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Original Article

Percutaneous transforaminal endoscopic discectomy is a safer approach for lumbar disc herniation

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Abstract: Objectives: Herein, we explored the safety and efficacy of the percutaneous transforaminal endoscopic discectomy (PTED) and fenestration discectomy (FD) in the treatment of lumbar disc herniation (LDH). Methods: The complete clinical data of 87 LDH patients, who were admitted to the Peking University People's Hospital between May 2018 and March 2020, were retrospectively analyzed. These patients were initially separated into a control (n=39, treated with FD) and research group (n=48, treated with PTED), based on the prescribed treatments. We compared the basic operational conditions between the two groups, and assessed the surgical outcomes using the visual analogue scale (VAS), Oswestry Disability Index (ODI), Japanese Orthopaedic Association Scores (JOA), and modified MacNab scale. Lastly, we analyzed the complication incidence and life quality of patients at 1-year follow up after surgery. Results: All participants in both groups completed the operation. The amount of intraoperative blood loss, surgical duration, length of surgical incision, postoperative ambulation start time, and length of hospital stay were all significantly shorter in the research group as compared to the control group (P<0.05). Moreover, the VAS and ODI scores of the patients in the research group were lower than the control group at 3-months after surgery, while the JOA score was markedly higher (all P<0.05). In addition, the success rate was higher, and the complication rate lower, in the research group, compared to the control group (all P<0.05). Lastly, no statistical differences were observed in the quality of life of patients before the operation, or at 1-year follow up (P>0.05). Conclusions: Based on our analyses, PTED and FD were both effective in treating LDH. However, PTED exhibited a higher success rate, faster recovery time, and was safer than FD.

Keywords: Lumbar disc herniation, percutaneous transforaminal discectomy, fenestration discectomy, lumbar function, complications, quality of life

Introduction

Lumbar disc herniation (LDH), often induced by trauma, is characterized by disc degeneration and rupture, resulting in the protrusion of the nucleus pulposus and compression of adjacent tissues [1-3]. The main clinical manifestation of LDH is pain in the lower back and legs [4]. An increasing number of people lead sedentary lifestyles, owing to alterations in living habits and work styles. This is resulting in an increase of LDH incidence [5]. Unfortunately, patients' insufficient understanding of surgery results in significant delays in procuring the best treatment. In the meantime, long-term lower waist and limb pain seriously damages patient's physical and mental health statuses [6]. LDH generally produces chronic lower back pain which can last a prolonged period of time, and it is prone to recurrence. One study reported that LDH-induced pain can seriously affect a patient's emotions, and trigger anxiety, depression, and insomnia [7]. Generally, pain experience is highly complex and subjective, and is often affected by factors like cognition, emotion, and belief. Additionally, in severe cases, it can directly affect the quality of life of the patients [8, 9].

Currently, LDH is treated with conservative treatments [10] and/or surgery [10]. Conservative treatments include relieving symptoms while improving functions via a series of physical interventions [11, 12]. Surgery, on the

Table 1. Patient baseline information

	Control group (n=39)	Research group (n=48)	χ^2/t	P
Gender [n (%)]			0.1275	0.7211
Male	21 (53.80)	24 (50.00)		
Female	18 (46.20)	24 (50.00)		
Mean age (year)	55.26±16.14	54.81±15.83	0.1321	0.8952
BMI (kg/m^2)	22.31±2.62	21.84±2.03	0.9427	0.3484
Course of disease (day)	10.26±4.33	10.73±4.06	0.5212	0.6036
Segment (n)			0.5624	0.7549
L3-L4	5 (12.82)	9 (18.75)		
L4-L5	26 (66.67)	30 (62.50)		
L5-S1	8 (20.51)	9 (18.75)		
Prominent type (n)			0.8681	0.8331
Side	27 (69.23)	35 (72.92)		
Central	6 (15.38)	5 (12.82)		
Near the central	4 (10.26)	4 (7.13)		
Lateral	2 (5.13)	4 (7.13)		

Note: Chi-squared test and independent sample t test were used to compare the differences between the two groups.

other hand, decompresses the spinal canal, and, if necessary, fusion internal fixation or other such method is employed to restore the mechanical stability of the spine while relieving symptoms [13].

Mixter and Barr [14] first reported that LDH-induced sciatica and nerve root compression can be cured by surgery. This has revolutionized the era of surgical treatment. Open surgery is the current clinical treatment for severe LDH. The development of minimally invasive technologies [15] for disc surgery has made the practice more popular in recent times. In contrast, open surgery is highly invasive, and requires extensive dissection of lower back muscles and soft tissues. This can result in severe trauma and postoperative pain [16]. FD discectomy is a modification of the traditional open surgery. LDH surgery can be performed by full or hemilaminectomy. Compared to full laminectomy, hemilaminectomy minimizes injuries and complications, and produces good efficacy with shorter recovery times. However, it cannot completely overcome the disadvantages of traditional open surgery [17].

Fortunately, minimally invasive spinal techniques [18] continue to emerge, and they do not require stripping of the paravertebral soft tissues. This vastly minimizes trauma, intraoperative bleeding, and postoperative pain, and offers faster recovery time. In addition, minimally invasive surgeries can overcome the operation limitation of spinal canal stenosis, while possessing unique advantages in terms of LDH treatment. In this study, we analyzed and compared the safety and efficacy of percutaneous transforaminal discectomy (PTED) and fenestration discectomy (FD) in treating LDH. Our goal was to report the most appropriate choice of surgical intervention for LDH.

Materials and methods

Research subjects

We retrieved the complete clinical information of 87 LDH patients, who were treated in Peking University People's Hospital between May 2018 and March 2020. We first separated our patient cohort into a control (n=39) and research group (n=48), based on their surgical interventions. The following subjects were included in our analysis: (1) those who presented with typical lumbar and leg pain or numbness and exhibited positive signs in the straight leg elevation test; (2) those who displayed obvious lumbar intervertebral disc herniation by magnetic resonance imaging; (3) those with confirmed diagnosis, but without marked improvement in symptoms, after a minimum of 3 months of strict conservative treatment; (4) those with complete clinical files and follow-up data. The following subjects were excluded from our analysis: (1) those with malignant tumors and liver or kidney dysfunction; (2) those with lumbar infection, tumor, instability, lumbar spondylolisthesis, or other lumbar diseases; (3) those with incomplete clinical files or missing follow-up data. No significant differences were observed between the two patient groups in terms of age, gender, stage of disease, course of disease, and other baseline characteristics. All patient information is summarized in **Table 1**. This study was approved by the Medical Ethics Committee of Peking University People's Hospital.

Surgical methods

The control group was treated with FD. Following successful anesthesia, the patients were placed in a prone position. The skin near and within the surgical area was disinfected with iodine and alcohol, and a sterile surgical drape was put in place. The C-arm of an X-ray machine was employed for fluoroscopy. Following disinfection, a 4-cm median incision was made, with the spinous process space of the diseased segment as the center. The skin was incised from the bony surface of the spinous process on the protruding side of the nucleus pulposus. Next, the tissues were sequentially separated, based on the upper and lower margins of the laminal space. The bone window was then opened, and the tissues were separated to expose the dural sac, nerve roots, and the protruding nucleus pulposus. The protruding nucleus pulposus tissue was excised while avoiding damage to the nerve root and dural sac. Finally, excess normal saline was used to wash the operative incision, and the dural sac was protected with a collagen sponge to prevent bleeding. Upon sufficient hemostasis, a drainage tube was put in place, and the operative incision was sutured layer by layer to complete the surgery.

The research group was treated with PTED. Following routine disinfection, a surgical drape was placed around the surgical field. Under the guidance of C-arm X-ray fluoroscopy, the location of the surgical incision on the skin was marked. Next, the local infiltration anesthesia was done with lidocaine, and an 18 G puncture needle was used to provide layer by layer anesthesia. Once the C-arm fluoroscopy confirmed that the puncture needle was located at the medial edge of the pedicle and the posterior edge of the vertebral body, the puncture needle was inserted into the intervertebral disc, and the guide wire was introduced. A dilator was used to expand the channel step by step while the endoscope was inserted. Under microscopic guidance, the diameter of the intervertebral foramen was found to be too small. Hence, the inner edge of the articular process was removed, using a power grinding drill, to ensure that the intervertebral foramen was expanded, and a proper endoscopic channel was established. Under endoscopic guidance, the nerve root was compressed by the protruding nucleus pulposus, and the nerve root was fully exposed. The protruding nucleus pulposus tissue was removed using nucleus pulposus forceps to relieve nerve root compression. Based on our endoscopic observation, we achieved sufficient decompression of the nerve root, with significant fluctuation. Subsequently, under direct observation, we removed the endoscope and working cannula, and the subcutaneous tissue and skin were sutured with absorbable sutures. The wound was covered with a sterile dressing, and the operation was completed.

All study participants were followed up for one year after surgery.

Observational indicators

(1) The surgical conditions of both groups were compared, including intraoperative blood loss, surgical duration, length of incisions, postoperative ambulation start time, and length of hospital stays.

(2) The visual analogue scale (VAS) was used to score the pain prior to surgery, after discharge, and at the 3- and 6-month follow-up [19]. The scale is a 10-point system in which 0 indicates no pain, and 10 indicates severe pain.

(3) The surgical efficacy was compared between the two groups. Six months post operation, the surgical efficacy was determined, based on the modified MacNab scoring standard [20]. Poor efficacy: no significant improvements were observed in the lumbar and leg pain, lower limb muscle strength, sensorimotor abilities, and straight leg elevation. Good efficacywas achieved when slight lumbar and leg pain still existed which did not affect life and work. Moreover, the muscle strength and sensorimotor abilities of the lower limbs were weakened, and the straight leg elevation was ≤70 degrees and ≥30 degrees. Excellent efficacy: the lumbar and leg pain disappeared, the muscle strength and sensorimotor abilities of the lower limbs was restored to normal, and the straight leg elevation was >70 degrees. The excellent and good rates were computed as follows: (excellent cases + good cases)/total number of cases ×100%.

(4) The Oswestry Disability Index (ODI) [21] was used to assess the impact of low back pain on the daily lives of patients prior to the operation, and at 3-, and 6-months, as well as 1-year fol-

Table 2. Comparison of the surgical conditions between the two groups

	Intraoperative blood loss (mL)	Time of operation (h)	Length of incision (cm)	Postoperative ground time (d)	Length of stay (d)
Control group (n=39)	131.65±25.14	1.97±0.34	0.77±0.18	3.34±0.41	14.87±3.94
Research group (n=48)	29.58±8.29	1.77±0.23	2.87±0.69	2.16±0.97	10.67±4.07
t	26.4450	3.2611	18.4839	7.0936	4.8556
P	<0.0001	0.0016	<0.0001	<0.0001	<0.0001

low-up. A higher score represented more serious dysfunction.

(5) Prior to surgery, and at each follow-up, the Japanese Orthopaedic Association Score (JOA) [22] was used to assess the lumbar spine function of patients, in terms of four dimensions, namely, objective symptoms, subjective symptoms, daily life restrictions, and urination function. A higher score represented better function.

(6) The complication incidences between the two groups were compared, including dural tears, nerve injury, dysesthesia of the limbs on the operative side, infections at the surgical incision, and spinal instability.

(7) The SF-36 scale [23] was used to assess the quality of life of patients prior to and 1 year after surgery. The scale covers physiological function, role-physical, physical pain, social function, energy, emotional function, mental health, and overall health dimension. The score of each dimension is scored 100 points, and higher scores represent higher quality of life. The scale mainly includes physical, cognitive, role, social, and emotional functions. A higher score reflected better quality of life.

Statistical analysis

The statistical analyses were performed using SPSS25.0 (SPSS Inc., Chicago, IL, USA). The measured data are presented as mean ± SD, and independent sample t test was employed for comparison of differences between the two groups; repeated-measures analysis of variance (repeated-measure ANOVA) followed by Bonferroni post hoc test was performed to compare the differences in ODI, JOA, and VAS scores within each group over time. Categorical data were provided as n (%), and the Chi-square test was employed for comparison of differences between the two groups. *P*-value <0.05 was set as the significance threshold.

Results

The operation status of the two groups of patients

The amount of intraoperative blood loss in the research group was markedly lower than the control. The surgical duration, length of incision, postoperative ambulation start time, and length of hospital stay were also shorter in the research group, as compared to the control group (P<0.05). The patient demographic data are summarized in **Table 2**.

The VAS scores of both groups of patients

We employed the VAS scores to compare the degrees of pain between the two patient groups prior to surgery, at discharge, and at the 3- and 6-month follow-up after surgery. Based on our results, there was no discernible difference in the preoperative VAS scores between the two groups (P>0.05). The patients in research group exhibited markedly lower VAS, as compared to the control group, at discharge, and at the 3-month follow up after surgery (P<0.05). However, at the 6-month follow up after surgery, we observed no significant difference in the VAS scores between the two groups (P>0.05). The VAS score data are presented in **Figure 1**.

The efficacy of PTED and FD

At the 6-month follow-up after surgery, the rate of excellent and good surgical outcomes in the research group was significantly higher than in the control group (P<0.05) (**Table 3**).

The ODI scores of both patient groups

We observed no discernible differences in the preoperative ODI scores between the two groups (P>0.05). From 3 months to 1 year after surgery, the ODI scores of both groups exhibited a downward trend (P<0.05). In particular,

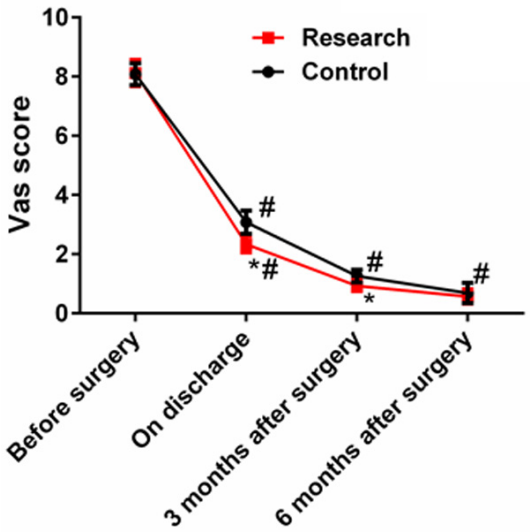

Figure 1. Comparison of VAS scores between the two groups. *P<0.05 *vs.* control group; #P<0.05 *vs.* before surgery in the same group; Independent sample t test was used to compare the differences between the two groups at different time point; repeated-measures analysis of variance followed by Bonferroni post hoc test was performed to compare the differences within each group over time.

the ODI scores of the research group patients were significantly lower, compared to the control group at 3 months after surgery (P<0.05). However, there was no significant difference in the ODI scores between the two groups at the 6-month and 1-year follow ups after surgery (P>0.05), as shown in **Table 4**.

The JOA scores of both patient groups

We observed no marked differences in the preoperative JOA scores between the two groups (P>0.05). From 3 months to 1 year after surgery, the JOA scores of both groups revealed an upward trend (P<0.05). In particular, the JOA scores of the research group were significantly higher than the control group at the 3-month follow-up after surgery (P<0.05). However, there was no difference in the JOA scores between the two groups at the 6-month and 1-year follow-up after surgery (P>0.05). The overall JOA results are presented in **Table 5**.

Complication incidences of both patient groups

In the research group, there was 1 case of hypoesthesia in the surgical limb, and 2 cases of incision infection, with a total complication incidence of 6.25%. In the control group, there was 1 case of dural tear, 1 case of nerve injury, 2 cases of hypoesthesia in surgical limb, 3 cases of incision infection, and 2 cases of spinal instability, with a total complication incidence of 23.07%, which was significantly higher than the research group (P<0.05). The complications are summarized in **Table 6**.

Quality of life of both patient groups

We next compared the quality of life between the research and control group in terms of their physical, cognitive, social, and emotional functions. Based on our analysis, prior to surgery, there were no significant differences in the quality of life indicators between the two groups (P>0.05). At the 1-year follow-up, we observed an upward trend in all quality of life indicators in both groups; however, they did not reach significance between the two groups (P>0.05). The quality of life indicators are summarized in **Figure 2**.

Discussion

The intervertebral disc is critical for spinal support. The intervertebral disc begins to degenerate with aging [24]. With a drastic decrease in the water content of the nucleus pulposus, prolapse risk gradually increases. In addition, the fibers in the annulus fibrosus become thick, brittle, and sometimes, develop cracks. Upon compression or even distortion, increased pressure of the nucleus pulposus contributes to protrusion from cracks, and into the spinal canal. This stimulates and compresses the spinal nerves and spinal cord, which produces a myriad of symptoms related to LDH [25]. LDH is caused by the disordered structure and function of the intervertebral disc. Patients with LDH often report pain, numbness, and other symptoms [26], and their quality of life is severely impacted. Currently, there is an unmet clinical need for the development of effective treatment for LDH patients. In this study, we analyzed the safety and efficacy of PTED and FD in treating LDH. All analyzed subjects completed surgery. Patients in the research group exhibited lower levels of intraoperative blood loss, surgical duration, incision length, postoperative ambulation start time, and hospital stay, relative to the control group. These findings were likely due to the proper visualization of the target PTED surgery. In addition, the rup-

Table 3. Comparison of treatment efficacy between the two groups

	Excellent [n (%)]	Good [n (%)]	Poor [n (%)]	Excellent and good rate [n (%)]
Control group (n=39)	22 (56.41)	9 (23.08)	8 (20.51)	31 (79.49)
Research group (n=48)	37 (77.08)	8 (16.67)	3 (6.25)	45 (93.75)
χ^2				3.9631
P				0.0465

Notes: The chi-squared test was used to compare between the two groups.

Table 4. Comparison of the ODI scores between the two groups

	Preoperative	Three months after surgery	Six months after surgery	The first year after surgery
Control group (n=39)	54.68±6.48	39.64±4.68*	14.68±2.84$^{*,\#}$	12.34±1.77$^{*,\#,\&}$
Research group (n=48)	53.84±7.21	24.15±3.22*	13.79±3.67$^{*,\#}$	12.19±1.48$^{*,\#,\&}$
t	1.4860	0.8494	0.7167	0.3484
P	0.5734	<0.0001	0.2177	0.6679

Note: *P<0.05 *vs.* preoperative; $^{\#}$P<0.05 *vs.* three months after surgery; $^{\&}$P<0.05 *vs.* six months after surgery; Independent sample t test was used to compare the differences between the two groups at different time point; repeated-measures analysis of variance followed by Bonferroni post hoc test was performed to compare the differences within each group over time.

Table 5. Comparison of the JOA scores between the two patient groups

	Preoperative	Three months after surgery	Six months after surgery	The first year after surgery
Control group (n=39)	12.64±1.38	16.48±2.06*	21.87±2.11$^{*,\#}$	23.84±3.24$^{*,\#,\&}$
Research group (n=48)	12.21±1.52	19.17±1.87*	22.73±2.46$^{*,\#}$	24.26±3.91$^{*,\#,\&}$
t	0.3145	0.4219	0.4980	0.7816
P	0.1752	<0.0001	0.0878	0.5924

Note: *P<0.05 *vs.* preoperative; $^{\#}$P<0.05 *vs.* three months after surgery; $^{\&}$P<0.05 *vs.* six months after surgery; Independent sample t test was used to compare the differences between the two group at different time point; repeated-measures analysis of variance followed by Bonferroni post hoc test was performed to compare the differences within each group over time.

Table 6. Comparison of complication incidences between the two groups

	Dural tear	Nerve injury	Numbness of sensation in operative limb	Infection of incisional wound	Spinal instability	Total incidence
Control group (n=39)	1 (2.56)	1 (2.56)	2 (5.13)	3 (7.69)	2 (5.13)	9 (23.07)
Research group (n=48)	0 (0.00)	0 (0.00)	1 (2.08)	2 (4.17)	0 (0.00)	3 (6.25)
χ^2						5.1241
P				0.0236		

Notes: The chi-squared test was used to compare between the two groups.

tured annulus fibrosus location was accurately identified prior to surgery using contrast to better reach the protruding position, as described before [27]. The nucleus pulposus removal, along with the direct decompression of the nerve roots, produces less damage to the spinal bone, paravertebral muscles, and soft tissue, thereby, inducing minimal postoperative complications. Moreover, in PTED, the incision was smaller, there was less blood loss, and the postoperative recovery was faster, which, in turn, shortened the hospital stay of patients.

The VAS scores of patients in the research group were significantly reduced, compared to the control group, both at discharge and at the 3-month follow up after surgery. However, there was no significant difference between the two groups at the 6-month follow up after surgery (P<0.05). Our results revealed that both surgi-

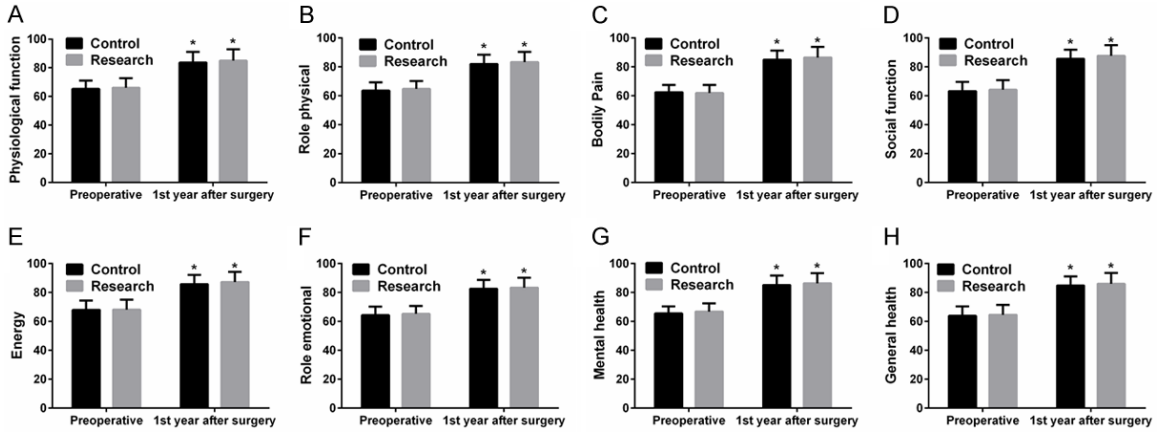

Figure 2. Comparison of quality of life between the two groups. A: Physiological function score; B: Role physical score; C: Bodily pain score; D: Social function score; E: Energy score; F: Role emotional score; G: Mental health score; H: General health score; *P<0.05 vs. same group before the operation. Sample t test was used to compare the differences between the two groups, whereas, paired t test was used to compare within groups.

cal procedures markedly improved LDH-induced pain. However, FD necessitated the stripping of the paravertebral muscles on the articular and spinous processes, which, in turn, injured the innervation nerve, and promoted muscle denervation, muscle degeneration, atrophy, and ultimately, postoperative lumbar pain [28]. PTED is a minimally invasive operation. Radiofrequency therapy can be used to repair the damaged annulus fibrosus, minimize intraoperative blood loss, as well as reduce the risk of postoperative nerve root adhesion and intraspinal scar formation. Moreover, radiofrequency therapy can denervate the intervertebral disc, and relieve pain [29]. Our comparison of the ODI and JOA scores at the 6-month and 1-year follow-up after surgery revealed that the ODI score of the research group was significantly lower than the control group. Moreover, at the 3-month follow up after surgery, the JOA score was significantly higher than the control group. Since pain is an essential factor that influences recovery of lumbar spine function following surgery, if the pain sensation is relatively low, the patient can leave the bed to conduct functional rehabilitation exercises, which can greatly shorten recovery time [30].

The complication incidence in the research group was significantly lower than in the control group. PTED guarantees the safety of anatomical positions, and with the help of an endoscope, can obtain a clear surgical field of vision. In addition, it can avoid damage to essential tissues and organs, such as, blood vessels and dura mater. Reducing local damage is highly beneficial to lowering the risks of postoperative complications, while maintaining the anatomical structure and biomechanical stability of the lumbar spine [31]. Furthermore, saline perfusion during PTED can also clear inflammatory mediators around the diseased intervertebral disc, and prevent the accumulation of by-products caused by heat treatment, thus preventing infection [32]. Finally, we compared the pre- and post-operative life quality scores of both groups of patients and revealed no significant differences between the two (P>0.05). Our results sugges that both surgical procedures are effective long-term.

This study has certain limitations. First, it was a retrospective analysis. In the future, a prospective, well-designed, randomized controlled trial is necessary to validate the efficacy of PTED. Secondly, our sample size was relatively small, which may have affected the results of this study. Therefore, additional investigations, involving a larger sample size, are warranted to further confirm the results. Finally, our follow up time was not long enough to obtain a long-term curative effect.

In conclusion, PTED and FD can effectively relieve pain and improve lumbar function in patients with LDH. However, PTED can significantly reduce intraoperative bleeding, trauma, recovery times, and incidence of postoperative complications. Given this evidence, PTDE is a safer approach, and we recommend its routine application in the clinic.

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Disclosure of conflict of interest

None.

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