Technical Tips for Percutaneous Transforaminal Endoscopic Discectomy: a three-step maneuver for puncture and early clinical experience

Ze Yan Liang  
Fujian Medical University Union Hospital

Shao Xiong Chen  
Fujian Medical University Union Hospital

Rui Wang  
Fujian Medical University Union Hospital

Chunmei Chen (cmchen2009@sina.com)  
Fujian Medical University Union Hospital  https://orcid.org/0000-0002-4483-7465

Technical advance

Keywords: Percutaneous Transforaminal Endoscopic Discectomy; Lumbar Disc Herniation; Three-Step Maneuver for Puncture; Kambin's Triangle; Approximating Rectangle; Visual Analogue Scale

DOI: https://doi.org/10.21203/rs.3.rs-18310/v1

License: © This work is licensed under a Creative Commons Attribution 4.0 International License.  
Read Full License
Abstract

Background: With respect to percutaneous transforaminal endoscopic discectomy (PTED), safe and accurate needle puncture is a key element for determining the difficulty of surgery and can also influence clinical outcomes. The transforaminal puncture method currently employed in PTED depends on a constant distance from the midline and estimated angles in anteroposterior and craniocaudal directions. TSMP is an alternative concept of puncture based on Kambin’s triangle. TSMP references the natural anatomy of patients to progressively advance the needle to target. We herein described a three-step maneuver for puncture (TSMP) in PTED, which is possible to introduce the needle more safely and gain easy access to the herniated disc.

Methods: We performed a retrospective review of 30 patients who underwent PTED using TSMP for lumbar disc herniation (LDH) and met inclusion criteria from January 2018 to September 2018. The primary outcome, leg or back pain, was assessed using Visual Analogue Scale (VAS). Patient surgical satisfaction was measured at 12 months post surgery using a five-point Likert scale. Potential prognostic factors measured were demographic characteristics, duration of symptom (DOS), and involved levels. Statistical analysis was performed using Fisher exact test and t-test.

Results: Preoperative mean VAS was 7.6 ± 1.19, which decreased to 1.4 ± 0.97 at 12 months following treatment (P < .0001). Rates of surgical satisfaction per Likert scale were as follows: very satisfied and satisfied in 26 patients (86.7%). VAS scores at 12 months varied significantly between L4-L5 level surgery and L5-S1 level surgery groups (P < .01).

Conclusion: TSMP is a reliable technique for puncture into the intervertebral foramen.

Background

For sciatica with lumbar disc herniation (LDH), surgery is recommended when patients are refractory to conservative treatment[11–4]. At present, conventional microdiscectomy (CMD) is still the standard surgical procedure for LDH[5–7]. In the past few decades, minimally invasive spine surgery (MISS) has become increasingly popular all over the world[8]. Percutaneous transforaminal lumbar discectomy (PTED) is one of the popular minimally invasive procedures for the treatment of lumbar disc herniation[9].

In 1987, Kambin, et al.[10] introduced the safe triangle (i.e., Kambin’s triangle) of percutaneous posterolateral extracanal approach for the management of LDH, reporting arthroscopic microdiscectomy in 1992[11]. Based on the concept of the “inside-out,” Yeung, et al.[12–14] developed the technique of Yeung Endoscopic Spine System (YESS). Surgeons maneuvered endoscopic instruments into the intervertebral disc via the Kambin’s triangle and progressively removed the herniated disc from within. In contrast, Hoogland, et al.[15], based on the concept of “outside-in,” proposed the Thomas Hoogland Endoscopic Spine System (THESSYS): inserting the working channel into the spinal canal via
intervertebral foramen with plasty, excising the herniated disc from the outside to the inside, releasing and decompressing the compressed nerve root. Since then, PTED has been widely used around the world, and the results of multiple randomized controlled trials and systematic reviews comparing the functional and pain improvements of PTED and CMD have revealed no significant difference between the two. PTED has the advantages of less trauma, less bleeding, quick recovery, less impact on spinal stability, and operation under local anesthesia. Gibson, et al. and Gadjradj, et al. have further elaborated on the PTED.

With respect to PTED, safe and accurate puncture is one of the key steps for determining the difficulty of surgery and clinical outcomes. At present, the transforaminal puncture method in PTED, nevertheless, still depends on a constant distance from the midline and estimated angles in anteroposterior and craniocaudal directions. PTED is usually performed with the aid of intraoperative C-arm imaging. However, the C-arm does not provide sufficient information to determine the optimal depth, angle and other important parameters for safe puncture. Therefore, the surgeon needs to integrate limited information during the process of puncture, which requires high-level ability in spatial thinking, factoring in the individual experiences of the surgeon. For beginners, redo punctures are almost inevitable; unfortunately, multiple punctures necessitate increased fluoroscopy time, operation time, and radiation exposure to doctors and patients, along with the increased risk of nerve injury. One of the urgent difficulties in PTED is how to locate and puncture quickly, accurately and safely.

With the three-step maneuver for puncture (TSMP) developed by the coauthors, it is possible to introduce the needle more safely and gain easy access to the herniated disc.

Methods

Rationale and Anatomy

Kambin, et al. reported a safe triangular working area (i.e., Kambin's triangle) consisting of a two-dimensional anatomic right triangle over the lateral recess of the lumbar spine. The triangle is bordered by the superior endplate of the lower vertebra (i.e., base of the triangle), the superior articular facet (i.e., the height of the triangle) and the exiting superior nerve root (i.e., the hypotenuse of the triangle) in a twodimensional plane (Fig. 1). Within this triangular area, there is no traversing nerve root or visceral structure of critical importance. Needles, guidewires and other instruments can be introduced through the described area with greater confidence in reduced incidence of complication, such as violation of the nerve root, etc.

Surgical Procedures

Anesthesia and Positioning
In general, PTED is performed under local anesthesia, and, if necessary, light sedation may be administered. Under light sedation alone, a patient might be responsive. In order to facilitate the execution of TSMP, the patient will be placed in a prone position on the radiolucent table. With respect to the lateral position, there may be many advantages, such as a larger safety zone with respect to the dura, less bleeding, and so on.\[^{20,29}\]. Another advantage of the prone position is that the position of patients is more stable, allowing less movement. Further, surgeons are quite familiar with the anatomy and its landmarks in this position.

**Target and entry point**

Using the mobile C-arm for anteroposterior and lateral radiographic control, the target and the entry point will be accurately positioned for operators. The target is located at the intersection of the superior endplate line of the lower vertebra and the inner line of lower vertebral pedicle in anteroposterior projection (Fig. 2A), or at the intersection of the trailing line of the lower vertebral body and the superior endplate line of the lower vertebra in lateral projection (Fig. 2B). The area of needle insertion is located on the patient's posterolateral side, which is an approximating rectangle (AR) formed by the line of spinous process, the line of transverse process, the superior endplate line of the upper vertebra and the superior endplate line of the lower vertebra in lateral projection (Fig. 3). During the operation, the appropriate entry point should be determined in the AR according to the location of the herniated disc: (1) The closer the position of the disc is to the center, the closer the needle point is to the ventral side; (2) The closer the position of the disc is to the cephalad side, the closer the needle point is to the caudal side. The line connecting the entry point to the target is the surgical approach (SA).

**TSMP**

After layer-by-layer local infiltration of anesthetic to the skin of the entry point with 1% lidocaine, an 18-gauge spinal needle will be inserted. Components of the TSMP are as follows:

Step 1: The needle is inserted through the appropriate entry point and advanced toward the spinous process by inches. The approach of puncture is parallel to the projected line of the SA on the back bed. When the needle tip reaches the bony structure (i.e., spinous process), the location of the tip will be determined by using biplanar C-arm images. The process is shown in Fig. 4A.

Step 2: The needle is pulled out an appropriate distance (about 3 to 5 cm). Then, after raising the needle tail properly, the needle will be advanced toward the superior articular facet. When the needle tip reaches the bony structure (i.e., superior articular facet), the location of the tip will be determined by using biplanar C-arm images. The process is shown in Fig. 4B.

Step 3: The needle is pulled out an appropriate distance again (about 2 to 3 cm). Then, after raising the needle tail properly, the needle will be advanced toward the target, and the surgeon will feel the needle tip slide into the intervertebral foramen along the superior articular facet. When the needle tip reaches the
bony structure (i.e., target), the location of the tip will be determined by using biplanar C-arm images. The process is shown in Fig. 4C.

**Foraminoplasty, placing of the working channel and introducing the endoscope**

The typical surgical procedures, including foraminoplasty, introduction of the working channel and endoscope, removal of the target disc and decompression of the nerve, continue, consistent with conventional techniques of PTED[15,22,30].

**Clinical Materials and Statistical Analysis**

We performed a retrospective review of 30 patients who underwent PTED using TSMP for LDH from January 2018 to September 2018. The inclusion criteria were as follows: (1) age 18 to 70 years; (2) single-level surgery; (3) informed consent; and (4) at least one year after surgery. Exclusion criteria consisted of: (1) previous surgery on the same or adjacent disc level; (2) spondylytic or degenerative spondylolisthesis; (3) severe somatic or psychiatric illness; and (4) history of psychiatric or psychological disorder. The primary outcome, leg or back pain, was assessed using the Visual Analogue Scale (VAS)[31]. Surgical satisfaction was measured using a five-point Likert scale[32], varying from “very satisfied” (5 points) to “very unsatisfied” (1 point). The following potential prognostic factors were measured: (1) demographic characteristics (e.g., age and gender); (2) duration of symptom (DOS); (3) involved levels. Statistical analysis was performed using Fisher exact test and t-test, and the P value < .05 was regarded as statistically significant. Ethical approval has been granted by the Ethics Committee of Fujian Medical University Union Hospital, Fuzhou, China (2018YF010-02).

**Results**

There were 30 patients with LDH who met the inclusion criteria and had undergone PTED using TSMP. The demographic findings are summarized in Table 1. The followup time was 1 year. The preoperative mean VAS was 7.6 ± 1.19, which decreased to 1.4 ± 0.97 at 12 months following treatment (P < .0001). Based on a five-point Likert scale, the rates of surgical satisfaction were as follows: very satisfied and satisfied in 26 patients (86.7%), general in three patients (13.3%). Three recurrent disc herniations of adjacent segmental levels were observed in the L5-S1 group at eight and 12 months after surgery. One of the patients with recurrence underwent tubular microdiscectomy at 12 months after undergoing PTED using TSMP. According to the subgroup analysis, there were significantly different VAS scores at 12 months postoperatively between the L4-L5 group and the L5-S1 group (P < .01). There were no significant influences at 12 months after PTED on the primary outcome from other factors, including gender, age, body mass index (BMI), and DOS (Table 2).
| Data                                | No. | Percent   |
|-------------------------------------|-----|-----------|
| **Gender**                          |     |           |
| Male                                | 17  | 56.70%    |
| Female                              | 13  | 43.30%    |
| **Age**                             |     |           |
| $\leq 40$ yrs                       | 8   | 26.70%    |
| $>40$ yrs                           | 22  | 73.30%    |
| **BMI (kg/m$^2$)**                  |     |           |
| $\leq 23$                           | 12  | 40%       |
| $>23$                               | 18  | 60%       |
| **Side**                            |     |           |
| Right                               | 9   | 30%       |
| Left                                | 21  | 70%       |
| **Duration of symptoms**            |     |           |
| $\leq 6$ months                     | 18  | 60%       |
| $>6$ months                         | 12  | 40%       |
| **Level**                           |     |           |
| L4/5                                | 14  | 46.70%    |
| L5/S1                               | 16  | 53.30%    |
| **Location**                        |     |           |
| Central                             | 11  | 36.70%    |
| Lateral                             | 7   | 23.30%    |
| Foraminal                           | 12  | 40%       |
| **5-Point Likert scale (12 months following treatment)** | | |
| $\leq 3$                            | 26  | 86.7%     |
| $>3$                                | 4   | 13.3%     |
Table 2
Primary Outcome and Clinical Factors

| Variable                        | Means ± Standard deviation(SD) | Sample | P value | Confidence interval(CI) |
|---------------------------------|---------------------------------|--------|---------|-------------------------|
| Visual Analogue Scale (VAS)     |                                 |        |         |                         |
| Preoperative                    | 7.6 ± 1.19                      | 30     | < 0.001 | [5.60, 6.73]             |
| 12 Months following treatment   | 1.4 ± 0.97                      | 30     |         |                         |
| Clinical factors affecting VAS (at 12 months following treatment) | | | | |
| Age ≤ 40 yrs                    | 1.13 ± 0.64                     | 8      | > 0.20  | [-1.09, 0.24]           |
| Age ≥ 40 yrs                    | 1.55 ± 1.06                     | 22     |         |                         |
| Male                            | 1.35 ± 0.79                     | 17     | > 0.60  | [-0.99, 0.61]           |
| Female                          | 1.54 ± 1.20                     | 13     |         |                         |
| BMI* ≤ 23                       | 1.75 ± 0.97                     | 12     | > 0.10  | [-0.21, 1.27]           |
| BMI ≥ 23                        | 1.22 ± 0.94                     | 18     |         |                         |
| DOS* ≤ 6 months                 | 1.61 ± 0.98                     | 18     | > 0.20  | [-0.29, 1.18]           |
| DOS ≥ 6 months                  | 1.17 ± 0.94                     | 12     |         |                         |
| L4/5                            | 0.93 ± 0.62                     | 14     | < 0.01  | [-1.59, -0.30]          |
| L5/S1                           | 1.88 ± 1.02                     | 16     |         |                         |

*BMI, Body Mass Index; DOS, duration of symptoms

Discussion

Accurate location for puncture is an essential step in most spinal surgery and is especially important to PTED. As for the conventional procedures of PTED, transforaminal puncture still depends on a constant distance from the midline and the estimated angles in anteroposterior and craniocaudal orientations\cite{15, 22, 30}. It is complicated and difficult for beginners to insert a needle into the intervertebral foramen relying on the traditional method. Therefore, the learning curve for PTED is often described as steep\cite{33}. Accurate needle puncture and trajectory is essential to safe, successful surgery. If the puncture were inaccurate, increased puncture frequency and increased fluoroscopy time would be inevitable, thus increasing radiation exposure to doctors and patients. Notably, radiation exposure has been found to increase the risk of some types of cancer for exposed surgeons\cite{34}. Han, et al.\cite{35} developed the obturator guiding technique in order to enhance safety and reduce drawbacks associated with the needle insertion process.
The traditional technique, nevertheless, still depends on the previously described distance and angles. In 2015, Fan, et al. \cite{36} designed and produced the He's lumbar location system (HELLO), which could improve puncture accuracy and reduce fluoroscopy time in the performance of PTED. However, the surgeon is required to repeatedly adjust the positioner and the C-arm for fluoroscopy, which amounts to extra time-consuming steps. Their system has not really been popular all over the world. Therefore, based on the anatomy of spine, this article introduced a simple and more accessible three-step maneuver for puncture (TSMP) in PTED.

TSMP is a three-step maneuver that builds on the concept of needle puncture site and trajectory determination based on the principles of Kambin’s triangle. First, accurate direction of the puncture is confirmed by inserting the needle horizontally. Then by gradually raising the needle tail in the manner described, the superior articular facet and the intervertebral foramen are sequentially located. Finally, the needle tip slides into the intervertebral foramen to reach the target superior articular facet. In this study, we performed a retrospective review on patients who underwent PTED using TSMP for LDH. Patients’ sciatica was significantly relieved at 12 months after PTED using TSMP. By subgroup analysis, there were better VAS scores about 12 months postoperatively in the L4-L5 group compared to the L5-S1 group (P < .01). The reason for this result may be that PTED performed in L5-S1 group was more easily influenced by iliac crest. For patients with the L5/S1 disc herniation, especially in case of high iliac crest, there are differences in the operation due to the anatomical obstruction: 1) require a more medial placement of the entry point; 2) a resection of the lateral one fourth of the facet joint \cite{14}.

TSMP relies on the natural anatomy of the individual patient to progressively deliver the needle to the target. For this reason, TSMP could prove to be a more stable surgical technique compared than the traditional puncture method. However, there are several limitations in our study: (1) The appropriate entry point should be determined in the AR according to the location of the herniated disc, but operators cannot locate the most accurate entry point through TSMP at present. (2) Pragmatic, precise and prospective RCT, with sufficient samples and long-term followup, comparing PTED using TSMP to conventional microdiscectomy, was not performed. Hence, comparing with other procedures, the efficacy and safety of PTED using TSMP need to be further evaluated.

**Conclusions**

TSMP is a stable surgical technique for inserting the needle into the intervertebral foramen. Patients who underwent PTED using TSMP fared significantly better with regard to leg and back pain at 12 months after surgery. Given these potential advantages, more research is needed to confirm the efficacy and safety of PTED using TSMP.

**Declarations**

**ABBREVIATIONS:** LDH, lumbar disc herniation; CMD, conventional microdiscectomy; MISS, minimally invasive spine surgery; PTED, percutaneous transforaminal endoscopic discectomy; YESS, Yeung
Endoscopic Spine System; **THESSYS**, Thomas Hoogland Endoscopic Spine System; **TSMP**, three-step maneuver for puncture; **AR**, approximating rectangle; **SA**, surgical approach; **VAS**, Visual Analogue Scale; **DOS**, duration of symptom

**Ethics approval and consent to participate:** This study has been granted by the Ethics Committee of Fujian Medical University Union Hospital, Fuzhou, China (2018YF010-02).

**Consent for publication:** Yes

**Availability of data and materials:** Through the email (cmchen2009@sina.com) to contact us for accessing data.

**Competing interests:** none

**Funding:** This work was funded by Technology and Innovation Foundation of Fujian, China (grant no 2018Y9060 to CM)

**Authors' contributions:**

Conception or design of the work: Chun Mei Chen

Acquisition of data: Shao Xiong Chen

Analysis of data: Shao Xiong Chen

Interpretation of data: Ze Yan Liang

Drafting the work: Ze Yan Liang

Revising the work for valuable intellectual content: Rui Wang

Final approval of the version: Chun Mei Chen

**Acknowledgements:** none

**References**

1. Konstantinou K, Dunn K: **Sciatica: review of epidemiological studies and prevalence estimates.** *Spine* 2008, **33**(22):2464-2472.

2. Jacobs WC, Arts MP, van Tulder MW, Rubinstein SM, van Middelkoop M, Ostelo RW, Verhagen AP, Koes BW, Peul WC: **Surgical techniques for sciatica due to hemiated disc, a systematic review.** *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society* 2012, **21**(11):2232-2251.

3. MP R, J S, JK L, A G: **Return to sport after open and microdiscectomy surgery versus conservative treatment for lumbar disc hemiation: a systematic review with meta-analysis.** *British journal of sports medicine* 2016, **50**(4):221-230.
4. BL C, JB G, HW Z, YJ Z, Y Z, J Z, HY H, YL Z, XQ W: **Surgical versus non-operative treatment for lumbar disc herniation: a systematic review and meta-analysis.** *Clinical rehabilitation* 2018, 32(2):146-160.

5. Gibson J, Waddell G: **Surgical interventions for lumbar disc prolapse.** *The Cochrane database of systematic reviews* 2007:CD001350.

6. Gibson JN, Waddell G: **Surgical interventions for lumbar disc prolapse: updated Cochrane Review.** *Spine* 2007, 32(16):1735-1747.

7. Rasouli M, Rahimi-Movaghar V, Shokraneh F, Moradi-Lakeh M, Chou R: **Minimally invasive discectomy versus microdiscectomy/open discectomy for symptomatic lumbar disc herniation.** *The Cochrane database of systematic reviews* 2014:CD010328.

8. Kamper S, Ostelo R, Rubinstein S, Nellensteijn J, Peul W, Arts M, van Tulder M: **Minimally invasive surgery for lumbar disc herniation: a systematic review and meta-analysis.** *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society* 2014, 23(5):1021-1043.

9. Alvi MA, Kerezoudis P, Wahood W, Goyal A, Bydon M: **Operative Approaches for Lumbar Disc Herniation: A Systematic Review and Multiple Treatment Meta-Analysis of Conventional and Minimally Invasive Surgeries.** *World neurosurgery* 2018, 114:391-407.e392.

10. P K, MD B: **Percutaneous posterolateral discectomy. Anatomy and mechanism.** *Clinical orthopaedics and related research* 1987, undefined(223):145-154.

11. P K: **Arthroscopic microdiscectomy.** *Arthroscopy: the journal of arthroscopic & related surgery: official publication of the Arthroscopy Association of North America and the International Arthroscopy Association* 1992, 8(3):287-295.

12. AT Y: **The evolution of percutaneous spinal endoscopy and discectomy: state of the art.** *The Mount Sinai journal of medicine, New York* 2000, 67(4):327-332.

13. Tsou PM, Yeung AT: **Transforaminal endoscopic decompression for radiculopathy secondary to intracanal noncontained lumbar disc herniations: outcome and technique.** *The spine journal: official journal of the North American Spine Society* 2002, 2(1):41-48.

14. AT Y, PM T: **Posterolateral endoscopic excision for lumbar disc herniation: Surgical technique, outcome, and complications in 307 consecutive cases.** *Spine* 2002, 27(7):722-731.

15. M S, T H: **Endoscopic transforaminal nucleotomy with foraminoplasty for lumbar disk herniation.** *Operative Orthopadie und Traumatologie* 2005, 17(6):641-661.

16. Gibson JNA, Subramanian AS, Scott CEH: **A randomised controlled trial of transforaminal endoscopic discectomy vs microdiscectomy.** *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society* 2017, 26(3):847-856.

17. Ruetten S, Komp M, Merk H, Godolias G: **Full-endoscopic interlaminar and transforaminal lumbar discectomy versus conventional microsurgical technique: a prospective, randomized, controlled study.** *Spine* 2008, 33(9):931-939.
18. R Q, B L, J H, P Z, Y Y, F Z, X C: Percutaneous Endoscopic Lumbar Discectomy Versus Posterior Open Lumbar Microdiscectomy for the Treatment of Symptomatic Lumbar Disc Herniation: A Systemic Review and Meta-Analysis. World neurosurgery 2018, 120(undened):352-362.

19. Nellensteijn J, Ostelo R, Bartels R, Peul W, van Royen B, van Tulder M: Transforaminal endoscopic surgery for symptomatic lumbar disc hemiations: a systematic review of the literature. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 2010, 19(2):181-204.

20. A S, PS G, BS H, JL vS, WC P, MW vT, MR dB, SM R: PTED study: design of a non-inferiority, randomised controlled trial to compare the effectiveness and cost-effectiveness of percutaneous transforaminal endoscopic discectomy (PTED) versus open microdiscectomy for patients with a symptomatic lumbar disc herniation. BMJ open 2017, 7(12):e018230.

21. JN G, JG C, MI: Transforaminal endoscopic spinal surgery: the future 'gold standard' for discectomy? - A review. The surgeon : journal of the Royal Colleges of Surgeons of Edinburgh and Ireland 2012, 10(5):290-296.

22. PS G, BS H: Percutaneous Transforaminal Endoscopic Discectomy for Lumbar Disk Herniation. Clinical spine surgery 2016, 29(9):368-371.

23. C B, M K, HF L, B W, S R: The current state of endoscopic disc surgery: review of controlled studies comparing full-endoscopic procedures for disc hemiations to standard procedures. Pain physician 2013, 16(4):335-344.

24. Ahn Y: Transforaminal percutaneous endoscopic lumbar discectomy: technical tips to prevent complications. Expert review of medical devices 2012, 9(4):361-366.

25. ML P, EC M, JS D, GR R: Comparison of image quality and radiation exposure from C-arm fluoroscopes when used for imaging the spine. Spine 2013, 38(16):1401-1404.

26. KL K, LM M, PS P, BS L, DG K, CY C: Measurements of surgeons' exposure to ionizing radiation dose during intraoperative use of C-arm fluoroscopy. Spine 2012, 37(14):1240-1244.

27. AF O, TS T, HC M, MF M, MA M, MS T, TO O: Anatomic Assessment of Variations in Kambin's Triangle: A Surgical and Cadaver Study. World neurosurgery 2017, 100(undened):498-503.

28. RH R, EF E, WT W: Cadaveric Analysis of the Kambin's Triangle. Cureus 2016, 8(2):e475.

29. Gibson JN, Cowie JG, Iprenburg M: Transforaminal endoscopic spinal surgery: the future 'gold standard' for discectomy? - A review. The surgeon : journal of the Royal Colleges of Surgeons of Edinburgh and Ireland 2012, 10(5):290-296.

30. 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 2016, 22:530-539.

31. JR C, DC N, JT H, RJ B, JD J, MJ M, MJ L: Evaluating common outcomes for measuring treatment success for chronic low back pain. Spine 2011, 36(null):S54-68.

32. CB C: Outcome assessments in the evaluation of treatment of spinal disorders: summary and general recommendations. Spine 2000, 25(24):3100-3103.
33. HT H, SJ C, SS Y, CL C: Learning curve of full-endoscopic lumbar discectomy. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society* 2013, **22**(4):727-733.

34. DS K, KDT T, AC W, FL M, PI W, TC S, PP: Radiation safety and spine surgery: systematic review of exposure limits and methods to minimize radiation exposure. *World neurosurgery* 2014, **82**(6):1337-1343.

35. IH H, BK C, WH C, KH N: The obturator guiding technique in percutaneous endoscopic lumbar discectomy. *Journal of Korean Neurosurgical Society* 2012, **51**(3):182-186.

36. Fan G, Guan X, Zhang H, Wu X, Gu X, Gu G, Fan Y, He S: Significant Improvement of Puncture Accuracy and Fluoroscopy Reduction in Percutaneous Transforaminal Endoscopic Discectomy With Novel Lumbar Location System: Preliminary Report of Prospective Hello Study. *Medicine* 2015, **94**(49):e2189.

**Figures**

![Diagram of Kambin's Triangle](image)

**Figure 1**

Kambin's Triangle In a two dimensional plane, the triangle (abc) is bordered by the superior endplate of the lower vertebra (bc), the superior articular facet (ab) and the exiting superior nerve root (ca).
Figure 2

Target of Puncture Target is located at the intersection of the superior endplate line of the lower vertebra and the inner line of lower vertebral pedicle in anteroposterior projection (Point a in Figure 2A), or at the intersection of the trailing line of the lower vertebral body and the superior endplate line of the lower vertebra in lateral projection (Point b in Figure 2B).
Figure 3

Area of Needle Insertion The area of needle insertion is located on patient’s posterolateral side, which is an approximating rectangle (abcd) formed by the line of spinous process (ab), the line of transverse process (cd), the superior endplate line of the upper vertebra (da) and the superior endplate line of the lower vertebra (bc) in lateral projection.
Three-step maneuver for puncture (TSMP) Step 1: Needle is inserted through appropriate entry point and advanced toward spinous process slowly (4A). Step 2: Needle is pulled out to appropriate length. Then, after raising needle tail properly, needle will be advanced toward superior articular facet (4B). Step 3: Needle is pulled out to appropriate length again. Then, after raising needle tail properly, needle is advanced toward the target, and needle tip will slide into the intervertebral foramen along superior articular facet (4C).