Address: Atlantic Spine Center, 475 Prospect Avenue, West Orange, NJ 07052

Fax: (732) 4941255

Phone: (732) 4941655

E-mail: doc@atlanticspinecenter.com

ABSTRACT

Background

Spinal pain is a serious health and social-economic problem. Endoscopic spine surgery as a treatment option for spinal pain has gained tremendous attention and growth in the past 2 decades, and a variety of endoscopic techniques have been developed to treat a wide range of spinal conditions.

Purposes

The purposes of the second part of this 2-part review article are to 1) summarize the applications of endoscopic spine surgery in treating various spinal conditions, and 2) evaluate the clinical evidence of the safety and effectiveness of these endoscopic techniques in treating some of the most common spinal conditions.

Methods

We searched the PubMed database for publications concerning endoscopic spine surgery and reviewed the relevant articles published in the English language.

Results

Endoscopic spine surgery provides comparable clinical outcomes to the gold standards for some spinal conditions but with less surgical morbidity and faster recovery. However, endoscopic spine techniques are associated with steep learning curves, and each of them has its own specific indications and requires rigid patient selection.

Conclusions

Endoscopic techniques may be considered safe alternatives to conventional open techniques for selected patients with specific spinal conditions such as lumbar disc herniation. High quality,

randomized studies are needed to compare the effectiveness of endoscopic techniques with that of open or microsurgical techniques.

Key Words: Endoscopic spine surgery, minimally invasive spine surgery, herniation, stenosis, failed back surgery syndrome

INTRODUCTION

Chronic pain is a serious health problem. Treatment of spinal pain generally starts with conservative options. But if conservative treatments fail to produce satisfactory pain relief, surgery may be considered. Because of its many advantages, endoscopic spine surgery has spurred tremendous interest in recent years. The main goal of the new endoscopic spine surgical techniques is to achieve at least comparable clinical outcomes to conventional surgical options while reducing the operation-related tissue damage and high morbidity rates.

In the past 10 to 15 years, many authors have reported their experience with endoscopic spine surgery for treating spinal conditions.¹⁻¹³ A number of retrospective and prospective studies have attempted to evaluate the feasibility and safety of different endoscopic techniques, and a few randomized controlled clinical studies have compared the clinical outcomes of endoscopic techniques with conventional open spine surgery techniques in treating some common spinal conditions.^{1-4, 7, 10, 14-16}

The objectives of this second part of our 2-part review article are to 1) summarize the applications of these techniques in treating various spinal conditions, and 2) evaluate the clinical evidence of the safety and effectiveness of these techniques in treating some of the major spinal conditions. Endoscopic spine techniques also play important roles in diagnosing spinal diseases and visualizing pain resources, but because of word limitation, this review article focuses on only the role of endoscopic spine techniques as a surgical treatment option.

METHODS

We searched the PubMed database for publications concerning endoscopic spine surgery and reviewed the relevant articles published in the English language.

RESULTS

Endoscopic Spine Surgery for Spinal Disc Herniation

Lumbar disc herniation

Lumbar disc herniations account for about 5% of lower back disorders. Techniques of endoscopic spine surgery for lumbar disc herniations have been well established, and encouraging results have been summarized in a number of review articles.^{17, 18}

A recent systematic literature review evaluated the effectiveness of transforaminal endoscopic spine surgery in treating patients with lumbar disc herniations, and compared the clinical outcomes of transforaminal endoscopic spine surgery with conventional microdiscectomy.¹⁸ The systematic review included a total of 39 clinical trials but only one was randomized controlled trial. The majority of the studies (37 of 39) were observational. The studies were heterogeneous in terms of patient selection, indications, surgical techniques, follow-up periods, and outcome measurement, which made it challenging to combine the data for further statistic analysis. The 8 comparative trials (1 randomized, 7 non-randomized) did not find any statistically significant difference between endoscopic techniques and microdiscectomy in terms of leg pain reduction, overall improvement, reoperation rate, and complication rate. And the systematic review was not able to conclude if transforaminal endoscopic surgery is more effective than microdiscectomy.

Another systematic review compared the effectiveness of posterior endoscopic discectomy, microdiscectomy, and open discectomy in treating single level lumbar disc herniations.¹⁹ Of the 10 randomized studies included in the review,²⁰⁻²⁹ 2 compared endoscopic technique with microdiscectomy,^{25, 26} and 3 compared endoscopic discectomy with open discectomy.^{21, 22, 27} The systematic review confirmed that all 3 techniques were effective in treating single level lumbar disc herniations in patients without degenerative vertebral deformities.

But the review, again, did not find statistically significant differences between the techniques regarding pain reduction, function improvement, and patient satisfaction. However, the review did find that the return-to-work time after endoscopic discectomy was significantly shorter than that after microdiscectomy, and that the intraoperative blood loss during endoscopic discectomy was significantly less than that during open discectomy.

Cervical disc herniation

A number of studies have reported the safety and feasibility of both endoscopic anterior cervical discectomy and endoscopic posterior laminoforaminotomy for treating cervical disc herniations.^{3, 15, 30-32} But no systematic review has been conducted to evaluate the overall safety and effectiveness of endoscopic techniques in treating cervical disc herniations, especially when compared with conventional gold standard, anterior cervical discectomy and fusion (ACDF). The only controlled studies comparing endoscopic techniques (endoscopic anterior decompression³¹ and posterior foraminotomy¹) with ACDF were conducted by Ruetten et al. Ruetten’s study found that both endoscopic anterior cervical discectomy (EACD) and ACDF led to significant ($P < 0.001$) and constant pain reduction. The patient satisfactory rate in the EACD group was slightly higher than that in the ACDF group, but the difference was not statistically significant. Compared with ACDF, EACD offered short operating time, minimal blood loss, low complication rate, short hospital stay, and fast recovery (Table1).

Table 1 Results of EACD and ACDF for primary, mediolateral, localized, soft disc herniations at the 2-year follow up³¹

	EACD	ACDF
Patient No	54	49

Operating Time* (minute)	32 (8-51)	62 (41-102)
Blood Loss (mL)	Not measurable	<10
Complication Rate	3.7%	14.3%
Revision Rate	7.4%	6.1%
Satisfactory Rate	90.7%	87.8%
Hospital Stay (day)	≤3	≤7
Percent of patients returned to work 3 months after the surgery*	84.3	62.0

*: Statistically significant $P < 0.001$. EACD: endoscopic anterior cervical discectomy; ACDF: anterior cervical discectomy and fusion

In a separate prospective controlled study, Ruetten et al compared endoscopic posterior foraminotomy (EPF) with ACDF in treating primary, lateral, localized cervical herniations.¹ Both EPF and ACDF were found effective in reducing pain. At the 2-year follow-up, 87.4% of all patients no longer had arm pain, and 9.2% occasionally had pain. Again, the clinical outcomes including revision and complication rates were similar between the two groups, but EPF showed obvious advantages over ACDF in operating time, blood loss, and rehabilitation (Table 2). Other advantages of EPF included reduced operation-related neck pain and preservation of neck mobility.

Table 2 Results of EPF and ACDF for lateral or foraminal, localized, single level cervical herniations at the 2-year follow up¹

	EPF	ACDF
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Patient No	86	89
Operating Time* (minute)	28 (19-50)	68 (48-105)
Blood Loss (mL)	Not measurable	< 10
Complication Rate	3.4%	5.6%
Revision Rate	6.7%	4.7%
Satisfactory Rate	96%	91%
Mean postoperative work disability* (day)	19	34

*: *Statistically significant* ($P < 0.001$). EPF: endoscopic posterior foraminotomy; ACDF: anterior cervical discectomy and fusion

Thoracic disc herniation

In 2002, Chiu ¹¹ reported the safety and efficacy of laser-assisted percutaneous endoscopic discectomy in treating patients with contained thoracic disc herniations. At the final follow-up (average: 44 months; range: 4-54 months), 96% of the patients achieved a good or excellent result and no operative complications were noted. Choi et al ³³ recently reported the feasibility of percutaneous endoscopic thoracic discectomy (PETD) through a transforaminal approach. In a small study involving 14 patients with soft lateral or central thoracic herniations, Choi et al removed the localized soft disc herniations after performing a foraminoplasty. No surgery-related complications were observed. At the final follow-up (mean: 60.2 months; range: 15-89 months), the patients' back pain and leg pain were drastically reduced. However, the PETD technique was not adequate to treat sequestered herniations and calcified or hard disc herniations.

Endoscopic Spine Surgery for Spinal Stenosis

Open laminectomy is the conventional surgical choice for degenerative spinal stenosis. Safety and feasibility of treating lumbar stenosis using endoscopic techniques have recently been investigated and reported. In a prospective 2-year study involving 72 patients with central lumbar spinal stenosis, Ruetten et al ⁷ achieved sufficient decompression using an endoscopic interlaminar technique through a unilateral approach. The surgery produced constant and significant ($P < 0.001$) reduction in leg pain and improvement in daily activities. At the 2-year follow up, 70.8% of the patients no longer or rarely had leg pain, and 22.2% occasionally had pain.

Endoscopic transforaminal approaches have also been used to treat spinal stenosis, including lateral recess stenosis, foraminal stenosis, as well as central spinal stenosis. In a recent systematic review, Nellensteijn et al ³⁴ evaluated the effectiveness of transforaminal endoscopic surgery for lumbar stenosis. According to the systematic review, 69-83% overall satisfactory rates were reported. Among all the studies included in the systematic review, only three studies, ³⁵⁻³⁷ however, included patients with central spinal stenosis, and the outcomes of this subgroup were not reported separately. It is therefore difficult to determine based on the review whether or not transforaminal endoscopic surgery was as effective for treating foraminal stenosis and lateral recess as for central spinal stenosis. In general, it is technically more challenging using transforaminal approaches to treat central spinal stenosis than foraminal stenosis or lateral recess stenosis.

In another prospective randomized controlled study, Ruetten et al ¹⁶ compared their endoscopic interlaminar technique with microsurgical techniques in treating lumbar lateral recess stenosis. Again, constant and significant ($P < 0.001$) reduction in leg pain and improvement in daily activities were achieved in both groups. The differences in pain reduction and activity improvement between the 2 groups were not statistically significant. However, the endoscopic technique afforded significantly lower complication rates than the conventional microsurgical

techniques (Table 3). In addition, the patients who underwent endoscopic surgery experienced significantly less ($P < 0.01$) postoperative pain and needed significantly less amount of pain medication.

Table 3 Results of endoscopic and microsurgical techniques in treating lumbar lateral recess stenosis ¹⁶

	Endoscopic	Microsurgical
Patient No.	80	81
Operating Time* (minutes)	34 (28-57)	48 (32-79)
Blood Loss (mL)	Not measurable	67 (15-275)
Complication Rate*	1.2%	8.8%
Revision Rate	2.5%	3.7%
Satisfactory Rate	92%	86%
Hospital Stay (day)	≤ 3	≤ 6

*: Statistically significant ($P < 0.05$)

Endoscopic Spine Surgery for Failed Back Surgery Syndrome

The causes of failed back surgery syndrome (FBSS) are multifactorial. Incomplete removal or recurrence of the spinal pathology such as disc herniations contributes to a large portion of FBSS cases. Patients with FBSS often need repeat operation. The feasibility and safety of endoscopic spine surgery for treating recurrent disc herniation was first evaluated by Ahn et al ⁹ in a retrospective study, in which the recurrent disc herniations were removed via percutaneous endoscopic lumbar discectomy (PELD) through posterolateral unscarred tissue planes under local

anesthesia. At the final follow-up (mean: 31 months; range: 24-39 months), 81.4% of the patients reported excellent or good results, 13.9% reported fair results, and 4.7% reported poor results.⁹ Further statistical analysis and radiologic findings suggested that younger patients (<40 years) and patients with duration of symptoms shorter than 3 months benefited from PELD much more than older patients and patients with duration of symptoms longer than 3 months, and that the technique was not sufficient enough for treating concurrent lateral recess stenosis.

In a larger prospective cohort study, Hoogland³⁸ performed endoscopic transforaminal discectomy (ETD) to treat patients with recurrent lumbar disc herniations after previous discectomy. At the 2-year follow-up, 85.7% of the 262 patients reported excellent or good results, 9.7% reported fair results, and 4.6% reported unsatisfactory results. Within 2 years after the surgery, the recurrent rate of disc herniation was 4.6%.

So far, the only randomized controlled study comparing endoscopic and microsurgical techniques for recurrent lumbar disc herniations after open discectomy was conducted by Ruetten et al.² The study found that both microdiscectomy and endoscopic discectomy (interlaminar and transforaminal) significantly improved patients' leg pain and daily functions, but the differences between the improvements were not statistically significant. However, the postoperative pain and pain medication usage in the endoscopic group was significantly ($P < 0.01$) lower than that in the microdiscectomy group. And the postoperative work disability period (28 days) after endoscopic surgery was significantly shorter ($P < 0.01$) than that after microdiscectomy (52 days). A recent retrospective study conducted by Shin et al³⁹ further confirmed the feasibility and effectiveness of endoscopic interlaminar and transforaminal discectomy in treating recurrent herniations.

Lee and colleagues⁴⁰ also compared the PELD with open discectomy for recurrent disc herniation in a retrospective study, and their result indicated that the clinical outcomes (back and leg pain reduction and function improvement) of PELD and open surgery were comparable but

PELD was associated with considerably lower complication and secondary recurrent rates (Table 4).

Table 4 Results of endoscopic spine surgery for recurrent lumbar disc herniation after open or microsurgery

Author	Year	Type of Study	Study Size	Follow-up Period (month)	Satisfactory Rate* (%)	Complication Rate (%)	Secondary Recurrent Rate (%)
Ahn <i>et al</i> ⁹	2004	Retrospective	43	31 (24-39)	95.3	4.7	-
Shin <i>et al</i> ³⁹	2011	Retrospective	41	16 (13-42)	92.2	9.8	4.8
Hoogland <i>et al</i> ¹⁴	2008	Prospective, cohort	262	24	95.4	3.8	4.6
Ruetten <i>et al</i> ²	2009	Prospective, randomized, controlled	87 (total) 45 (FE) 42 (MD)	24	95.0 (FE) 86.0 (MD)	6.0 (FE) 21.0 (MD)	6.7 (FE) 4.8 (MD)
Lee <i>et al</i> ⁴⁰	2009	Retrospective, comparative	54 (total) 25 (PELD) 29 (MD)	34.2 (25-41)	-	4.0 (PELD) 10.3 (MD)	4.0 (PELD) 10.3 (MD)

*: including excellent, good, and fair results. FE: full-endoscopic interlaminar or transforaminal discectomy; PELD: percutaneous endoscopic lumbar discectomy; MD: microdiscectomy

Overall published data suggest that endoscopic spine surgery is effective and relatively safe in treating FBSS caused by recurrent lumbar disc herniations. Compared with

microdiscectomy, endoscopic techniques provide comparable clinical outcomes in terms of pain reduction and function improvement but with markedly lower complication rates, shorter hospital stay, faster recovery, and less postoperative pain. However, most of the studies are retrospective and the study sizes are small. To confirm the effectiveness of endoscopic techniques compared with traditional microdiscectomy, large scale prospective randomized controlled studies are needed.

Endoscopic Spine Surgery for Spondylolisthesis

Decompression with or without fusion is the conventional surgical treatment option for isthmic spondylolisthesis. Knight et al ⁶ assessed the safety and feasibility of managing isthmic spondylolisthesis through posterolateral endoscopic laser foraminoplasty (ELF) in a prospective study involving 24 symptomatic patients with Grade I-III isthmic spondylolisthesis. At the 2-year follow up, 79% of the patients achieved good to excellent improvement in disability; 21% were pain free, 63% had a good result in pain reduction, 8% had a poor result, and 8% experienced worse pain. The two patients with worse pain experienced significant pain relief after undergoing spinal fusion operations elsewhere. No surgical complications were noted in the study. Results of this study indicate that laser-assisted endoscopic technique can be a safe alternative for selected patients with painful spondylolisthesis.

Endoscopic Spine Surgery for Other Spinal Conditions

Besides treating spinal pain caused by disc herniations, degenerative diseases, FBSS, and spondylolisthesis, endoscopic-assisted techniques also have been used to treat other spinal diseases including spinal infections and tumors.^{41, 42} However, publications on endoscopic

techniques for treating these conditions are very limited. To confirm the safety and effectiveness of endoscopic techniques in treating these conditions, large scale randomized controlled studies are needed.

DISUCSSION

All of the endoscopic techniques discussed in this article are associated with steep learning curves, and each of them has its own limitations and none of them are suitable for all spinal conditions. The clinical outcome of endoscopic spine surgery in treating various spinal conditions can be markedly affected by the surgeon's skill, surgical technique used, and patient selection. And despite the many advantages of endoscopic spine surgery, not all procedures (eg, spinal fusion and fixation procedures), however, can be done endoscopically. It is particularly challenging to adequately treat spinal diseases involving spinal instability such as spondylolisthesis using current endoscopic techniques. Although Knight et al ⁶ reported encouraging results in treating spondylolisthesis using endoscopic posterolateral techniques, similar results have not been reported by other authors. It is therefore difficult to say at this point whether or not similarly encouraging results can be achieved by others using the same techniques. Our own experience indicates that if a patient's primary symptoms are severe leg pain and lower back pain, transforaminal foraminoplasty is an effective approach. Once the nerve compression is reduced, the patient's leg pain, but not severe lower back pain, is usually relieved. We believe that if a patient's primary complaint is lower back pain, endoscopic lumbar foraminotomy is contraindicated for isthmic spondylolisthesis.

Like any type of surgery, endoscopic spine surgery is also associated with certain amount of risk of complications. Potential intraoperative complications of endoscopic spine surgery include injuries to the nerves, dura tears, infections, bleeding, and penetration to the peritoneum

and damage to the organs. And potential postoperative complications include airway compression, atelectasis (collapse of a lung), and transient neurological dysfunction caused by stretching, compressing, or bruising the nerve during the surgical procedure.⁴³ Symptoms of transient neurological dysfunction following endoscopic spine surgery include tingling, numbness, burning and throbbing pain, and sometimes muscle weakness. The symptoms normally last a few days to a few weeks, and can be taken care of with antiinflammatory medication, oral steroid, or steroid injection.

Currently there are only a few prospective, randomized clinical trials comparing endoscopic spine surgery with traditional open spine surgery, or microsurgical approaches. A large portion of these trials were done by only a few groups that have substantial experience in the field (eg, Ruetten's group). A concern is that these groups' high success rates of endoscopic spine surgery may not be easily achieved by less experienced surgeons. Another concern is that in the limited number of comparative studies, the effectiveness of endoscopic spine surgery in treating cervical disc herniations were compared with that of ACDF, when it actually might be fairer to compare the effectiveness of endoscopic techniques with that of microsurgical transmuscular approaches using a tubular retractor because the two types of techniques use very similar ways to gain access to the disc herniation. The main differences between endoscopic spine surgery techniques and microsurgical transmuscular techniques using a tubular retractor are the instruments (endoscopic working channel vs tubular tractor) and magnification systems (endoscope vs microscope) used. However, microsurgical transmuscular approaches using a tubular retractor is likely to involve larger skin incision, more soft tissue removal, more bleeding, and possible longer recovery than endoscopic spine surgery.

In a recent report on outcomes of a randomized controlled trial, Arts et al⁴⁴ compared the outcomes and time to recovery in patients treated with tubular discectomy and conventional microdiscectomy. The study involved a total of 328 patients (167 in the tubular discectomy group;

161 in the microdiscectomy group) with persistent leg pain that lasted longer than 8 weeks due to lumbar disk herniations. Based on intention-to-treat analysis, 1 year after the surgery, the differences in outcomes (Roland-Morris Disability Questionnaire score) of tubular discectomy and conventional microdiscectomy were not statistically significant. Compared with conventional microdiscectomy, tubular discectomy, which is considered less invasive, surprisingly, resulted in less favorable results in terms of patient self-reported leg pain, back pain, and recovery.

While published data have proved the safety of endoscopic spine surgery, more surgical reports from different groups are needed to confirm the effectiveness of endoscopic spine techniques, and more randomized studies are needed to compare the effectiveness of endoscopic spine techniques with that of open surgical techniques, conventional microdiscectomy, as well as microsurgical transmuscular approaches using a tubular retractor.

CONCLUSION

Current clinical evidence suggests that for strictly selected patients with specific spinal conditions, endoscopic spine techniques can be safe and effective alternatives to conventional microsurgical techniques for disc herniations, spinal stenosis, and FBSS. However, endoscopic spine surgical techniques are associated with steep learning curves. The clinical outcome and success rate may vary from one surgeon to another depending on the surgeon's knowledge, experience, and familiarity with a particular endoscopic technique.

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