



Historical Review and Pros and Cons of Different Surgical Approaches: Outside-In Vs. Inside-Out

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1 Introduction

In the 1970s, Kambin [1] and Hijikata [2] reported the first intradiscal debulking procedure through percutaneous posterolateral lumbar approach to treat degenerative lumbar disc disease. Ever since, endoscopic spine surgery has been evolved. The improvement of spinal endoscopes and endoscopic instruments has contributed to the development of full endoscopic discectomy techniques.

Initially, transforaminal endoscopic spine surgery was known as an intradiscal procedure

achieved by indirect decompression, used to treat contained disc herniation. Since then, the working space of transforaminal endoscopic spine surgery limited to intradiscal space switched to the epidural space, allowing treatment of various types of extruded disc herniations. At the same time, endoscopic foraminal decompression techniques to treat lumbar foraminal stenosis were also developed, expanding the clinical indications of transforaminal endoscopic spine surgery. The inside-out and outside-in techniques are known as the two main categories of transforaminal approaches to treat degenerative lumbar disc disease (Fig. 1).

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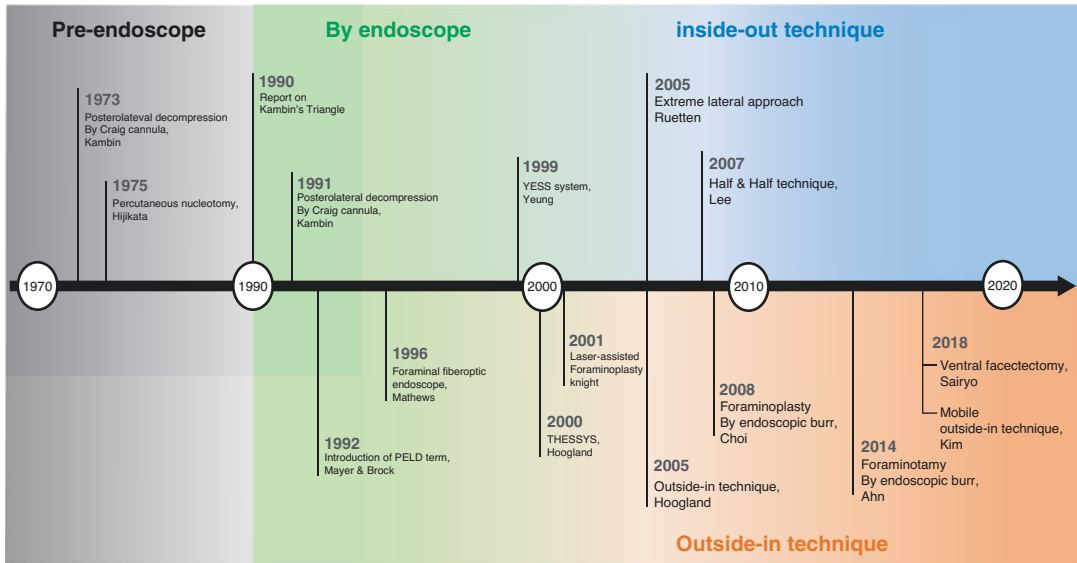


Fig. 1 The evolution and inventors of percutaneous endoscopic transforaminal approach from 1970 to 2020. PELD, percutaneous endoscopic lumbar discectomy.

YESS Yeung Endoscopic Spine System, THESSYS Thomas Hoogland Endoscopic Spine System

2 Inside-Out Technique

In the mid-1980s, Kambien et al. reported a percutaneous disc decompression by nucleotomy using Craig Cannula through the posterolateral approach. They reported an 88% of success rate in a study of 50 patients [1]. Hijukata et al. also reported a 72% of success rate treating 136 patients by percutaneous posterolateral approach [2]. The concept of nonvisualized percutaneous transforaminal disc decompression was introduced. The transforaminal approach began to make great strides in 1990 when Kambin announced the Kambin triangle, a safe working zone that allows access to disc space through the foramen [3]. In addition, the optics of spinal endoscopes began to be developed.

In 1991, Lue devised a foraminoscope to treat foraminal and extraforaminal disc herniation and [4] Mathews also reported foraminal epidural endoscopic surgery using a fiber-optic endoscope for the first time [5].

In 1997, Yeung designed the Yeung Endoscopic Spine System (YESS, continuous saline irrigation, multichannel, angled endoscope) [6] by applying joint arthroscopy and published the

original “inside-out technique” in 1999. After placing the cannula in the intradiscal space through Kambin’s triangle, the intradiscal pain generator was removed.

This technique was primarily applied to treat contained disc herniations. However, it was not advanced enough to treat sequestered disc herniation or foraminal stenosis [3, 7]. The technique was based on the principle of identification of in vivo visualization of pain generators in the foramen and replaced previous indirect percutaneous discectomy technique.

In 2002, Yeung and Tsou published the results of 307 patients treated with the inside-out technique. Central or paramedian disc herniation as well as foraminal or extraforaminal disc herniation was included and had a follow-up period of 19 months. Satisfactory results were obtained in 89.3% and reoperation was performed in 4.2%. Remarkably, low incidence of dysesthesia was noted with 1.9% (6/307) [8]. If necessary, foraminal decompression was performed using holmium yttrium-aluminum-garnet laser.

Tzaan also treated 134 patients with contained disc or non-contained disc with contiguous disc

herniation using the inside-out technique and obtained satisfactory results in 89% during the 8 months follow-up period. Reoperation was performed in 4.5% (6/134) and the incidence of dysesthesia was 6% (8/134) [9].

A lot of experience was accumulated through these two endoscopic techniques in the 2000s. An inside-out modified technique called “the half-and-half technique” was published by Lee et al. [10] using the YESS system. The window of the beveled working sheath is approached across the disc space so that the epidural space and the annulus and PLL are visible together in the endoscopic view.

In the mid-2000s, Ruetten et al. published another inside-out technique, “the extreme lateral access technique.” This technique reaches at an angle of 10° with the cannula landing on the dorsal annulus and the posterior longitudinal ligament then performed intradiscal and extradiscal decompression. However, this technique has difficulty accessing L5-S1 or the upper lumbar spine.

When removing a contained central disc herniation, another inside-out technique, “the intraannular approach,” may be used to preserve the intact disc as much as possible and to remove only the herniated disc [11]. This method reported by Shin is an application of the approach used in percutaneous endoscopic annuloplasty [12]. It is important to place the working channel directly on the annular defect site, and then perform a herniotomy removing the herniated disc preserving the posterior longitudinal ligament (PLL). The approach angle is lower than the conventional transforaminal approach (intraannular subligamentous herniotomy). This approach is not recommended in case that extruded disc penetrated the PLL highly migrated from the disc space, and if the foraminal or disc space narrowing is severe.

The inside-out technique is performed on the ipsilateral side of disc herniation.

However, If the cannula is positioned further to the opposite side, it is possible to access the contralateral side including lateral recess, allowing the removal of the contralateral disc herniation. In other words, both sides of the posterior annulus can be checked. In the early 2000s, Yeom

and Kim et al. treated highly migrated herniated disc using a contralateral approach [13, 14].

When treating huge central disc herniation or highly migrated disc, the conventional inside-out technique may be associated with a high failure rate of 4.3 to 10% if foraminoplasty is not performed [15, 16]. Therefore, when implementing the inside-out technique, foraminoplasty may be performed after intradiscal work or levering the cannula against the ventral facet to direct the cannula trajectory to the dorsal or ventral disc cavity [17].

3 Outside-In Technique

In 1996, Mathews reported on the treatment of patients with paramedian or foraminal, or extraforaminal HNP that contained disc herniation using a foraminal epidural endoscope that he developed in the early 1990s [5]. However, Hoogland experienced the limitations of treating diseases such as sequestered disc herniation and foraminal disc herniation with the foraminal epidural endoscope made by Mathews. So, he had thought that foraminoplasty was necessary to treat various types of herniated disc and developed the “Tom-Shidi reamer system” for foraminoplasty in 1994. He built the Thomas Hoogland Endoscopic Spine System (THESSYS) with Joimax, introducing the “outside-in technique” using THESSYS. It is a technique based on serial dilation of the intervertebral foramen with dilators, cannulated reamers or trephines, etc. Unlike the inside-out technique developed by Yeung, the procedure begun from the foraminal epidural space.

Laser is not only used to realize annulotomy in the disc herniation, but also to perform foraminoplasty. In 2001, Knight reported 716 cases of patients with back pain and sciatica treated with endoscopic foraminoplasty using laser, a technique published back in 1991. He reported that the complications were much lower (1.6%) than those presented during open surgery [18]. However, it has been reported that postoperative transient dysesthesia increases by up to 19% when excessive side-firing lasers are used during foraminoplasty [19].

With the evolution of endoscopic drills in the mid-2000s, Choi [20] et al. announced a foraminoplasty technique including partial pediclectomy using endoscopic drill in 2008. This technique allowed safer removal of highly migrated discs without transient dysesthesia. Since then, the use of endoscopic drill in foraminoplasty became increasingly popular [21].

With the evolution of foraminoplasty technique in the 2010s, it allowed the treatment of foraminal stenosis caused by severe bony stenosis. Ahn et al. reported the results of 33 patients with foraminal stenosis who underwent foraminotomy using an endoscopic drill in 2014. Based on the modified MacNab criteria, excellent or good results were obtained in 81.8% of the patients, and dysesthesia was observed in 2 patients and 1 patient required fusion surgery due to incomplete decompression with 2 years follow-up.

The difference in incidence rate of transient dysesthesia caused by exiting nerve root irritation depending on whether the SAP tip is removed or the base of the SAP is removed during foraminoplasty was also reported [22]. Yang et al. reported transient dysesthesia in 6.4% (5/78) of patients with disc herniation accompanying lateral recess stenosis after foraminoplasty with removing tip of the SAP. However, there was no dysesthesia when the base of the SAP was removed. Other researchers also reported that the incidence rate of dysesthesia was as low as 3.5% (3/85) ~ 3.7% (5/134) when performing foraminoplasty with removing the base of the SAP instead of removing the tip of the SAP [23, 24]. This is much lower than the incidence of dysesthesia (10.5%) reported by Yeung using the inside-out technique.

At the end of 2010, Sairyo et al. further developed endoscopic foraminotomy and performed ventral facetectomy through a transforaminal approach. In order to more extensively remove the lateral recess stenosis as well as the foraminal stenosis, the tip of SAP, a portion of the inferior articular process (IAP), and part of the pedicle were removed. This technique was named “percutaneous endoscopic ventral facetectomy” [25]. However, it has been reported that the case of patients with foraminal stenosis accompanying

lateral recess stenosis (entry zone foraminal stenosis) has poorer outcomes compared to patients with extraforaminal or midforaminal stenosis [26].

As the foraminoplasty technique became common, Madhavan et al. performed endoscopic foraminotomy for patients with foraminal stenosis and disc herniation (16 patients, coronal deformity 10–41 degree) accompanying scoliosis and reported good short-term results [27].

Recently, Kim et al. [28] presented “a mobile outside-in technique.” Is a modified technique that takes advantages of both inside-out and outside-in techniques? Intradiscal pathology removal and free movement of cannula in the epidural space are the main advantages of this technique. The working cannula is landed on Kambin’s triangle like the outside-in technique and intradiscal decompression is sufficiently performed under half-and-half view. Working channel levered downwards to achieve a “half-and-half” view in which the dorsal half shows PLL, epidural space, dura, and traversing nerve root while the ventral half shows annulus and disc fragment ventral to the PLL. And then targeted fragmentectomy is performed. A total of 184 patients with up-migration or down-migration disc herniation were treated. The results showed satisfactory results according to the MacNab criteria in 97.3% (179/184) of the patients. Recurrence was seen in 15 patients (7.89%), and all of them underwent repeated PELD or open discectomy.

4 Results

4.1 Disc Herniation Treatment by Inside-Out Technique

4.1.1 Evidence Level 2 Data

Ruetten et al. treated 463 patients with disc herniation using the inside-out technique with extreme lateral access. Satisfactory results were obtained in 95% and the recurrence rate was 6.9% (32/463), of which 90% (29/32) had recurrence within 5 months after surgery in 1-year follow-up [29].

4.1.2 Evidence Level 3 Data

As previously mentioned, Yeung and Tsou reported in 2002 the treatment of disc herniation using the inside-out technique in 307 patients. The subjects were patients with central or foraminal or extraforaminal HNP, and foraminal decompression using laser was also implemented. Mean follow-up was 19 months; 89.3% of the patients showed excellent or good outcome and 4.2% (13/307) underwent surgery. Transient dysesthesia was rare, reported at 1.9% (6/307) [8]. Tzaan reported on the treatment of patients using the inside-out technique, in which excellent or good outcome was achieved in 89% in the 8-month follow-up; 4% (6/134) received an additional surgery and 6% (8/134) developed dysesthesia [9].

In the 2014 review article of the inside-out technique on HNP by Yeung and Gore, postoperative dysesthesia was reported as high as 14.6% (20/137).

4.2 Disc Herniation Treatment by Outside-In Technique

4.2.1 Evidence Level 2 Data

Lee treated 116 patients with migrated disc herniation using foraminoplasty. From the 14.5-month follow-up, 91.3% (106/116) displayed good or excellent outcome, and no recurrence or complication was reported [10].

Hoogland reported on the treatment of postoperative recurrent disc herniation using the outside-in technique in 262 patients. In the 2-year follow-up, 85.7% showed good or excellent outcome and 7.1% underwent reoperation [30]. Li et al. reported treatment of uncontained disc herniation in 148 patients with 92% (124/134) having excellent or good outcome and 3.7% (5/134) with dysesthesia and recurrence, individually [23]. The authors removed the base of SAP when performing foraminoplasty. Kim et al. treated 184 patients using mobile outside-in technique and reported successful outcome in 97.3% (179/184) from the 19 months follow-up. Recurrence was found in 7.9% of the patients (15/190) and they received repeated PELD or open discectomy.

4.2.2 Evidence Level 3 Data

Krzok et al. reported a 1-year follow-up of 137 lumbar disc herniation patients after outside-in technique (transforaminal approach for 124 and transpedicular approach for 13), and 92% of the patients displayed good or excellent outcome and 5.12% reported overall disc recurrence [31]. Choi et al. treated 59 patients with highly migrated disc herniation using partial pediculectomy or half-and-half technique. In the 25.4-month follow-up, 91.4% displayed satisfactory outcome and 10% (6/59) received reoperation [20].

4.3 Foraminal Stenosis Treatment by Inside-Out Technique

4.3.1 Evidence Level 3 Data

The meta-analysis of studies implementing endoscopic transforaminal foraminotomy on foraminal stenosis (14 total studies; 600 total patients) shows excellent or good postoperative outcome in 85% (78–90%); same level recurrent foraminal stenosis rate and revision surgery rate were low at 1.4% (0–4.3%) and 1.2% (0–3.7%), respectively [32]. However, the authors conducted an analysis without differentiating inside-out and outside-in techniques in the included studies.

In 2019, Yeung et al. [33] reported a 5-year follow-up study of foraminal stenosis with disc herniation after inside-out technique in 86 patients. After the operation, 83% of the patients displayed good or excellent outcome and nine patients (10.5%) had disc recurrence. Among them, six patients (6.9%) received additional surgery. Dysesthesia was reported in nine patients (10.5%).

4.4 Foraminal Stenosis Treatment by Outside-In Technique

4.4.1 Evidence Level 2 Data

Ahn et al. reported a 2-year follow-up of 33 patients with foraminal stenosis after treatment, and 81.1% showed excellent or good outcome. Foraminotomy was performed by removing the base of SAP. Dysesthesia was found in 6% (2/33)

and fusion was performed in one patient (3%) due to incomplete decompression. No other complications were reported [34].

Knight et al. reported a 34-month follow-up of 24 patients with isthmic spondylolisthesis after performing foraminal decompression using laser; 79% (19/24) displayed excellent or good outcome, and two patients (8.3%) later received fusion after their symptoms worsened. No dysesthesia was reported [35].

4.4.2 Evidence Level 3 Data

Lewandrowski reported that patients with foraminal stenosis accompanying lateral recess stenosis (entry zone foraminal stenosis) did not have as good outcomes as patients with extraforaminal or midforaminal stenosis [26]. However, Li reported good outcomes using the outside-in technique even in lateral recess stenosis [24]. The 2-year follow-up of 96 patients showed 90.5% excellent or good outcome (dysesthesia 3.5% [3/85], recurrence 2.3% [2/85]).

In 2020, Lewandrowski [36] reported a 5-year follow-up of 90 patients with foraminal stenosis after treatment using the outside-in technique. After surgery, 93% of the patients displayed good or excellent outcome, but 17 patients (18.8%) had disc recurrence and received additional surgery (the recurrence occurred in the ipsilateral side in nine patients and on the opposite side of the same level in eight patients). Dysesthesia was found in eight patients (8.9%). Compared to Yeung's study using the inside-out technique (dysesthesia 10.5%, recurrence 10.5%), [33] there was no significant difference in dysesthesia and the recurrence rate was higher when the outside-in technique was used.

In 2020, Yeung and Lewandrowski reported a 5-year follow-up of patients with back pain and radiating pain caused by foraminal stenosis after treatment using inside-out and outside-in techniques, [37] comparing data from two studies [33, 36]. The reoperation rate was significantly higher in the outside-in group (35.6%) than the inside-out group (8.1%) when the surgery of the adjacent level was also included. The secondary fusion rate was also higher in the outside-in group (8.9%) than in the inside-out group (2.3%). The authors speculated that the inside-out technique has a low

reoperation rate in long-term follow-up because it allows direct visualization of the patho-anatomy by placing a working cannula inside the intervertebral disc and sufficiently removing the source of pain, compared to the outside-in technique which does not employ intradiscal visualization.

5 Summary

Inside-out and outside-in technique. Which technique is superior?

Pathologies in the posterior annulus at the ventral side of the dura can be examined using the inside-out technique. Although the surgery begins from the inside of the disc, epidural space can be visualized via discectomy at the area of the annular tear [33]. Also, contralateral lateral recess can be approached by further insertion of the cannula [13, 14]. Therefore, it has the advantage that allows examination of both sides of the posterior annulus and ventral dura. In case of foraminal narrowing or highly migrated or severe central herniation, foraminal widening using outside-in technique is required.

Outside-in technique will be useful in painful conditions associated with the foramen caused by inflamed disc, inflamed nerve, hypertrophied superior articular process, and superior foraminal facet osteophyte [18]. Furthermore, if annular pathology accompanying disc herniation needs to be examined, additional inside-out technique might be necessary.

Rather than determining which method is superior, a proper identification of pain generator in symptomatic motion segment of the patient will be more important to determine the adequate technique.

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