Original Article

Analysis of the therapeutic effect and postoperative complications associated with 3-dimensional computed tomography navigation-assisted intervertebral foraminoscopic surgery in lumbar disc herniation in the elderly: a retrospective cohort study

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Background: With the increasing aging of the population, the incidence of lumbar disc herniation (LDH) is gradually increasing. The 3-dimensional (3D) computed tomography (CT) navigation-assisted intervertebral foraminoscopic surgery for LDH is minimally invasive, and due to its localization and guidance features, it can precisely reach the target location. This study sought to investigate the treatment effect and the incidence of postoperative complications of 3D CT navigation-assisted intervertebral foraminoscopic surgery in elderly patients with LDH to provide a reference basis for improving patient prognosis.

Methods: We retrospectively included 213 elderly patients with LDH admitted to our hospital from October 2017 to October 2021 in this study and followed them up for 1 year. Among them, 103 patients (Group A) underwent conventional C-arm fluoroscopy-assisted system alone intervertebral foraminoscopic surgery, and 110 patients (Group B) underwent 3D CT navigation-assisted intervertebral foraminoscopic surgery. The general characteristics of the participants were compiled using a general information questionnaire designed by the investigator. The *t*-test and chi-square test were used to analyze the relationship between the treatment outcomes and surgical modalities. Binary logistics regression was used to analyze the independent risk factors affecting patient outcomes.

Results: The patients who underwent 3D CT navigation-assisted intervertebral foraminoscopic surgery had significantly better outcomes than those who underwent conventional C-arm fluoroscopy-assisted system alone intervertebral foraminoscopic surgery. The binary logistic regression analysis results showed that in addition to the surgical method [odds ratio (OR) =0.258, P=0.042], the history of lumbar trauma (OR =11.001, P=0.005), usual work intensity (OR =4.589, P=0.002), disease duration (OR =3.587, P=0.017), the presence of diabetes (OR =3.315, P=0.026), the presence of a ruptured annulus fibrosus (OR =3.485, P=0.012), the degree of disc degeneration (OR =3.899, P=0.009), and the number of punctures (OR =0.412, P=0.034) were independent risk factors affecting patient outcomes.

Conclusions: 3D CT navigation-assisted intervertebral foraminoscopic surgery for LDH effectively reduced the number of punctures, decreased intraoperative bleeding and postoperative drainage volumes, shortened the length of hospitalization, bed rest time and operative time, reduced stress reactions, decreased the degree of low-back pain, and the risk of complications, had better overall efficacy, and significantly improved patient prognosis.

Keywords: Lumbar disc herniation (LDH); 3-dimensional computed tomography (3D CT); transforaminal endoscopic lumbar discectomy (TELD); complications; elderly

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Introduction

Lumbar disc herniation (LDH) is a disease in which the fibrous annulus of the intervertebral disc ruptures, causing the nucleus pulposus to protrude and compress the spinal and cauda equina nerves, thereby causing an inflammatory response. LDH does not affect the life safety of patients (1); however, LDH patients may experience clinical symptoms, such as limb numbness, pain, and neurological disability (2), and in severe cases, incontinence or paraplegia may occur (3). Given the high degree of osteoporosis and obvious physiological degeneration of the vertebrae of the elderly, the incidence of LDH is significantly higher in the middle aged and elderly population than other populations (4). According to the data, the incidence of LDH is about 6/100 people, and increases with age, with the increase being more pronounced in women after the age of 60 (3). Since the elderly have a low tolerance for pain, the pain index of the elderly is higher than that of other people, which greatly affects the quality of life of patients (5).

LDH can be relieved by physical conservative treatment in a significant proportion of patients, and bed rest for 1 week is generally recommended before the gradual resumption of normal activities to minimize the pressure on the intervertebral disc (4). For patients whose symptoms are not relieved after 6 weeks of conservative treatment, surgery is recommended to avoid irreversible changes in the nerve root structure due to chronic compression. Approximately 10–20% of patients in whom conservative treatment has failed require surgical treatment (6). The traditional open surgical method can achieve certain therapeutic effects, but it often leads to a lack of structural integrity in the lumbar spinal canal of patients. The surgery itself is traumatic and the intraoperative blood loss is high. Further, such patients are bedridden for a long time after surgery and serious complications, such as venous thrombosis of the lower limbs and wound infection, are likely to occur (7).

Due to the issues associated with traditional open posterior interlaminar opening surgery, minimally invasive intervertebral foraminoscopic surgery, which offers comparable efficacy and safety with less collateral damage, has received increasing attention in recent years (8). Percutaneous endoscopic transvertebral foraminal access surgery is a minimally invasive procedure with minimal surgical trauma and rapid postoperative recovery, which does not require general anesthesia and does not damage the stable structure of the posterior spinal column. It can be performed under local anesthesia, especially in elderly patients who are frail and have underlying diseases, and thus effectively avoids the risks associated with general anesthesia (9,10). Thus, in recent years, minimally invasive surgery has gradually replaced traditional open surgery as the standard procedure for the treatment of LDH (11).

At present, clinical intervertebral transforaminal endoscopic lumbar discectomy (TELD) mainly uses C-arm machine fluoroscopic navigation, which is a low cost and simple operation (12). However, it can only clearly display the bony structure, with low resolution of the soft tissue, and thus it is difficult to truly reflect the location, morphology, and anatomical relationship between the dural sac and nerve roots of the intervertebral disc tissue, and there is also the disadvantage of fluoroscopic overlap. Repeated fluoroscopy may cause harm to both medical and nursing staff and patients (13). Besides, in a retrospective study (14), of 194 patients who underwent TELD procedures, 32 patients (16.5%) had incomplete clinical improvement and 12 patients (6.1%) required revision surgery. Thus, the search for a more accurate and effective navigation scheme has become a popular area of clinical research.

The 3-dimensional (3D) computed tomography (CT) navigation-assisted intervertebral foraminoscopic surgery is performed under 3D CT guidance. 3D CT accurately displays the anatomical relationship between the protruding disc tissue and the surrounding tissues, enabling the optimal puncture path to be determined within a safe range and the optimal puncture level, puncture angle, and puncture depth to be selected, which in turn makes the puncture process intuitive and clear and ensures the working trocar reaches the target location. It reduces the number of intraoperative punctures and the amount of soft tissue stripped, which consequently reduces the likelihood of infection and the incidence of multiple postoperative complications. 3D CT navigation is superior to the C-arm machine in terms of data acquisition and image quality; it can achieve higher navigation accuracy, visual guidance, and is independent of instruments, and thus improves the

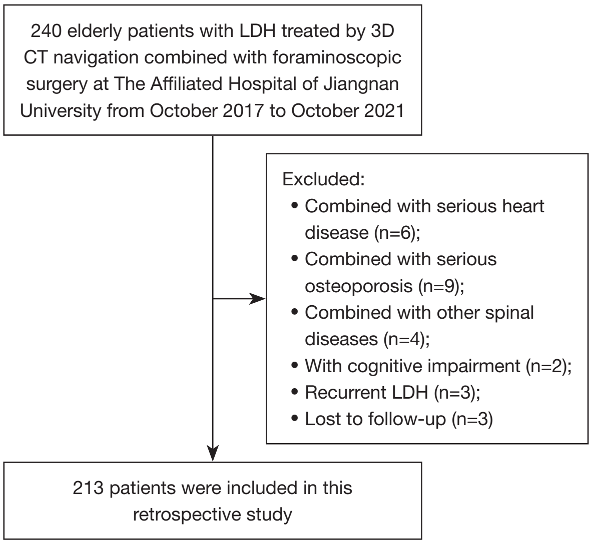

Figure 1 Flow chart of patient selection. LDH, lumbar disc herniation; 3D CT, 3-dimensional computed tomography.

surgical accuracy, reduces the intraoperative blood loss, shortens the operative time and length of hospital stay, decreases the complication rate, and reduces medically-induced injuries (15,16). In addition, studies have shown that the radiation dose generated by navigation-guided nail implantation during minimally invasive transforaminal lumbar interbody fusion surgery is significantly reduced compared to that of conventional X-ray fluoroscopy (17,18), which also indicates that real-time 3D CT navigation technology effectively reduces the radiation dose (19) and protects the health of healthcare workers and patients to a greater extent.

This study sought to analyze the therapeutic effects of 3D CT navigation combined with TELD in elderly LDH patients to identify the relevant risk factors as early as possible and provide a reference basis for reducing the occurrence of postoperative complications, improving the prognosis of patients, and improving their quality of life. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-319/rc).

Methods

Research participants

In total, 240 elderly patients with LDH admitted to The Affiliated Hospital of Jiangnan University from October 2017 to October 2021 were included in this study. The inclusion criteria were as follows: (I) LDH confirmed by CT, magnetic resonance imaging (MRI), and other examinations; symptoms and signs consistent with the imaging manifestations; meet the diagnostic criteria for LDH; (II) aged ≥60 years; (III) have a single segment lesion; (IV) have undergone conservative treatment for 3 months, which was ineffective; (V) be able to tolerate surgery after assessment; and (VI) have voluntarily signed the informed consent form. The exclusion criteria were as follows: (I) recurrent LDH; (II) LDH combined with other spinal diseases, such as lumbar spine tumor, lumbar spine tuberculosis, or lumbar spine infection; (III) LDH combined with serious heart, lung, liver, kidney, and other vital organ diseases; (IV) LDH combined with serious osteoporosis; (V) patients with spinal instability; (VI) had previously undergone surgery resulting in unclear bony anatomy and serious dural sac scar adhesions; (VII) had not been treated and had been discharged, had an unclear diagnosis, or had incomplete information; and/or lacked consciousness or had a communication impairment (*Figure 1*).

The general rule of binary logistic regression requires a ratio of items to a sample size of 1:5 to 1:10. Thus, the required sample size of the study population for this study was 240 patients. The method of random consecutive inclusion of cases was used, and those with incomplete data information were excluded. Finally, after randomization, the patients were divided into 2 groups of 120 cases each, taking into account their wishes. A total of 27 patients were excluded and lost to follow-up; ultimately, 213 patients were included in the analysis. The study was followed up for one year, with the last follow-up occurring in October 2022.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of The Affiliated Hospital of Jiangnan University. Informed consent was provided by all patients.

Grouping and surgical methods

Group A was treated with conventional C-arm fluoroscopy-assisted system alone, and Group B was treated with 3D CT navigation-assisted foraminal surgery based on an electromagnetic navigation system. Patients in both groups were operated on by the same team of surgeons (5 surgeons). (I) Approach design: Siemens double-row Spirit CT scanner (Siemens, Erlangen, Germany) was adopted, the current was 230 m As, the voltage was 120 kV, and the layer thickness was 3 mm. The scanning bed was set as

X axis horizontally, Y axis vertically, and Z axis vertically. The surgical path was designed according to the idea of "point, surface, angle, and direction" by referring to CT images. The injection position, angle, path, and depth were simulated. The infrared navigation system was connected to the intraoperative CT. The imaging data obtained from the CT scan was calculated and reconstructed as a 3D graphic and transmitted to the appropriate navigation software, and the CT scan can be performed and the navigation information updated at any time during the operation, depending on the surgical situation. (II) Catheter insertion operation: 1% lidocaine under local anesthesia, puncture was performed according to the designed path, the puncture needle could reach the articular process bone surface: a CT scan was conducted to confirm that the puncture angle and level were close to or coincided with the predetermined target point, and then the operation was continued. If the position is inappropriate, the injection angle and puncture depth could be adjusted under the guidance of CT until a satisfactory position was achieved. During the CT scan, the operator, assistants, and anesthetist could directly observe the patient in a protected area, and all medical workers were not exposed to radiation during the scan. After auto-registration, a double accuracy check and further confirmation of the accuracy of the navigated images was performed by means of bony markers on the body surface and a reference frame. If intraoperatively the navigation was not accurate enough or if the operator suspected that the navigation was not sufficiently accurate, it was required to repeat the CT scan and registration until the navigation became sufficiently accurate. Although the likelihood of such a situation is very small, it still needs to be treated with caution. The above conditions did not occur in the cases of this study. (III) Removing the nucleus pulposus: after connecting the aperture mirror system, the blue-stained nucleus pulposus tissue was removed under internal vision: the angle of the working channel and the direction of the lens for exploration were adjusted. If the nucleus pulposus protruded and compressed the nerve root and dural sac, it was removed. The residual nuclear tissue was treated by radiofrequency ablation after the nerve root and dural sac were observed, and the annulus fibrosus was crumpled and formed to ensure the removal of the protrusions in the operative area. The operative area was irrigated, the incision was closed, and the drainage tube was placed. Group A underwent conventional C-arm fluoroscopic navigation-assisted foraminal surgery; the C-arm fluoroscopic navigation puncture, cannula insertion, and nucleus pulposus removal methods were the same as those of Group B.

General information questionnaire

A general information questionnaire was designed to gather patients' demographic data [e.g., gender, age, and body mass index (BMI)] and clinical data (e.g., the presence of hypertension, hyperlipidemia, or diabetes, the duration of the disease, the presence of a ruptured fibrous ring, degree of degeneration Pfirmann classification, operative time, length of hospitalization, intraoperative bleeding, number of punctures, postoperative bed rest time, postoperative drainage volume, preoperative work intensity, responsible segment, and a number of laboratory indicators and postoperative complications).

Serum stress response measurement

Fasting venous blood was drawn from patients on the first day of admission and 7 days after surgery, and centrifuged at 3,000 rpm for 5 minutes to separate the serum, which was used for the relevant tests within 1 hour. If the test could not be performed in time, it was immediately stored at −20 ℃ for backup. The specimen was reconstituted and stored in the refrigerator at 2–8 ℃, and the test was completed within 24 hours. The normal range of interleukin 6 (IL-6) was <5 pg/mL; the normal range of C-reactive protein (CRP) was 0–5 mg/L; the normal range of angiotensin II (AngII) was 10–25 ng/L; the normal range of 5-hydroxytryptamine (5-HT) was 10–25 ng/L.

Evaluation of low back disability

The Oswestry disability index (ODI) score was used. The questionnaire comprises 10 questions, that are mainly directed at (I) the degree of pain in the low back or legs; (II) the ability to perform daily activities and take care of oneself; (III) the ability to lift objects; (IV) the distance to walk; (V) the time to remain sitting; (VI) the time to remain standing; (VII) the interference of the pain with sleep; (VIII) social activities; (IX) travel situation; and (X) the effect of the pain on their sexual life. Each question has 6 options with scores ranging from 0 to 5 (low to high). The scores of the 10 questions are summed to calculate a total score out of 50. Higher scores represent more severe functional impairment. The last follow-up occurred in April 2022.

Evaluation of pain level

The visual analogue scale (VAS) was used to evaluate pain.

The VAS asks patients to indicate the degree of pain on a scale of 0 to 10, on which 0 represents no pain; 1–3 represents mild pain that can be tolerated; 4–6 represents pain that disturbs sleep but is still tolerable; and 7–10 represents severe, intolerable pain that severely affects appetite and sleep (20).

Evaluation of efficacy

The MacNab evaluation criteria were used to evaluate efficacy. The MacNab evaluation criteria are as follows: (I) excellent: symptoms completely disappeared, able to live and work normally; (II) good: occasional pain, able to perform lighter work; (III) fair: symptoms were relieved compared to before treatment, but pain was still present; (IV) poor: nerve root compression symptoms were still present, requiring another surgical treatment (17). The following formula was used to calculate the excellent-and-good rate = (excellent + good)/total number of cases × 100%.

Evaluation of prognosis

The Generic Quality of Life Inventory 74 (GQOL-74) was used to evaluate prognosis. This 74-item questionnaire assesses the health-related quality of life across the following 4 dimensions: (I) somatic function; (II) psychological function; (III) social function; and (IV) material life. Each dimension is scored on a 100-point scale, with higher scores indicating a better quality of life (21). The last follow-up occurred in January 2022.

Statistical analysis

The results of each scale were entered into a computer for the score conversion and statistical analysis, which was performed using SPSS 26.0 (IBM Corp., Armonk, NY, USA). The measurement data were expressed as the mean and standard deviation (SD), and the count data were expressed as the frequency and percentage. The statistical analysis between groups was performed using the *t*-test and chi-square test, and the independent risk factors for assessing patient outcomes were analyzed using a binary logistics regression. P values <0.05 were considered statistically significant.

Results

Baseline data

The baseline data are shown in *Table 1*. A total of 213 elderly patients were included in this study. Group A had a mean age of 68.51±4.84 years and a BMI of 20.98±2.30 kg/m^2. Group B had a mean age of 68.03±5.11 years and a BMI of 21.28±2.54 kg/m^2. In Group A, 5 patients (4.85%) had a history of lumbar trauma, 39 had hypertension (37.86%), 19 (18.45%) had diabetes mellitus, 20 (19.42%) had hyperlipidemia, 51 (49.51%) had a disease duration ≥5 years, 57 (55.34%) had a ruptured annulus fibrosus, 27 (26.21%) had disc metamorphosis ≥ grade III, 32 (31.07%) had a high work intensity, and 76 (73.79%) had a disc level of L4–S1. In Group B, 5 patients (4.55%) had a history of lumbar trauma, 47 (42.73%) had hypertension, 20 (18.18%) had diabetes, 18 (16.36%) had hyperlipidemia, 55 (50.00%) had a disease duration ≥5 years, 47 (42.73%) had a ruptured fibrous annulus, 24 (21.82%) had a disc metamorphosis ≥ grade III, 29 (26.36%) had a high work intensity, and 77 (70.00%) had a responsible segment located between L4–S1. The chi-square test showed no statistically significant differences between the 2 groups in relation to any of the above factors.

In Group A, the operative time was 70.44±9.75 minutes, the length of hospital stay was 9.27±1.95 days, the intraoperative bleeding volume was 68.50±7.79 mL, the number of punctures was 1.65±0.68, the postoperative drainage volume was 58.38±7.86 mL, and the postoperative bed rest time was 6.31±1.24 days. In Group B, the operative time was 57.96±8.09 minutes, the length of hospital stay was 7.46±1.38 days, the intraoperative bleeding volume was 51.86±11.93 mL, the number of punctures was 1.41±0.51, the postoperative drainage volume was 40.01±6.59 mL, and the postoperative bed rest time was 4.78±1.21 days. The *t*-test results revealed significant differences between Group A and Group B in terms of the operative time, length of hospital stay, intraoperative bleeding volume, number of punctures, postoperative drainage volume, and postoperative bed rest time (P<0.05).

Comparison of serum stress response indicators and between the 2 groups

The *t*-test results showed that the preoperative Ang II, IL-6, CRP, and 5-HT stress indicators did not differ significantly between Group A and Group B. In Group B, the mean IL-6 was 9.12±1.59 pg/mL, the mean CRP was 5.09±1.59 mg/L, and the mean 5-HT was 1.15±0.28 ng/mL at 7 days postoperatively. In Group A, the mean IL-6 was 12.90±2.16 pg/mL, the mean CRP was 5.58±1.60 mg/L, and the mean 5-HT was 1.27±0.25 ng/mL at 7 days postoperatively. CRP and 5-HT differed significantly between the 2 groups at 7 days

Table 1 Baseline data of the included patients in the 2 groups

Items	Group A	Group B	χ^2/t	P value
Age (years)	68.51±4.84	68.03±5.11	0.714	0.476
Gender			0.013	0.908
Male	61 (59.22)	66 (60.00)		
Female	42 (40.78)	44 (40.00)		
BMI (kg/m^2)	20.98±2.30	21.28±2.54	–0.909	0.365
History of traumatic injury			0.011	0.915
Yes	5 (4.85)	5 (4.55)		
No	98 (95.15)	105 (95.45)		
Hypertension or not			0.523	0.470
Yes	39 (37.86)	47 (42.73)		
No	64 (62.14)	63 (57.27)		
Diabetes or not			0.002	0.960
Yes	19 (18.45)	20 (18.18)		
No	84 (81.55)	90 (81.82)		
Hyperlipidemia or not			0.338	0.561
Yes	20 (19.42)	18 (16.36)		
No	83 (80.58)	92 (83.64)		
Course of the disease (years)			0.005	0.944
<5	52 (50.49)	55 (50.00)		
≥5	51 (49.51)	55 (50.00)		
Fiber ring rupture or not			3.387	0.066
Yes	57 (55.34)	47 (42.73)		
No	46 (44.66)	63 (57.27)		
Degree of degeneration (Pfirmann classification)			0.564	0.453
≥ Grade III	27 (26.21)	24 (21.82)		
< Grade III	76 (73.79)	86 (78.18)		
Operative time (min)	70.44±9.75	57.96±8.09	10.187	<0.001
Length of hospitalization (days)	9.27±1.95	7.46±1.38	7.862	<0.001
Intraoperative bleeding (mL)	68.50±7.79	51.86±11.93	11.968	<0.001
Number of punctures	1.65±0.68	1.41±0.51	2.933	0.004
Postoperative drainage (mL)	58.38±7.86	40.01±6.59	18.516	<0.001
Postoperative bed rest time (days)	6.31±1.24	4.78±1.21	9.129	<0.001
Preoperative work intensity			0.576	0.448
No/light manual labor	71 (68.93)	81 (73.64)		
Long walking and standing/heavy physical labor	32 (31.07)	29 (26.36)		
Disc level			0.377	0.539
L1–L4	27 (26.21)	33 (30.00)		
L4–S1	76 (73.79)	77 (70.00)		

Data are represented as mean ± SD or n (%). Group A: underwent conventional C-arm fluoroscopy-assisted system alone intervertebral foraminoscopic surgery; Group B: underwent 3D CT navigation-assisted intervertebral foraminoscopic surgery. χ^2, chi-square test; *t*, *t*-test; BMI, body mass index; SD, standard deviation; 3D CT, 3-dimensional computed tomography.

Table 2 Comparison of the serum stress response indicators between the 2 groups

Items	N (%)	AngII (ng/L)	IL-6 (pg/mL)	CRP (mg/L)	5-HT (ng/mL)
Preoperative					
Group A	103 (48.36)	23.50±6.64	8.35±1.76	3.51±1.22	1.57±0.45
Group B	110 (51.64)	23.84±6.42	8.70±1.82	3.47±1.16	1.56±0.41
t		–0.371	–1.422	0.272	0.203
P value		0.711	0.157	0.786	0.839
7 days postoperative					
Group A	103 (48.36)	32.55±6.53	12.90±2.16	5.58±1.60	1.27±0.25
Group B	110 (51.64)	31.59±6.05	9.12±1.59	5.09±1.59	1.15±0.28
t		1.117	14.642	2.268	3.446
P value		0.265	<0.001	0.024	0.001

Data are represented as mean ± SD or n (%). Group A: underwent conventional C-arm fluoroscopy-assisted system alone intervertebral foraminoscopic surgery; Group B: underwent 3D CT navigation-assisted intervertebral foraminoscopic surgery. AngII, angiotensin II; IL-6, interleukin 6; CRP, C-reactive protein; 5-HT, 5-hydroxytryptamine; *t*, *t*-test; SD, standard deviation; 3D CT, 3-dimensional computed tomography.

Table 3 Comparison of the lumbar VAS scores between the 2 groups

Items	N (%)	Preoperative	7 days post operation
Group A	103 (48.36)	5.74±1.41	3.50±1.20
Group B	110 (51.64)	5.48±1.56	3.12±1.28
t		1.255	2.226
P value		0.211	0.027

Data are represented as mean ± SD or n (%). Group A: underwent conventional C-arm fluoroscopy-assisted system alone intervertebral foraminoscopic surgery; Group B: underwent 3D CT navigation-assisted intervertebral foraminoscopic surgery. VAS, visual analogue scale; *t*, *t*-test; SD, standard deviation; 3D CT, 3-dimensional computed tomography.

postoperatively (P<0.05; *Table 2*).

Comparison of lumbar VAS scores between the 2 groups

Group B had a preoperative VAS score of 5.48±1.56, and Group A had a preoperative VAS score of 5.74±1.41. There was no significant difference between the VAS scores of the patients in the 2 groups before surgery. On postoperative day 7, Group B had a VAS score of 3.12±1.28, and Group A had a VAS score of 3.50±1.20, and the VAS score of Group A was significantly higher than that of Group B (P<0.05; *Table 3*).

Comparison of postoperative complications between the 2 groups of patients

A chi-square test analysis showed that low-back pain and vascular plexus injury differed significantly between Group A and Group B (P<0.05). In Group B, 9 patients (8.18%) had low-back pain, and 101 patients (91.82%) did not have low-back pain. In Group A, 18 patients (17.48%) had low-back pain, and 85 patients (82.52%) did not have low-back pain. In Group B, 2 patients (1.82%) had vascular plexus injury, and 108 patients (98.18%) did not have vascular plexus injury. In Group A, 8 patients (7.77%) had vascular plexus injury, and 95 patients (92.23%) did not have vascular plexus injury. The postoperative complications of cerebrospinal fluid leak, intervertebral space infection, and delayed body movement did not differ significantly between the 2 groups (*Table 4*).

Comparison of lumbar ODI scores between the 2 groups

The ODI scores did not differ significantly between Group A and Group B preoperatively and at 6 months postoperatively, but did differ significantly at 3 months postoperatively (P<0.05). Group B had a mean preoperative ODI score of 34.75±2.08, a mean postoperative ODI score of 22.05±3.71 at 3 months, and a mean postoperative score ODI of 15.66±3.08 at 6 months. Group A had a mean preoperative ODI score of 34.55±2.12, a mean postoperative ODI score of 25.50±2.65 at 3 months postoperatively, and a mean postoperative ODI score of 16.05±2.84 at 6 months postoperatively (*Table 5*).

Table 4 Comparison of postoperative complications between the 2 groups of patients

Items	Low-back pain		Cerebrospinal fluid leakage		Vascular plexus injury		Intervertebral space infection		Bradykinesia	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Group A	18 (17.48)	85 (82.52)	3 (2.91)	100 (97.09)	8 (7.77)	95 (92.23)	2 (1.94)	101 (98.06)	10 (9.71)	93 (90.29)
Group B	9 (8.18)	101 (91.82)	2 (1.82)	108 (98.18)	2 (1.82)	108 (98.18)	2 (1.82)	108 (98.18)	5 (4.55)	105 (95.45)
χ^2	4.151		0.278		4.207		0.004		2.166	
P value	0.042		0.598		0.040		0.947		0.141	

Data are represented as n (%). Group A: underwent conventional C-arm fluoroscopy-assisted system alone intervertebral foraminoscopic surgery; Group B: underwent 3D CT navigation-assisted intervertebral foraminoscopic surgery. χ^2, chi-square test; 3D CT, 3-dimensional computed tomography.

Table 5 Comparison of the ODI scores between the 2 groups

Items	N (%)	Preoperative	3 months post-operation	6 months post-operation
Group A	103 (48.36)	34.55±2.12	25.50±2.65	16.05±2.84
Group B	110 (51.64)	34.75±2.08	22.05±3.71	15.66±3.08
t		–0.699	7.759	0.945
P value		0.485	<0.001	0.346

Data are represented as mean ± SD or n (%). Group A: underwent conventional C-arm fluoroscopy-assisted system alone intervertebral foraminoscopic surgery; Group B: underwent 3D CT navigation-assisted intervertebral foraminoscopic surgery. ODI, Oswestry disability index; *t*, *t*-test; 3D CT, 3-dimensional computed tomography.

Table 6 Comparison of the MacNab evaluation rates between the 2 groups

Items	N (%)	Excellent	Good	Fair	Poor	The total of excellent and good
Group A	103 (48.36)	46 (44.66)	33 (32.04)	18 (17.48)	6 (5.83)	79 (76.70)
Group B	110 (51.64)	72 (65.45)	27 (24.55)	9 (8.18)	2 (1.82)	99 (90.00)
χ^2			11.111			6.853
P value			0.011			0.009

Data are represented as n (%). Group A: underwent conventional C-arm fluoroscopy-assisted system alone intervertebral foraminoscopic surgery; Group B: underwent 3D CT navigation-assisted intervertebral foraminoscopic surgery. χ^2, chi-square test; 3D CT, 3-dimensional computed tomography.

Comparison of lumbar MacNab evaluations between the 2 groups

The chi-square analysis showed that the MacNab scores differed significantly between Group A and Group B, as did the excellent-and-good rates of both groups (P<0.05). In Group B, 72 patients (65.45%) had excellent scores, 27 (24.55%) had good scores, 9 (8.18%) had fair scores, and 2 (1.82%) had poor scores, with an excellent-and-good rate of 99.00%. In Group A, 46 patients (44.66%) had excellent scores, 33 (32.04%) had good scores, 18 (17.48%) had fair scores, and 6 (5.83%) had poor scores, with an excellent-and-good rate of 76.70% (*Table 6*).

Risk factors of poor efficacy analyzed by binary logistic regression models

The binary logistic regression analysis results showed that the surgical procedure, history of traumatic injury, work intensity, course of the disease, presence or absence of diabetes, presence or absence of a ruptured fiber ring, degree of disc degeneration, and number of punctures were independent risk factors for treatment efficacy (*Table 7*, *Figure 2*).

Table 7 Risk factors of poor efficacy analyzed by binary logistic regression models

Items	B	SE	Wald	P value	OR	95% CI	
						Upper	Lower
Operation methods	–1.358	0.813	2.912	0.042	0.258	1.243	0.051
Age	0.028	0.051	0.297	0.581	1.028	1.116	0.942
Gender	0.072	0.484	0.001	0.977	1.014	2.620	0.392
BMI	0.197	0.094	3.739	0.054	1.243	1.443	0.998
History of traumatic injury	2.256	0.862	8.025	0.005	11.001	37.102	2.215
Course of the disease	1.236	0.536	6.216	0.017	3.587	9.244	1.089
Hypertension or not	–0.256	0.512	0.405	0.547	0.712	2.125	0.271
Hyperlipidemia or not	0.329	0.506	0.257	0.553	1.423	4.269	0.437
Diabetes or not	1.168	0.557	4.853	0.026	3.315	9.542	1.156
Preoperative work intensity	1.552	0.526	9.154	0.002	4.589	11.345	1.725
Disc level	–0.405	0.516	0.552	0.456	0.662	1.856	0.224
Fiber ring rupture or not	1.255	0.512	6.235	0.012	3.485	9.325	1.354
Degree of degeneration (Pfirmann classification)	1.352	0.524	6.824	0.009	3.899	10.745	1.569
Operative time	0.011	0.028	0.081	0.772	1.110	1.218	0.947
Intraoperative bleeding	–0.008	0.026	0.148	0.709	0.981	1.095	0.922
Number of punctures	–0.876	0.389	4.692	0.034	0.412	0.997	0.116

SE, standard error; OR, odds ratio; CI, confidence interval; BMI, body mass index.

Figure 2 Binary logistic regression analysis of poor treatment efficacy. OR, odds ratio; BMI, body mass index.

Comparison of GQOL-74 scores between the 2 groups of patients

In relation to the preoperative GQOL-74 score, the patients in Group A had a psychological function score of 62.21±8.31, a social function score of 73.16±3.93, a material life score of 63.79±7.84, and a somatic function score of 70.57±4.43, whereas those in Group B had a psychological function score of 61.05±7.19, a social function score of 74.29±4.80, a material life score of 62.28±7.05, and a somatic function score of 69.71±6.40. The 2 groups did not differ significantly across any of the 4 dimensions.

In relation to the GQOL-74 scores, 3 months after surgery, the patients in Group A had a psychological function score of 87.26±4.97, a social function score of 88.24±4.18, a material life score of 82.76±7.14, and a

Table 8 Comparison of the GQOL-74 scores between the 2 groups of patients

Items	Psychological function	Social function	Material life	Somatic function
Preoperative				
Group A	62.21±8.31	73.16±3.93	63.79±7.84	70.57±4.43
Group B	61.05±7.19	74.29±4.80	62.28±7.05	69.71±6.40
t	1.091	−1.894	1.475	1.151
P value	0.277	0.060	0.142	0.251
Postoperative				
Group A	87.26±4.97	88.24±4.18	82.76±7.14	87.08±4.66
Group B	87.96±4.66	87.14±4.66	85.12±5.99	90.05±4.52
t	−1.063	1.821	−2.606	−4.732
P value	0.289	0.070	0.010	<0.001

Data are represented as mean ± SD. Group A: underwent conventional C-arm fluoroscopy-assisted system alone intervertebral foraminoscopic surgery; Group B: underwent 3D CT navigation-assisted intervertebral foraminoscopic surgery. GQOL-74, Generic Quality of Life Inventory 74; *t*, *t*-test; SD, standard deviation; 3D CT, 3-dimensional computed tomography.

somatic function score of 87.08±4.66, whereas those in Group B had a psychological function score of 87.96±4.66, a social function score of 87.14±4.66, a material life score of 85.12±5.99, and a somatic function score of 90.05±4.52. The 2 groups differed significantly across the 2 dimensions of somatic function and material life (P<0.05; *Table 8*).

Discussion

LDH is a disease that causes mechanical irritation or compression of the adjacent tissues (mainly the nerve roots, sinus vertebral nerves, or spinal cord) after degenerative changes in the human lumbar intervertebral discs under the action of external forces, which induce painful symptoms in the bones of the back and legs (22). It is a common spinal surgical disease, which mainly manifests clinically as lumbago, sciatica, lower limb numbness, and cauda equina syndrome (23). Epidemiological surveys have reported that LDH is the most common cause of nerve root compression in the lumbosacral region (24). In China, the incidence of LDH is about 7.62%, and it is increasing year by year (25,26). It mostly occurs in those aged 20–50 years, and the lesions, which are mostly in L4–5 and L5–S1, seriously affect patients' quality of life and place a serious burden on the medical system and patients' families (27,28).

Non-surgical treatment can be used to clinically relieve symptoms and improve patients' daily life, but surgical treatments should be actively considered if the conventional non-surgical treatment is ineffective or for those in whom the condition is relatively more severe. A study showed that about 15–20% of patients with LDH require surgical treatment due to severe neurological symptoms (29). Traditional open surgery plays a large therapeutic role (with limitations), but it is difficult to achieve satisfactory results. TELD technology, which has gradually matured, can remove larger nucleus pulposus tissues under direct vision and has a strong decompression effect, and thus addresses the shortcomings of traditional surgery (30,31). Feng *et al.* (32) conducted a meta-analysis and found that TELD is the best surgical modality for the treatment of LDH.

There are several surgical treatment modalities available in the clinic, and minimally invasive surgical therapies, such as early collagenase discolysis, ozone (O_3) discolysis, radiofrequency ablation, and laser vaporization decompression, have developed rapidly in the past 20 years, and have been widely used. Among them, percutaneous TELD is a relatively recent surgery, which has a number of advantages, including less trauma, better efficacy, faster recovery, and fewer complications, and it is increasingly being used clinically with more satisfactory treatment results (33,34). At present, minimally invasive surgery for LDH is mainly performed with fluoroscopic navigation using a C-arm machine, which is inexpensive and simple to operate, but it uses 2-dimensional (2D) imaging and requires multiple fluoroscopies. Previously, minimally invasive surgery was performed under the supervision of a general X-ray C-arm machine, which is difficult to locate and puncture, requires more practical experience, and is prone to complications (35,36). 3D CT navigation is superior to C-arm fluoroscopy in terms of data acquisition and image quality, but there are few studies on the therapeutic effects of 3D CT navigation combined with TELD in elderly LDH patients; this study sought to further analyze these issues.

The findings of this study indicate that the use of 3D CT navigation in combination with intervertebral foraminoscopy is associated with significant reductions in operative time, length of hospital stay, postoperative bed rest, intraoperative bleeding, postoperative drainage, and the number of punctures, which suggests that the use of 3D CT navigation is likely to significantly improve the outcome of the procedure. In addition, the laboratory stress indicators, such as IL-6, CRP, and 5-HT, were significantly lower in Group B than Group A at 7 days after surgery, but there was no significant difference in the above indicators before surgery.

A study has shown that the body undergoes a strong stress response during surgical trauma, accompanied by changes in the levels of various stress-related factors in the serum (37). Edema occurs after the prolonged compression of spinal nerves, which in turn leads to the production of large amounts of inflammatory substances in the surrounding area. IL-6 is a pro-inflammatory mediator with multiple biological functions and plays an important role in the regulation of the inflammatory response and immune response (38). CRP is an acute temporal response protein synthesized by the liver, and its serum level is positively correlated with the inflammatory response of the body (39). These results suggest that 3D CT navigation-assisted laminectomy is associated with a reduction in the stress response of the body. This may be because 3D CT improves the accuracy of punctures by revealing the optimal puncture path before surgery, which in turn reduces the damage to the surrounding tissues, the abnormal expression of stress factors, and the stress response of patients.

In this study, no significant difference was found between the VAS scores of the 2 groups before surgery; however, the scores of Group B were significantly lower than those of Group A at 7 days after surgery. Thus, 3D CT navigation-assisted intervertebral foraminoscopic surgery is strongly associated with a reduction in the patients' postoperative pain. The ODI score at 3 months postoperatively was also lower in Group B than in Group A, but there was no difference between the 2 groups preoperatively and 6 months postoperatively. Thus, the application of 3D CT navigation technology is significantly associated with a reduction in the possibility of postoperative lumbar and leg disability in the patients after surgery; however, the same effect was achieved after a long period of postoperative recuperation with little difference from those in whom the 3D CT navigation technology was not applied.

The MacNab score reflects the overall efficacy of the surgery. This study showed that the application of the 3D CT navigation technology produced a significant postoperative outcome. In addition, in this study, the postoperative complications of the 2 groups were compared, and it was found that the postoperative complication rate of the patients in whom 3D CT navigation was used was significantly lower than that in whom the 3D CT navigation was not used, which further demonstrates that 3D CT navigation-assisted intervertebral foraminoscopy may have a higher safety profile. Performing 3D CT navigation-assisted intervertebral under 3D CT guidance enables the operator to clearly understand the condition of the intervertebral disc and the proximity of the surrounding important tissues, and thus avoid the adjacent nerves and blood vessels, thereby greatly reducing the possibility of postoperative complications and improving the overall efficacy of the surgery (40).

The postoperative follow-up results of this study showed that Group B was significantly better than Group A in terms of both material life and somatic function in the postoperative period. Thus, 3D CT navigation-assisted intervertebral foraminoscopic surgery significantly improved the prognosis of patients. In traditional foraminoscopic surgery, the narrow endoscopic field of view and the lack of sufficient operating space for the operator to determine the degree of decompression easily leads to the incomplete removal of the herniated disc tissue, which is an important factor affecting the prognosis of LDH patients (41). Conversely, CT has a high spatial and density resolution, which creates the maximum operating space and optimal operating force line while ensuring patient safety, and clearly displays the morphology, location, size, and relationship between the nerve roots and the herniated disc tissue. This allows the surgeon to reach the target hole with intraoperative precision, reduces the amount of soft tissue stripping, and reduce's patient trauma, which in turn can accelerate the patients postoperative recovery. During the operation, the CT value measures whether the herniated disc has been completely removed, and if any residue is found, its position and angle can be determined according to the CT image, so that the direction of the lingual opening of the trocar can be adjusted for further removal to ensure the complete removal of the herniated disc, thus reducing patients' back and leg pain. However, there are many factors affecting the long-term effect of surgery, which may also be related to each patient's daily life and work intensity. In conclusion, 3D CT navigation-assisted intervertebral foraminoscopic surgery for LDH is generally effective and safe and may have a significant role in reducing postoperative complications and improving the prognosis and quality of life of patients after surgery.

The main limitation of this study was that the follow-up period was relatively short due to time and manpower limitations, and the postoperative survival rate of patients in both groups was not examined; it is recommended that a longer follow-up period be used in future studies. The current 3D CT technology has a wide range of applications and should not be limited to the application of local anesthesia surgery, but in the future its effectiveness in general anesthesia surgery should be further explored.

Conclusions

3D CT navigation-assisted intervertebral foraminoscopic surgery for LDH effectively reduces the number of punctures, decreases the intraoperative bleeding and postoperative drainage volumes, shortens the length of hospitalization, bed rest time, and operative time, reduces stress reactions, decreases the degree of low-back pain and the risk of complications, has better overall efficacy, and significantly improves patient prognosis.

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Footnote

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Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-319/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of The Affiliated Hospital of Jiangnan University. Informed consent was provided by all patients.

References

1. Wang Z, Chen Z, Wu H, Wang X, Wang K, Duan W, Guan J, Liu Z, Jian F. Treatment of high-iliac-crest L5-S1 lumbar disc herniation via a transverse process endoscopic transforaminal approach. Clin Neurol Neurosurg 2020;197:106087.
2. Yu P, Mao F, Chen J, Ma X, Dai Y, Liu G, Dai F, Liu J. Characteristics and mechanisms of resorption in lumbar disc herniation. Arthritis Res Ther 2022;24:205.
3. Xu J, Ding X, Wu J, Zhou X, Jin K, Yan M, Ma J, Wu X, Ye J, Mo W. A randomized controlled study for the treatment of middle-aged and old-aged lumbar disc herniation by Shis spine balance manipulation combined with bone and muscle guidance. Medicine (Baltimore) 2020;99:e23812.
4. Wan S, Xue B, Xiong Y. Three-Dimensional Biomechanical Finite Element Analysis of Lumbar Disc Herniation in Middle Aged and Elderly. J Healthc Eng 2022;2022:7107702.
5. El Tumi H, Johnson MI, Dantas PBF, Maynard MJ, Tashani OA. Age-related changes in pain sensitivity in healthy humans: A systematic review with meta-analysis. Eur J Pain 2017;21:955-64.
6. Ma C, Li H, Zhang T, Wei Y, Zhang H, Yu F, Lv Y, Ren Y. Comparison of Percutaneous Endoscopic Interlaminar Discectomy and Open Fenestration Discectomy for Single-Segment Huge Lumbar Disc Herniation: A Two-year Follow-up Retrospective Study. J Pain Res 2022;15:1061-70.
7. Kale A, Oz II, Onk A, Kalaycı M, Büyükuysal Ç. Unilaterally posterior lumbar interbody fusion with double expandable peek cages without pedicle screw

support for lumbar disc herniation. Neurol Neurochir Pol 2017;51:53-9.
8. Jitpakdee K, Liu Y, Heo DH, Kotheeranurak V, Suvithayasiri S, Kim JS. Minimally invasive endoscopy in spine surgery: where are we now? Eur Spine J 2023;32:2755-68.
9. Knight MT, Jago I, Norris C, Midwinter L, Boynes C. Transforaminal endoscopic lumbar decompression & foraminoplasty: a 10 year prospective survivability outcome study of the treatment of foraminal stenosis and failed back surgery. Int J Spine Surg 2014;8:21.
10. Jasper GP, Francisco GM, Aghion D, Telfeian AE. Technical considerations in transforaminal endoscopic discectomy with foraminoplasty for the treatment of spondylolisthesis: Case report. Clin Neurol Neurosurg 2014;119:84-7.
11. Han Q, Meng F, Chen M, Lu X, Zhao D, Wu D, Wang T, Qin R. Comparison Between PE-TLIF and MIS-TLIF in the Treatment of Middle-Aged and Elderly Patients with Single-Level Lumbar Disc Herniation. J Pain Res 2022;15:1271-82.
12. Hofstetter CP, Ahn Y, Choi G, Gibson JNA, Ruetten S, Zhou Y, et al. AOSpine Consensus Paper on Nomenclature for Working-Channel Endoscopic Spinal Procedures. Global Spine J 2020;10:111S-21S.
13. Yang Y, Dong J, Liu Z, Chen R, Chen Z, Zhai Z, Qi J, Rong L. Clinical study on real-time three-dimensional CT navigation-guided full-endoscopic lumbar interbody fusion. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2022;36:665-71.
14. Jitpakdee K, Liu Y, Kim YJ, Kotheeranurak V, Kim JS. Factors associated with incomplete clinical improvement in patients undergoing transforaminal endoscopic lumbar discectomy for lumbar disc herniation. Eur Spine J 2023;32:2700-8.
15. Arif S, Brady Z, Enchev Y, Peev N, Encheva E. Minimising radiation exposure to the surgeon in minimally invasive spine surgeries: A systematic review of 15 studies. Orthop Traumatol Surg Res 2021;107:102795.
16. Klingler JH, Scholz C, Hohenhaus M, Volz F, Naseri Y, Krüger MT, Vasilikos I, Roelz R, Brönner J, Hoedlmoser H, Sircar R, Hubbe U. Radiation Exposure to Scrub Nurse, Assistant Surgeon, and Anesthetist in Minimally Invasive Spinal Fusion Surgery Comparing 2D Conventional Fluoroscopy With 3D Fluoroscopy-based Navigation: A Randomized Controlled Trial. Clin Spine Surg 2021;34:E211-5.
17. Konieczny MR, Krauspe R. Navigation Versus Fluoroscopy in Multilevel MIS Pedicle Screw Insertion: Separate Analysis of Exposure to Radiation of the Surgeon and of the Patients. Clin Spine Surg 2019;32:E258-65.
18. Vaishnav AS, Merrill RK, Sandhu H, McAnany SJ, Iyer S, Gang CH, Albert TJ, Qureshi SA. A Review of Techniques, Time Demand, Radiation Exposure, and Outcomes of Skin-anchored Intraoperative 3D Navigation in Minimally Invasive Lumbar Spinal Surgery. Spine (Phila Pa 1976) 2020;45:E465-76.
19. Reed MD, Van Nostran W. Assessing pain intensity with the visual analog scale: a plea for uniformity. J Clin Pharmacol 2014;54:241-4.
20. Macnab I. Negative disc exploration. An analysis of the causes of nerve-root involvement in sixty-eight patients. J Bone Joint Surg Am 1971;53:891-903.
21. Hong Y, Yan H, Wurichayihu, Zhang G. The effects of comprehensive nursing interventions on the negative emotions, quality of life, and nursing satisfaction in intracerebral hemorrhage patients. Am J Transl Res 2021;13:4860-7.
22. Wei FL, Zhou CP, Zhu KL, Du MR, Liu Y, Heng W, Wang H, Yan XD, Sun LL, Qian JX. Comparison of Different Operative Approaches for Lumbar Disc Herniation: A Network Meta-Analysis and Systematic Review. Pain Physician 2021;24:E381-92.
23. Stevens S, Agten A, Timmermans A, Vandenabeele F. Unilateral changes of the multifidus in persons with lumbar disc herniation: a systematic review and meta-analysis. Spine J 2020;20:1573-85.
24. Wang N, Sun D, Zhang X, Xi Z, Li J, Xie L. Nerve abnormalities in lumbar disc herniation: A systematic review and meta-analysis of diffusion tensor imaging. PLoS One 2022;17:e0279499.
25. Yuan S, Lin X, Hong J, Qiu C, Chen D. Effects of traditional Chinese exercise on lumbar disc herniation: A protocol of network meta-analysis of randomized controlled trials. Medicine (Baltimore) 2020;99:e18781.
26. Chen BL, Guo JB, Zhang HW, Zhang YJ, Zhu Y, Zhang J, Hu HY, Zheng YL, Wang XQ. Surgical versus non-operative treatment for lumbar disc herniation: a systematic review and meta-analysis. Clin Rehabil 2018;32:146-60.
27. Delgado-López PD, Rodríguez-Salazar A, Martín-Alonso J, Martín-Velasco V. Lumbar disc herniation: Natural history, role of physical examination, timing of surgery, treatment options and conflicts of interests. Neurocirugia (Astur) 2017;28:124-34.
28. Yin M, Mo W, Wu H, Xu J, Ye J, Chen N, Marla AS,

Ma J. Efficacy of Caudal Epidural Steroid Injection with Targeted Indwelling Catheter and Manipulation in Managing Patients with Lumbar Disk Herniation and Radiculopathy: A Prospective, Randomized, Single-Blind Controlled Trial. World Neurosurg 2018;114:e29-34.
29. Zhang B, Xu H, Wang J, Liu B, Sun G. A narrative review of non-operative treatment, especially traditional Chinese medicine therapy, for lumbar intervertebral disc herniation. Biosci Trends 2017;11:406-17.
30. Harper R, Klineberg E. The evidence-based approach for surgical complications in the treatment of lumbar disc herniation. Int Orthop 2019;43:975-80.
31. Stienen MN, Cadosch D, Hildebrandt G, Gautschi OP. The lumbar disc herniation - management, clinical aspects and current recommendations. Praxis (Bern 1994) 2011;100:1475-85.
32. Feng F, Xu Q, Yan F, Xie Y, Deng Z, Hu C, Zhu X, Cai L. Comparison of 7 Surgical Interventions for Lumbar Disc Herniation: A Network Meta-analysis. Pain Physician 2017;20:E863-71.
33. Yeung AT, Tsou PM. Posterolateral endoscopic excision for lumbar disc herniation: Surgical technique, outcome, and complications in 307 consecutive cases. Spine (Phila Pa 1976) 2002;27:722-31.
34. Hoogland T, Schubert M, Miklitz B, Ramirez A. Transforaminal posterolateral endoscopic discectomy with or without the combination of a low-dose chymopapain: a prospective randomized study in 280 consecutive cases. Spine (Phila Pa 1976) 2006;31:E890-7.
35. Ahn Y, Lee HY, Lee SH, Lee JH. Dural tears in percutaneous endoscopic lumbar discectomy. Eur Spine J 2011;20:58-64.
36. Lee SH, Kang BU, Ahn Y, Choi G, Choi YG, Ahn KU, Shin SW, Kang HY. Operative failure of percutaneous endoscopic lumbar discectomy: a radiologic analysis of 55 cases. Spine (Phila Pa 1976) 2006;31:E285-90.
37. Manchikanti L, Pampati V, Benyamin RM, Hirsch JA. Cost Utility Analysis of Lumbar Interlaminar Epidural Injections in the Treatment of Lumbar Disc Herniation, Central Spinal Stenosis, and Axial or Discogenic Low Back Pain. Pain Physician 2017;20:219-28.
38. Purdy M, Kokki M, Anttila M, Aspinen S, Juvonen P, Korhonen R, Selander T, Kokki H, Eskelinen M. Does the Rectus Sheath Block Analgesia Reduce the Inflammatory Response Biomarkers' IL-1ra, IL-6, IL-8, IL-10 and IL-1β Concentrations Following Surgery? A Randomized Clinical Trial of Patients with Cancer and Benign Disease. Anticancer Res 2016;36:3005-11.
39. VanDevanter DR, Heltshe SL, Skalland M, West NE, Sanders DB, Goss CH, Flume PA. C-reactive protein (CRP) as a biomarker of pulmonary exacerbation presentation and treatment response. J Cyst Fibros 2022;21:588-93.
40. Ren H, Shen Y, Zhang YZ, Ding WY, Xu JX, Yang DL, Cao JM. Correlative factor analysis on the complications resulting from cement leakage after percutaneous kyphoplasty in the treatment of osteoporotic vertebral compression fracture. J Spinal Disord Tech 2010;23:e9-15.
41. Pan L, Zhang P, Yin Q. Comparison of tissue damages caused by endoscopic lumbar discectomy and traditional lumbar discectomy: a randomised controlled trial. Int J Surg 2014;12:534-7.

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