

The influence of intervertebral disc vacuum phenomenon on the clinical efficacy of different approaches for lumbar spinal stenosis: a retrospective cohort study

Lei Liu

Xuzhou Central Hospital

Tongqu Song

Xuzhou Central Hospital

Hengcai Zhou

Xuzhou Central Hospital

Qi Cheng

Xuzhou Central Hospital

Chao Ma

Xuzhou Central Hospital

Jie Shang

Xuzhou Central Hospital

Meng Han

Xuzhou Central Hospital

Bin Wu

986213812@qq.com

Nanjing University of Chinese Medicine

Research Article

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Abstract

Background

Intervertebral disc vacuum phenomenon (IDVP) is a specific manifestation of advanced intervertebral disc degeneration. The current point of contention is whether different surgical approaches yield consistent clinical outcomes for the treatment of lumbar spinal stenosis (LSS) combined with IDVP. The purpose of this study was to investigate the influence of the IDVP on the clinical outcomes of unilateral biportal endoscopy (UBE) and transforaminal lumbar interbody fusion (TLIF) in the treatment of LSS.

Methods

A retrospective cohort study. A total of 70 patients with LSS who underwent surgical treatment, between 1 January 2021 and 31 December 2023, were included. All patients underwent either UBE or TLIF surgery. General information on patients had been recorded, including age, sex, visual analogue scale (VAS) scores for low back pain, leg pain, IDVP segment, ODI score, JOA score, and 1-month, and 12-month end-of-study follow-ups. The patients were divided into two groups based on surgical technique: the UBE group and the TLIF group. Descriptive statistics, independent samples t-test, paired samples t-test, and repeated measures analysis of variance (ANOVA) were used for statistical analysis according to the type of data.

Results

70 patients with LSS were successfully included and all were followed up for at least 12 months, with no complications during the follow-up period. (1) A comparison of baseline characteristics between the two groups showed no statistically significant differences ($P > 0.05$). (2) Preoperative differences in leg pain VAS, lumbar JOA score, and ODI between groups were not statistically significant ($P > 0.05$ for all) (3) No interaction effects were observed for lumbar pain VAS score, leg pain VAS score, JOA score, or ODI between groups. (4) Both groups demonstrated significant improvement in JOA score and ODI outcomes at postoperative follow-up ($P < 0.05$ for both), with no statistically significant difference between groups ($P > 0.05$ for both); both lumbar pain VAS score and leg pain VAS score improved compared to preoperative levels ($P < 0.05$ for both), with statistically significant differences between groups ($P < 0.05$ for both). No severe complications were observed in either group.

Conclusion

IDVP plays a role in low back pain caused by lumbar disc degeneration, and fusion surgery can more effectively alleviate clinical symptoms in patients with LSS combined with IDVP.

Background

Lumbar spinal stenosis (LSS) is a common lumbar degenerative disease in the elderly, usually requiring surgery if conservative treatment fails. Transforaminal lumbar interbody fusion (TLIF) is a common

surgical method for LSS, using unilateral transforaminal approach, unilateral facet resection, and placement of an interbody fusion cage. The unilateral biportal endoscopy (UBE) has been widely used in the treatment of LSS and has the advantages of flexible operation, wide surgical vision, less tissue damage, and superior clinical efficacy.

The intervertebral disc vacuum phenomenon (IDVP) is recognized as one of the imaging markers associated with intervertebral disc degeneration, typically presenting as a low-density area on X-ray or CT. Previous studies have demonstrated that IDVP is a radiographic feature of intervertebral instability and an important contributor to low back pain. Some investigators have suggested that fusion surgery is more suitable for LSS when the surgical segment is associated with IDVP[1]. Other scholars have proposed that endoscopic laminectomy decompression alone can also yield satisfactory clinical outcomes in patients with LSS complicated by IDVP [2].

A current controversy concerns whether different surgical approaches yield comparable clinical outcomes in the treatment of LSS combined with IDVP. Furthermore, no consensus has been reached regarding whether IDVP can be considered a definitive indication for TLIF. Therefore, the aim of this study was to compare the postoperative clinical outcomes of TLIF and UBE surgery in the treatment of LSS combined with IDVP, and to investigate the impact of IDVP on the clinical efficacy of the two surgical procedures.☒

This study was approved by the Ethics Committee of Xuzhou Central Hospital. Patient informed consent was waived.

1 Inclusion and Exclusion Criteria

Inclusion criteria were as follows: (1) patients with single-segment LSS who had significant symptoms and showed no response to at least 3 months of standardized conservative treatment; (2) received treatment with UBE surgery or TLIF surgery; (3) preoperative imaging examinations confirming that the IDVP was located at the operated segment; (4) complete follow-up data and postoperative follow-up > 12 months.

Exclusion criteria were as follows: (1) patients who underwent revision surgery due to adjacent segment disease, recurrent disc herniation after minimally invasive surgery, or other causes; (2) concomitant severe degenerative spinal diseases such as scoliosis or kyphotic deformity; (3) LSS caused by burst fractures of the lumbar spine, vertebral metastasis of malignant tumors, or other conditions; (4) some other orthopedic specialty diseases such as spinal tuberculosis or infection; (5) postoperative follow-up of less than 12 months.

2 Methods

This was a retrospective cohort study. Clinical data were collected from patients with LSS who underwent UBE or TLIF surgery in the Department of spinal surgery at Xuzhou Central Hospital between

January 1, 2021, and December 31, 2023. After case selection according to the inclusion and exclusion criteria, 70 patients were included in the study. The patients were divided into the UBE group and the TLIF group according to the surgical procedures.

Baseline patient data, including age, gender, IDVP location, and surgical approach, were collected from the electronic medical records system. Visual analogue scale (VAS) score for both low back pain and leg pain, Japanese Orthopaedic Association (JOA) score, and Oswestry disability index (ODI) were evaluated before operation, at 1 month postoperatively, and at 12 months postoperatively. Surgery-related complications, including but not limited to neurological deterioration, dura tear and cerebrospinal fluid leakage, infection, instrument failure, and reoperation, were documented at follow-up in all groups.

3 Surgical Methods

All surgeries were performed by the same surgical team.

TLIF procedure: Under general anesthesia, the patient was placed in the prone position with the abdomen suspended and supported by a lumbar bridge. A posterior midline incision was made centered on the spinous process of the responsible segment. The skin, subcutaneous tissue, and thoracolumbar fascia were incised layer by layer, and the paravertebral muscles on both sides were stripped to expose the laminae up to the level of the facet joints. The surgical segment was confirmed by C-arm fluoroscopy. Two pedicle screws were inserted into each vertebral body of the responsible segment. The inferior articular process and the superomedial portion of the superior articular process on the symptomatic side were resected, the intervertebral foramen was opened, and the corresponding lamina was removed to enlarge the nerve root canal, achieving thorough decompression of the superior and inferior nerve roots on that side. The thickened ligamentum flavum and herniated disc tissue were removed, and the adherent nerve roots were released. Under the protection of cottonoids, the superior and inferior nerve roots were retracted to expose the intervertebral space. An annular fenestration was performed at the lateral margin of the dural sac, the nucleus pulposus was extracted, and the disc tissue was removed as thoroughly as possible. The intervertebral space was enlarged and distracted using a reamer, and the disc tissue and superior and inferior cartilaginous endplates were removed while preserving the bony endplates. The size of the interbody fusion cage was selected based on the intervertebral space height. Bone fragments obtained during decompression were morselized and implanted into the anterior portion of the intervertebral space, compacted with a trial prosthesis, and a single interbody fusion cage filled with autologous bone was inserted obliquely into the intervertebral space from the posterolateral direction. After C-arm fluoroscopy confirmed satisfactory positioning of the internal fixation, connecting rods were installed and the entire fixation system was locked. The surgical field was irrigated with copious amounts of normal saline. After meticulous hemostasis, a drainage tube was placed, and the incision was closed layer by layer (Fig. 1).

UBE procedure: The patient was placed in the prone position with the lumbar skin exposed. The responsible segment was localized under C-arm fluoroscopy, followed by routine disinfection and sterile

draping. Two approximately 1 cm incisions were made at the projection of the pedicle on the affected side, sequentially incising the skin, subcutaneous tissue, and thoracolumbar fascia. After confirming the position with a localization needle, a dilator was inserted through the caudal incision to expand the working channel, and a protective sheath was inserted through the cephalad incision, followed by introduction of the endoscope. Continuous irrigation with normal saline was maintained to ensure a clear surgical field. A laminectomy rongeur was used to remove the inferior portion of the lamina of the superior vertebral body and part of the hypertrophic ligamentum flavum, exposing the dorsolateral aspect of the dural sac and the traversing nerve root. A herniated disc was observed compressing the traversing nerve root. A radiofrequency ablation electrode was used for hemostasis, adhesions were dissected, and the nerve root and dural sac were released. As needed, a pituitary rongeur was used to remove the herniated disc tissue and loose or free nucleus pulposus fragments within the disc space. Restoration of dural sac pulsation and relaxation with recession of the nerve root were observed. After confirming the absence of active bleeding, the guide rod was withdrawn. The wounds were sutured and covered with sterile dressings (Fig. 2).

4 Postoperative Management and Follow-up

The drainage tube was removed 24 to 36 hours postoperatively. Patients were instructed to ambulate under the protection of a brace within 1 week after surgery. Excessive bending and weight-bearing were avoided for 3 months, and the brace was gradually discontinued. Regular postoperative follow-up was conducted, and anteroposterior and lateral lumbar radiographs were obtained at 1 month and 12 months postoperatively.

5 Statistical methods

Data were processed using SPSS 20.0 statistical software. Continuous variables following a normal distribution were expressed as mean $\pm$ standard deviation ($-x \pm s$). Descriptive statistics, independent samples t-test, paired samples t-test, and repeated measures analysis of variance (ANOVA) were used for statistical analysis according to the type of data. P value < 0.05 was considered statistically significant. The quantitative variables were independently assessed by two spine surgeons, each blinded to the other's evaluation, and a single assessment was conducted by each surgeon.

6 Results

Based on the inclusion and exclusion criteria, a total of 70 patients with LSS were enrolled in this study, among whom there were 40 males and 30 females, with a mean age of 66.66 ± 4.19 years. All patients underwent X-ray examinations, CT plain scanning + sagittal reconstruction, and MR scans. The involved segments were L3/4 in 8 cases, L4/5 in 50 cases, and L5/S1 in 12 cases. According to the kind of surgery, patients were divided into two groups: the UBE group ($n = 38$), for patients who underwent UBE surgery, and the TLIF group ($n = 32$), for patients who underwent TLIF surgery. After the surgery, all

patients recovered during the perioperative period safely without complications such as high fever, wound infection, and cerebrospinal fluid leakage.

There was no significant difference in the general data between the two groups ($P > 0.05$). (Table 1)

The low back pain VAS scores were tested for normality using the Shapiro-Wilk test and were found to follow a normal distribution. According to the sphericity test, Mauchly's $W = 0.818$, $\chi^2 = 1.495$, $P = 0.401$, indicating that the assumption of sphericity was satisfied. ANOVA revealed no significant interaction between group and time ($F = 1.948$, $P = 0.156$). However, there was a statistically significant difference in VAS scores between groups ($F = 18.550$, $P < 0.001$). Additionally, VAS scores were not equal across all time points, with a statistically significant difference observed ($F = 84.222$, $P < 0.001$). At 1 and 12 months postoperatively, VAS scores were significantly lower than preoperative scores (both $P < 0.05$). (Table 2).

The leg pain VAS scores were tested for normality using the Shapiro-Wilk test and were found to follow a normal distribution. According to the sphericity test, Mauchly's $W = 0.937$, approximate $\chi^2 = 4.386$, $P = 0.112$, indicating that the assumption of sphericity was satisfied. ANOVA revealed no significant interaction between group and time ($F = 2.996$, $P = 0.062$). There was a statistically significant difference in VAS scores between groups ($F = 16.454$, $P < 0.001$). In addition, VAS scores differed significantly across time points ($F = 57.108$, $P < 0.001$). At 1 and 12 months postoperatively, VAS scores were significantly lower than preoperative scores (all $P < 0.05$). (Table 3).

The ODI were tested for normality using the Shapiro-Wilk test and were found to follow a normal distribution. According to the sphericity test, Mauchly's $W = 0.995$, approximate $\chi^2 = 0.358$, $P = 0.836$, indicating that the assumption of sphericity was met. Repeated-measures analysis of variance showed no significant interaction between group and time ($F = 0.752$, $P = 0.475$), and no statistically significant difference in ODI between groups ($F = 1.586$, $P = 0.212$). However, the ODI were not all equal across time points, with a statistically significant difference ($F = 61.406$, $P < 0.001$). The ODI at 1 and 12 months postoperatively differed significantly from the preoperative values (both $P < 0.05$). (Table 4).

The JOA scores were tested for normality using the Shapiro-Wilk test and were found to follow a normal distribution. According to the sphericity test, Mauchly's $W = 0.956$, approximate $\chi^2 = 3.032$, $P = 0.220$, indicating that the assumption of sphericity was satisfied. Repeated-measures analysis of variance showed no significant interaction between group and time ($F = 1.733$, $P = 0.185$), and no statistically significant difference in JOA scores between groups ($F = 0.713$, $P = 0.989$). However, JOA scores were not all equal across time points, and the difference was statistically significant ($F = 36.241$, $P < 0.001$). At 1 and 12 months postoperatively, JOA scores were significantly different from those before surgery (all $P < 0.05$). (Table 5).

7 Discussion

7.1 IDVP affects clinical symptoms

IDVP is an imaging manifestation of advanced lumbar disc degeneration. The occurrence of IDVP is associated with the Pfirrmann grade of disc degeneration, Modic changes of the endplates, and subchondral sclerosis. IDVP contributes to chronic low back pain by altering the biomechanical loading of the intervertebral disc, thereby inducing intervertebral instability [3]. IDVP may also accelerate disc degeneration, further aggravating patients' low back pain symptoms. In some patients with IDVP, gas accumulation in the epidural space may compress the nerve roots, ultimately leading to radiating pain in the lower extremities [4][5]. The presence of IDVP not only causes or exacerbates low back pain but also adversely affects postoperative clinical outcomes in patients with LSS [6]. Our study also found that patients who underwent TLIF had lower VAS scores for leg pain than those in the UBE group, suggesting that IDVP may also be associated with lower extremity pain. We propose that the instability caused by IDVP may increase irritation of the nerve roots, thereby aggravating patients' radiating pain. These findings are consistent with those of certain previous studies [6], indicating that IDVP is an important factor affecting surgical outcomes, and it has been suggested that TLIF may yield better long-term clinical outcomes in the treatment of IDVP.

7.2 Mechanism of IDVP causing clinical symptoms

The primary mechanisms by which IDVP causes low back and leg pain include accelerated spinal degeneration, biomechanical imbalance, and stimulation of nerve roots by inflammatory factors. The first two mechanisms mainly contribute to the clinical symptoms of low back pain, while the latter is the principal cause of leg pain [7]. The herniated nucleus pulposus may not be the sole factor responsible for the persistence of clinical symptoms [8]. The intervertebral micromotion caused by IDVP not only exacerbates the enlargement of annular fissures but also leads to abnormal stress distribution that continuously stimulates mechanoreceptors in the intervertebral disc and surrounding ligaments, thereby inducing pain. The abnormal stimulation caused by the local unstable state may further stimulate the nerve roots and lead to the chronification and further aggravation of neuropathic pain. Furthermore, the reduction in intervertebral disc height results in segmental instability and a decrease in the intervertebral foramen area, and local mechanical and biochemical factors may also give rise to radicular pain in the lower extremities.

The release of inflammatory cytokines may also contribute to low back and leg pain [9]. During the progression of IDVP, inflammatory cytokines and growth factors are significantly upregulated in patients, and the locally aberrant release of inflammatory cytokines stimulates nerve endings and aggravates low back pain by activating pain signaling pathways [10]. Exceptionally, when gas within the intervertebral disc enters the spinal canal and accumulates around the nerve roots, it forms an epidural gas-occupying lesion that compresses the nerve roots and may produce radiating pain in the lower extremities [11].

7.3 IDVP affects surgical efficacy

Our study found that IDVP is a factor affecting clinical outcomes after surgery. IDVP influences postoperative leg pain in patients with LSS. UBE surgery relieves mechanical compression of the nerve roots by removing the herniated disc tissue and achieving thorough decompression of the nerve roots,

and the removal of necrotic disc tissue reduces the inflammatory response. However, its improvement of intradiscal inflammation and spinal instability is often limited, which may explain why LSS patients with IDVP still experience a certain degree of low back pain, leg pain, and lumbar dysfunction after UBE treatment. The differences in clinical outcomes among LSS patients undergoing different decompression or fusion surgeries were statistically significant. This finding is consistent with previous studies [12]. Patients who underwent UBE surgery exhibited more severe low back pain and leg pain postoperatively, and these pain symptoms were more pronounced at long-term follow-up. We believe this may be attributable to the fact that in the late stage of lumbar degeneration, patients already have problems such as abnormal spinal curvature and muscle fatigue. IDVP disrupts the structure of the intervertebral disc, rendering it unable to properly support the vertebrae. In addition, UBE surgery causes a certain degree of damage to the posterior spinal column. The combined effects of these factors contribute to the occurrence of long-term low back and leg pain. In contrast, patients in the TLIF group had lower VAS scores for low back pain and leg pain. A possible reason is that fusion surgery achieves local stability and resolves nerve root irritation caused by local instability, while the implantation of the fusion cage can also address the loss of intervertebral disc height.

In our observations, we also found that some patients with IDVP exhibited Modic changes of the endplate on imaging, which is also one of the causes of low back pain. Fusion surgery can address the endplate tissue of the vertebral body, thereby alleviating the long-term low back pain associated with endplate pathology. UBE surgery removes the herniated disc tissue and achieves thorough decompression of the nerve roots, thereby resolving the mechanical compression of the nerve roots; the removal of disc tissue also reduces the inflammatory response. However, the ability of UBE surgery to improve intradiscal inflammation and spinal instability is often limited, which may explain why patients with LSS accompanied by IDVP still experience a certain degree of low back pain, leg pain, and lumbar dysfunction after surgery.

7.4 Fusion surgery can improve the clinical symptoms of patients with IDVP

Lumbar interbody fusion surgery can provide anterior column stability postoperatively, maintain disc height, and preserve proper sagittal alignment. Lewandrowski et al. [2] demonstrated that in patients with lumbar disc herniation accompanied by IDVP and radicular pain treated with UBE, those with a disc height greater than 3 mm had favorable outcomes; however, if severe disc height loss was present, interbody fusion should be considered. Yen et al. [13] also advocated that for patients with LSS complicated by IDVP, interbody fusion is required to restore disc height and spinal stability, and follow-up studies have shown favorable clinical outcomes after fusion surgery. Therefore, for patients with LSS presenting with symptomatic foraminal and lateral recess stenosis as well as mechanical back pain, if IDVP is also present, decompression combined with interbody fusion surgery may be considered.

There is currently no consensus on whether fusion surgery is required for the treatment of IDVP. Li et al. [14] suggested that degeneration of the cartilaginous endplate may be the underlying cause of IDVP, as endplate degeneration predisposes the intervertebral disc to the formation of IDVP when subjected to

compression or altered stress. To prevent the progression of IDVP, it may be necessary to address the cartilaginous endplate tissue. Endplate sclerosis is one of the latest radiographic manifestations of intervertebral disc degeneration and resembles the endplate sclerosis observed in Modic type III changes [15]. It impedes the diffusion of oxygen and nutrients through the cartilaginous endplate into the intervertebral disc, potentially contributing to the development and progressive aggravation of IDVP. Patients with severe IDVP may benefit from endplate management to slow disease progression [16]. Willhuber et al. [17] also found that patients with severe IDVP are more suitable candidates for lumbar fusion surgery, with higher rates of postoperative symptom relief and satisfaction. Lewandrowski et al. [1] suggested that IDVP is associated with vertical instability of the spine and disc collapse, and that interbody fusion is more reliable than decompression alone; when IDVP coexists with intervertebral space collapse, interbody fusion should be considered [2]. Research by Yen et al. [13] demonstrated that patients with IDVP who underwent TLIF exhibited better postoperative lumbar stability and intervertebral disc height restoration, which was conducive to the recovery of physiological lumbar lordosis. An et al. [18] performed fusion surgery on patients with IDVP complicated by lumbar spondylolisthesis and found that interbody fusion effectively restored disc height and reestablished spinal stability, with a high fusion rate [19]. Ohya et al. [20] treated all patients with lumbar spondylolisthesis and concurrent IDVP using TLIF, and the results showed that TLIF had significant therapeutic efficacy in patients with IDVP. The authors suggested that TLIF should be performed in such patients to provide anterior column stability, maintain disc height, and preserve sagittal alignment of the vertebral bodies. In summary of the aforementioned literature, we believe that fusion surgery can effectively improve the clinical symptoms of patients with IDVP. Furthermore, IDVP patients present with spinal sagittal instability and intervertebral space collapse, and fusion surgery offers greater advantages in restoring spinal stability and intervertebral disc height. We propose that the specific indications for selecting TLIF in IDVP patients should be considered from the following aspects: (1) presence of severe endplate degeneration; (2) presence of intervertebral space height loss; (3) presence of lumbar spondylolisthesis; (4) presence of spinal kyphotic/scoliotic deformity.

7.5 Limitations

Our study has several limitations. First, the sample size was relatively small, which may have affected our results; therefore, clinical studies with larger cohorts are needed to validate these findings. Second, although TLIF and UBE were used as representative surgical techniques, they may not fully represent the clinical outcomes of open surgery or decompression-only surgery, respectively.

7.6 Conclusions

Following surgical treatment, patients with LSS accompanied by IDVP experienced substantial improvement in clinical symptoms. IDVP had a certain degree of influence on postoperative low back pain and lower extremity pain in patients with LSS, and it may serve as an indication for interbody fusion surgery.

Abbreviations

Lumbar spinal stenosis, LSS

Transforaminal lumbar interbody fusion, TLIF

unilateral biportal endoscopy, UBE

intervertebral disc vacuum phenomenon, IDVP

Visual analogue scale, VAS

Japanese Orthopaedic Association, JOA

Oswestry disability index, ODI

Declarations

Ethics approval and consent to participate—Consent for this study was obtained from our ethics committee. The name of the ethics committee is medical ethics committee of Xuzhou Central Hospital. The ethical review batch number: XZXY-LJ-20160120-044.

The experimental protocol was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Human Ethics Committee of Xuzhou Central Hospital. All methods were carried out in accordance with relevant guidelines and regulations.

Informed consent was obtained from all subjects and/or their legal guardian(s).

We determined that informed consent for participation was obtained from all participants in the study.

Consent for publication—The patients gave written informed consent to their personal or clinical details and any identified images to be published in this study.

Availability of data and materials—The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing Interests—The authors declare that they have no competing interests.

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Author contributions—

Lei Liu, Bin Wu: Article writing and data collection.

Lei Liu, Tongqu Song, Hengcai Zhou, Qi Cheng, Chao Ma, Jie Shang, Meng Han, Bin Wu: Article review and data collection

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Table

Table 1 Comparison of clinical baseline data between the two groups

group	n	sex (n, F/M)	age (year, $\bar{x}$ $\pm$ s)	operation segment (n, L3/4,L4/5,L5/S1)
UBE group	38	20/18	67.06 $\pm$ 4.25	4/26/8
TLIF group	32	18/14	66.32 $\pm$ 4.16	4/24/4
χ^2/t		0.0917	0.741	0.057
<i>P</i>		0.762	0.461	0.972

Table 2 Comparison of VAS scores of low back pain between the two groups at different time points

group	n	Preoperative	1 month after surgery	12 months after surgery	Total ($\bar{x}$ $\pm$ SE)
UBE group($\bar{x}$ $\pm$ s)	38	7.84 $\pm$ 1.33	2.87 $\pm$ 0.94 ^a	2.97 $\pm$ 0.82 ^a	4.56 $\pm$ 2.55 ^b
TLIF group($\bar{x}$ $\pm$ s)	32	7.94 $\pm$ 1.50	2.16 $\pm$ 0.72 ^a	1.72 $\pm$ 0.68 ^a	3.94 $\pm$ 3.02
Total ($\bar{x}$ $\pm$ SE)	70	7.89 $\pm$ 0.17	2.51 $\pm$ 0.10 ^a	2.35 $\pm$ 0.91 ^a	

Note: the Total is the marginal estimated mean; SE is the standard error; ^aP<0.05, compared with preoperative values; ^bP<0.05, compared with the TLIF group.

Table 3 Comparison of VAS scores of leg pain between the two groups at different time points

group	n	Preoperative	1 month after surgery	12 months after surgery	Total ($\bar{x}$ $\pm$ SE)
UBE group($\bar{x}$ $\pm$ s)	38	7.47 $\pm$ 1.22	3.00 $\pm$ 0.85 ^a	2.79 $\pm$ 0.96 ^a	4.42 $\pm$ 2.39 ^b
TLIF group($\bar{x}$ $\pm$ s)	32	7.66 $\pm$ 1.14	1.88 $\pm$ 0.75 ^a	2.00 $\pm$ 0.88 ^a	3.84 $\pm$ 02.86
Total ($\bar{x}$ $\pm$ SE)	70	7.57 $\pm$ 0.14	2.44 $\pm$ 0.10 ^a	2.40 $\pm$ 0.11 ^a	

Note: the Total is the marginal estimated mean; SE is the standard error; ^aP<0.05, compared with preoperative values; ^bP<0.05, compared with the TLIF group.

Table 4 Comparison of ODI between the two groups at different time points

group	n	Preoperative	1 month after surgery	12 months after surgery	Total ($\bar{x} \pm SE$)
UBE group($\bar{x} \pm s$)	38	52.26 $\pm$ 4.42	27.61 $\pm$ 6.74 ^a	30.89 $\pm$ 7.20 ^a	36.92 $\pm$ 12.60 ^b
TLIF group($\bar{x} \pm s$)	32	52.47 $\pm$ 3.97	26.22 $\pm$ 7.77 ^a	28.66 $\pm$ 7.53 ^a	35.78 $\pm$ 13.42
Total ($\bar{x} \pm SE$)	70	52.37 $\pm$ 0.51	26.91 $\pm$ 0.81 ^a	29.78 $\pm$ 0.88 ^a	

Note: the Total is the marginal estimated mean; SE is the standard error; ^aP<0.05, compared with preoperative values; ^bP<0.05, compared with the TLIF group.

Table 5 Comparison of JOA scores between the two groups at different time points

group	n	Preoperative	1 month after surgery	12 months after surgery	Total ($\bar{x} \pm SE$)
UBE group($\bar{x} \pm s$)	38	13.84 $\pm$ 2.72	25.21 $\pm$ 2.07 ^a	25.21 $\pm$ 2.07 ^a	21.42 $\pm$ 5.84 ^b
TLIF group($\bar{x} \pm s$)	32	13.34 $\pm$ 2.57	24.94 $\pm$ 1.76 ^a	25.97 $\pm$ 1.96 ^a	21.41 $\pm$ 6.12
Total ($\bar{x} \pm SE$)	70	13.59 $\pm$ 0.32	25.07 $\pm$ 0.23 ^a	25.59 $\pm$ 0.24 ^a	

Note: the Total is the marginal estimated mean; SE is the standard error; ^aP<0.05, compared with preoperative values; ^bP<0.05, compared with the TLIF group.

Figures

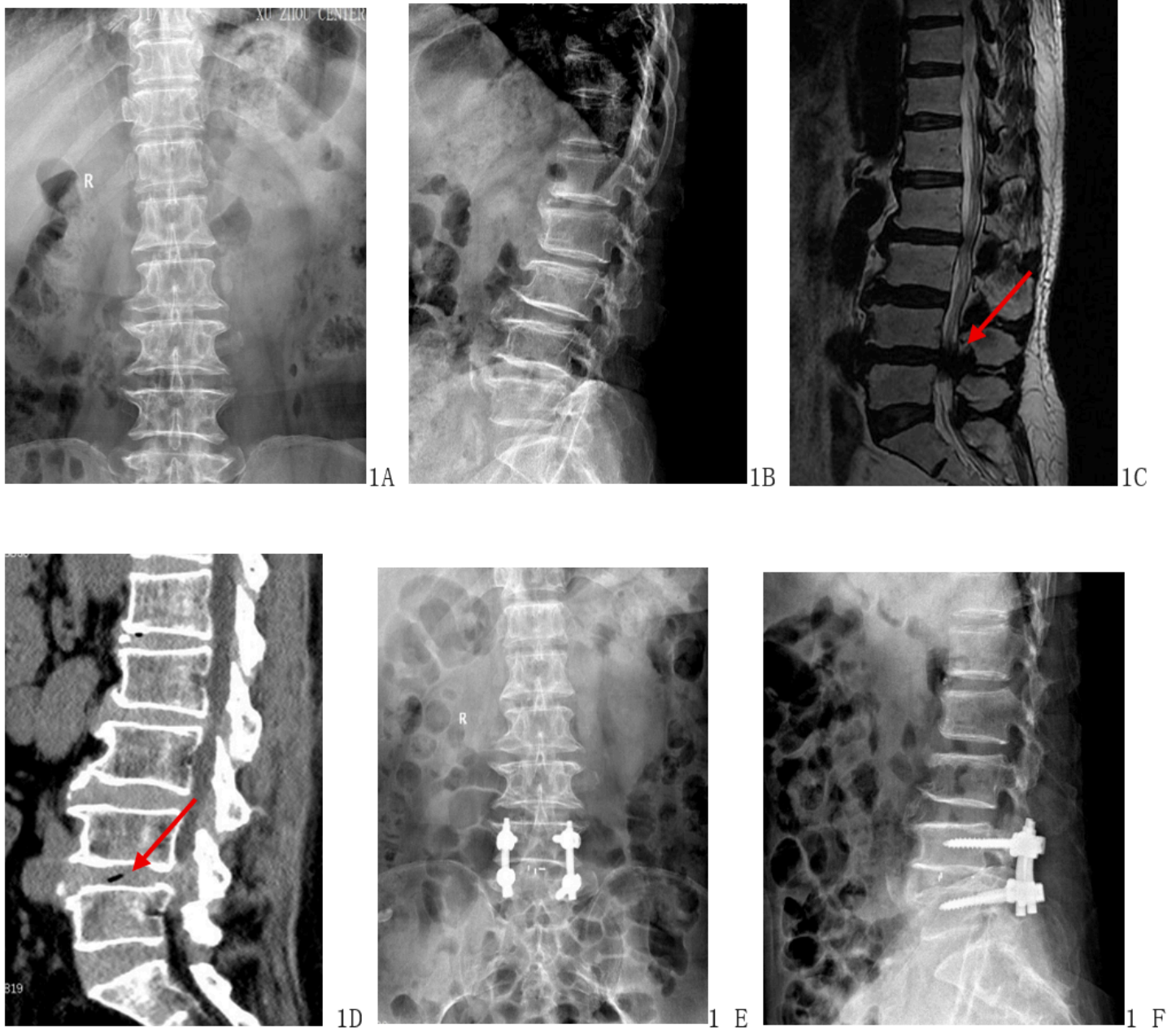


Figure 1

A 66-year-old female with LSS combined with IDVP, treated with TLIF. Fig 1A, 1B: Preoperative anteroposterior and lateral radiographs showing degenerative changes of the lumbar spine. Fig 1C: Preoperative T2-weighted MRI demonstrating L4/5 disc herniation with secondary lumbar spinal stenosis (red arrow). Fig 1D: Preoperative sagittal CT reconstruction showing L4/5 disc herniation with secondary spinal stenosis and IDVP at the L4/5 disc level (red arrow). Fig 1E, 1F: Anteroposterior and lateral radiographs obtained 12 months postoperatively demonstrating internal fixation at the L4/5 vertebral bodies and intervertebral space.

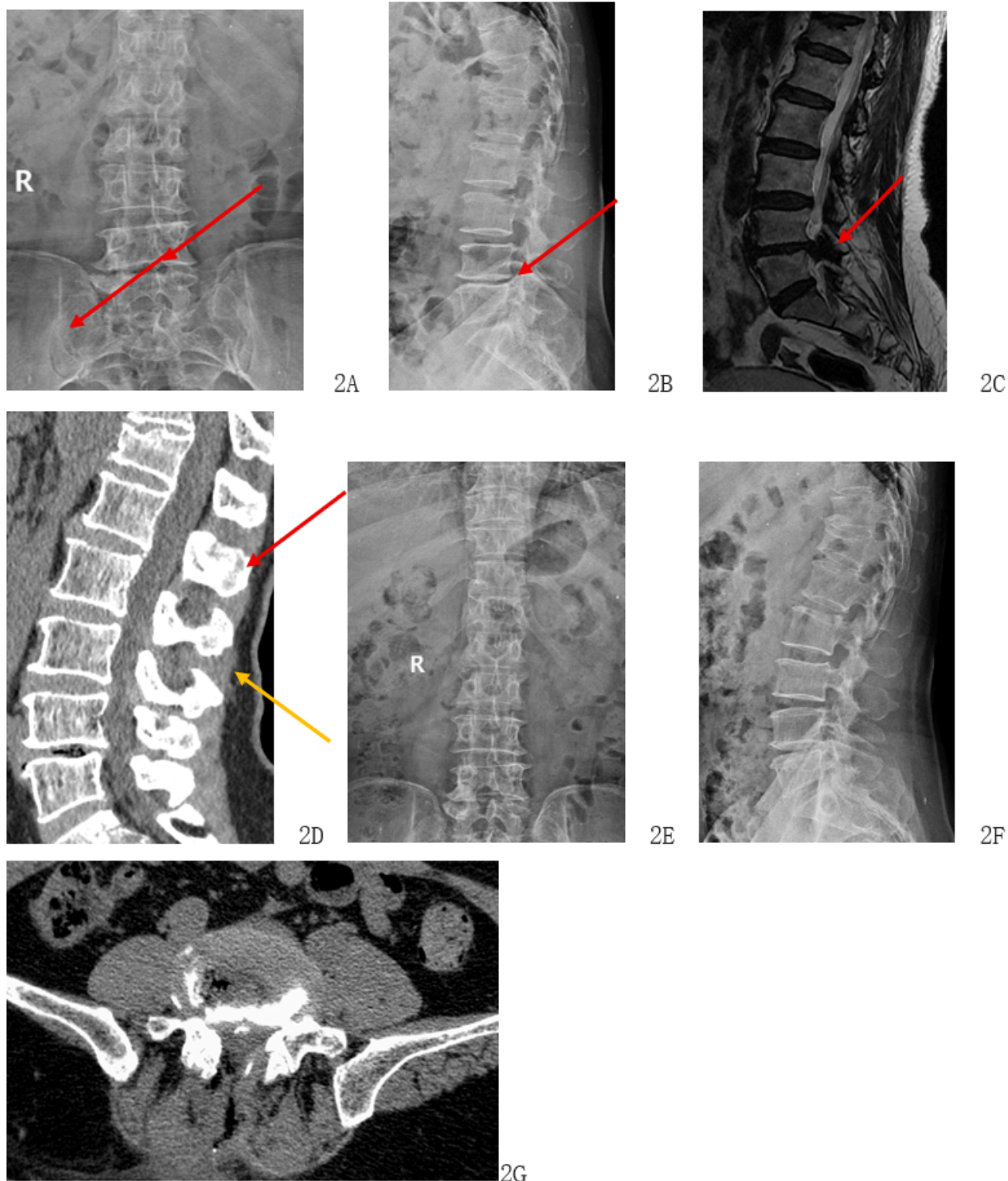


Figure 2

A 62-year-old female patient with LSS combined with IDVP, treated with UBE. Fig 2A, 2B Preoperative anteroposterior and lateral radiographs showing decreased intervertebral disc height at L4/5 and IDVP at the L4/5 disc space (red arrow). Fig 2C Preoperative T2-weighted MR image showing lumbar spinal stenosis secondary to L4/5 disc herniation (red arrow). Fig 2D Preoperative CT scan showing spinal stenosis secondary to L4/5 disc herniation and IDVP at the L4/5 disc (red arrow). Fig 2E, 2F

Anteroposterior and lateral radiographs obtained 1 month postoperatively showing degenerative changes of the lumbar spine. Fig 2G CT scan obtained 1 month postoperatively showing a local laminar defect (yellow arrow) and IDVP of the disc (red arrow).