Clinical Outcomes of Lateral Lumbar Interbody Fusion Combined with Percutaneous Endoscopic Lumbar Discectomy During the Treatment of Low-grade Spondylolisthesis

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Abstract

Background

Minimally invasive lateral lumbar interbody fusion (LLIF) in combination with percutaneous endoscopic lumbar discectomy (PELD) can achieve interbody fusion and direct decompression, but their combined use has not been widely reported. In this study, the clinical outcomes of LLIF in combination with PELD in low-grade spondylolisthesis was evaluated, particularly in cases of a requirement for direct decompression.

Methods

Patients with single-level low-grade spondylolisthesis, undergoing LLIF in combination with PELD were included. The severity of lower back and leg pain was reported using visual analog scale (VAS). The Oswestry disability index (ODI) was used to evaluate functional improvements of patients. A comparison of preoperative and postoperative indicators was performed through repeated measures of analysis of variance. $P < 0.05$ was considered as a statistically significant difference.

Results

A total of 48 patients (20 males and 28 females) were included. The intraoperative blood loss was 112.60ml ± 43.69 and the average operation time was 116.35min ± 22.31. VAS and ODI were significantly improved in all stages after operation. The fusion rate at the final follow-up was 93.7%. No injuries occurred to the vessels, nerves and organs during the perioperative period.

Conclusions

LLIF in combination with PELD achieved adequate decompression and intervertebral fusion, with precise and reliable clinical outcomes. In addition, the procedure was minimally invasive, resulting in small tissue injury and rapid postoperative recovery. Multi-center prospective comparative studies are now needed to further confirm the superiority of this combination.

Background

Fusion and decompression were common surgical procedures for the treatment of lumbar degenerative disc disease [1]. Posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF) were first proposed by Cloward [2] and Harms [3], respectively. Using these methods, nerves were decompressed and 3D stability was provided, but the paraspinal muscle was seriously injured. Lateral lumbar interbody fusion (LLIF) was a procedure whereby the spine was accessed from the retroperitoneal space. The advantages of LLIF included its minimal invasiveness, simple access, lack of injury to the posterior structure of the spinal canal, and high rates of interbody fusion. Since its introduction, the use of LLIF has increased [4, 5]. Moreover, lateral interbody fusion can tighten the posterior ligament, increase the volume of the spinal canal, and indirectly decompress the nerve through restoration of the height of the intervertebral space and intervertebral foramen [5]. For patients with large lumbar disc herniation, herniated nucleus pulposus or extreme lateral lumbar disc herniation, indirect decompression of LLIF failed to alleviate nerve decompression. Thus, LLIF had limited indirect decompression capabilities.

Kambin et al. [6] firstly proposed percutaneous endoscopic lumbar discectomy (PELD) in 1986 and nerve decompression was achieved through the Kambin's triangle. With advances in technical and theoretical knowledge, surgical procedures for the treatment of degenerative disc disease have gradually improved, including various types of transforaminal and translaminar approach, such as the Yeung endoscopic spine system (YESS), transforaminal endoscopic spine system (TESSYS), and biportal endoscopic spinal surgery (BESS) [7–13]. To date, the scope of decompression adaptation of percutaneous endoscopic lumbar surgery continues to expand. This procedure can treat various types of disc herniation, intervertebral foramen stenosis, spinal canal stenosis caused by hypertrophy of the ligamentum flavum, and joint hyperplasia. Studies have confirmed that endoscopic lumbar surgery achieved nerve decompression, avoiding the disadvantages of soft tissue injury [14, 15]. Relieving nerve compression under endoscopy failed to achieve lumbar stability and long-term efficacy was poor for patients under conditions of intervertebral instability or spondylolisthesis. As such, percutaneous endoscopic lumbar surgery was limited for lumbar interbody fusion.

LLIF completed interbody fusion through the retroperitoneal approach for the treatment of low-grade (the displacement of spondylolisthesis is less than half of the vertebral body) spondylolisthesis. However, indirect decompression of LLIF could not alleviate radicular symptoms in some cases. Minimally invasive LLIF in combination with PELD achieved interbody fusion and adequate decompression, but their combined use has not been widely reported. In this study, the clinical outcomes of minimally invasive LLIF in combination with PELD in cases of low-grade spondylolisthesis and a requirement for supplementary decompression were evaluated.

Materials And Methods

This study was approved by the Hospital Ethics Committee. All patients were informed of data collection. Patients with single-level low-grade spondylolisthesis underwent LLIF. Low-grade spondylolisthesis was defined as that displacement of spondylolisthesis was less than half of the vertebral body. But LLIF could not alleviate radicular symptoms in some cases (low-grade spondylolisthesis combined with large lumbar disc herniation, herniated nucleus pulposus or extreme lateral lumbar disc herniation) because its indirect nerve decompression effect was limited. For these patients, we used PELD for supplementary decompression in the 2nd stage. Patients undergoing LLIF in combination with PELD in our center since May 2017 were included. Inclusion criteria was as followed: (1) 3-months conservative treatment for low-grade spondylolisthesis was ineffective. (2) Large disc herniation, herniated nucleus pulposus, or extreme lateral herniation combined with single-level low-grade spondylolisthesis. Exclusion criteria was as followed: (1) thoracolumbar spine trauma, tumor, infection. (2) Patients who underwent lumbar spine surgery. (3) Incomplete follow-up data.

Operative procedure of the combined operation

In the first stage, the patient was lying on the right side under general anesthesia, bending the hip and knees. Preoperative fluoroscopy was used to determine the operative segment, and the body surface was located and marked. The surgeon incised the skin, subcutaneous fat, and obtusely separated the later abdominal wall muscles into the retroperitoneal space. The surgeon used left index finger to find out the psoas major and the lateral vertebral body, and the right hand held the guide needle to implant into the responsible vertebral space through the psoas major. The psoas major muscle was expanded with a step-by-step guide rod dilator when the lateral fluoroscopy confirmed that the position of the guide needle was satisfactory. We placed the operation corridor, exposed the lateral vertebral space, and paid attention to avoid the injury of lumbar plexus. The surgeon used a long-handle knife to cut the fibrous rings and treated intervertebral space with nucleus pulposus forces, various types of curettes and bone files. The bone endplate was exposed. Suitable Cage mode was selected under fluoroscopy after breaking the contralateral fibrous rings. A PEEK cage filled with allogenic bone was inserted. The frontal and lateral cage position was confirmed satisfactory. Lateral plate and screw internal fixation was implemented as required. After sufficient hemostasis, the incision was sutured. There was no lateral plate internal fixation material in our center in the early stage. We needed to change their position to prone position and then performed posterior percutaneous internal fixation for patients who met the conditions of internal fixation. LLIF could not alleviate radicular symptoms in the case series. we used PELD for supplementary decompression in the 2nd stage. PELD was performed under local anesthesia to relieve nerve compression according to the compression source of radicular symptoms.

Patient data including age, gender, ect was collected. Surgical segments and internal fixation was recorded. We usually used internal fixation for patients with osteoporosis or intraoperative end plate injuries. Otherwise, stand-alone surgery was performed. The severity of lower back and leg pain was reported using visual analog scale (VAS). The Oswestry disability index (ODI) was used to evaluate functional improvements of the patients. We used postoperative computed tomography (CT) to evaluate the interbody fusion. The presence of trabecular junction of interbody for more than two consecutive levels was considered as a solid interbody fusion. If the measurement data conformed to a normal distribution, it was expressed as the mean ± standard deviation. If the data did not conform, it was expressed as the median (interquartile range). Count data was expressed as a percentage. A comparison of preoperative and postoperative indicators was performed through repeated measures of analysis of variance. Bonferroni correction was used to compare the two indicators at different time points. $P < 0.05$ was considered as a statistically significant difference.

Results

A total of 48 patients (20 males and 28 females) were included (Table 1). The average age of patients was 52.60 which ranged from 37 to 70. The intraoperative blood loss was 112.60ml ± 43.69 and the average operation time was 116.35min ± 22.31. All patients underwent single-level lumbar surgery, with 4 cases at the level of L2/L3, 11 cases at the level of L3/L4 and 33 cases at the level of the L4/L5. Of the 48 cases, 26 cases were standing alone, 12 cases were with posterior percutaneous internal fixation, 10 cases were with lateral plate and screw internal fixation. The average follow-up time was 18 months.

The VAS and ODI of the case series before surgery, 3 months after surgery, 6 months after surgery, 12 months after surgery, and at the last follow-up were shown in Table 2. The mean ± standard deviation of the preoperative VAS was 6.67 ± 1.51 and preoperative ODI was 50.02 ± 9.45. The mean ± standard deviation of VAS at the last follow-up was 0.96 ± 0.62 and the ODI was 13.13 ± 3.81. The VAS and ODI of each postoperative stages were significantly lower than those before operation. The mean of VAS and ODI after surgery decreased with follow-up time (Fig. 1). The VAS and ODI followed up after 6 months were significantly lower than those at 3months. The VAS at the last follow-up was significantly lower than at 6months post-surgery. There were no significant differences in ODI at 6 months, 12months post-surgery and at the last follow-up. Intervertebral fusion rates at 3 months, 6 months, 12months post-surgery and at the last follow-up were 43.7%, 77.1%, 93.7%, and 93.7%, respectively.

A single case had severe upper endplate injury. The percutaneous pedicle screw fixation was performed during the operation. Intervertebral fusion was good, and no obvious cage subsidence occurred. Two cases had numbness and pain in the left thigh combined with weakness in the psoas muscle. The condition returned normal on the 5th day post-surgery. No injuries occurred to the vessels, nerves and organs during the perioperative period.

A typical case (Fig. 2): A 60-year woman had low back pain and right lower extremity pain for 2 years, and conservative treatment was ineffective. She was diagnosed as spondylolisthesis at the level of L4/L5. The nerve was depressed causing severe pain in the right lower limb. The patient therefore received LLIF to recover lumbar stability. The patient's right lower limb pain did not alleviate, requiring removal of the nucleus pulposus to relieve nerve compression. The patient was supplemented with PELD. The two operations took 124 min and 80 ml of blood was lost. The treatment achieved decompression, fusion, and the reconstruction of spinal stability. Injury to the soft tissue and muscle was minimal. The VAS of leg pain was 8 points before surgery, 1 point 3 months post-surgery, 1 point 6 months post-surgery, and 1 point 12 months post-surgery.

Discussion

Minimally invasive surgery had the advantage of minimal trauma and rapid recovery. Open lumbar surgery for the treatment of lumbar degenerative diseases was effective, but slow recovery rates and postoperative complications remained a concern. Studies also indicated that open PLIF, TLIF, or the removal of the nucleus pulposus by posterior fenestration of vertebral plate lead to injury of the paraspinal muscles [16, 17]. Some patients may suffer post-surgical low back pain. Percutaneous spinal endoscopic surgery can complete the removal of the nucleus pulposus under local anesthesia through the intervertebral foramen or the interlaminar approach with short operation time, lower blood loss and mild soft tissue injury [9, 18]. Numerous studies have confirmed the curative and reliable efficacy of PELD [9, 10, 12]. A meta-analysis showed that the average postoperative recurrence rates of PELD in the treatment of lumbar disc herniation were 3.6%. Old age, obesity, upper lumbar disc herniation, and central disc herniation were risk factors for disease recurrence [19]. Percutaneous endoscopic discectomy and interbody fusion (PEDIF) was not commonly used during surgery due to controversy regarding their clinical efficacy [20]. The fusion rate was low and the curative effect was not good, which was often related to the incomplete curettage of the upper and lower endplates of the intervertebral space and the small amount of bone graft [20]. LLIF was performed through the retroperitoneal space to the lateral intervertebral space. The intervertebral space was completely treated using minimally invasive methods. A large number of bone grafts are employed, leading to high intervertebral fusion rates. In addition, indirect spinal decompression is achieved. Large disc herniation, herniated nucleus pulposus, and extreme lateral herniation were contraindications to LLIF. Lumbar endoscopic surgery acted on decompression and LLIF focused on fusion. The combination of the two minimally invasive surgeries could correct the deficits of each individual procedure. The combination of LLIF and PELD for the treatment of lumbar degenerative diseases has not been widely reported. The aim of this study was to evaluate the clinical efficacy and safety of this combined and minimally invasive technique for the treatment of lumbar low-grade spondylolisthesis.

A total of 48 patients were included in the case series and LLIF under general anesthesia followed by lumbar endoscopic surgery under local anesthesia was performed. The average operation time of the combination surgery was 116.35min ± 22.31, and the average blood loss was 112.60ml ± 43.69. In previous meta-analysis comparing PLIF to TLIF, the mean PLIF time was 150–182 min and the blood loss was 245–994 ml; the operative time for TLIF was 105–165 min and the blood loss was 215–867 ml [21]. The total operation time and blood loss of the combined surgery were thus lower. The small incision size, decompression by endoscopy and intraoperative radiofrequency electrocoagulation for hemostasis were key reasons for lower blood loss. In addition, LLIF was performed from the retroperitoneal space which was distant from the blood vessels leading to minimal blood loss. The VAS and ODI of the case series at 3, 6, 12 months post-surgery, and the last follow-up were significantly lower than those before surgery, suggesting good clinical efficacy. Previous studies have concentrated on the clinical efficacy of single minimally invasive surgery. Furthermore, lumbar endoscopic surgery and LLIF for the treatment of lumbar degenerative diseases for a range of indications are reliable [22, 23]. The combination of minimally invasive surgery could achieve direct decompression and interbody fusion, covering shortfalls of each single minimally invasive procedure. Assessment of intervertebral fusion rates using CT in previous studies showed that the rate of intervertebral fusion at 1-year post-retroperitoneal anterolateral interbody fusion was approximately 85–97% [24–26]. The fusion rate at the latest follow-up of patients in this study was 93.7% and thus similar. The combined minimally invasive surgery demonstrated a high degree of operational safety. A single patient experienced severe upper endplate injury, and two patients had postoperative left anterior thigh numbness and pain combined with psoas muscle weakness. Some patient factors may lead to intraoperative endplate injury, including osteoporosis, stenosis of the intervertebral space, a high sacral ridge, and obesity. In addition, less experience in the initial procedures, excessive use of the sharp reamer, and the wrong direction of curettage of intervertebral disc could also result in intraoperative endplate injury [27]. Endplate injury could cause endplate collapse, cage subsidence, and/or displacement during follow-up. Timely posterior internal fixation to strengthen intervertebral stability could reduce postoperative cage subsidence and displacement [5, 28]. The patient with endplate injury in this study was supplemented with internal fixation and there was no obvious cage subsidence during the follow-up period. Intervertebral fusion was good at the last follow-up. The patients had postoperative left anterior thigh numbness and pain combined with psoas muscle weakness, caused by the excessive involvement of lumbar plexus during LLIF splitting psoas major muscle. The symptoms disappeared on the 5th post-surgical day. With improved technology, the safety of lumbar endoscopic surgery was gradually increasing. Surgeon should operate gently and carefully in order to avoid dura and nerve injury.

In this study, a combined minimally invasive technique that combined lumbar endoscopic surgery with LLIF for the treatment of lumbar degenerative diseases was proposed. Due to rapid developments in lumbar endoscopic techniques, the technical obstacles for the adequate decompression of various types of disc herniation were overcome. Endoscopic technique was characterized by flexibility, minimally invasive and direct decompression. Lateral fusion using LLIF achieved exact and robust intervertebral fusion with no disruption to the posterior lumbar muscles, ligaments, and bony structures [26]. Combination of two minimally invasive techniques can be used to overcome complex lumbar problems. Similarly, we envisaged the possibility of combining lateral lumbar fusion technology with MED or microscopic lumbar decompression surgery to provide a beautiful “combination blow” according to the actual situation of patients with lumbar diseases.

There were some limitations in this study. The sample size was small and further enlargement of sample size will be needed to make the conclusion more convincing. This was a retrospective case series study and the internal fixation method was not unified in advance. The type of internal fixation may influence VAS and ODI, which was the limitation of the retrospective study. In future studies, we will unify internal fixation standard. This study was also a single-center case series and no control group was established. In future studies, we will compare this combination of minimally invasive techniques with the traditional open surgery of lumbar posterior approach to further demonstrate its superiority. Cases included in this study only involved single-segment surgery. The clinical efficacy of the combination of minimally invasive surgery for double-segment lumbar surgery requires further analysis.

Conclusion

The rapid development of the minimally invasive technique of lumbar spine created the basic condition for the combination of different minimally invasive techniques to solve more complex lumbar degenerative diseases. LLIF in combination with PELD achieved adequate decompression and intervertebral fusion, with precise and reliable clinical outcomes. In addition, the procedure was minimally invasive, leading to reduced tissue damage and rapid postoperative recovery. Multi-center prospective comparative studies are now needed to further confirm the superiority of this combination.

Abbreviations

PLIF: Posterior lumbar interbody fusion TLIF: Transforaminal lumbar interbody fusion LLIF: Lateral lumbar interbody fusion PELD: Percutaneous endoscopic lumbar discectomy YESS: Yeung endoscopic spine system TESSYS: Transforaminal endoscopic spine system BESS: Biportal endoscopic spinal surgery VAS: Visual analogue scale ODI: Oswestry disability index CT: computed tomography PEDIF: Percutaneous endoscopic discectomy and interbody fusion

Declarations

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Availability of data and materials

Date requests are available from corresponding author.

Authors' contributions

LJQ and ZW designed the study. LJQ, SYP, ZF, WXZ and GL collected data, performed the statistical analysis. LJQ, SY and SYP drafted the manuscript. All authors read and approved the final manuscript.

Authors' information

Not applicable.

Ethics approval and consent to participate

This study was approved by the Institutional Ethics Board of the 3rd Hospital of Hebei Medical University and informed consent was obtained from all individual participants included in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1 Description of demographic characteristics

Values	
Age (year)	52.60±8.86
Sex (male/female)	20/28
Operation time (min)	116.35±22.31
Intraoperative blood loss (ml)	112.60±43.69
Follow-up time (month)	18 (4.75)
Internal fixation	
posterior percutaneous internal fixation	12 (25.0%)
lateral plate and screw internal fixation	10 (20.8%)
no	26 (54.2%)
Levels treated	
L2-3	4 (8.3%)
L3-4	11 (22.9%)
L4-5	33 (68.8%)

ble 2 Clinical efficacy and intervertebral fusion rate

Values	Pre-op	3month	6month	12month	Last follow-up	P (2-tailed)
VAS	$6.67\pm1.51_{a}$	$1.83\pm0.88_{b}$	$1.37\pm0.61_{c}$	$1.14\pm0.50_{cd}$	$0.96\pm0.62_{d}$	$<0.001^{*}$
ODI (100%)	$50.02\pm9.45_{a}$	$14.31\pm4.51_{b}$	$13.56\pm3.79_{c}$	$13.42\pm3.70_{c}$	$13.13\pm3.81_{c}$	$<0.001^{*}$
Fusion (n. yes/no)	--	$21/27_{a}$	$37/11_{b}$	$45/3_{c}$	$45/3_{c}$	$<0.001^{\#}$

S indicated visual analogue scale; ODI, oswestry disability index; *, repeated measurement analysis of variance; #, Pearson Chi-square test; ltiple comparisons of each variable at different time points were used bonferroni method, and at least one identical subscript letter (a, b, c l d) denoted no significant difference from each other.

Figures

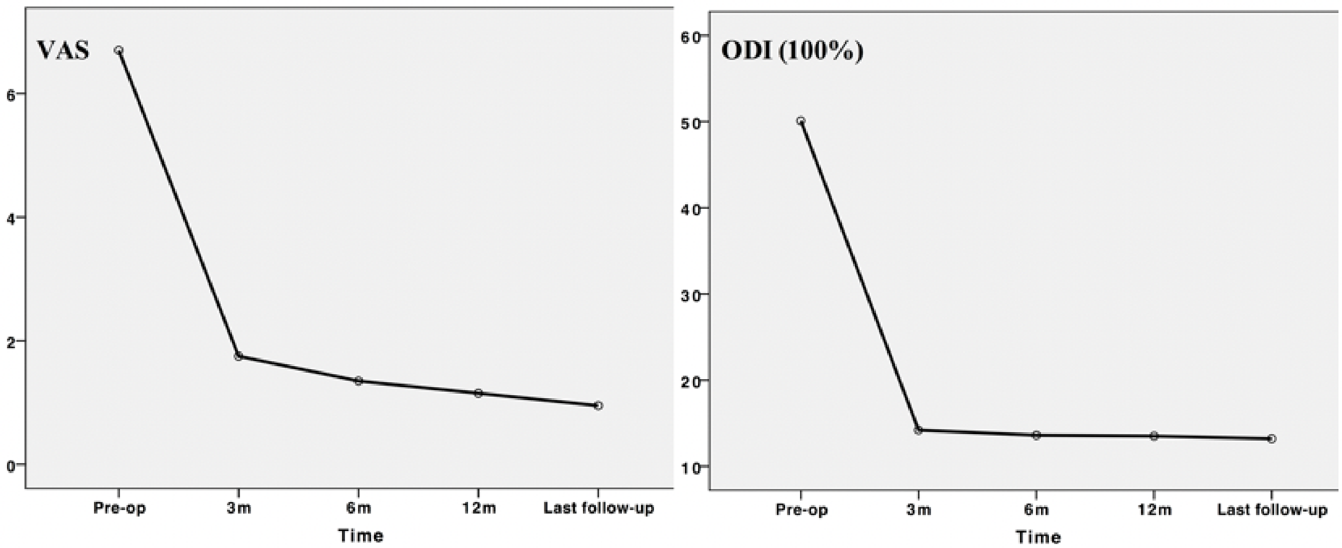

Figure 1

Postoperative VAS and ODI were significantly reduced compared with those of preoperation. VAS, visual analogue scale; ODI, Oswestry disability index.

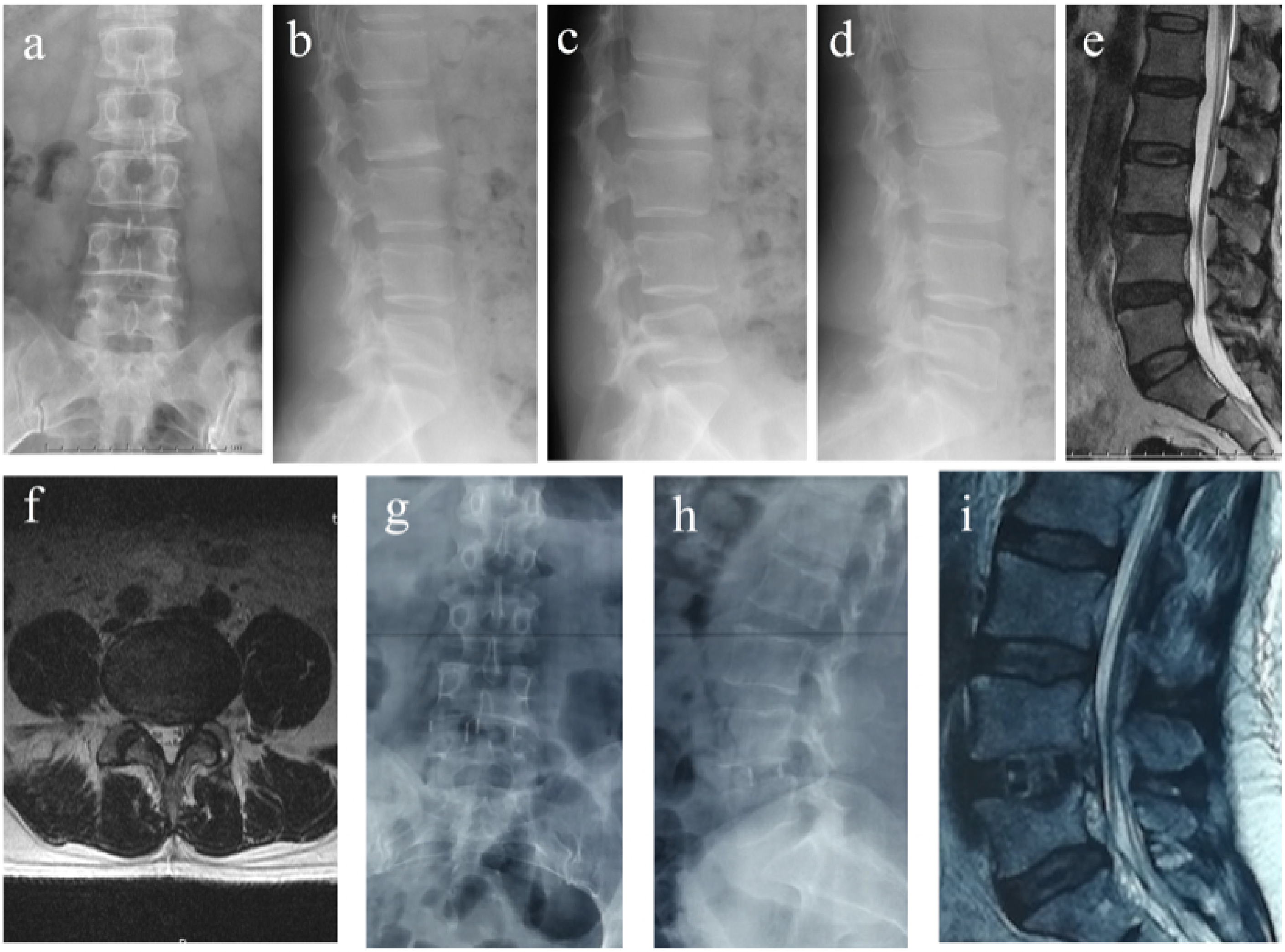

Figure 2

A typical case of low-grade spondylolisthesis at the level of L4/L5. (a) and (b) Preoperative X-rays in anteroposterior and lateral position. (c) and (d) Preoperative X-ray in hyperextension and flexion of lumbar spine. (e) and (f) Preoperative MRI revealed L4/L5 intervertebral disc prolapse. (g) and (h) Anteroposterior and lateral X-ray after combination of LLIF and PELD. (i) Postoperative sagittal T2-weighted MRI scan showed that no disc herniation was observed after operation at the level of L4/L5 disc. LLIF, lateral lumbar interbody fusion; PELD, Percutaneous endoscopic lumbar discectomy.