Video Article

A Mobile Outside-in Technique of Transforaminal Lumbar Endoscopy for Lumbar Disc Herniations

Hyeun Sung Kim[1], Nitin Adsul[1], Ankur Kapoor[1], Sung Ho Choi[2], Jeong Hoon Kim[2], Ki Joon Kim[2], Jeong Soo Bang[1], Kyun Hoong Yang[1], Seok Han[1], Jae Hyun Lim[1], Jee-Soo Jang[2], Il-Tae Jang[1], Seong-Hoon Oh[3]

[1]Department of Neurosurgery, Nanoori Hospital

[2]Department of Neurosurgery, Nanoori Suwon Hospital

[3]Department of Neurosurgery, Nanoori Incheon Hospital

Correspondence to: Ankur Kapoor at dr.ankurkapoor@gmail.com

URL: https://www.jove.com/video/57999
DOI: doi:10.3791/57999

Keywords: Medicine, Issue 138, PETLD, endoscopy, transforaminal, outside-in, inside-out, migrated disc, canal compromise

Date Published: 8/7/2018

Citation: Kim, H.S., Adsul, N., Kapoor, A., Choi, S.H., Kim, J.H., Kim, K.J., Bang, J.S., Yang, K.H., Han, S., Lim, J.H., Jang, J.S., Jang, I.T., Oh, S.H. A Mobile Outside-in Technique of Transforaminal Lumbar Endoscopy for Lumbar Disc Herniations. *J. Vis. Exp.* (138), e57999, doi:10.3791/57999 (2018).

Abstract

Percutaneous endoscopic transforaminal lumbar discectomy (PETLD) has now become a standard of care for the management of lumbar disc disease. There are two techniques for the introduction of a working cannula with respect to disc—outside-in and inside-out. The aim of this prospective study is to describe the technical aspects of a novel mobile outside-in method in dealing with different types of disc prolapse. A total of 184 consecutive patients with unilateral lower limb radiculopathy due to lumbar disc prolapse were operated on with the mobile outside-in technique of PETLD. Their clinical outcomes were evaluated based on the type of disc prolapse they had, a visual analog scale (VAS) leg pain score, the Oswestry Disability Index (ODI), and the Macnab criteria. The completeness of the decompression was documented with a postoperative magnetic resonance imaging. The mean age of the patients was 50 ± 16 years and the male/female ratio was 2:1. The mean follow-up was 19 ± 6 months. A total of 190 lumbar levels were operated on (L1–L2: n = 4, L2–L3: n = 17, L3–L4: n = 27, L4–5: n = 123, and L5–S1: n = 19). Divided into types, the patient distribution was central: n = 14, paracentral: n = 74, foraminal: n = 28, far lateral: n = 13, superior-migrated: n = 8, inferior migrated: n = 38, and high canal compromise: n = 9. The mean operative time was 35 ± 12 (25 - 56) min and the mean hospital stay was 1.2 ± 0.5 (1–3) days. The VAS score for leg pain improved from 7.5 ± 1 to 1.7 ± 0.9. The ODI improved from 70 ± 8.3 to 23 ± 5. According to the Macnab criteria, 75 patients (40.8%) had excellent results, 104 patients (56.5%) had good results, and 5 patients (2.7%) had fair results. Recurrence (including early and late) was seen in 15 out of the 190 levels that were operated on (7.89%). This article presents a novel outside-in approach that relies on a precise landing within the foramen in a mobile manner and does not solely depend upon the enlargement of the foramen. It is more versatile in application and useful in the management of all types of disc prolapse, even in severe canal compromise and high migration.

Video Link

The video component of this article can be found at https://www.jove.com/video/57999/

Introduction

fChronic low back pain and leg pain are common ailments in any society. The treatment modalities to combat degenerative lumbar disc diseases have been continuously evolving. The armamentarium has been wide, from open surgery and fixation to microlumbar discectomy, and now the endoscopic route[1,2,3,4]. The transforaminal pathway, initially suggested by Parvez Kambin, is now gradually becoming a standard of care[5,6,7]. The advantages of full-endoscopic spine surgeries are less soft-tissue dissection, less blood loss, reduced hospital admission days, an early functional recovery, and an enhancement in the quality of life[8].

The traditional outside-in approach of PETLD, given by Schubert and Hoogland[4], deals with the introduction of a working cannula in the foramen and then an enlargement of the foramen by using reamers. The rationale behind the novel technique of the outside-in approach mentioned here is that it does not solely depend on enlarging the foramen in all cases. The technique focuses on the precise placement of the working cannula within the foramen and then guiding the movement of the cannula toward the target fragment, under endoscopic vision[9,10]. Anatomically, there are three different routes into the transforaminal space, and if used effectively, percutaneous endoscopic spine surgery with the outside-in technique can be applied to a wider range of lumbar disc herniation. Central, paracentral, and high canal compromised Lactic Acid Dehydrogenase (LDH) is approached by the intervertebral route; foraminal, superiorly migrated, and far lateral LDH is approached by the foraminal route, and inferiorly migrated LDH is approached by the suprapedicular route[6]. The advantage of this technique is that it preserves the normal anatomical structures with less discal injury, the epidural exposure is easy, and the manipulation of a working cannula in the foramen is not difficult. The technique described differs from the earlier one because it provides a precise vision of the structures within the foramen and focuses on the accurate placement of the cannula within the foramen, rather than on enlarging the foramen. The technique is equally safe as inside-out technique and provides an easy handling of structures, especially the extruded fragments. The goal of this study is to prove the versatility of this novel approach in managing different types of disc prolapse as central, paracentral, foraminal, far lateral, and up and down migration, and in high-canal compromise cases. The technique, however, demands a longer learning curve and so beginners need to be patient while learning.

Protocol

The protocol follows the guidelines of Nanoori Hospital's human research ethics committee. A written informed consent was obtained from all the patients with unilateral lower limb radiculopathy due to lumbar disc prolapse. The exclusion criteria were the presence of segmental instability, spondylolisthesis (more than grade 1), and the presence of significant spinal stenosis.

1. Patient Position and Skin Marking

1. Place the patient in the prone position on the radiolucent operating table with the spine in slight flexion.
   NOTE: Indications for surgery in patients are as follows: intractable, frequently unilateral radiculopathy resistant to conservative measures (for at least 6–8 weeks), with or without associated axial back pain, a positive tension sign on physical examination, and radiculopathy correlating with radiographic evidence on confirmatory MRI studies.
2. Mark the midline of the spine, as well as the extent of the iliac crest, with a marking pen under an image intensifier.
3. Mark the paraspinal skin entry point along the center of the disc space using the manual back assessment method[6]: check the borderline between the back muscles and the abdominal muscles. Mark the skin entry points just medial to this borderline in mid-disc level both in Antero-Posterior (AP) and lateral X-rays.

2. Local Anesthesia and Incision

1. Infiltrate subcutaneous local anesthetic (2 mL of 1% lidocaine) around the entry point and then perform the skin incision of about 1 cm and infiltrate the trajectory with the local anesthetic (3 mL of 1% lidocaine) through a 23 G needle.
2. Insert an 18 G spinal needle through the skin incision at a 25–35° angle to horizontal.
3. Pass the needle under the image intensifier through the fascia and the back muscles. Then, dock the needle at Kambin's triangle near the intervertebral disc.
   NOTE: Kambin's triangle is present at the posterolateral aspect of the disc. The hypotenuse is the exiting nerve root, the base is the superior border of the inferior vertebra, and the height is the thecal sac/traversing nerve root.
4. Check the free epidural space in Kambin's triangle by injecting 1.5 mL of contrast dye under the image intensifier. Provide local anesthesia in Kambin's triangle by injecting 8–10 mL of 1% lidocaine in the foraminal space followed by a booster injection of 2–4 mL of 1.6% lidocaine (8 mL of 2% lidocaine with 2 mL of saline plus 0.05 mL of epinephrine) 4–5 min after the initial injection.

3. Discography

1. Insert the needle in the discal space under fluoroscopy and perform discography by injecting 2 mL of 0.8% indigo carmine mixed with contrast.

4. Insertion of Endoscope

1. Insert a guide wire in the discal space through the needle and then remove the needle.
2. Through the inserted guide wire, slide the obturator in Kambin's triangle and anchor it over the surface of the disc space.
3. Insert the working cannula through the obturator and, thereafter, introduce the endoscope into the Kambin's triangle.
   NOTE: The working cannula is the beveled type with an 8 mm outer diameter. The endoscope has a 30° viewing angle, a 7.3 mm outer diameter, a 4.7 mm-diameter working channel, and 251 mm of total length. The entire procedure is performed using constant saline irrigation.

5. Surgical Procedure

1. Observe the epidural fat and soft tissues in the Kambin's triangle through the endoscope prior to the entry into the disc (**Figure 1A**).
2. Clear the soft tissue and blood vessels over the annulus using the radiofrequency coagulator. Perform the annular fenestration with an annular cutter and enter the annulus under endoscopic vision.
   NOTE: To avoid any injury to the exiting and traversing nerve root during the approach, the operation proceeds with continuous feedback from the patient.
3. Obtain a half-and-half view of the epidural space and the disc space by inserting the bevel type of the cannula in the fenestrated annulus.
   NOTE: In the dorsal half of the half-and-half, the posterior longitudinal ligament, the epidural space, and the traversing nerve root and dura can be seen. In the ventral half, the annulus and the disc ventral to the posterior longitudinal ligament can be seen.
4. Lever the working cannula downwards to achieve an exact half-and-half view[7] (**Figure 2A** and **2B**).
   NOTE: Using the bevel-type working cannula, it is not easy for beginners to manipulate the exiting nerve root safely, so a round working cannula can also be used (**Figure 3**).

6. Targeted Fragmentectomy

1. After decompressing the protruded disc sufficiently, change the trajectory of working toward the symptomatic disc area.

NOTE: The working channel is directed toward the suprapedicular notch in the inferior-migrated disc, the epidural space in the high-canal compromised disc and foraminal space in the superior-migrated disc (**Figure 3**).

2. Confirm that all free fragments of the disc are removed by checking the free-floating dural sac, the exiting root, and the traversing root, and free the epidural space by rotating the working channel and the endoscope.
NOTE: All patients undergo MRI on the day following the surgery (**Figure 4** and **Figure 5**).

Representative Results

Outcome Evaluation:

The outcome of the surgery was measured by the VAS leg pain score[11], the ODI[12], and the Macnab criteria[13]. These were measured in the preoperative period and during follow-up visits (1 week after the surgery, 3 months after the surgery, and at the last follow-up).

Baseline Characteristics:

The mean age of the study group was 50 ± 16 years and the male/female ratio was 2:1. The mean follow-up of the study was 19 ± 6 months. A total of 190 lumbar levels were operated on (L1–L2: *n* = 4, L2–L3: *n* = 17, L3–L4: *n* = 27, L4–L5: *n* = 123, and L5–S1: *n* = 19). Divided into types, the patient distribution was central: *n* = 14, paracentral: *n* = 74, foraminal: *n* = 28, far lateral: *n* = 13, superior-migrated: *n* = 8, inferior-migrated: *n* = 38, and high-canal compromise: *n* = 9. The demographic data and the baseline characteristics, including the preoperative MRI characteristics and the intraoperative findings, are summarized in **Table 1**. The mean operative time was 35 ± 12 (25–56) min and the mean hospital stay was 1.2 ± 0.5 (1–3) days.

Clinical Outcome:

The VAS score for leg pain improved from 7.5 ± 1 to 1.7 ± 0.9. The ODI improved from 70 ± 8.3 to 23 ± 5. The improvement in the VAS score and the ODI was noticed immediately after the surgery and remained statistically significant at the follow-up (**Table 2**, **Figure 6**). The motor improvement was complete in almost all patients. According to the Macnab criteria, 75 patients (40.8%) had excellent results, while good results were seen in 104 patients (56.5%), and the remaining 5 patients (2.7%) had fair results. Recurrence was seen in 15 out of the 190 levels that were operated on (7.89%); out of these, 11 patients underwent revision PETLD (5.98%), while 4 patients underwent an open foraminotomy (2.17%).

Back pain and leg pain have troubled human for ages. The surgical approach to lumbar disc disease has been evolving. The main advantage of percutaneous endoscopic spine surgery is to preserve the normal anatomical structures as much as possible, thereby maintaining the functional status as it was prior to the surgery. PETLD has gained significant importance in the last few years, owing to the extensive work done on it all around the globe[6,7,14,15,16]. The early results have been promising as compared to microdiscectomy, with early mobilization, less blood loss, a smaller incision, better pain relief, and a better long-term outcome with a good quality of life[6,7,17,18]. The surgical armamentarium of the transforaminal route is quite wide, with nearly all types of herniations as central, paracentral, foraminal, far lateral, and superior and inferior migrated discs being managed by it efficiently[19,20,21,22,23].

In previous studies, Tzaan showed a good or excellent outcome in 89% of his patients[1], while Yeung and Tsou achieved a 90% patient satisfaction rate after transforaminal surgery on 307 patients[15]. Similarly, Ruetten *et al.* were successful in 79% of their endoscopic discectomies in patients with recurrent lumbar disc herniation[24]. In 2013, a study by Jasper *et al.* focused on geriatric patients with lumbar disc disease that were managed by transforaminal endoscopy[19]. The results were good in 71.4% as per the Macnab criteria, and the VAS score decreased from 9.2 in the preoperative period to 2.63 at the 6 month follow-up. The recurrence rate in the described outside-in technique with a mean follow-up of 19 ± 6 months was 7.89%. This stands well in the range of the previously reported recurrence rate of 5 - 18%[14,25,26]. Schubert and Hoogland have shown a recurrence rate of 3.6% on a study population of 611 patients[4], while Hoogland *et al.*[14] have shown that the recurrence rate can vary depending on the extent of the follow-up. While 7 out of the total 262 operated patients in their study developed early recurrence within 3 months post-surgery, by the end of 2 years after surgery, the total recurrence cases had increased to 11 (4.62%).

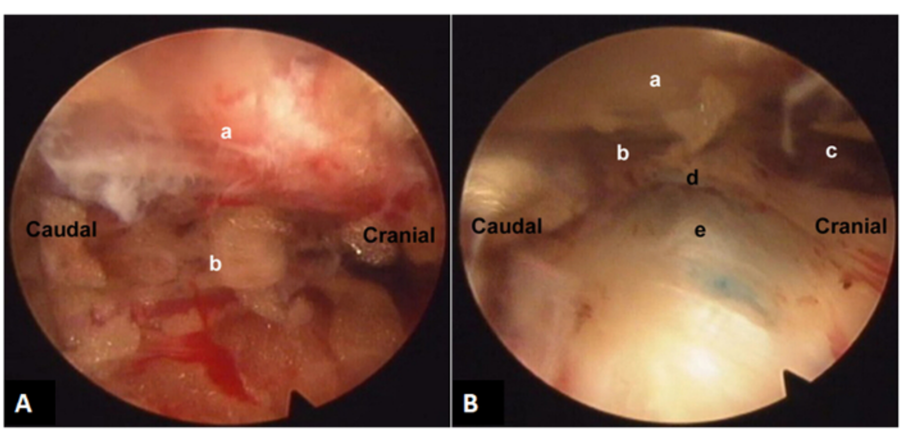

Figure 1: Intraoperative endoscopic view of the outside-in transforaminal approach. (**A**) This panel shows an initial endoscopic view of the transforaminal space under the outside-in approach, with (**a**) the facet and (**b**) soft tissues in the foramen over the disc. (**B**) This panel shows the endoscopic view after the clearing of the transforaminal space by using radiofrequency, with (**a**) the foraminal ligament, (**b**) the suprapedicular notch area, (**c**) the cranial foraminal area, (**d**) the epidural area, and (**e**) the disc. Please click here to view a larger version of this figure.

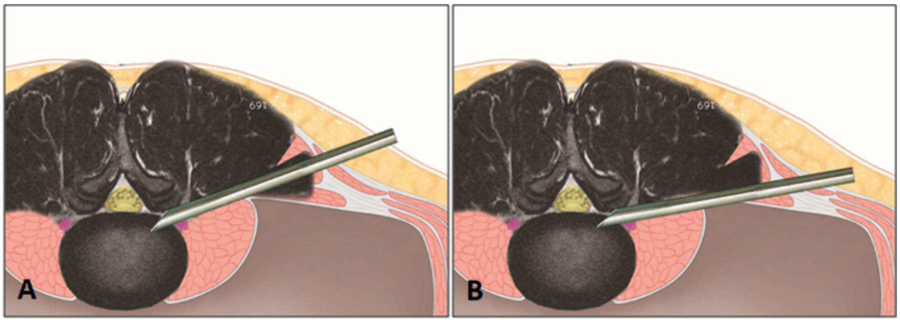

Figure 2: Illustrative surgical view of the cannula placement during a transforaminal surgery. (**A**) This panel shows the initial placement of the cannula in the transforaminal approach. (**B**) This panel shows the downward levering of the working cannula to achieve a half-and-half view. Please click here to view a larger version of this figure.

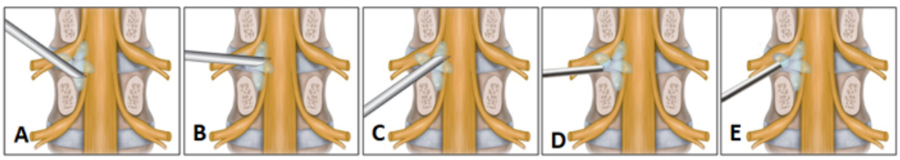

Figure 3: Illustrative surgical view of a percutaneous endoscopic transforaminal lumbar discectomy. (**A**) This panel shows the suprapedicular route. (**B**) This panel shows the intervertebral route. (**C**) This panel shows the foraminal route. (**D**) This panel shows the round cannula placement for the far lateral disc. Please click here to view a larger version of this figure.

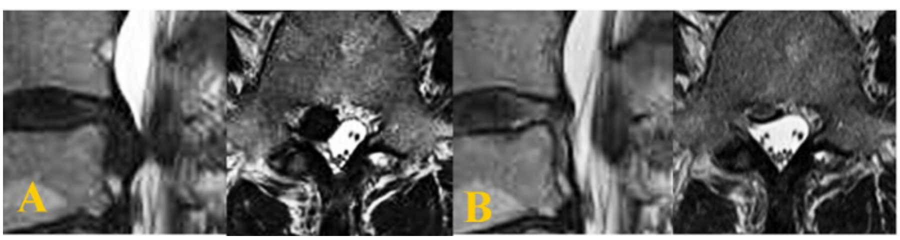

Figure 4: MR images of a patient with an inferior-migrated disc. (**A**) These are preoperative T2-weighted sagittal and axial images showing a high inferior-migrated disc prolapse at L4–L5 level with a significant compression on the right side. (**B**) These are postoperative T2-weighted sagittal and axial images showing the complete fragment removal using the outside-in technique. Please click here to view a larger version of this figure.

Figure 5: MR images of a patient with a high-canal compromise. (**A**) These are preoperative T2-weighted sagittal and axial images showing a high-canal compromise with a disc prolapse at L3–L4 level. (**B**) These are postoperative T2-weighted sagittal and axial images showing the decompressed thecal sac with the complete fragment removal. Please click here to view a larger version of this figure.

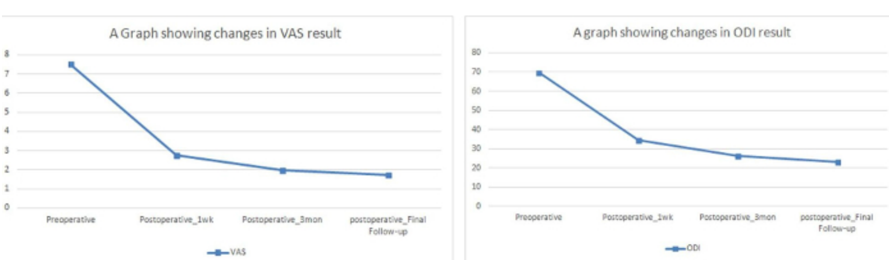

Figure 6: Clinical outcome of the outside-in technique of transforaminal endoscopy. The *y*-axis represents the score of the visual analog scale (VAS) and the Oswestry Disability Index (ODI), while the *x*-axis represents the time period. (**A**) This graph shows the VAS for leg pain. (**B**) This graph shows the ODI. Please click here to view a larger version of this figure.

Factors	Patients (n = 184)
Age (years)	50±16 (15-86)*
Male/female ratio	2:01
Levels involved (n=190)	
L1-L2	4 (2.1)ǂ
L2-L3	17 (9)ǂ
L3-L4	27 (14.2)ǂ
L4-L5	123 (64.7)ǂ
L5-S1	19 (10)ǂ
Type of Disc Prolapse	
Central	15 (7.9)ǂ
Paracentral	75 (39.5)ǂ
Foraminal	29 (15.3)ǂ
Far Lateral	16 (8.4)ǂ
Superior migrated	8 (4.2)ǂ
Inferior migrated	38 (20)ǂ
High canal compromise	9 (4.7)ǂ
Follow-up (months)	19±6 (9-29)*
MacNab criteria	
Excellent	75 (40.8)ǂ
Good	104 (56.5)ǂ
Fair	5 (2.7)ǂ
Recurrence	15 (7.89)ǂ
Drilling required	46 (24.2%)
*All values expressed as mean ± standard deviation (range). ǂ All values expressed as number (%).	

Table 1: Patient characteristics of the mobile outside-in technique.

Parameter	Preop	Post op	P value	3 months	P value	Final follow up	Pvalue
Visual analogue scale(VAS)	7.51±0.99	2.76±0.71	<0.0001	1.96±0.83	<0.0001	1.73±0.85	<0.0001
Oswestry disability index(ODI)	69.66±8.25	34.41±5.32	<0.0001	26.47±5.56	<0.0001	23.15±5.83	<0.0001

Table 2: Comparative analysis of the preoperative and postoperative values of the visual analog scale and the Oswestry Disability Index.

Discussion

The study is based on the prospective analysis of 184 patients with lumbar disc disease that were managed at our institute. X-ray imaging, computed tomography (CT), and magnetic resonance imaging (MRI) were done in all cases to confirm the diagnosis and to rule out other pathologies. The findings demonstrated on the CT and MRI scans were correlated with a neurologic examination. After the proper diagnosis, patients were operated on with the mobile outside-in technique of PETLD. The exclusion criteria were the presence of segmental instability, spondylolisthesis of more than grade 1, and a presence of significant spinal stenosis. A written informed consent was obtained from all patients.

The critical steps in the above-described technique are the precise placement of a working cannula in the foramen and obtaining a half-and-half view of the foramen and the disc space. The next critical step is directing the working cannula within the foramen toward the target fragment. The technique described here is different from the earlier described outside-in technique by Schubert and Hoogland[4] that needed reaming. In the current protocol, the working cannula is placed in the Kambin's triangle (**Figure 1**) to allow mobility toward the target fragment as per location. In this technique, the epidural fat and soft tissue structures can be adequately visualized prior to entering the disc space. Entering the disc space under vision is another critical step and prevents any further discal injury and migration of the disc fragment. Following the intervertebral, foraminal or suprapedicular route, depending on the location of the target fragment, is next critical step[6]. Thus, foraminoplasty is required in only a small subset of the patients.

The described technique has several advantages over previously described techniques. Foremost is the wide variation in the location of the prolapsed disc that is effectively managed by the mobile outside-in technique. The varied locations of the disc include central, paracentral, foraminal, far lateral up- and down-migrated, as well as ones with canal compromise.[6] The initial landing within the foramen is the most crucial part and gives the surgeon an overall view of the foramen. It gives the flexibility to move the cannula in different directions as per the need of the prolapsed disc. Another major advantage is that the annulus is entered under vision, and so further damage to the disc or migration of the fragment by blind puncture is avoided. The vision of the structures within the foramen is always better in an outside-in technique compared to inside-out technique, the extruded disc fragment is handled early, and the mobilization of the cannula is more comfortable and enables handling the up- and down-migrated discs[20,21]. The outside-in technique permits to target the fragment specifically and so foraminoplasty is needed in selected patients only. In a total of 190 levels operated on with this technique, drilling was required in only 46 patients (25%). Foraminoplasty was mostly required in those with a significant down migration and those with canal compromise. Part of the superior articular process and the upper part of the pedicle were drilled to create adequate space. Using curved forceps and a probe further aid in removing the migrating fragment. We have successfully utilized the mobile outside-in approach to manage all different types of lumbar disc herniations. The use of the mobile outside-in technique merits a special mention when used for a down-migrated disc, which is usually considered to be difficult for endoscopy. The authors managed 38 patients with down-migrated fragments. Of these, an excellent outcome according to the Macnab criteria was seen in 23 patients (60.5%) and good outcome in the remaining 15 patients (39.5%).

We did not find any major limitations to the technique presented in this article. Of course, the outside-in technique of PETLD has a learning curve which beginners need to take into account. As compared to earlier isolated reports mentioning the risk of injury to neurovascular and ligamentous structures in the outside-in technique[7,8], our experience has shown that the outside-in technique with selective foraminotomy is equally safe and effective compared to earlier described outside-in techniques. This technique is different from earlier described outside-in techniques and does not depend solely on enlarging the foramen[4,27,28]. The earlier described outside-in technique by Schubert and Hoogland mentions enlargement of the foramen as a usual component in all the patients[4]. The technique presented here focuses on the accurate placement of the cannula toward the target fragment, thus needing an enlargement of the foramen in selected patients only. Therefore, the technique provides a better overall view of the foramen and its surrounding structures. The wide range of disc prolapses, including canal compromise, being effectively managed by this technique affirms that there is no contraindication to the outside-in technique.

The future applications of the described technique are for a wide array of lumbar disc prolapse. Even patients with high-canal compromise and a down-migrated disc can be adequately managed by PETLD. Thus, the horizon of the technique is on the rise. By precisely targeting the compressing element of the disc, this technique can provide an optimum vision within the foramen and help in achieving the desired results.

The mobile outside-in technique of PETLD can be used to deal with all types of lumbar disc herniation, including high-canal compromise, due to the mobility of the working cannula toward the target point. It does come with a learning curve and requires a thorough knowledge of the spine anatomy. This technique can be applied to all types of lumbar disc herniation and at all lumbar levels.

Disclosures

The authors have nothing to disclose.

Acknowledgements

We would like to acknowledge scientific team members Jae Eun Park and Kyeong-rae Kim for providing their assistance in acquiring full-text articles and managing the digital works.

References

1. Tzaan, W. Transforaminal percutaneous endoscopic lumbar discectomy. *Chang Gung medical journal.* **30** (3), 226 (2007).
2. Morgenstern, R., Morgenstern, C. Percutaneous Transforaminal Lumbar Interbody Fusion (pTLIF) with a Posterolateral Approach for the Treatment of Degenerative Disk Disease: Feasibility and Preliminary Results. *International journal of spine surgery.* **9** (2015).
3. Ying, J.*, et al.* The effect and feasibility study of transforaminal percutaneous endoscopic lumbar discectomy via superior border of inferior pedicle approach for down-migrated intracanal disc herniations. *Medicine.* **95** (8) (2016).
4. Schubert, M., Hoogland, T. Endoscopic transforaminal nucleotomy with foraminoplasty for lumbar disk herniation. *Operative Orthopadie und Traumatologie.* **17** (6), 641-61 (2005).
5. Telfeian, A.E., Jasper, G.P., Francisco, G.M. Transforaminal endoscopic treatment of lumbar radiculopathy after instrumented lumbar spine fusion. *PainPhysician.* **18** (2), 179-84 (2015).
6. Kim, H.S.*, et al.* Analysis of clinical results of three different routes of percutaneous endoscopic transforaminal lumbar discectomy for lumbar herniated disk. *Worldneurosurgery.* **103**, 442-8 (2017).
7. Gore, S., Yeung, A. The "inside out" transforaminal technique to treat lumbar spinal pain in an awake and aware patient under local anesthesia: results and a review of the literature. *International journal of spine surgery.* **8** (2014).
8. Choi, G., Pophale, C.S., Patel, B., Uniyal, P. Endoscopic Spine Surgery. *Journal of Korean Neurosurgical Society.* **60** (5), 485 (2017).
9. Hoogland, T., Schubert, M., Miklitz, B., Ramirez, A. Transforaminal posterolateral endoscopic discectomy with or without the combination of a low-dose chymopapain: a prospective randomized study in 280 consecutive cases. *Spine.* **31** (24), E890-E7 (2006).
10. Ruetten, S., Komp, M., Godolias, G. An extreme lateral access for the surgery of lumbar disc herniations inside the spinal canal using the full-endoscopic uniportal transforaminal approach-technique and prospective results of 463 patients. *Spine.* **30** (22), 2570-8 (2005).
11. Johnson, E.W. *Visual analog scale (VAS).* LWW (2001).
12. Fairbank, J. Oswestry disability index. *Journal of neurosurgery Spine.* **20** (2), 239 (2014).
13. Macnab, I. Negative Disc Exploration: an analysis of the causes of nerve-root involvement in sixty-eight patients. *The Journal of bone and joint surgery.* **53** (5), 891-903 (1971).

14. Hoogland, T., van den Brekel-Dijkstra, K., Schubert, M., Miklitz, B. Endoscopic transforaminal discectomy for recurrent lumbar disc herniation: a prospective, cohort evaluation of 262 consecutive cases. *Spine.* **33** (9), 973-8 (2008).
15. Yeung, A.T., Tsou, P.M. Posterolateral endoscopic excision for lumbar disc herniation: surgical technique, outcome, and complications in 307 consecutive cases. *Spine.* **27** (7), 722-31 (2002).
16. Kambin, P., Gellman, H. Percutaneous Lateral Discectomy of the Lumbar Spine A Preliminary Report. *Clinical Orthopaedics and Related Research.* **174**, 127-32 (1983).
17. Hoogland, T. Percutaneous endoscopic discectomy. *Journal of neurosurgery.* **79** (6), 967-8 (1993).
18. Knight, M., Goswami, A. Management of isthmic spondylolisthesis with posterolateral endoscopic foraminal decompression. *Spine.* **28** (6), 573-81 (2003).
19. Pain, B., Telfeian, A.E. A retrospective evaluation of the clinical success of transforaminal endoscopic discectomy with foraminotomy in geriatric patients. *Painphysician.* **16**, 225-9 (2013).
20. Kim, H.S., Ju, C.I., Kim, S.W., Kim, J.G. Endoscopic transforaminal suprapedicular approach in high grade inferior migrated lumbar disc herniation. *Journal of Korean Neurosurgical Society.* **45** (2), 67 (2009).
21. Chae, K.H.*, et al.* Strategies for noncontained lumbar disc herniation by an endoscopic approach: transforaminal suprapedicular approach, semi-rigid flexible curved probe, and 3-dimensional reconstruction CT with discogram. *Journal of Korean Neurosurgical Society.* **46** (4), 312 (2009).
22. Anichini, G.*, et al.* Lumbar endoscopic microdiscectomy: Where are we now? An updated literature review focused on clinical outcome, complications, and rate of recurrence. *BioMed research international.* (2015).
23. Gotecha, S.*, et al.* The role of transforaminal percutaneous endoscopic discectomy in lumbar disc herniations. *Journal of craniovertebral junction & spine.* **7** (4), 217 (2016).
24. Ruetten, S., Komp, M., Merk, H., Godolias, G. Recurrent lumbar disc herniation after conventional discectomy: a prospective, randomized study comparing full-endoscopic interlaminar and transforaminal versus microsurgical revision. *Clinical Spine Surgery.* **22** (2), 122-9 (2009).
25. Weir, B., Jacobs, G. Reoperation rate following lumbar discectomy. An analysis of 662 lumbar discectomies. *Spine.* **5** (4), 366-70 (1980).
26. Österman, H., Sund, R., Seitsalo, S., Keskimäki, I. Risk of multiple reoperations after lumbar discectomy: a population-based study. *Spine.* **28** (6), 621-7 (2003).
27. Xin, G., Shi-Sheng, H., Hai-Long, Z. Morphometric analysis of the YESS and TESSYS techniques of percutaneous transforaminal endoscopic lumbar discectomy. *Clinical Anatomy.* **26** (6), 728-34 (2013).
28. Pan, Z., Ha, Y., Yi, S., Cao, K. Efficacy of transforaminal endoscopic spine system (TESSYS) technique in treating lumbar disc herniation. *Medical science monitor: international medical journal of experimental and clinical research.* **22**, 530 (2016).