CLINICAL ARTICLE

Technical Tips for Percutaneous Transforaminal Endoscopic Discectomy: A Three-step Maneuver for Puncture and Early Clinical Experience

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Objective: To investigate the feasibility and efficacy of percutaneous transforaminal endoscopic discectomy (PTED) with three-step maneuver for puncture (TSMP) for lumbar herniated disc (LDH).

Methods: We performed a retrospective review of 30 patients who underwent PTED using TSMP for 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. 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.

Results: Preoperative mean VAS was 7.6 ± 1.19, which decreased to 1.4 ± 0.97 at 12 months following treatment ($P < 0.0001$). Rates of surgical satisfaction per Likert scale were as follows: very satisfied and satisfied in 26 patients (86.7%). Three recurrent disc herniations of adjacent segmental levels were observed in the L5-S1 group at eight and 12 months after surgery. VAS scores at 12 months varied significantly between L4-L5 level surgery and L5-S1 level surgery groups ($P < 0.01$).

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

Key words: Approximating rectangle; Kambin's Triangle; Lumbar disc herniation; Percutaneous transforaminal endoscopic discectomy; Three-step maneuver for puncture

Introduction

For sciatica with lumbar disc herniation (LDH), surgery is recommended when patients are resistant to conservative treatment[1–4]. At present, conventional microdiscectomy (CMD) is still the standard surgical procedure for LDH[5,6]. In the past few decades, minimally invasive spine surgery (MISS) has become increasingly popular all over the world[7]. Percutaneous transforaminal lumbar discectomy (PTED) is one of the popular minimally invasive procedures for the treatment of lumbar disc herniation[8].

In 1987, Kambin *et al.*[9] introduced the safe triangle (i.e., Kambin's triangle) of percutaneous posterolateral extracanal approach for the management of LDH, reporting arthroscopic microdiscectomy in 1992[10]. Based on the concept of the "inside-out," Yeung *et al.*[11–13] developed the technique of the Yeung Endoscopic Spine System (YESS).

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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.*[14], 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[15–18] 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[19]. Gibson *et al.*[20] and Gadjradj *et al.*[21] 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[22]. 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[21,23]. 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[24,25]. One of the urgent difficulties in PTED is how to locate and puncture quickly, accurately and safely.

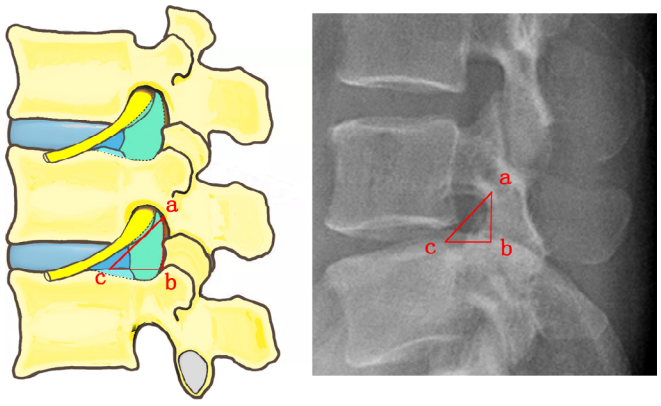

Fig 1 Kambin's triangle. In a two-dimensional plane, the triangle (abc) is bordered by the superior endplate of the lower vertebra (bc), the superior articular facet (ab) and the exiting superior nerve root (ca).

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

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: (i) age 18 to 70 years; (ii) single-level surgery; (iii) informed consent; and (iv) at least one year after surgery. Exclusion criteria consisted of: (i) previous surgery on the same or adjacent disc level; (ii) spondylytic or degenerative spondylolisthesis; (iii) severe somatic or psychiatric illness; and (iv) history of psychiatric or psychological disorder. The primary outcome, leg or back pain, was assessed using the Visual Analogue Scale (VAS)[26]. Surgical satisfaction was measured using a five-point Likert scale[27], varying from "very satisfied" (5 points) to "very unsatisfied" (1 point). The following potential prognostic factors were measured: (i) demographic characteristics (e.g., age and gender); (ii) duration of symptom (DOS); (iii) involved levels. Statistical analysis was performed using Fisher exact test and t-test, and the P value <0.05 was regarded as statistically significant.

Rationale and Anatomy

Kambin *et al.*[9] 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[28,29]. 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 two-dimensional 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]. 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.

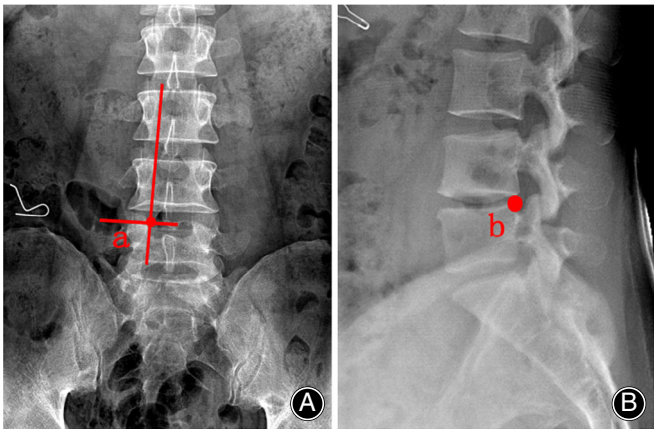

Fig 2 Target of puncture. Target is located at the intersection of the superior endplate line of the lower vertebra and the inner line of lower vertebral pedicle in anteroposterior projection (Point a in Fig. 2A), or at the intersection of the trailing line of the lower vertebral body and the superior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

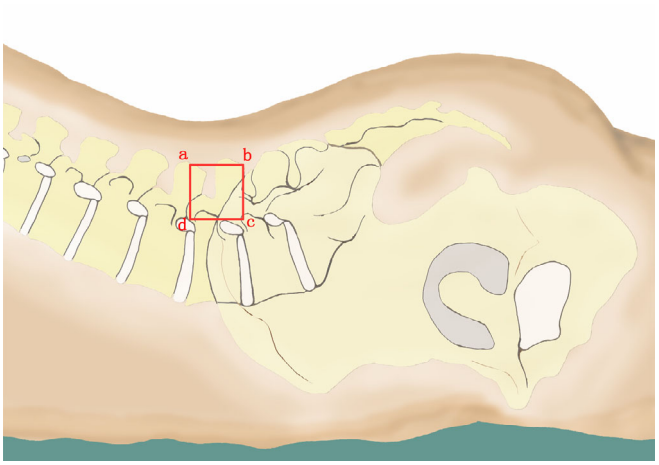

Fig 3 Area of needle insertion. The area of needle insertion is located on patient's posterolateral side, which is an approximating rectangle (abcd) formed by the line of spinous process (ab), the line of transverse process (cd), the superior endplate line of the upper vertebra (da) and the superior endplate line of the lower vertebra (bc) in lateral projection.

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: (i) the closer the position of the disc is to the center, the closer the needle point is to the ventral side; and (ii) 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. (Fig. 4A and B).

Step 2. The needle is pulled out an appropriate distance (about 2 to 3 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. (Fig. 4C and D).

Step 3. The needle is pulled out an appropriate distance again (about 1 to 2 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. (Fig. 4E and F).

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[14,21,30]. (Fig. 5).

Results

Patient Characteristics

There were 30 patients with LDH who met the inclusion criteria and had undergone PTED using TSMP, 17 were men and 13 were women. The demographic findings are summarized in Table 1. The follow-up time was 1 year.

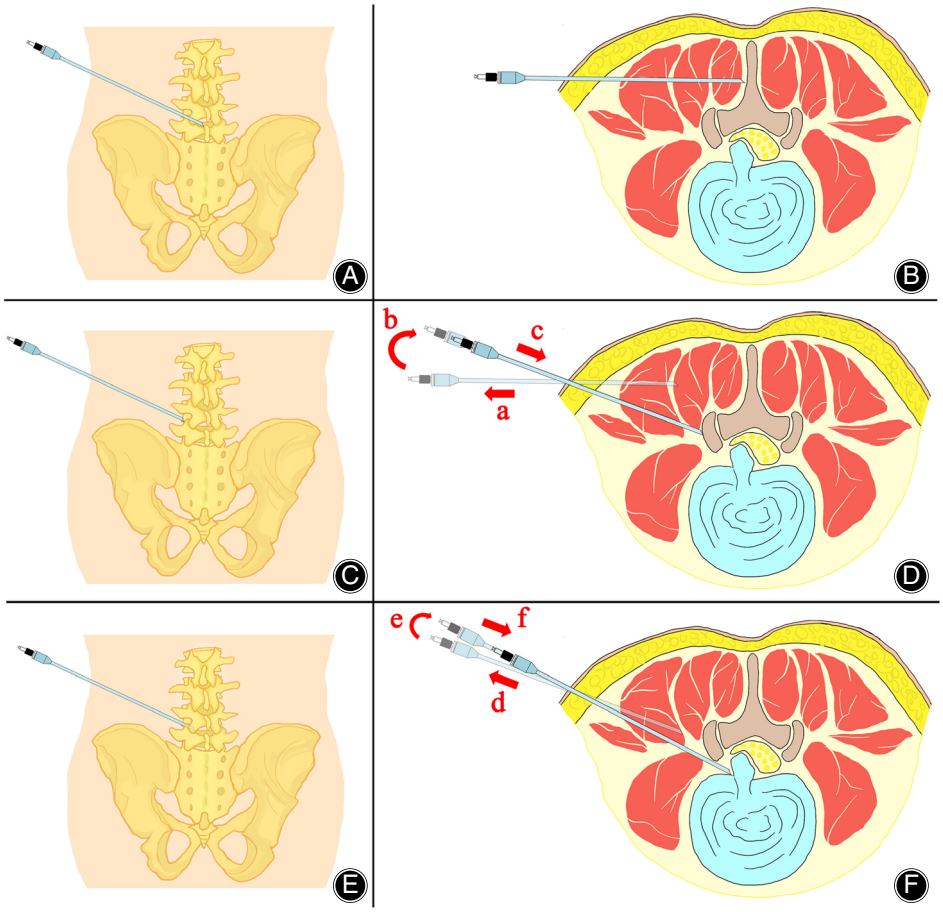

Fig 4 Three-step maneuver for puncture (TSMP). *Step 1* (A and B): needle is inserted through appropriate entry point and advanced toward spinous process slowly. *Step 2* (C and D): needle is pulled out to appropriate length (*the direction as the arrow a*). Then, after raising needle tail properly (*the direction as the arrow b*), needle will be advanced toward superior articular facet (*the direction as the arrow c*). *Step 3* (E and F): needle is pulled out to appropriate length again (*the direction as the arrow d*). Then, after raising needle tail properly, needle is advanced toward the target (*the direction as the arrow e*), and needle tip will slide into the intervertebral foramen along superior articular facet (*the direction as the arrow f*).

General Results

The preoperative mean VAS was 7.6 ± 1.19, which decreased to 1.4 ± 0.97 at 12 months following treatment ($P < -0.0001$). 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 (Table 2).

Subgroup Analysis

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 ($P < 0.01$). There were no significant influences at 12 months after PTED on the primary outcome from other factors, including gender ($P > 0.60$), age ($P > 0.20$), body mass index (BMI) ($P > 0.10$), and DOS ($P > 0.20$) (Table 2).

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[14,21,30]. 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[31]. 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[32]. Han *et al.*[33] 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.*[34] designed and produced the HEs 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

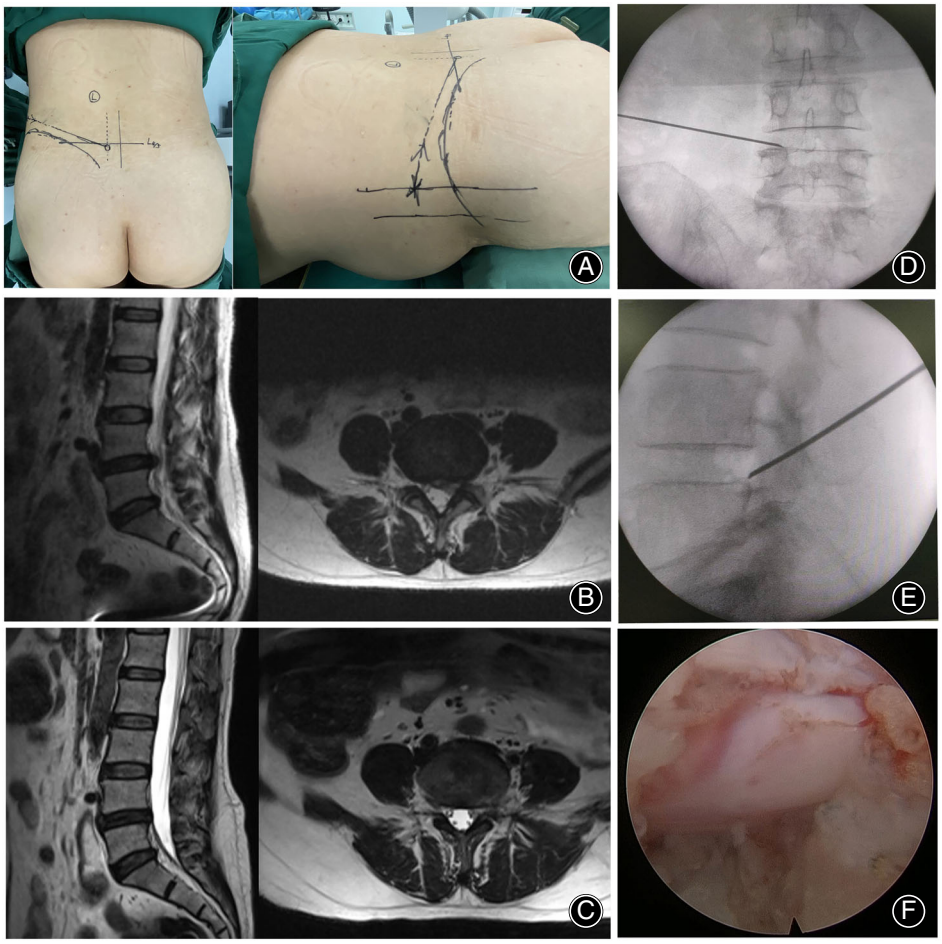

Fig 5 (A) Using the mobile C-arm for anteroposterior and lateral radiographic control, the directional line of puncture is marked with a marker. (B) Preoperative magnetic resonance image (MRI) revealed L4-5 disc herniation. (C) Follow-up MRI showed revealed that the herniated disc was removed totally, and there was no recurrent herniation. (D) and (E) Intraoperative anteroposterior and lateral radiographic images revealed the tip of this needle reached the target. (F) After the removal of all fragments, a pulsation of the nerve root should be visible under the endoscope.

TABLE 1 Demographic characteristics

Data	No.	Percent
Gender		
Male	17	56.70%
Female	13	43.30%
Age		
≤40 yrs	8	26.70%
>40 yrs	22	73.30%
BMI (kg/m^2)		
≤23	12	40%
>23	18	60%
Side		
Right	9	30%
Left	21	70%
Duration of symptoms		
≤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)		
>3	26	86.7%
≤3	4	13.3%

of the 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 ($P < 0.01$). 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 the case of high iliac crest, there are differences in the operation due to the anatomical obstruction: (i) require a more medial placement of the entry point; and (ii) a resection of the lateral one fourth of the facet joint[13].

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.

Limitations

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: (i) 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; and (ii) pragmatic, precise and prospective RCT, with sufficient samples and long-term followup, comparing PTED using TSMP to conventional microdiscectomy, was not performed. Hence, compared to other procedures, the efficacy and safety of PTED using TSMP needs 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.

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).

Availability of Data and Materials

Contact us through email (cmchen2009@sina.com) to access our data.

Authors' Contributions

Conception or design of the work: Chun Mei Chen. Acquisition of data: Xin Yao Chen. Analysis of data: Xin Yao Chen. Interpretation of data: Ze Yan Liang. Drafting the work: Ze Yan Liang. Revising the work for valuable intellectual content: Rui Wang and Ze Yan Liang. Final approval of the version: Chun Mei Chen.

References

1. Konstantinou K, Dunn K. Sciatica: review of epidemiological studies and prevalence estimates. Spine, 2008, 33: 2464–2472.
2. Jacobs WC, Arts MP, van Tulder MW, *et al*. Surgical techniques for sciatica due to herniated disc, a systematic review. Eur Spine J, 2012, 21: 2232–2251.
3. Reiman MP, Sylvain J, Loudon JK, Goode A. Return to sport after open and microdiscectomy surgery versus conservative treatment for lumbar disc herniation: a systematic review with meta-analysis. Br J Sports Med, 2016, 50: 221–230.
4. Chen BL, Guo JB, Zhang HW, *et al*. Surgical versus non-operative treatment for lumbar disc herniation: a systematic review and meta-analysis. Clin Rehabil, 2018, 32: 146–160.
5. Gibson JN, Waddell G. Surgical interventions for lumbar disc prolapse: updated Cochrane review. Spine (Phila Pa 1976)., 2007, 32: 1735–1747.
6. Rasouli M, Rahimi-Movaghar V, Shokraneh F, Moradi-Lakeh M, Chou R. Minimally invasive discectomy versus microdiscectomy/open discectomy for symptomatic lumbar disc herniation. Cochrane Database Syst Rev, 2014, 4: CD010328.
7. Kamper S, Ostelo R, Rubinstein S, *et al*. Minimally invasive surgery for lumbar disc herniation: a systematic review and meta-analysis. Eur Spine J, 2014, 23: 1021–1043.
8. 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 Neurosurg, 2018, 114: 391–407.
9. Kambin P, Brager MD. Percutaneous posterolateral discectomy. Anatomy and mechanism. Clin Orthop Relat Res, 1987, 223: 145–154.
10. Kambin P. Arthroscopic microdiscectomy. Spine J, 2003, 3: 60s–64s.
11. Tsou PM, Yeung AT. Transforaminal endoscopic decompression for radiculopathy secondary to intracanal noncontained lumbar disc herniations: outcome and technique. Spine J, 2002, 2: 41–48.
12. Yeung AT. The evolution of percutaneous spinal endoscopy and discectomy: state of the art. Mt Sinai J Med, 2000, 67: 327–332.

13. Yeung AT, Tsou PM. Posterolateral endoscopic excision for lumbar disc herniation: surgical technique, outcome, and complications in 307 consecutive cases. Spine (Phila Pa 1976)., 2002, 27: 722–731.
14. Schubert M, Hoogland T. Endoscopic transforaminal nucleotomy with foraminoplasty for lumbar disk herniation. Operat Orthop Traumatol, 2005, 17: 641–661.
15. Gibson JNA, Subramanian AS, Scott CEH. A randomised controlled trial of transforaminal endoscopic discectomy vs microdiscectomy. Eur Spine J, 2017, 26: 847–856.
16. 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 (Phila Pa 1976)., 2008, 33: 931–939.
17. Nellensteijn J, Ostelo R, Bartels R, Peul W, van Royen B, van Tulder M. Transforaminal endoscopic surgery for symptomatic lumbar disc herniations: a systematic review of the literature. Eur Spine J, 2010, 19: 181–204.
18. Qin R, Liu B, Hao J, *et al*. Percutaneous endoscopic lumbar discectomy versus posterior open lumbar microdiscectomy for the treatment of symptomatic lumbar disc herniation: a systemic review and meta-analysis. World Neurosurg, 2018, 120: 352–362.
19. Seiger A, Gadjradj PS, Harhangi BS, *et al*. 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: e018230.
20. Gibson JN, Cowie JG, Iprenburg M. Transforaminal endoscopic spinal surgery: the future 'gold standard' for discectomy? A review. Surgeon, 2012, 10: 290–296.
21. Gadjradj PS, Harhangi BS. Percutaneous transforaminal endoscopic discectomy for lumbar disk herniation. Clin Spine Surg, 2016, 29: 368–371.
22. Birkenmaier C, Komp M, Leu HF, Wegener B, Ruetten S. The current state of endoscopic disc surgery: review of controlled studies comparing full-endoscopic procedures for disc herniations to standard procedures. Pain Physician, 2013, 16: 335–344.
23. Ahn Y. Transforaminal percutaneous endoscopic lumbar discectomy: technical tips to prevent complications. Expert Rev Med Devices, 2012, 9: 361–366.
24. Prasarn ML, Coyne E, Schreck M, Rodgers JD, Rechtine GR. Comparison of image quality and radiation exposure from C-arm fluoroscopes when used for imaging the spine. Spine (Phila Pa 1976), 2013, 38: 1401–1404.
25. Lee K, Lee KM, Park MS, Lee B, Kwon DG, Chung CY. Measurements of surgeons' exposure to ionizing radiation dose during intraoperative use of C-arm fluoroscopy. Spine (Phila Pa 1976), 2012, 37: 1240–1244.
26. Chapman JR, Norvell DC, Hermsmeyer JT, *et al*. Evaluating common outcomes for measuring treatment success for chronic low back pain. Spine (Phila Pa 1976)., 2011, 36: S54–S68.
27. Bombardier C. Outcome assessments in the evaluation of treatment of spinal disorders: summary and general recommendations. Spine (Phila Pa 1976), 2000, 25: 3100–3103.
28. Ozer AF, Suzer T, Can H, *et al*. Anatomic assessment of variations in Kambin's triangle: a surgical and cadaver study. World Neurosurg, 2017, 100: 498–503.
29. Hoshide R, Feldman E, Taylor W. Cadaveric analysis of the Kambin's triangle. Cureus, 2016, 8: e475.
30. Pan Z, Ha Y, Yi S, Cao K. Efficacy of transforaminal endoscopic spine system (TESSYS) technique in treating lumbar disc herniation. Med Sci Monit, 2016, 22: 530–539.
31. Hsu HT, Chang SJ, Yang SS, Chai CL. Learning curve of full-endoscopic lumbar discectomy. Eur Spine J, 2013, 22: 727–733.
32. Reid SA, Rivett DA, Katekar MG, Callister R. Comparison of mulligan sustained natural apophyseal glides and maitland mobilizations for treatment of cervicogenic dizziness: a randomized controlled trial. Phys Ther, 2014, 94: 466–476.
33. Han IH, Choi BK, Cho WH, Nam KH. The obturator guiding technique in percutaneous endoscopic lumbar discectomy. J Korean Neurosurg Soc, 2012, 51: 182–186.
34. Fan G, Guan X, Zhang H, *et al*. 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: e2189.