



Endoscopic Spine Surgery: A Review of Current Evidence, Techniques, and Future Directions

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Received:- 25/06/2026, Revised:- 30/07/2026, Accepted:- 20/08/2026, Published:- 31/08/2026

Abstract

In the spine literature, endoscopic spine surgery (ESS) is set to be the most widely discussed subject by the year 2026, as shown by the large number of systematic reviews, comparisons of techniques, studies of the learning curve, and growing interest within health systems regarding same-day outpatient (SDO) care. It provides a minimally invasive option compared with conventional open and microscopic methods for treating degenerative disc disease, spinal stenosis, and is now being applied to an increasing number of cervical, thoracic, and fusion procedures. This review brings together the existing uniportal and biportal techniques, provides a quantification of recent outcome and complication data, looks at the learning curve barrier which is still influencing adoption patterns, and identifies the new developments such as AI-assisted planning, navigation, and expansion into fusion and oncologic applications.

Keywords: Endoscopic spine surgery; Uniportal full-endoscopic spine surgery (UESS); Unilateral biportal endoscopic spine surgery (UBE); Minimally invasive spine surgery; Learning curve; Lumbar discectomy; Spinal stenosis; Dural tear; Endoscopic lumbar interbody fusion; Same-day outpatient spine surgery.

1. Introduction

Over the last twenty years, minimally invasive spine surgery has gradually taken the place of open surgery, and endoscopic methods now form the most advanced part of this change. Instead of completely replacing microdiscectomy or decompression, endoscopic spine surgery (ESS) is intended to minimise tissue damage, blood loss, and the length of recovery whilst maintaining surgical accuracy by means of high-definition visualization and the use of small-diameter channels. Recent interest in this area has increased for two interrelated reasons: the availability of an increasing amount of comparative and long-term outcome data, and the wider trend among ambulatory surgery centres to carry out outpatient, same-day spine procedures, a trend that favours less invasive techniques. Leadership within professional societies has clearly identified the shift in the site of service as one of the key developments in spine care by 2026, with minimally invasive and endoscopic techniques seen as the clinical tools that will enable this transition.

2. Techniques currently in use

ESS techniques are generally grouped into two families:

Uniportal full-endoscopic spine surgery (UESS), it is also known as percutaneous endoscopic or full-endoscopic surgery, involves using a single portal for both the endoscope and the instruments used for surgery, this portal most often being reached through transforaminal or interlaminar corridors in order to carry out a discectomy and provide foraminal decompression.

Unilateral biportal endoscopic spine surgery (UBESS/UBE). Separate viewing and working portals allow use of conventional open-surgery instruments alongside endoscopic visualization, which many surgeons as an easier transition from open or microscopic surgery.

Both of these methods began with operations on the lumbar spine for discectomy and stenosis and have since developed a great deal. The more recent literature includes endoscopic techniques for the cervical and cervicothoracic spine, endoscopic-assisted anterior odontoid screw fixation, endoscopic treatment of thoracic disc herniation, endoscopic methods for repairing a spontaneous CSF leak, and full-endoscopic or biportal-assisted lumbar interbody fusion—areas which a few years ago were regarded as investigational. Other related innovations, such as navigated guides for placing pedicle

screws and patient-specific 3D-printed instrumentation for cortical bone trajectory screws, are currently being studied as complementary technologies that accompany rather than replace endoscopic visualization.

A good way of considering the decision between the uniportal and biportal methods is that UESS tends to involve smaller working channels and results in less morbidity associated with the approach, especially in the case of a simple discectomy, whereas UBE tends to be preferred by surgeons who are coming from open surgery since it maintains the familiar bimanual control of the instruments and provides more space for carrying out bony decompression in cases of stenosis.

3. Clinical Outcomes

3.1 Cervical applications

A systematic review carried out in 2026 on endoscopic cervical spine surgery (ECSS) concluded that it provides a feasible minimally invasive option for certain cases of cervical stenosis and has potential benefits regarding tissue preservation, length of hospital stay, and functional recovery; the authors, however, stressed that prospective, controlled trials are still required in order to establish these advantages against those of open cervical surgery.

3.2 Lumbar applications

Data on the outcomes of lumbar endoscopic discectomy are still being collected on a large scale and are becoming more frequently presented over multi-year rather than short-term follow-up periods, which shows the increasing confidence in the durability of endoscopic decompression. A five-year study of transforaminal endoscopic lumbar discectomy for lateral recess stenosis—this study included patients with chronic systemic diseases—and case series involving prone endoscopic lateral lumbar interbody fusion demonstrate the change in the field from reporting on feasibility to focusing on longer-term functional results. In contrast, conventional single-level open lumbar discectomy has had reoperation rates of about 14.4% after five years according to registry data, a figure against which the durability of endoscopic procedures is now being compared.

3.3 Thoracic applications

Full-endoscopic thoracic discectomy has always been avoided owing to the risks linked with open thoracic surgery, but is now supported by an increasing amount of single-arm evidence. A pooled meta-analysis of 13 studies involving 285 patients who had

thoracic disc herniation—most of whom were treated transforaminally under local anesthesia with sedation—found there were no infections or deaths, and the combined complication rates for dural tear, dysesthesia, recurrent herniation, myelopathy, epidural hematoma, and reoperation were all under 5%. Thus, endoscopic thoracic discectomy can be regarded as a comparatively low-morbidity procedure for a part of the body that has historically been considered high-risk, although the authors once more urged for controlled comparative trials with open surgery.

4. Complications: What the Aggregated Data Reveal

The largest dataset of complications includes 117 studies and 20,020 patients (10,405 UESS and 9,615 UBESS), with adverse events being classified according to technique, spinal region, and type of procedure (discectomy/decompression as opposed to fusion). The main findings of this dataset are:

The most clinically important complications following endoscopic discectomy and decompression are transient neurological deficit, a dural tear, and dysesthesia.

Late complications, especially those involving mechanical implant failure, are typical of endoscopic interbody fusion, which serves as a reminder that fusion has a different risk profile than decompression-only procedures even when the fusion is carried out endoscopically.

The issue of dural tear rates has been looked at in more detailed comparative studies. A meta-analysis involving 67 studies and 10,491 patients (4,657 undergoing the biportal approach and 5,834 having the uniportal approach) first revealed a higher rate of incidental dural tears with the biportal technique (3.16%) as compared to the uniportal technique (1.69%), a difference that was statistically significant. Yet, a more closely matched analysis of 25 of those studies showed no significant difference (1.4% for uniportal and 1.1% for biportal), indicating that a large part of the apparent discrepancy is likely due to study heterogeneity rather than representing a real difference in risk caused by the technique. To put this in context, older meta-analyses have combined dural tear rates from both open and minimally invasive spine surgeries at around 5.8%, which means that endoscopic techniques might do well on this particular measure, although the risk does vary greatly depending on the diagnosis—reported rates

ranging from about 1.1% in cases of lumbar disc herniation up to 37.5% in cases with synovial cysts.

In addition, a systematic review that concentrated on rare complications associated with uniportal spinal endoscopy confirmed that although ESS is generally considered to be safer and to have fewer complications than open surgery, unusual events still require surgeons to be aware of them, especially since an increasing number of surgeons are using the technique in outpatient settings where the need for quick recognition and management is greater because of the shorter discharge times. The way in which intraoperative dural tears are managed is itself a field that is undergoing ongoing technical development, a flowchart-based approach (based on data from 14 studies and involving approximately 68,500 patients) suggesting strategies depending on the size of the tear, ranging from observation and the use of haemostatic agents for small tears to endoscopic patch repair or conversion to open surgery in the case of larger tears or those involving a nerve root.

5. The Learning-Curve Barrier

Even though there has been favourable outcome data, the adoption of ESS in the United States has been slower than in parts of Asia and Europe, and one common point in the comments of 2026 is that the steep learning curve — not its efficacy — is the main obstacle to greater acceptance.

When aggregate data are considered, a large meta-analysis of both individual and aggregated data found that about 60 cases are needed to achieve full proficiency in endoscopic lumbar surgery, although the steepest section of the learning curve — around 80% of the possible improvement — is attained within the first 20 cases. This same analysis calculated that an 80% improvement in postoperative leg-pain scores would require approximately 96 cases when the analysis started from a VAS of 2.7, and the improvement trajectories for interlaminar and biportal discectomy were similar.

When it comes to uniportal and biportal techniques, a systematic review included in the March 2026 edition of *The Spine Journal*—which looked at 29 studies (18 involving the uniportal method and 11 involving the biportal method; comprising 1,493 patients who had uniportal procedures and 1,005 who had biportal procedures)—showed that the median number of cases needed to achieve proficiency was

considerably lower for the uniportal technique (20 cases) than for the biportal technique (37.5 cases). Interestingly, however, when the analysis was broken down by type of specific procedure, the difference between the two techniques disappeared and became non-significant—indicating that the overall gap might in part be due to the fact that certain procedures are usually the first ones attempted with each technique. The same review also discovered that operative time improved more and faster with biportal discectomy than with uniportal discectomy, even though it took longer to reach the proficiency threshold with the biportal method—a trend the authors attributed to the fact that biportal discectomy is typically the first procedure that novice endoscopic surgeons try.

A single-centre comparative study also points in the same direction: a retrospective analysis of 160 consecutive patients with lumbar disc herniation who were treated by two fellowship-trained surgeons showed proficiency cutoff points of 11 to 14 cases for the unilateral endoscopic technique and 27 to 31 cases for the uniportal full-endoscopic technique—this serves as a reminder that the learning-curve thresholds reported vary significantly depending on the institution, the surgeon's background, and the analytical method used, and therefore should be regarded as ranges rather than as fixed values.

The practical significance of these findings extends well beyond mere academic interest: they have an impact on the way surgical organisations construct their credentialing programmes, on how many mentored cases a new endoscopic programme should plan to allocate, and on which technique—uniportal or biportal—a particular surgeon might prefer depending on their previous training; surgeons who have been trained in open surgery generally find the bimanual instrument handling associated with the biportal technique to be an easier starting point, even though the full proficiency curve for this approach is longer.

6. Emerging Directions

The use of AI in planning and navigation. Increasingly, advances in endoscopic instruments are being combined with AI-powered preoperative planning and real-time navigation with the aim of improving accuracy and possibly reducing the learning curve without replacing the surgeon's judgment. Comment from the industry in 2026 describes this as the "augmented"

phase of spine surgery as a whole, where AI-enabled surgical planning, robotic assistance, real-time navigation, and augmented reality all serve to enhance—not replace—surgeon expertise.

The move is now towards fusion. Rather than just consisting of technical case reports, both full-endoscopic and biportal-assisted interbody fusion techniques are undergoing larger feasibility studies, which indicates that endoscopic methods could eventually be used meaningfully beyond procedures that involve only decompression. This change also affects the balance of complications, as late complications specific to fusion—such as implant failure—are different from the complications that usually occur during decompression surgery.

The use of endoscopic techniques is being investigated in the field of spinal oncology and in the repair of cerebrospinal fluid leaks—areas which have until now been the domain of open surgery—thus extending the application of the technique beyond degenerative conditions.

The facilities needed for training are appearing as the learning-curve data develops, with formal training programmes being introduced to help surgeons make the transition from using tubular or open methods to endoscopic techniques, such as mentorship-based series of cases which are specifically designed to reduce the length of the early, complication-prone stage of adoption.

Regarding site of care and the economic aspects, same-day outpatient spine surgery is designated as a structural priority for 2026, since endoscopic and other minimally invasive methods are at the heart of this transition because they reduce perioperative morbidity sufficiently to allow for outpatient recovery routes. Yet surgeons who have been using the biportal endoscopic technique for many years point out that the initial capital equipment costs and the per-case disposable costs still represent a real limitation on adoption as these procedures move into cost-conscious ambulatory surgery centres — indicating that the obstacle to wider acceptance of ESS is not solely clinical but also financial.

7. The limitations of the present evidence base

A large portion of the literature on endoscopic surgical surgery is retrospective, based on single centres or registries, and there are relatively few randomized controlled trials that directly compare

endoscopic with open or microscopic techniques in cases that are matched—this shortcoming has been explicitly recognized by the authors in all of the reviews covering the cervical, thoracic, and lumbar regions. There is also a tendency for publications to come from centres that have a well-established reputation in endoscopic surgical surgery, a factor which could lead to an overestimation of the results that can be achieved during a surgeon's early learning phase, a period when complication rates are known to be high. The learning-curve thresholds differ from study to study according to the surgeon's background, the mix of cases at the institution, and the statistical method employed to define "proficiency", meaning that it is not possible to apply any one figure (for example, "20 cases" or "60 cases") with precision to an individual surgeon's training programme. As is the case with many minimally invasive innovations, the gap between technical feasibility and proven comparative superiority—ideally established through prospective, controlled trials—remains the main open question that the field is currently attempting to resolve.

8. Conclusion

Endoscopic spine surgery has progressed from being a minor minimally invasive option to becoming a major subject of discussion in the field of spine care, as shown by the increase in systematic reviews, comparisons of techniques, and analyses of complications up to 2026. The existing evidence indicates that ESS can be considered a reasonable choice for an ever-widening variety of degenerative cases—and in some instances for fusion, oncological, and complex conditions too—with tissue-sparing, recovery, and complication rates that are favourable when compared to the standards established by traditional open surgery. The main obstacles to wider acceptance are the well-defined yet variable learning curve associated with the technique, the equipment and disposable costs involved in ambulatory settings, and the ongoing requirement for prospective comparative trials, rather than any basic lack of clinical value. With the continued development of AI-assisted planning, navigation, and structured training programmes, ESS is set to become even more widely used in fusion procedures, in the cervical and thoracic regions, and in outpatient spine care.

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