Application of Percutaneous Endoscopic Interlaminar Discectomy (PEID) with Modified Sensation-Motion Separation Anesthesia in the Treatment of L5-S1 Disc Herniation

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Abstract

Study Design: A retrospective cohort study.

Purpose: To compare the clinical effects of local anesthesia (LA), general anesthesia (GA) and modified sensation-motion separation anesthesia (MA) in percutaneous endoscopic interlaminar discectomy (PEID) for treating L5/S1 lumbar disc herniation (LDH) and guide the junior surgeons.

Patients and methods: Eighty-four patients with L5/S1 LDH underwent PEID using three anesthesia methods. Patients in groups LA (26), GA (29) and MA (29) were given a follow-up examination retrospectively. General parameters, preparation and anesthesia time, operation time, recovery time, incidence rate of complications, ambulation time, length of hospital stay, severe complications, and reoperation rate were compared, and clinical outcomes were analyzed using a visual analog scale (VAS), the Oswestry Disability Index (ODI), and the Short-Form Health Survey 36 (SF-36).

Results: MA demonstrated obvious advantages over the other two methods in operation time and led a better intraoperative experience than LA. Group MA and LA required less time in bed postoperatively and shorter hospital stays than group GA. The mean postoperative VAS score, ODI score and SF-36 score were significantly better than the preoperative values in all groups ($P < 0.05$), but no significant differences were found among the three groups ($P > 0.05$). Three cases (3/29) of nervous disorder occurred in the GA group. Two cases in the GA (1/29) and LA (1/26) groups were revised among all three groups, with a total recurrence rate of 2.4% (2/84).

Conclusions: Modified anesthesia with sensation-motion separation was a suitable method for spinal surgeons who were inexperienced with PEID in the treatment of L5/S1 disc herniation due to its high safety and good patient tolerance.

Introduction

Percutaneous endoscopic lumbar discectomy (PELD) is a minimally invasive technique for the treatment of a common spinal pathology, symptomatic lumbar disc herniation (LDH). The technique is effective for almost all locations of disc herniations, with an overall failure rate of 4.3%, reoperation rate of 2.4–8.5% and recurrence rate of 0.8%.^{1–3} In cases of a high-riding iliac crest or hypertrophied local transverse processes, lateral insertion into the working channel is difficult, which poses a challenge to PELD.^{4,5} Hence, Rutten in 2005 and Choi in 2007 independently described a novel approach, percutaneous endoscopic interlaminar discectomy (PEID).^{6–9} The corridor for PEID is similar to that for traditional microendoscopic discectomy (MED), except the working channel can be docked through the ligamentum flavum (LF) between the interlaminar space, whereas in MED, the working channel is docked upon the interlaminar space without tough dura, which makes PEID a higher risk procedure than MED. Traditionally, while the patient is under general anesthesia (GA), any procedures that require a working channel that enters or exits the spinal canal will potentially injure the neural structures, especially when the surgeon is a beginner. With the intraoperative feedback of patients, local anesthesia (LA) is an alternative method

applied in PEID that benefits patients by reducing the risk of iatrogenic nerve injury and postoperative cognitive dysfunction (POCD).^{10,11} However, pain induced by cutting the ligamentum flavum (LF) with scissors, manipulating the disc annulus fibrosus and rotating the working channel may cause extreme nervousness in the patients and make the surgery under LA a tough process. Since epidural anesthesia (EA, referred to here as MA, modified anesthesia) with ropivacaine can preserve motor function of lower limbs and selectively blocks sensation during surgery¹², in the current research, we introduced a modified anesthesia technique based on the sensation-motion separation effect of ropivacaine with the synergistic effect of sufentanil¹³ as a compromise method, in which both the patients and surgeons could achieve favorable intraoperative experiences.

The purpose of this study was to compare the efficacy of PEID under three different types of anesthesia, namely, LA, GA and MA, and provide an excellent strategy for beginners to reduce the risk of neurological complications and associated anesthetic accidents and improve the efficiency of the operation.

Methods

Patients

The clinical data of 84 patients with lumbar disc herniation at L5/S1 who underwent PEID performed by the same surgeon between October 2017 and December 2018 were retrospectively analyzed. The subjects were divided into three groups LA (26), GA (29), and MA (29), according to the methods of anesthesia they selected voluntarily preoperatively. The cost of the different anesthesia methods, in order from most to least was GA, MA, LA; and the cost was the main determinant that the patients made based their decision on. At admission, all patients complained of unilateral sciatica and had no lateral recess stenosis radiologically.

Surgical Procedure

The L5/S1 interlaminar window in most patients was wide enough to accommodate the working cannula; otherwise, patients were kept in the prone position with flexion of the knees and hip joints to increase the interlaminar space. Furthermore, a Karrison rongeur was used to enlarge the space.

A posterior transverse 7 mm incision was made approximately 5 mm adjacent to the spinous process. The procedural technique varied slightly. PEID was carried out via the endoscopic spine system (Joinmax, Karlsruhe, Germany). In group LA, the skin, lumbodorsal fascia and attachment between the ligamentum flavum and lamina were anesthetized with a 10 ml mixture of 1% lidocaine and 0.5% ropivacaine at a 1:1 ratio, and the extradural intraspinal canal or surrounding zone of nerve roots was anesthetized with a 5–10 ml mixture of 0.5% lidocaine and 0.25% ropivacaine at a 1:1 ratio. Anesthetic would be added intraoperatively if necessary. In direct communication with the patient and to achieve adequate pain management, the puncture needle and working cannula were introduced at the dorsal part of LF in turn under fluoroscopic guidance; then followed by drilling and/or cutting or splitting of LF and removing the herniated disc under endoscopic view according to the preference of professor Choi⁶. In group MA, the

procedure was carried out under standard epidural anesthesia technique with a puncture at the L2/3 segment and catheter approximately 4 cm into the epidural space. Once the patient was in the prone position, the anesthesiologist injected a mixture of 5 ml 0.25% or 0.2% ropivacaine and 5 ml sufentanil (250 µg) according to the height, weight and pain threshold of the patient. In detail, a total of mixture 3 mL was applied initially and if the leg could move 5 minutes later, it indicated that the anesthetic was not in the subarachnoid space. The second time residual mixture was added to adjust the sensory level and achieve the aim of sensory-motor separation. The optimal state of anesthesia was patients can still encounter sustainable minimized pain while motor nerves was not blocked. After successful epidural anesthesia, the puncture needle and the working channel were placed at the level of the herniated disc in sequence, just dorsal to the ligamentum flavum. The rest of the procedure remained similar: separating or dissecting the ligamentum flavum, relocating the working channel, identifying the nerve root and the herniated disc, and completing discectomy under endoscopy according to the procedure introduced before.^{6–8} In group GA, since the patient was completely under unconscious conditions, the puncture needle and working channel were placed with a technique similar to that in group MA.

Follow-up Evaluations

The clinical outcomes were compared among the three groups using a self-reported visual analog scale (VAS), the Oswestry Disability Index (ODI), and the Short-Form Health Survey 36 (SF-36), the scores of which were recorded before and after the operation. Peri- and postoperative data were collected including the preparation and anesthesia time, operation time (from skin incision to closure), recovery time (from incision closure to leaving operating room), complications, length of hospital stay, ambulation time, and reoperation rate. Spinal MRI was performed to evaluate the extent of decompression and removal of the nucleus pulposus on postoperative day 1 and at 6 months' follow-up. The recurrence of disc herniation was classified as disc herniation on the primary operative site after a successful initial removal of the protruding disc and a pain-free interval that lasted for at least longer than 2 weeks, that was revealed on the following MRI.

Statistical Analysis

Statistical analysis was completed using SPSS 17.0 software. For demographic information and clinical parameters before and after the operation, group differences were examined with χ^2 test, one-way ANOVA, the least significant difference t-test (LSD-t) and Fisher's test, as applicable. Measurement data was expressed as mean value with standard deviation (SD). The statistical significance was defined as P-values of < 0.05.

Results

All patients who suffered from L5/S1 lumbar disc herniation in the three groups underwent PEID. The demographic characteristics of the three groups are summarized in Table 1. Group LA included 17 males and 9 females, with a mean age of 34.2 years (range 16–71 years), and their mean symptom duration was 11.7 months (1.5–102 months). Eight patients suffered from disc herniation with epiphysis annulus

separation or calcifications. In group GA, there were 18 men and 11 women with a mean age of 38.8 years (range 22–68 years), and the mean symptom duration was 12.5 months (1–108 months). Seven patients suffered from disc herniation with epiphysis annulus separation or calcification. In group MA, 19 males and 10 females with a mean age of 37.4 years (range 17–65 years) and a mean symptom duration of 11.5 months (1–96 months) were included. Eight patients suffered from disc herniation with epiphysis annulus separation or calcification. The mean follow-up periods were 16.4 months (11–26 months), 15.6 months (10–24 months) and 15.1 months (11–23 months), respectively. No differences were found in the above data or the composition of herniated disc type among the three groups.

Table 1
Preoperative Demographic and Clinical Characteristics

Characteristics		LA	GA	MA	P Value
Number		26	29	29	
Gender	Male	17	18	19	0.95
	Female	9	11	10	
Mean Age (years)		34.2 (16–71)	38.8 (22–68)	37.4 (17–65)	0.81
Mean Duration (months)		11.7 (1.5–102)	12.5 (1–108)	11.5 (1–96)	0.98
Protrusion	Soft Disc	18	22	21	0.86
	Disc with Epiphysis Annulus Separation	8	7	8	
Herniation Type	Central	9	11	11	0.92
	Paramedian	12	14	15	
	Migrated	5	4	3	
Follow-up period (months)		16.4 (11–26)	15.6 (10–24)	15.1 (11–23)	0.39
LA, local anesthesia; GA, general anesthesia; MA, modified sensation-motion separation anesthesia.					

The perioperative characteristics are summarized in Table 2. MA demonstrated obvious advantages over the other two methods in operation time and led to a better intraoperative experience than LA. The average operation time after the skin incision was 54.23 ($P < 0.001$ vs MA) minutes in group LA, 58.75 ($P < 0.001$ vs MA) minutes in group GA and 42.51 minutes in group MA. In group LA, most of the patients complained of frequent pain (4.35, $P < 0.05$ vs 2.62 in MA) during the operation around the nervous tissue (Table 3) that always influenced mentality and required proper management from the surgeon, which was considered the main cause of the prolonged operation time. The mean preparation and anesthesia time was 5.5 ($P < 0.001$ vs MA) minutes in group LA, 21.93 ($P < 0.001$ vs MA) minutes in group GA and 12.59

minutes in group MA. Conducting the procedure of epidural anesthesia in MA often requires a certain amount of time. In the other hand, group MA (min) required almost identical recovery time before leaving operating room as LA (min), which was faster than that in GA (min). In regard to nerve root or dura damage, three patients in group GA (3/29, 10.34%) showed obvious sciatica after anesthesia recovery that was ascribed to intraoperative working tube adjustments without patient feedback. Moderate postoperative sensory paralysis due to an overdose from the anesthetic injection was observed in one patient in group MA (1/29, 3.45%), who recovered 6 hours after returning to the ward, but no statistical significance was identified among the three groups. Also, the ambulation time data indicated that faster rehabilitation was achieved in groups LA (5.5 hours) and MA (5.79 hours) than in group GA (11.41 hours). Moreover, the mean length of hospital stay was 2.96 days in group LA ($P > 0.05$ vs MA) and 3.10 days in group MA, both of which were shorter than the 4.76 days in group GA ($P < 0.001$ vs MA/LA). During the follow-up period, disc herniation recurrence requiring subsequent reoperation was observed in one patient in group GA (1/29) and one patient in group LA (1/26), with a total recurrence rate of 2.4% (2/84).

Table 2
Summary of Perioperative Outcomes, Complication, and Reoperation

Difference among three groups (P-values)							
Parameters	LA(26)	GA(29)	MA(29)	Total Rate	LA vs GA	LA vs MA	GA vs MA
Preparation and Anesthesia time(min)	5.50 ± 0.99	21.93 ± 4.86	12.59 ± 3.48	< 0.001	< 0.001	< 0.001	< 0.001
Operation Time(min)	54.23 ± 7.32	58.75 ± 5.98	42.51 ± 5.17	< 0.001	< 0.01	< 0.001	< 0.001
Recovery Time(min)	8.69 ± 2.03	32.72 ± 5.69	8.90 ± 2.36	< 0.001	< 0.001	0.37	< 0.001
Ambulation Time(hour)	5.50 ± 1.17	11.41 ± 2.06	5.79 ± 1.05	< 0.001	< 0.001	0.17	< 0.001
Hospitality(day)	2.96 ± 0.82	4.76 ± 0.86	3.10 ± 0.74	< 0.001	< 0.001	0.24	< 0.001
Neurological Disorders(n) ^a	0/26	3/29	1/29	0.32	0.24	1	0.61
Reoperation rate(n) ^a	1/26	1/29	0/29	0.76	1	0.47	1
LA, local anesthesia; GA, general anesthesia; MA, modified sensation-motion separation anesthesia. ^a Statistical analysis was conducted by Fisher's exact test							

Table 3
Clinical Improvement According to the Parameters

Difference among three groups (P-values)							
Parameters	LA(26)	GA(29)	MA(29)	Total Rate	LA vs GA	LA vs MA	GA vs MA
Pre-VAS	8.25 ± 0.99	8.41 ± 1.01	8.29 ± 0.91	> 0.05	0.54	0.89	0.63
Intra-VAS	4.35 ± 1.45	-	2.62 ± 1.29	-	-	< 0.05	-
Post-VAS	1.84 ± 0.89 ^a	2.03 ± 0.94 ^a	1.93 ± 0.88 ^a	> 0.05	0.22	0.36	0.33
Pre-ODI	38.79 ± 11.19	42.25 ± 6.17	38.64 ± 11.16	> 0.05	0.19	0.96	0.17
Post-ODI	4.71 ± 5.56 ^b	5.04 ± 5.94 ^b	4.61 ± 5.09 ^b	> 0.05	0.83	0.94	0.83
Pre-SF-36	327.34 ± 69.57	331.94 ± 67.26	344.95 ± 65.74	> 0.05	0.80	0.33	0.48
Post-SF-36	492.70 ± 31.93 ^c	493.13 ± 31.25 ^c	497.76 ± 30.00 ^c	> 0.05	0.96	0.54	0.58
LA, local anesthesia; GA, general anesthesia; MA, modified sensation-motion separation anesthesia; VAS, visual analogue scale; ODI, Oswestry Disability Index; SF-36, Short-Form Health Survey 36.							
^{a b c} P < 0.05 compared with preoperative correlates.							

The preoperative and postoperative scoring parameters are shown in Table 3. The mean postoperative VAS, ODI and SF-36 scores were all obviously improved compared with the preoperative values in the three groups ($P < 0.05$), and no significant differences were found among the three groups ($P > 0.05$), indicating that similar clinical efficacy was obtained. Nevertheless, as mentioned above, subjects who received local anesthesia were more sensitive to nerve stimulation and exhibited higher intraoperative VAS scores (4.35) than those in the MA (2.62) group ($P < 0.05$). When the nerve root was exposed and the herniated disc was removed, the intraoperative VAS scores of all patients in groups LA and MA, especially the former, increased suddenly; however, this increase lasted only seconds. Among the three groups, all patients had good MRI findings at the last follow-up (Fig. 1, 2).

Discussion

PEID is an effective and alternative surgery for the treatment of L5/S1 lumbar disc herniation and even for special cases of L4/5 disc herniation, since this procedure could be easily carried out by spinal surgeons with extensive experience in open surgery and local anatomy. In comparison with percutaneous endoscopic transforaminal discectomy (PETD), the wide space between the L5/S1 interlamina makes it easy to enter the spinal canal, decompress the nerve root and remove the protruded disc.^{14,15} However,

the operating procedure involves entering the spinal canal and retracting the nerve root directly, potentially causing postoperative complications. Commonly, most spinal surgeons prefer to perform PEID to treat L5/S1 disc herniation, while other physicians, such as pain specialists and interventional radiologists, always select PETD for all types of lumbar disc herniation, even those with high iliac crests. In our department, PETD is mostly applied to treat far lateral disc herniation at the L5/S1 level. In regard to long-term clinical efficacy, PEID and PETD do not seem to always differ significantly.¹⁶

Both PETD and PEID, other than the method of anesthesia, truly reflect the nature and techniques of minimally invasive surgery (MIS) in the treatment of degenerative diseases. Endoscopic discectomy is a complicated procedure that relies heavily on patient feedback during surgery. This goes for both the transforaminal approach and the interlaminar approach. General anesthesia has been widely adopted in almost all spinal surgeries due to the ease of controlling vital signs. Nonetheless, general anesthesia also has obvious drawbacks, such as no timely feedback while the patient is unconscious, as well as a higher requirement regarding the skills and experience of surgeons.¹⁷ Relevant studies showed GA may have greater risk of neurological complications, rendering patients unable to cooperate with the surgeon.¹⁷ Compared to those of PETD, the complications of PEID are much more troublesome and serious.¹⁸ Since the spinal canal is opened and the dura matter or nerve root must be retracted during the surgical procedure, complications such as dural avulsion, nerve root damage, and epidural hematoma are more likely to occur¹⁹. In this study, a total of 3 patients among the 29 patients in group GA experienced neurological deficits after the operation, which is as higher proportion than that in the other two groups. Possibly, the lack of a significant difference could be attributed to the small amount of sample. However, the occurrence of nerve injury in patients in group GA, highlights the potential importance of real-time intraoperative patient feedback within these procedures. In the early stage of learning PEID under general anesthesia, junior surgeons might have difficulty in distinguishing nerve root from the surrounding tissue accurately. Although under endoscopic view, the process of inserting working cannula (with an external diameter of 6.9 mm or 6.3 mm) through the ligament flavum and relocating the instrument in the spinal canal might tear the dura directly. Sometimes, to dissect the far migrated discs, the nerve root or dura would be roughly handled and prolonged or strenuously retracted without any reaction from the patients. Fortunately, all 3 patients recovered well after 3 months. Based on our experience, any steps or movement toward the nerve roots should be careful and slow enough to establish a “more controlled” environment and avoid damage because there are no subjective responses from unconscious patients during the operation. Consequently, the operation time and duration of anesthesia increased with the use of general anesthesia (58.75 ± 5.98 minutes, Table 2), and thus, anesthetic accidents or postoperative nausea and emesis are more likely to occur in patients with poor physical condition.²⁰ Mostly, intraoperative neurophysiological monitoring should be considered if general anesthesia is applied, and that may raise treatment expense (data not shown).

Local anesthesia has always been employed by pain specialists and interventional practitioners for the purposes of reducing the risk of nerve injury²¹. During this procedure, patients can provide instant feedback on their feelings and communicate their physical information to the doctor, especially any

sensations of temporary and sharp pain ²². However, sometimes the sharp pain and agitation could disturb the progress of the surgery (54.23 ± 7.32 minutes, Table 2) and increase the mental burden on surgeons, especially inexperienced novices, because they are always worried about nerve damage while progressing through the procedure, and thus the procedure may have to be stopped.²³ In fact, the patients usually had a poor surgical experience under local anesthesia, but the surgeon also usually experienced unpleasant challenges.

For spine surgeons and beginners in the early period of learning PEID, in order to minimize discomfort and pain and allow for real-time communication by receiving continuous feedback from patients to prevent neural damage and help monitor clinical improvements during the operation, we attempted a modified anesthesia method with the assistance of the sensation-motion separation effect of ropivacaine and synergistic effect of sufentanil to maintain a condition of consciousness, painlessness and freedom of movement during the operation. Patients could also move their lower limbs when the surgeons required to identify nerve injury. On the other hand, literatures have suggested the concentration of ropivacaine played important role in the alleviation of pain ²⁴. Kathuria ²⁵ and Zhu ²⁶ et.al separately reported that low concentrations of ropivacaine such as 0.25% or 0.375% could only block the sensory nerves without motor nerves being completely blocked, thus had better effectiveness in pain management when used in EA. Previously we tried different concentrations of ropivacaine according to the body condition of various patients with the help of anesthesiologists, and the concentrations ranged from 0.1–0.375%. For most patients, ropivacaine of 0.2% or 0.25% could be the ideal concentrations and 10 ml total would be a satisfactory volume. Another advantage of MA was the ease in controlling the dosage of anesthetics. Nevertheless, attention should also be paid to individual diversity in pain and drug responses, as well as nerve root anomalies.

It is not surprising that patients undergoing spinal anesthesia had a better intraoperative experience than patients received local anesthesia. Of the 29 patients who received MA, we obtained a satisfactory result that all patients achieved free movement of the lower limbs, and simultaneously did not complain about severe pain (with intra-VAS score of 2.62 ± 1.29 , Table 3). Since no difference was identified in the type and location of protrusions (Table 1), the difference in intraoperative pain intensity between groups LA and MA was not associated with operational discrepancies between individuals. Only one patient had lower limb paresthesia, which was found to be caused by an excessive concentration and dosage of anesthetic injection in the attempt to obtain a satisfactory painless condition at the early stage, and the disorder subsided 6 hours later. By receiving indispensable feedback and avoiding unnecessary distractions from the patients, the surgeon could complete the operation in a more leisurely manner, which could explain why the operation period in group MA was significantly shortened ($P < 0.001$ vs GA and LA).

Another noteworthy matter was the similar recovery rate after surgery in the MA and LA groups. Because of the efficacy of sensation-motion separation and faster metabolism of anesthetics, patients under MA could be resuscitated more quickly from anesthesia than patients under GA, and could immediately cooperate with the routine examination of lower limb activity after leaving the operating table, and thus

could return to the wards faster (Table 2). Ye et.al²⁷ also demonstrated a higher score of postoperative cognitive function in patients received PEID under epidural anesthesia than GA group, suggesting that epidural anesthesia had positive significance for the improvement of cognitive function. In the current study, the ambulation time in group MA, as well as that in group LA, was obviously shorter than that in group GA ($P < 0.001$). Moreover, vital signs were usually monitored and evaluated for 24 hours before discharge for those who received general anesthesia. Hence, the length of hospital stay in group GA was prolonged ($P < 0.001$ vs LA and MA).

With regard to the reoperation rate in this study, only one patient in group GA received revision surgery at 2 months postoperation because of a fall while intoxicated, which made it difficult to analyze if there were statistically significant correlations between reoperation rate and different anesthesia method for PEID. Previous studies have suggested that the incidence of recurrence was 5.5% after PEID with annular sealing and 13.5% after PEID without annular sealing, and age was correlated with overall recurrence and late recurrence, whereas operative technique only correlated with early recurrence.²² Noteworthy, here we identified no significant difference in the recurrence rate among the three groups, and the reason for the low reoperation rate in this study may be due to the relatively small sample size and short follow-up period.

In addition, postoperative dysuria is side effect of excessive EA which need to be considered^{17,28}. Even though that didn't occur in this study and was reported to normally disappear in hours. In the case of MA, an experienced anesthesiologist is recommended to avoid spinal cord damage/cauda equina damage and for control sensory-motor separation.

According to the current findings, for spinal surgeons who are inexperienced with PEID to treat L5/S1 disc herniation, MA would be superior choice because of its effectiveness in avoiding nerve root injury, increasing the pain tolerance and easing the anxiety of the beginner surgeons, as well as speeding recovery. Our practical experience is, that LA is suggested to be applied once the doctors have gained sufficient operational experience of various endoscopic surgeries in more than 100 cases and have less fear of distractions from patients. After attaining sufficient endoscopic operational experience in more than 200 cases, the surgeon could perform endoscopic surgery perfectly and deal with complex situations, and GA would be more proper for PEID.

Limitations

Retrospective design of the study, limited cases are the main inherent defects which may lead to biases. A larger sample size is needed to corroborate the favorable effect of MA in PEID for treating L5/S1 LDH.

Conclusion

As an alternative and efficient procedure, PEID can be widely used to treat the L5/S1 disc herniation. The study successfully demonstrated that modified anesthesia of sensation-motion separation was a

suitable method for spinal surgeons who are inexperienced with PEID in the treatment of L5/S1 disc herniation.

Abbreviations

EA: Epidural anesthesia

GA: General anesthesia

LA: Local anesthesia

LDH: Lumbar disc herniation

LF: Ligamentum flavum

MA: Modified sensation-motion separation anesthesia

MED: Microendoscopic discectomy

ODI: Oswestry Disability Index

PEID: Percutaneous endoscopic interlaminar discectomy

PELD: Percutaneous endoscopic lumbar discectomy

PETD: Percutaneous endoscopic transforaminal discectomy

POCD: Postoperative cognitive dysfunction

SF-36: Short-Form Health Survey 36

VAS: Visual analog scale

Declarations

Statement

Ethics approval and consent to participate

This study was approved by the ethics committees of the Affiliated Hospital of Qingdao University. All patients involved gave verbal informed consent for their medical records to be reviewed.

Availability of data and materials

The detailed data and materials of this study were available from the corresponding author through emails on reasonable request.

Competing interests

The author reports no conflicts of interest in this work.

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Contributions

Chuanli Zhou and Xuexiao Ma designed the study and revised the manuscript. Meng Kong, Changtong Gao and Chao Wang acquired, and analyzed the data and drafted the paper. Shuo Han, Derong Xu, Guanghui Li and Xing Han searched relevant literature, Meng Kong approved the final version of the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1

Preoperative MRI (A) and CT (B) of a male patient received PEID at L5/S1 level using MA. PEID, percutaneous endoscopic interlaminar discectomy; MA, modified sensation-motion separation anesthesia.

Figure 2

One-year postoperative MRI (A) and CT (B) of the patient mentioned in Fig. 1.