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Retrospective Evaluation

Lower Learning Difficulty and Fluoroscopy Reduction of Transforaminal Percutaneous Endoscopic Lumbar Discectomy with an Accurate Preoperative Location Method

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Background: Transforaminal percutaneous endoscopic lumbar discectomy (tPELD) poses great challenges for junior surgeons. Beginners often require repeated attempts using fluoroscopy causing more punctures, which may significantly undermine their confidence and increase the radiation exposure to medical staff and patients. Moreover, the impact of an accurate location on the learning curve of tPELD has not been defined.

Objective: The study aimed to investigate the impact of an accurate preoperative location method on learning difficulty and fluoroscopy time of tPELD.

Study Design: Retrospective evaluation.

Setting: Patients receiving tPELD by one surgeon with a novel accurate preoperative location method were regarded as Group A, and those receiving tPELD by another surgeon with a conventional fluoroscopy method were regarded as Group B.

Methods: From January 2012 to August 2014, we retrospectively reviewed the first 80 tPELD cases conducted by 2 junior surgeons. The operation time, fluoroscopy times, preoperative location time, and puncture-channel time were thoroughly analyzed.

Results: The operation time of the first 20 patients were 99.75 ± 10.38 minutes in Group A and 115.7 ± 16.46 minutes in Group B, while the operation time of all 80 patients was 88.36 ± 11.56 minutes in Group A and 98.26 ± 14.90 minutes in Group B. Significant differences were detected in operation time between the 2 groups, both for the first 20 patients and total 80 patients ($P < 0.05$). The fluoroscopy times were 26.78 ± 4.17 in Group A and 33.98 ± 2.69 in Group B ($P < 0.001$). The preoperative location time was 3.43 ± 0.61 minutes in Group A and 5.59 ± 1.46 minutes in Group B ($P < 0.001$). The puncture-channel time was 27.20 ± 4.49 minutes in Group A and 34.64 ± 8.35 minutes in Group B ($P < 0.001$). There was a moderate correlation between preoperative location time and puncture-channel time ($r = 0.408$, $P < 0.001$), and a moderate correlation between preoperative location time and fluoroscopy times ($r = 0.441$, $P < 0.001$). Mild correlations were also observed between preoperative location time and operation time ($r = 0.270$, $P = 0.001$). There were no significant differences in preoperative back visual analogue scale (VAS) score, postoperative back VAS, preoperative leg VAS, postoperative leg VAS, preoperative Japanese Orthopaedic Association (JOA) score, postoperative JOA, preoperative Oswestry disability score (ODI), or postoperative ODI ($P > 0.05$). However, significant differences were all detected between preoperative abovementioned scores and postoperative scores ($P < 0.05$). Moreover, there was no significant differences in Macnab satisfaction between the 2 groups ($P = 0.179$). There were 2 patients with recurrence in Group A and 3 patients in Group B. Twelve patients with postoperative disc remnants were identified in Group A and 9 patients in Group B. No significant difference was identified between the 2 groups ($P = 0.718$).

Limitations: The preoperative lumbar location method is just a tiny step in tPELD, junior surgeons still need to focus on their subjective feelings during punctures and accumulating their experience in endoscopic discectomy.

Conclusions: The accurate preoperative location method lowered the learning difficulty and reduced the fluoroscopy time of tPELD, which was also associated with lower preoperative location time and puncture-channel time.

Key words: Learning difficulty, fluoroscopy reduction, transforamimal percutaneous endoscopic lumbar discectomy, preoperative location

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Low back pain is a leading cause of disability and health care cost around the world (1), for which lumbar disc herniation (LDH) is a chief culprit (2). There was a stepped-care scheme for the management of LDH-caused low back pain, including conservative treatment, minimally invasive spine surgery (MISS), and open fusion surgery (3). When the conservative treatment fails, MISS technique or open surgery can be a secondary option for LDH in current clinical practice. Microdiscectomy has been well validated as an effective treatment for LDH (4), but it often causes more muscular injury, resects the lamina and facet joint, scars the dural sac, and retracts the nerve, which are often regarded as the primary reasons for post-discectomy syndrome (5). In contrast, the MISS technique has been gradually developed to avoid the above-mentioned disadvantages (6). Transforaminal percutaneous endoscopic lumbar discectomy (tPELD) is one alternative technique to microdiscectomy or open discectomy (7,8). tPELD has several advantages over open discectomy, such as preservation of normal paraspinal structures, minimal postoperative pain, low risk of postoperative epidural scar formation and latrogenic instability with less blood loss, less postoperative pain, shorter hospital stay, and earlier return to work (9,10).

However, tPELD poses great challenges to junior surgeons mostly because they need to place the working channel percutaneously into an ideal position (11). Therefore, beginners often require repeated attempts using fluoroscopy causing more punctures, which may significantly undermine their confidence (12). There were many identified factors influencing the command of tPELD and its clinical outcomes, including surgical volume, surgical training, and patient selection (13-18). On the other hand, accurate location of surgical target is critical to patient safety and maximizing clinical outcomes in the MISS technique (19). However, there were no studies investigating the impact of accurate location on the learning curve of tPELD. Our previous studies have demonstrated that our self-made surface locator produced an accurate preoperative location of the surgical target in various spine surgeries (20-22). Therefore, the current study aimed to compare the difference in learning difficulty and clinical outcomes of our preoperative location method versus the conventional fluoroscopy method.

Methods

General Information

From January 2012 to August 2014, we retrospectively reviewed the 160 LDH patients undergoing tPELD by 2 surgeons in our department. Permission was obtained from the local ethical commission prior to the review of the medical records. The diagnosis of symptomatic LDH was based on the all-round clinical evaluation including classic symptoms and radiographic signs on magnetic resonance imaging (MRI) or computed tomography (CT). Inclusion criteria for the surgery were 1) single L3-4, L4-5, or L5-S1 LDH; 2) paracentral LDH, central LDH, foraminal LDH; 3) over 18 years old but less than 70 years old; and 4) conservative therapy duration of no less than 6 months. Exclusion criteria for the surgery were 1) severe mental illnesses; 2) severe obesity or diabetes; 3) previous lumbar surgery history; 4) combined with spinal instability, active infection, vertebral fractures, calcified fragments, lumbar sacralization at the L5-S1 level.

Both surgeons have been trained for several months before conducting tPELD on their own. Patients receiving tPELD by one surgeon using the novel preoperative location method were regarded as Group A, and those receiving tPELD by another surgeon using the conventional fluoroscopy method were regarded as Group B. The first 80 tPELD cases of the 2 surgeons were extracted respectively and analyzed. Both groups were divided into subgroups, namely, Group A1-20, Group A21-40, Group A41-60, Group A61-80, Group B1-20, Group B21-40, Group B41-60, and Group B61-80.

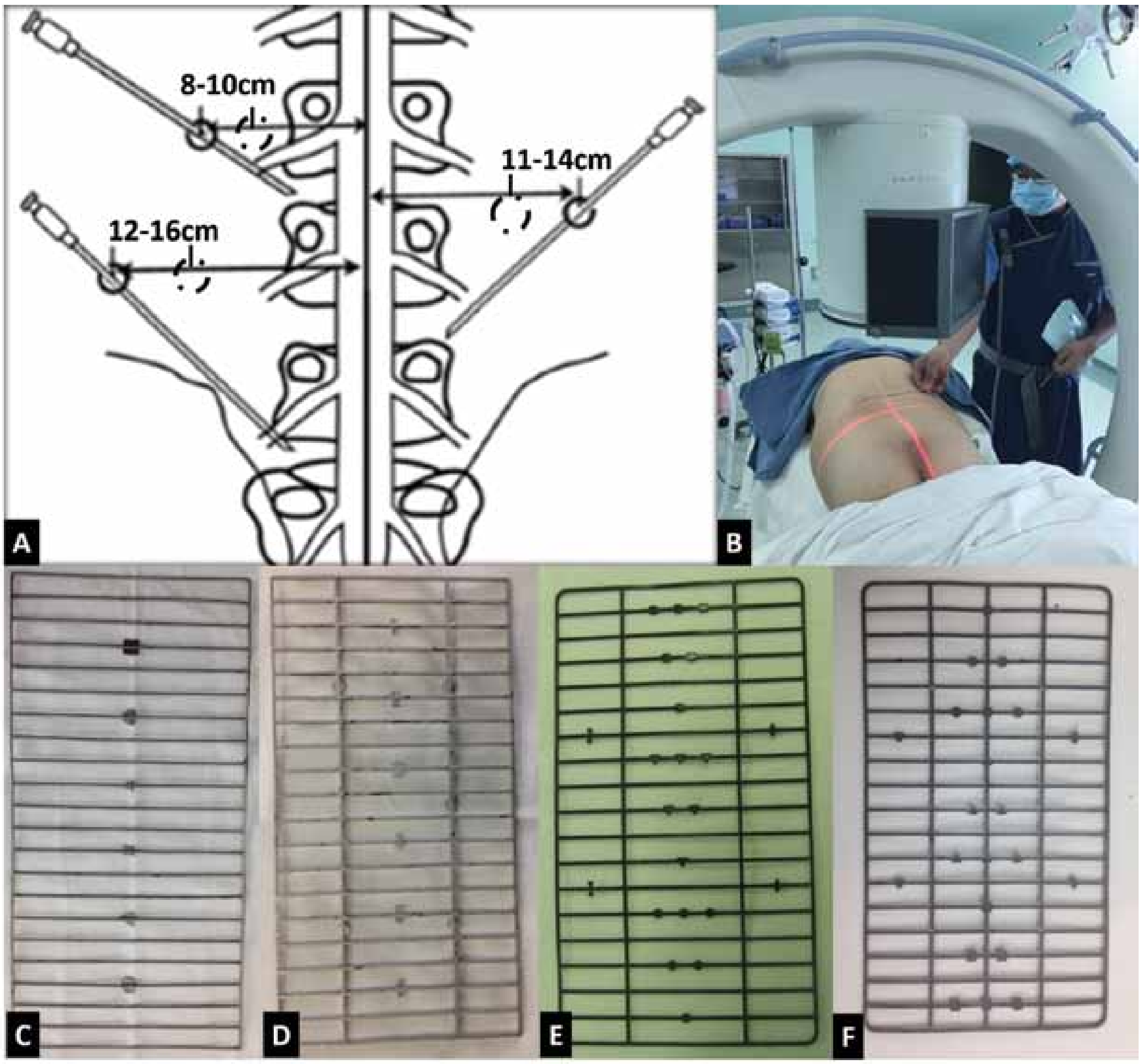

Fig. 1. *The necessity of a definite pathway with an accurate location of the preoperative surface locator. A: The selection of the entry point was subjective and variable with the conventional location method at different levels. B: conventional fluoroscopy method with K wire in a trial-and-error manner; C: first version of stainless steel; D: second version of titanium alloy; E: third version with various makers; F: fourth version of radiopaque polymer material.*

Surgical Procedure

Conventional Location Methods

Patients in Group B underwent PELD with the conventional fluoroscopy method. Briefly, the patients were placed in a prone position on the operation table. Then we used surgical instruments (e.g., K wire or nucleus pulposus clamp) with repeated fluoroscopy to plan the pathway and select the entry point for the punctures (Fig. 1A – B). According to the typical Thessys technique, the angle between the horizontal line and the planned pathway marked on the back was subjectively estimated by surgeons with 25 – 35°at the L3-L4 level, 30 – 40°at the L4-L5 level, and 40 – 50°at the L5-S1 level (23,24). As for the selection of the entry point, the distance from the midline of the spinous process was 8 – 10 centimeters at the L3-L4 level, 11 – 14 centimeters at the L4-L5 level, and 12 – 16 centimeters at the L5-S1

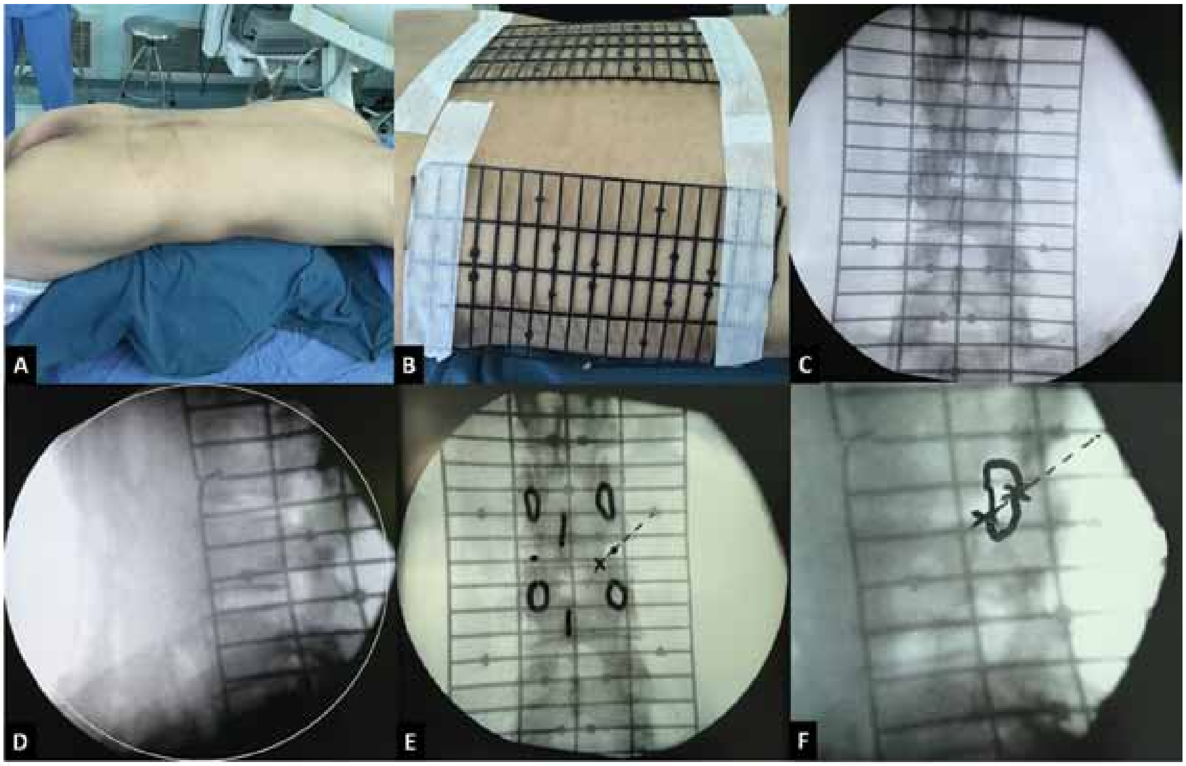

Fig. 2. *Planned pathway with the surface locator under fluoroscopy. A: even prone position with cushions under the belly; B: posterior and lateral attachments of the surface locator by adhesive tapes; C: anteroposterior fluoroscopy with surface locator; D: lateral fluoroscopy with surface locator; E: puncture target point and the tips of the superior facet joint determines the posterior projection of the virtually ideal pathway. F: puncture target point and the tips of the superior facet joint determines the lateral projection of the virtually ideal pathway.*

level (12,25). These parameters were variable and the final selection of the entry point was determined by the specific conditions of the patient (body size, gender, anatomic features) according to the surgeon's experience. Repeated fluoroscopy was conducted to calibrate the puncture and the working channel placement. The following surgical procedure followed the conventional endoscopic discectomy.

Novel Preoperative Location Method

We used our self-made surface locator to assist in planning the pathway and the entry point selection with one anteroposterior fluoroscopy and one lateral fluoroscopy. The locator consists of 20 horizontal crossbars and 4 longitudinal rods and it is made up of radiopaque material (Fig. 1C – F). Each horizontal crossbar is about 9 cm, whereas each longitudinal rod is about 18 cm. It is about 1 cm between each crossbar and some different marks (different numbers or different graphical elements) are made on the crossbars. Four longitudinal rods can also be distinguished with different marks.

Patients in Group A undergoing tPELD received the novel preoperative location method. Patients were placed in a prone position on a radiolucent operating table. Then, 2 locators were attached to the patient's skin over the approximate spinal levels of interest with one on the back and the other on the lateral skin (Fig. 2). Thereafter, the locators were fixed with adhesive plaster. The anteroposterior and lateral fluoroscopy were obtained so we could recognize the surgical target with our radiopaque locator on the film. The surrounding vertebral arches of the target level and the puncture target were confirmed and marked with a marker pen according to the different markers on the locator. The iliac crest was also marked if necessary. On anteroposterior fluoroscopy film, the posterior projection of the planned pathway was pointed to the herniated disc through the tip of the superior facet joint. At the L5-S1 level,

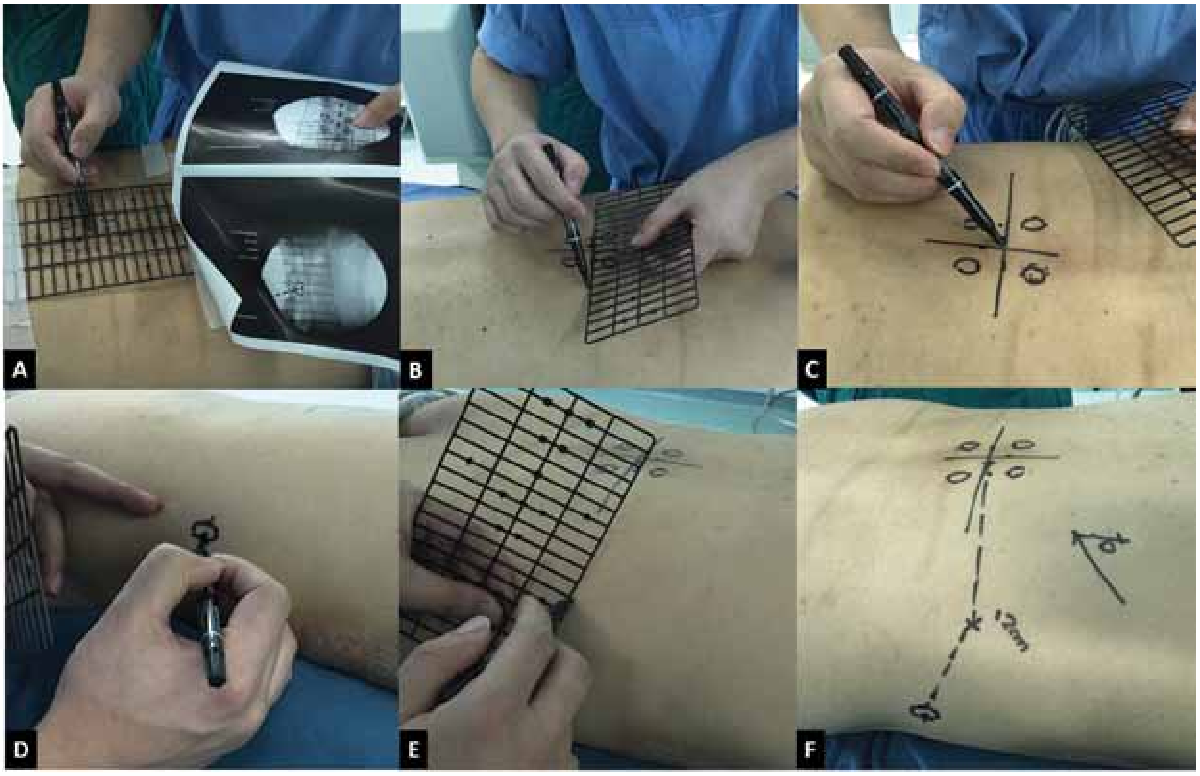

Fig. 3. *Marking the definite pathway on the skin. A: Mark the anatomic features on the back. B: Draw the upper edge of the inferior vertebrae with surface locator. C: Mark the puncture target point and the tips of the superior facet joint. D: Mark the puncture target point and isthmus. E: Draw the projections of plan pathway. F: The intersection of lateral and posterior projections of the planned pathway defines the entry point.*

the entry point usually was over the mark of the iliac crest on the skin. On lateral fluoroscopy film, the lateral projection of the planned pathway was pointed to the herniated disc through the tip of the superior facet joint. Then we marked the posterior projection line and lateral projection line of the planned pathway on the skin (Fig. 3). The intersection of the lateral and posterior projections of the planned pathway was the entry point for the puncture. We also used a surface locator to measure the distance between the midline and the intersection point to reconfirm the final selection. After that, the area was disinfected and local anesthesia was administered, and an 18G needle was used to puncture into the target. During the puncture procedure, we used the lateral projection of the puncture target to determine the depth of the punctures (simple demonstration by a video was available at: http://yun.baidu.com/s/1eQNcjdw). The following procedures were the same as conventional full-endoscopic discectomy (Fig. 4).

Observational Parameters

Basic information such as gender, age, body mass index (BMI), conservative therapy time, surgical segment, and fluoroscopy voltage and current were recorded and analyzed. Operation time, fluoroscopy time, preoperative location time, and puncture-channel time of the 2 groups were also compared and analyzed. In addition, preoperative and postoperative visual analogue scale (VAS), Oswestry disability index (ODI), and Japanese Orthopaedic Association (JOA) scores were also recorded and analyzed. Macnab criteria was used to assess the patients' satisfaction.

Statistical Analysis

All statistical analysis were conducted in SPSS 19.0 (IBM Corporation, Chicago, USA). The student t-test was used to compare the continuous variables between Group A and Group B. The Chi-square test was used to compare the enumeration data between the 2 groups.

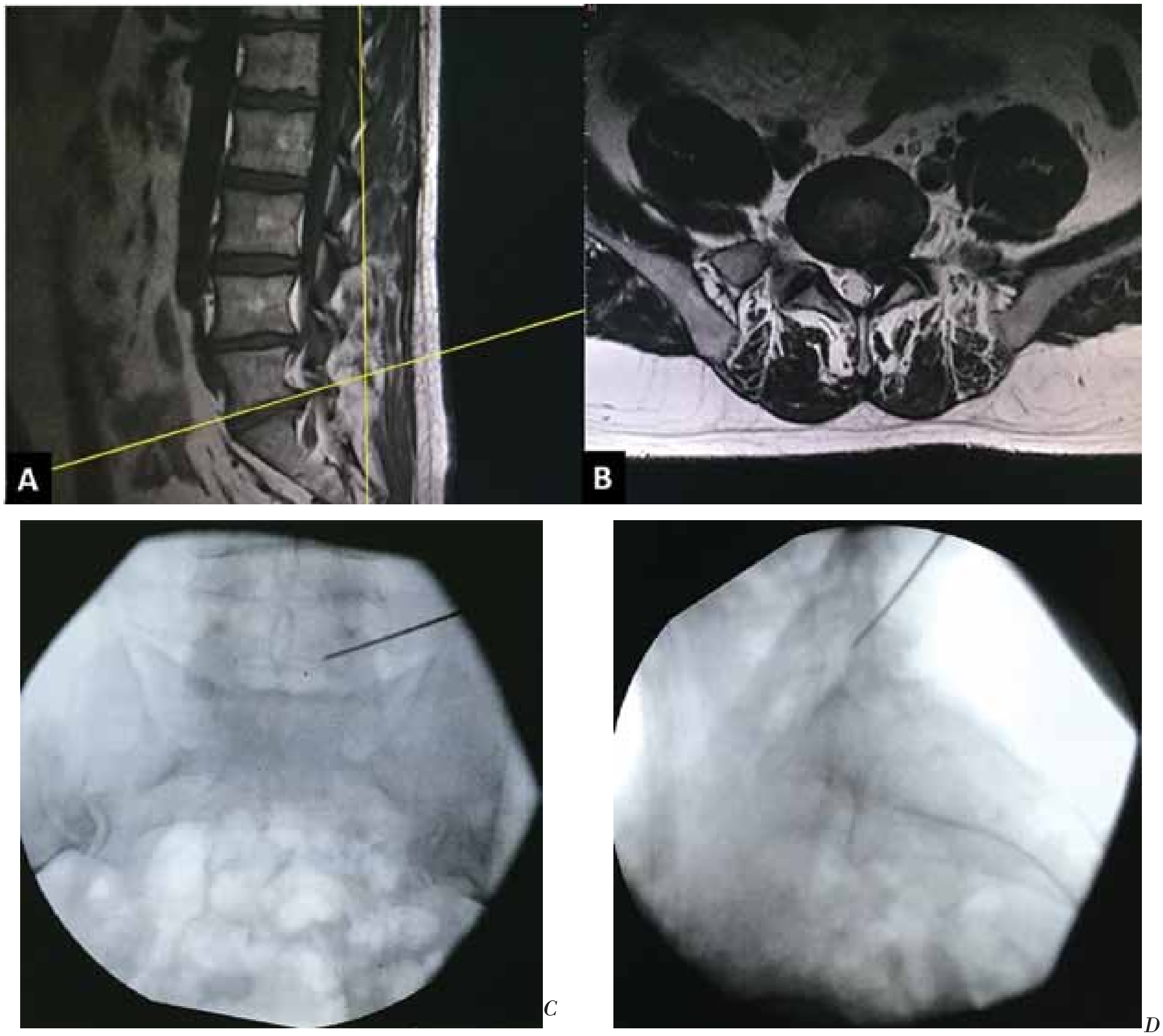

Fig. 4. *Typical case presentation of ideal punctures at L5-S1 level with the accurate preoperative location method. A: lumbar disc herniation at L5-S1 level on magnetic resonance image; B: corresponding cross section of magnetic resonance image showing left paracentral lumbar disc herniation; C: ideal puncture under anteroposterior fluoroscopy; D: ideal puncture under lateral fluoroscopy.*

The analysis of variance (ANOVA) test was used to compare the differences of relevant parameters between the subgroups. The Pearson Correlation test was used to investigate the potential correlation among total fluoroscopy time, operation time, preoperative time, and puncture-channel time. The result was considered statistically significant if the P value was less than 0.05.

Results

The basic characteristics of a total of 160 LDH patients undergoing tPELD are demonstrated in Table 1. There were 34 men and 46 women in Group A and 38 men and 42 women in Group B ($P = 0.525$). The average age was 50.13 ± 9.71 years old in Group A and 51.88 ± 4.37 years old in Group B ($P = 0.144$). BMI was 23.19 ± 1.66 kg/m2 in Group A and 23.12 ± 1.45 kg/m2 in Group B ($P = 0.768$). Conservative therapy time was 10.04 ± 2.52 months in Group A and 9.84 ± 2.26 months in Group B ($P = 0.598$). There were 18 cases at the L3-4 level, 35 cases at the L4-5 level, and 27 cases at the L5-S1 level in Group A, while there were 10 cases at the L3-4 level, 36 cases at the L4-5 level, and 34 cases at the L5-S1

Table 1. *Basic characteristics of included patients undergoing transforaminal percutaneous endoscopic lumbar discectomy.*

Variables	Group A	Group B	*P* value
Gender (men/women)	34/46	38/42	0.525
Age	50.13 ± 9.71	51.88 ± 4.37	0.144
BMI (kg/m2)	23.19 ± 1.66	23.12 ± 1.45	0.768
Conservative therapy time (month)	10.04 ± 2.52	9.84 ± 2.26	0.598
Surgical segment	-	-	0.212
L3/4	18	10	-
L4/5	35	36	-
L5/S1	27	34	-
Anteroposterior voltage (kV)	73.36 ± 4.13	74.35 ± 5.12	0.181
Lateral voltage (kV)	3.17 ± 0.33	3.15 ± 0.31	0.388
Anteroposterior current (mA)	4.16 ± 0.33	4.17 ± 0.43	0.759
Lateral current (mA)	3.17 ± 0.33	3.15 ± 0.31	0.747

level in Group B ($P = 0.212$). There were no significant differences in anteroposterior voltage, lateral voltage, anteroposterior current, and lateral current between the 2 groups ($P > 0.05$).

The fluoroscopy time was 26.78 ± 4.17 in Group A and 33.98 ± 2.69 in Group B ($P < 0.001$). The operation time was 88.36 ± 11.56 minutes in Group A and 98.26 ± 14.90 minutes in Group B ($P < 0.001$). The preoperative location time was 3.43 ± 0.61 minutes in Group A and 5.59 ± 1.46 minutes in Group B ($P < 0.001$). The puncture-channel time was 27.20 ± 4.49 minutes in Group A and 34.64 ± 8.35 minutes in Group B ($P < 0.001$). As it was demonstrated in Fig. 5, a strong correlation was detected between operation time and puncture-channel time (r = 0.804, $P < 0.001$). In addition, there was a moderate correlation between preoperative location time and puncture-channel time (r = 0.408, $P < 0.001$), and a moderate correlation between preoperative location time and fluoroscopy times (r = 0.441, $P < 0.001$). Mild correlations were also observed between preoperative location time and operation time (r = 0.270, $P = 0.001$), as well as between fluoroscopy times and puncture-channel time (r = 0.309, $P < 0.001$). However, there was a negligible correlation between the fluoroscopy times and the operation time (r = 0.174, $P = 0.028$).

As shown in Table 2, the operation time of the first 20 patients was 99.75 ± 10.38 minutes in Group A and 115.7 ± 16.46 minutes in Group B, while the operation time of all 80 patients was 88.36 ± 11.56 minutes in Group A and 98.26 ± 14.90 minutes in Group B. Significant differences were detected in operation time between the 2 groups, both the first 20 patients and the total 80 patients ($P < 0.05$). The ANOVA test showed that there were significant differences in operation time among the 4 subgroups of Group A ($P < 0.001$) and the 4 subgroups of Group B ($P < 0.001$). Similarly, there were significant differences in puncture-channel time among the 4 subgroups of Group A ($P < 0.001$) and the 4 subgroups of Group B ($P < 0.001$). However, there were no significant differences in fluoroscopy time among the 4 subgroups of Group A ($P = 0.930$) and the 4 subgroups of Group B ($P = 0.437$). Moreover, there were no significant differences in preoperative location time among the 4 subgroups of Group A ($P = 0.455$) and the 4 subgroups of Group B ($P = 0.398$).

As demonstrated in Table 3, there were no significant differences in preoperative back VAS, postoperative back VAS, preoperative leg VAS, postoperative leg VAS, preoperative JOA, postoperative JOA, preoperative ODI, and postoperative ODI ($P > 0.05$). However, significant differences were detected between the abovementioned preoperative scores and postoperative scores ($P < 0.05$). Moreover, there was no significant differences in Macnab satisfaction between the 2 groups ($P = 0.179$). There were no major complications in either group, and the intraoperative blood loss was negligible. There were 2 patients with recurrence in Group A and 3 patients in Group B. Twelve patients with postoperative disc remnants were identified in Group A and 9 patients in Group B. No significant difference was identified between the 2 groups ($P = 0.718$).

Discussion

To ensure accurate localization of the puncture target, tPELD relies heavily on repeated fluoroscopy (26). Junior surgeons may be frustrated by multiple

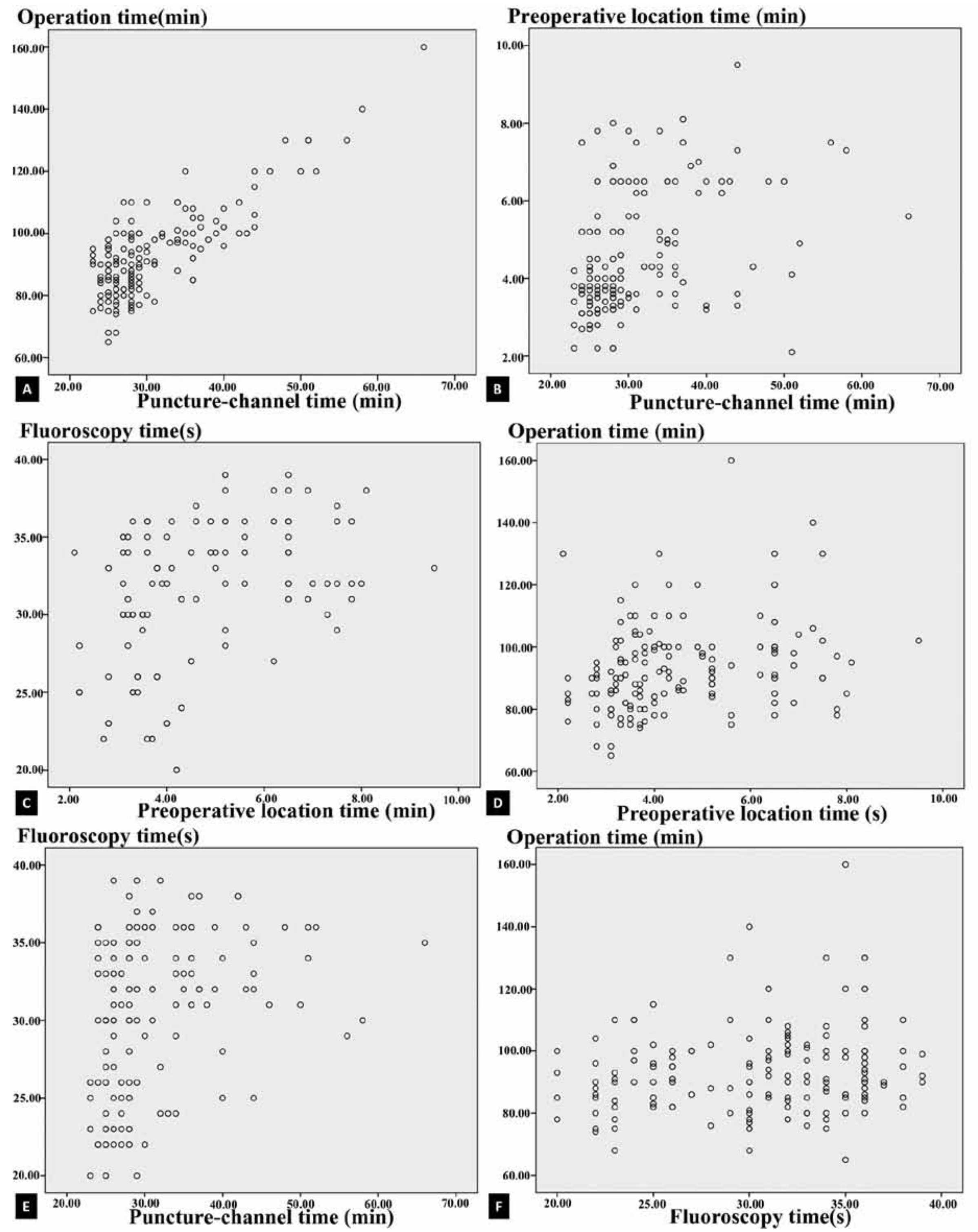

Fig. 5. *Potential correlations among operation time, preoperative location time, puncture-channel time, and fluoroscopy time. A: operation time and puncture-channel time; B: puncture-channel time and preoperative location time; C: preoperative location time and fluoroscopy times; D: operation time and preoperative location time; E: puncture-channel time and fluoroscopy times; F: operation time and fluoroscopy times.*

Table 2. *Clinical outcomes of PTED in subgroups of Group A and Group B.*

Variables		1 – 20	21 – 40	41 – 60	61 – 80	Total
Total fluoroscopy times	Group A	26.85 ± 3.39	26.25 ± 3.39	27.10 ± 5.13	26.90 ± 4.77	26.78 ± 4.17
	Group B	33.95 ± 2.50*	33.45 ± 2.96*	35.05 ± 2.95*	33.45 ± 2.14*	33.98 ± 2.69*
Operation time (min.)	Group A	99.75 ± 10.38	88.35 ± 9.24	83.50 ± 8.71	81.85 ± 8.98	88.36 ± 11.56
	Group B	115.7 ± 16.46*	99.10 ± 7.15*	91.10 ± 6.17*	87.15 ± 7.65*	98.26 ± 14.90*
Preoperative location time (min.)	Group A	3.63 ± 0.66	3.37 ± 0.72	3.38 ± 0.63	3.36 ± 0.39	3.43 ± 0.61
	Group B	5.58 ± 1.69*	5.75 ± 1.43*	5.13 ± 1.30*	5.88 ± 1.42*	5.59±1.46*
Puncture-channel time (min.)	Group A	30.85 ± 7.51	26.80 ± 1.82	25.50 ± 1.54	25.65 ± 1.42	27.2 ± 4.49
	Group B	43.75 ± 9.95*	34.20 ± 5.77*	30.65 ± 4.02*	29.95 ± 3.73*	34.64 ± 8.35*

* $P < 0.05$, significant difference between the 2 groups

Table 3. *Patient-reported outcomes and complications of PTED in the 2 groups.*

Variables	Group A	Group B	*P* value
Preoperative back VAS	6.03 ± 0.99	5.99 ± 1.04*	0.816
Postoperative back VAS	1.39 ± 0.56	1.38 ± 0.56*	0.888
Preoperative leg VAS	5.84 ± 0.95	5.91 ± 1.06*	0.637
Postoperative leg VAS	1.54 ± 0.75	1.49 ± 0.67*	0.657
Preoperative JOA	15.23 ± 1.76	15.36 ± 1.76*	0.622
Postoperative JOA	22.99 ± 1.51	22.76 ± 1.54*	0.353
Preoperative ODI	42.25 ± 8.39	42.08 ± 8.95*	0.899
Postoperative ODI	14.25 ± 3.70	14.68 ± 3.84*	0.477
Macnab satisfaction	-	-	0.151
1	30	31	-
2	36	43	-
3	8	5	-
4	6	1	-
Complications	-	-	0.718
Recurrence	2	3	-
Remnants	12	9	-

fluoroscopy attempts and punctures during their beginning phase of learning tPELD. Therefore, an accurate preoperative location and timesaving puncture period are of great importance, which can reduce the soft-tissue injury and minimize the radiation exposure to both the medical staff and the patients. Moreover, it may lower the learning difficulty of tPELD and increase the confidence of junior surgeons. The current study used a novel preoperative location method, which induced significantly lower preoperative location time, puncture-channel time, fluoroscopy times, and operation time. Additionally, preoperative location time was mildly or moderately correlated with puncture-channel time, fluoroscopy times, and operation times. To the best of our knowledge, this was the first study to identify the impact of accurate preoperative location on the learning difficulty of tPELD.

Conventional localization methods include palpation of the spinous processes of the spine and iliac crests (27,28) and using surgical instruments (clips, Kirschner wires, or spinal needles). The palpation method sometimes is a great challenge when considering a combination of many factors, such as a patient's size, scapular shadows (29), and decreased bone density (i.e., osteoporosis). Moreover, a connecting line of the iliac crests does not always cross the spinous process of L4 or the L4-5 intervertebral space (1), which makes the localization of bony landmarks through palpation not accurate enough. Therefore, this conventional localization method requires numerous radiographic images in a trial-and-error manner. The Kirschner wire method is more frequently used in clinical practice. However, this method may require repeated moving of the Kirschner wire and the C-arm fluoroscopy to make sure the location of the bony landmark. As a result, this method may increase the radiation exposure (30) to both the medical staff and the patients. In addition, the spinal needles method, inserting spinal needles perpendicularly to the skin approximately 3 finger widths lateral to the spine, may increase the risk of infection, and it may also increase the radiation exposure (31). More importantly, the conventional method of planning a pathway and entry point selection were not objectively definite for specific patients, relying heavily on surgeons' experience in assessing patient size, gender, anatomic features, and so on (24). However, beginners might need more tPELD cases to accumulate this experience and overcome this difficulty, which was confirmed in our study.

The novel lumbar location method, however, was very convenient and benefited beginners a lot when performing tPELD. It is mainly based on the surrounding relationship between the surface locator, the surgical target, and the planned pathway. Our previous studies have demonstrated that the surface locator was very efficient in reducing preoperative location time in all kinds of lumbar surgeries (20-22). The application of our surface locator might be more important in tPELD because an accurate preoperative location of the puncture target was the key to an accurate puncture and an ideal placement in the working channel, which are the most difficult procedures and the critical parts of tPELD. We used the surface locator to mark the surrounding vertebral arches, target level, iliac crest, anteroposterior projection, and lateral projection of the puncture target. The intersection point of the anteroposterior projection and lateral projection of an ideally virtual pathway defined the entry point, and the herniated disc location defined the puncture target. Herein, a definite pathway was determined by the puncture target and the entry point (2 points determine a line). During the puncture procedure, the lateral projection of the puncture target might also contribute to the depth of the punctures. Therefore, as we observed in the current study, this practical lumbar location method significantly induced lower preoperative location times. Moreover, lower preoperative location time was associated with lower puncture-channel time, fluoroscopy time, and operation time. Thus, we assumed that accurate preoperative location of the puncture target actually induced less puncture-channel time and fluoroscopy time and finally influenced the operation time.

Generally, the learning curve of tPELD is very deep (17). A deep learning curve might be not bad news for beginners, because they would quickly get command of this technique by conducting tPELD on a small-scale of patients. However, the confidence of the beginners would be certainly destroyed if they punctured dozens of times and needed hundreds of attempts at fluoroscopy. Thus, an accurate location of the puncture target might help beginners manage tPELD more easily. In our study, the operation time of first 20 patients was 99.75 ± 10.38 minutes in Group A and 115.7 ± 16.46 minutes in Group B, which was consistent with similar studies (15,32). An average reduction of 15.95 minutes would definitely increase the confidence of the beginner who used the novel location method. Moreover, the learning curve of Group A was shallower than that of Group B, and the total operation time in Group B was about 10 minutes more on average. These data all indicated that the novel location method reduced the learning difficulty of tPELD.

More importantly, accurate preoperative location of the puncture target might reduce the fluoroscopy times. Radiation exposure is a great concern for medical staff and involved patients (33,34). Conventional localization methods were always associated with more fluoroscopy time and resulted in more ionizing radiation because of the trial-and-error manner. To minimize the radiation exposure, we could use the lead shields, stay away from the emission source, optimize the fluoroscopy setting, and reduce the fluoroscopy time. In the current study, the average fluoroscopy time was 26.78 ± 4.17 in Group A and 33.98 ± 2.69 in Group B, so an average reduction of 7.2 times was observed. Thus, our novel location method potentially minimizes the radiation exposure by reducing the fluoroscopy time.

When using our preoperative lumbar location method in tPELD, the following issues should be noted: (1) to prevent interference of anatomic variations such as lumbarization and lumbar sacralization (29), the radiographs (anteroposterior and lateral films) and MRI should be taken prior to the surgery; (2) the patient should be placed in a prone position on a radiolucent operating table in order to localize the bone landmarks accurately; (3) the x-ray tube of the mobile C-arm fluoroscopy should be vertical to the patients as the tilting of tube may influence the accuracy of localization; (4) the preoperative lumbar location method is just a tiny step in tPELD, and junior surgeons still need to focus on their subjective feelings during punctures and accumulating their experience in endoscopic discectomy.

Conclusions

The accurate preoperative location method lowered the learning difficulty and reduced the fluoroscopy time of tPELD, which was also associated with lower preoperative location time and puncture-channel time.

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