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Contralateral radiculopathy after unilateral transforaminal lumbar interbody fusion: causes and prevention

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Abstract

Background: Unilateral transforminal lumbar interbody fusion (TLIF) with a single cage can provide circumferential fusion and biomechanical stability. However, the causes and prevention of contralateral radiculopathy following unilateral TLIF remain unclear.

Methods: In total, 190 patients who underwent unilateral TLIF from January 2017 to January 2019 were retrospectively reviewed. Radiological parameters including lumbar lordosis, segmental angle, anterior disc height, posterior disc height (PDH), foraminal height (FH), foraminal width, and foraminal area (FA) were measured preoperatively and postoperatively. Preoperative and postoperative visual analog scale scores were also recorded.

Results: The incidence of contralateral radiculopathy after unilateral TLIF was 5.3% (10/190). The most common cause was contralateral foraminal stenosis. Unilateral TLIF could increase the lumbar lordosis, segmental angle, and anterior disc height but decrease the PDH, FA, and FH in patients with symptomatic contralateral radiculopathy. The intervertebral cage should be placed to cover the epiphyseal ring and cortical compact bone of the midline, and the disc height can be increased to enlarge the contralateral foramen.

Conclusion: The most common cause of contralateral radiculopathy is contralateral foraminal stenosis. Careful preoperative planning is necessary to achieve satisfactory outcomes. Improper unilateral TLIF will decrease the PDH, FA, and FH, resulting in contralateral radiculopathy.

Keywords

Contralateral radiculopathy, unilateral, transforaminal interbody fusion, foraminal stenosis, single cage, preoperative planning

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Introduction

Lumbar fusion with posterior instrumentation is the standard procedure for treatment of degenerative lumbar diseases. Many lumbar fusion methods are available, including posterior lumbar interbody fusion (PLIF), transforminal lumbar interbody fusion (TLIF), anterior lumbar interbody fusion (ALIF), and lateral lumbar interbody fusion (LLIF). PLIF was first introduced by Briggs and Milligan[1] in 1944, but the procedure was associated with a risk of nerve root and cauda equina injuries because of retraction. TLIF was introduced by Harms and Jeszenszky[2] in 1998. The classic TLIF procedure was performed by the foramen approach on the side of the symptomatic radiculopathy.[3] Some studies have shown that TLIF has a higher success rate and lower complication rate than other methods.[4,5] ALIF is associated with a risk of blood vessel injury due to blood vessel bifurcation, and LLIF is associated with a risk of approach-related complications such as neurological morbidity due to damage to the lumbar plexus and psoas weakness.[6]

TLIF can reduce retraction of the nerve root and dura and preserve a more normal structure when compared with PLIF. TLIF also avoids the risk of the anterior approach and reduces the incidence of neurological complications. However, correction of spinal deformity and restoration of lumbar lordosis (LL) is more difficult with TLIF than with ALIF and LLIF. Several recent studies have shown that postoperative contralateral radiculopathy is a complication of unilateral TLIF or TLIF using minimally invasive surgery (MIS-TLIF).[7–9] The rate of postoperative contralateral radiculopathy is low because the unilateral TLIF cage increases the disc height and foraminal height (FH), achieving indirect decompression of the contralateral foramen.

The causes and prevention of contralateral radiculopathy following unilateral TLIF have not been well described. In the present study, we aimed to identify the causes and preventive methods for symptomatic contralateral radiculopathy.

Patients and methods

Patient population

Patients who underwent unilateral TLIF from January 2017 to January 2019 were retrospectively reviewed. The inclusion criteria were low back pain with unilateral radiculopathy, degenerate spinal stenosis, spondylolisthesis, recurrent postoperative disc herniation, surgery involving two or fewer levels, and surgery between L3 and S1. The exclusion criteria were congenital spinal stenosis, spinal infection, spinal tumor or acute lumbar fracture, surgery involving more than three levels, revision surgery after previous lumbar fusion, and bilateral TLIF and decompression for patients with bilateral radicular symptoms. The reporting of this study conforms to the STROBE statement.[10] The study was approved by the ethics committee of Ningbo No. 6 Hospital.

All patients underwent conservative treatment for more than 6 months before surgery. Unilateral TLIF was performed by two senior surgeons in the same institution.

The enrolled patients were divided into a symptomatic and an asymptomatic group. The symptomatic group comprised patients who presented with new leg symptoms including pain, hypoesthesia, paresthesia, and motor weakness in the leg contralateral to the incision side within 1 week after surgery. The asymptomatic group comprised patients without contralateral symptoms after surgery. Written informed consent was obtained from all patients for publication of their clinical details and/or clinical images.

Operative technique

All unilateral TLIF procedures were performed by two senior surgeons (W-Y.J. and W-H.M.). Following general anesthesia, the patient was positioned prone with lumbar extension on a radiolucent table. After a midline incision, unilateral facetectomy was performed on the symptomatic side. The superior articular process of the lower vertebra was partially removed with preservation of the pedicle. Contralateral-side decompression was not performed, and the contralateral ligamentum flavum was saved. After meticulous endplate preparation, the disc space was filled with autologous bone and a PEEK cage. Pedicle screws (Medtronic, Minneapolis, MN, USA) were subsequently placed using the freehand technique with a pedicle probe. Two rods were then placed on the screws and tightened with even compression force bilaterally. The incision was closed in layers following wound hemostasis and irrigation.

Postoperative management

After the patients had recovered from anesthesia, nonsteroidal anti-inflammatory drugs (NSAIDs) and methylprednisolone were administered to relieve pain and inflammation of the nerve root. Radiographs and computed tomography (CT) scans were obtained for all patients after removal of drainage. Magnetic resonance imaging was performed if further evaluation was needed according to the patient's condition. All patients began walking on day 2 or 3 postoperatively while wearing a brace. If radiculopathy occurred on the contralateral side, NSAIDs were administered as the first treatment. Nerve block was performed if necessary to ensure the diagnosis of contralateral foraminal stenosis. Revision surgery was immediately performed when root compression was definitive on imaging studies or motor weakness occurred. Revision surgeries, such as discectomy, screw repositioning, hematoma removal, and facetectomy, were performed for contralateral pathologies.

Radiological parameter measurement

LL and segmental angle (SA) were measured on lateral radiographs preoperatively and postoperatively. Anterior disc height (ADH), posterior disc height (PDH), FH, foraminal width (FW), and foraminal area (FA) were measured on CT images using software of a picture archiving and communication system.

LL was measured as the angle between the upper endplates of L1 and S1. SA was measured by the Cobb method using the inferior and superior endplate line at the surgical level. ADH was defined as the distance between the anterior end of the inferior and superior endplates, and PDH was defined as the distance between the posterior endplates. FH was measured as the distance between pedicles. FW was defined as the maximum width between the posterior vertebral body line and anterior border of the inferior articular process of the upper vertebra. FA (mm^2) was defined as the area of the intervertebral foramen using the sagittal view at the center of the pedicle (Figure 1).

Clinical outcomes

Clinical outcome assessment was performed in our outpatient department. Visual analog scale (VAS) scores were recorded to assess the differences in clinical outcomes between the two groups before surgery and 6 months after surgery.

Statistical analysis

Statistical analysis was performed with IBM SPSS Statistics for Windows, Version

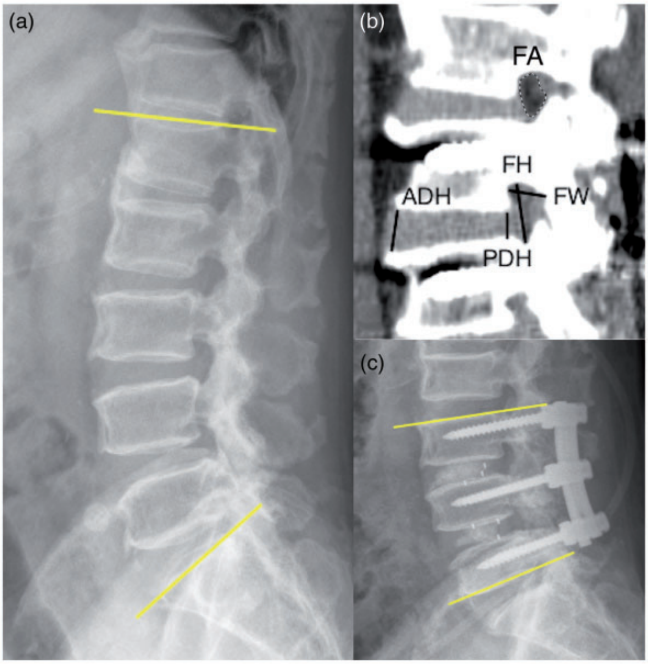

Figure 1. Measurements of radiological parameters. (a) LL. (b) ADH, PDH, FA, FH, and FW. (c) Segmental angle.
LL, lumbar lordosis; ADH, anterior disc height; PDH, posterior disc height; FA, foraminal area; FH, foraminal height; FW, foraminal width.

22.0 (IBM Corp., Armonk, NY, USA), and a p-value of <0.05 was considered statistically significant. Data obtained through the measured VAS scores, LL, SA, FH, FW, and FA were analyzed using the t-test.

Results

In total, 190 patients were included in this study (180 in the asymptomatic group and 10 in the symptomatic group). The incidence of contralateral radiculopathy after unilateral TLIF was 5.3% (10/190). There were no statistically significant differences in age, sex, diagnosis, operation time, or surgical levels between the two groups (Table 1).

The most common cause of contralateral radiculopathy was contralateral foraminal stenosis (4 patients, 30%), followed by facet subluxation (2 patients, 20%), hematoma formation (2 patients, 20%), a newly herniated disc (1 patient, 10%), and screw malpositioning (1 patient, 10%) (Figure 2).

Seven patients in the symptomatic group attained relief after using NSAIDs, dehydration, and steroids (Figure 3). Two patients underwent revision surgery because of facet subluxation and screw malpositioning. One patient with a hematoma was treated with epidural injection (Figure 4).

There were no statistically significant differences in any preoperative or postoperative radiological and clinical outcomes except for the postoperative FH, FW, and FA between the symptomatic and asymptomatic groups. Postoperative FH, FW, and FA were significantly smaller in the symptomatic than asymptomatic group ($p < 0.05$) (Table 2). Postoperative PDH

Table 1. Demographic data of patients in symptomatic and asymptomatic groups.

	Age (years)	Sex		Diagnosis			Operation time (minutes)	Surgical levels	Follow-up (months)
		Male	Female	Spinal stenosis	Spondylolisthesis	Lumbar disc herniation			
Symptomatic group	62.00 ± 9.46	4	6	5	3	2	81.73 ± 22.61	1.50 ± 0.53	10.18 ± 2.82
Asymptomatic group	57.83 ± 6.63	98	82	84	58	38	77.39 ± 20.73	1.46 ± 0.50	12.36 ± 3.35
p value	0.06	0.65		0.88		0.57	0.83	0.06	

Data are presented as mean ± standard deviation or n.

(3.03 ± 1.08 mm) and postoperative FA ($46.70 \pm 23.05\ mm^2$) were much smaller than the preoperative values (3.91 ± 1.74 mm and $58.50 \pm 27.66\ mm^2$, respectively) in the symptomatic group ($p < 0.05$). Preoperative and postoperative FH in the symptomatic group were 13.85 ± 4.00 and 11.72 ± 4.24 mm, respectively, with a significant difference ($p < 0.05$). Postoperative LL, SA, and ADH in the symptomatic group were significantly higher than the preoperative values ($p < 0.05$). There was no significant difference between preoperative and postoperative FW in the symptomatic group.

The mean preoperative VAS scores were 7.00 ± 0.67 and 7.53 ± 0.62 in the symptomatic and asymptomatic groups, and the mean 6-month postoperative VAS scores were 2.30 ± 0.48 and 1.93 ± 0.57, respectively, with no significant difference between the two groups.

Discussion

The goal of lumbar interbody fusion is to restore normal anatomy, including disc height, FA, and sagittal and coronal balance. Unilateral TLIF with a single cage can provide circumferential fusion and biomechanical stability.[11] Kim et al.[12] reported that unilateral MIS-TLIF can achieve indirect decompression of the contralateral foramen by increasing its height, width, and area. However, cases of contralateral radiculopathy following unilateral TLIF are still being reported. The incidence ranges from 1.9% to 5.9% after open TLIF and 2.0% to 8.5% after MIS-TLIF,[8] which is consistent with our study (5.3%).

Our study showed that unilateral TLIF can increase the LL, SA, and ADH but decrease the PDH, FA, and FH in patients with symptomatic contralateral radiculopathy. The most common cause of contralateral radiculopathy is contralateral foraminal stenosis, including facet

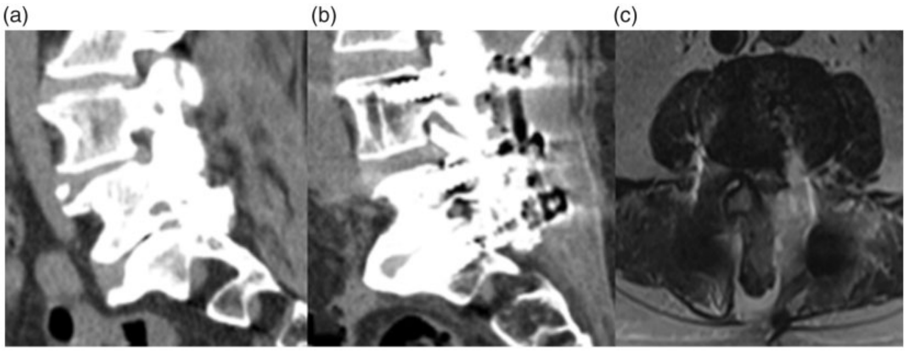

Figure 2. Main causes of contralateral radiculopathy. (a) Previous preoperative contralateral foramen stenosis. (b) Superior facet subluxation. (c) Postoperative hematoma.

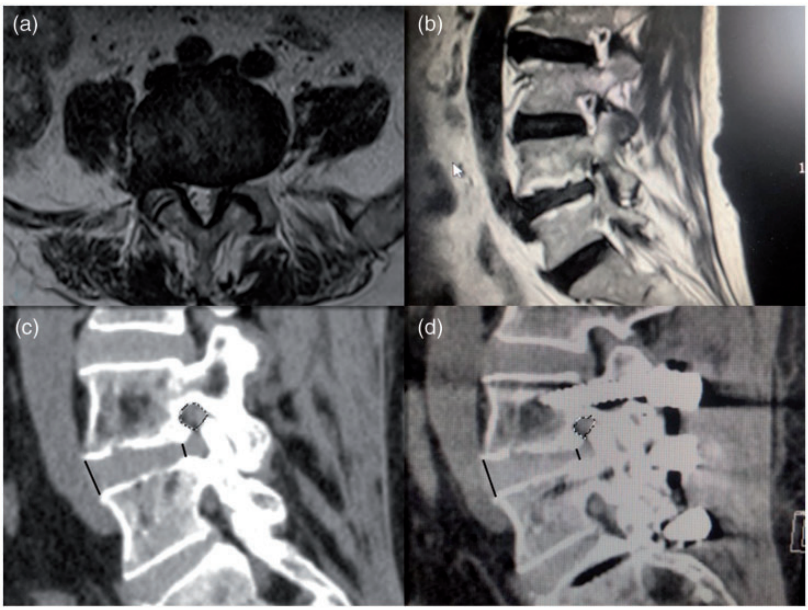

Figure 3. (a) Preoperative axial magnetic resonance imaging showed far lateral disc herniation on the right side and lateral recess stenosis on the left side. (b, c) Preoperative sagittal magnetic resonance imaging and computed tomography showed contralateral foramen stenosis. PDH was 3.97 mm, FH was 18.15 mm, FW was 8.88 mm, and FA was 0.54 mm^2. (d) Postoperative computed tomography showed that the PDH was 3.24 mm, FH was 14.8 mm, FW was 8.13 mm, and FA was 0.33 mm^2.
PDH, posterior disc height; FH, foraminal height; FW, foraminal width; FA, foraminal area.

subluxation, a newly herniated disc, and hematoma formation.[8,13]

During unilateral TLIF, the rods are precurved to achieve LL. Lordosis is restored by compressing the pedicle screws and inserting a lordotic cage. However, LL and the SA may worsen the contralateral foramen and compress the exiting nerve root.[14] Moreover, excessive compression on the pedicle screws after inserting the

Figure 4. (a) Preoperative computed tomography showed that the PDH was 1.25 mm, FH was 8.47 mm, FW was 7.99 mm, and FA was 0.25 mm^2. (b) Postoperative computed tomography showed that the PDH was 0.64 mm, FH was 8.06 mm, FW was 6.93 mm, and FA was 0.15 mm^2. (c) Postoperative radiograph showed good reduction of spondylolisthesis. (d) The contralateral radiculopathy was relieved after an injection procedure.
PDH, posterior disc height; FH, foraminal height; FW, foraminal width; FA, foraminal area.

cage will decrease the contralateral FH and lead to facet subluxation, resulting in contralateral radiculopathy.[7]

The cage position is also a risk factor for detrimental changes in the contralateral FH. Cho et al.[15] found that when the cage was on the ipsilateral side, the ipsilateral FH increased significantly while the contralateral FH decreased. We once assessed a new “cylinder wall theory,” revealing that the epiphyseal ring and cortical compact bone have the effect of supporting the cage.[16] The intervertebral cage should be placed to cover the epiphyseal ring and cortical compact bone of the midline, and the disc height can be increased to enlarge the contralateral foramen. Our relatively low incidence (5.3%) of contralateral radiculopathy may be associated with our intraoperative protocol highlighting the details of the endplate preparation and cage placement.

Table 2. Preoperative and postoperative radiological and clinical outcomes between symptomatic and asymptomatic groups.

	Symptomatic group	Asymptomatic group	p value
Preoperative			
Lumbar lordosis	38.46 ± 11.21	37.98 ± 5.88	0.92
Segmental angle	18.30 ± 8.28	16.09 ± 5.90	0.59
Anterior disc height	9.07 ± 2.82	7.67 ± 1.29	0.19
Posterior disc height	3.91 ± 1.74	3.63 ± 1.13	0.81
Foraminal area	58.50 ± 27.66	70.67 ± 22.11	0.10
Foraminal height	13.85 ± 4.00	13.50 ± 1.84	0.94
Foraminal width	6.69 ± 1.09	7.65 ± 2.11	0.34
VAS score	7.00 ± 0.67	7.53 ± 0.62	0.14
Postoperative			
Lumbar lordosis	45.53 ± 11.51*	42.43 ± 5.69	0.35
Segmental angle	21.69 ± 8.93*	17.22 ± 6.05	0.32
Anterior disc height	10.93 ± 2.58*	10.22 ± 1.99	0.69
Posterior disc height	3.03 ± 1.08*	5.15 ± 0.92	0.96
Foraminal area	46.70 ± 23.05*	97.33 ± 29.49	<0.001
Foraminal height	11.72 ± 4.24*	16.05 ± 2.73	0.02
Foraminal width	6.14 ± 1.15	8.68 ± 1.98	0.02
VAS score	2.30 ± 0.48*	1.93 ± 0.57	0.44

Data are presented as mean ± standard deviation.
VAS, visual analog scale.
*$p < 0.05$ when compared with preoperatively.

A contralateral newly herniated disc is related to insufficient disc removal and decompression. The unilateral cage may push the disc material to the contralateral side, resulting in contralateral new disc herniation.[9] Careful review of the preoperative CT scans and magnetic resonance images is necessary, especially on the contralateral side. Careful preoperative planning is also important to determine the most appropriate size and location of the cage. Light compression or even no compression on the pedicle screws on the contralateral side is better for patients with contralateral foraminal stenosis. For some patients, prophylactic decompression is necessary to reduce this complication, even without contralateral symptoms preoperatively. Most patients with contralateral radiculopathy can achieve significant symptom relief after the use of medications, such as NSAIDs, or injections. Only a few patients require revision surgery.

This study has several limitations. First, the effects of the risk factors may have been underestimated, and a more robust risk factor analysis is needed in future studies. Second, CT is not sensitive for soft tissue, preventing analysis of postoperative changes in soft tissues such as ligaments or paraspinal muscles. Third, the radiographic parameter measurements may have been affected by different body positions, leading to potential bias of the results. Finally, the follow-up period was short for some patients; therefore, long-term follow-up with assessment of other clinical outcomes is needed.

Conclusion

The incidence of contralateral radiculopathy after unilateral TLIF was 5.3%. The most common cause of contralateral radiculopathy was contralateral foraminal stenosis. Careful preoperative planning is necessary to achieve satisfactory outcomes. Improper unilateral TLIF will decrease the PDH, FA, and FH, resulting in contralateral radiculopathy.

Author contributions

All authors participated in the management of the patients. CYL drafted the manuscript. CYL and WY collected the clinical data. JWY and HXD wrote the discussion and introduction. JWY and MWH supervised the patients' care and the writing of the manuscript. All authors read and approved the manuscript.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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References

1. Briggs H and Milligan PR. Chip fusion of the low back following exploration of the spinal canal. *J Bone Joint Surg Am* 1944; 26: 125–130.
2. Harms JG and Jeszenszky D. Die posteriore, lumbale, interkorporelle Fusion in unilateraler transforaminaler Technik. *Oper Orthop Traumatol* 1998; 10: 90–102.
3. Salehi SA, Tawk R, Ganju A, et al. Transforaminal lumbar interbody fusion: surgical technique and results in 24 patients. *Neurosurgery* 2004; 54: 368–374.
4. Hey HW and Hee HT. Lumbar degenerative spinal deformity: surgical options of PLIF, TLIF and MI-TLIF. *Indian J Orthop* 2010; 44: 159–162.
5. Lee YS, Kim YB, Park SW, et al. Comparison of transforaminal lumbar interbody fusion with direct lumbar interbody fusion: clinical and radiological results. *J Korean Neurosurg Soc* 2014; 56: 469–474.
6. Epstein NE. More nerve root injuries occur with minimally invasive lumbar surgery, especially extreme lateral interbody fusion: a review. *Surg Neurol Int* 2016; 7: S83–S95.
7. Hu HT, Ren L, Sun XZ, et al. Contralateral radiculopathy after transforaminal lumbar interbody fusion in the treatment of lumbar degenerative diseases: a case series. *Medicine (Baltimore)* 2018; 97: e0469.
8. Yang Y, Liu ZY, Zhang LM, et al. Risk factor of contralateral radiculopathy following microendoscopy-assisted minimally invasive transforaminal lumbar interbody fusion. *Eur Spine J* 2018; 27: 1925–1932.
9. Jang KM, Park SW, Kim YB, et al. Acute contralateral radiculopathy after unilateral transforaminal lumbar interbody fusion. *J Korean Neurosurg Soc* 2015; 58: 350–356.
10. Von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Ann Intern Med* 2007; 147: 573–577.
11. EL Masry MA, Khayal H and Salah H. Unilateral transforaminal lumbar interbody fusion (TLIF) using a single cage for treatment of low grade lytic spondylolisthesis. *Acta Orthop Belg* 2008; 74: 667–671.

12. Kim MC, Park JU, Kim WC, et al. Can unilateral-approach minimally invasive transforaminal lumbar interbody fusion attain indirect contralateral decompression? A preliminary report of 66 MRI analysis. *Eur Spine J* 2014; 23: 1144–1149.
13. Hwang SH, Park SW and Kim YB. Risk factors for symptomatic contralateral foraminal stenosis after unilateral transforaminal lumbar interbody fusion. *World Neurosurg* 2020; 133: e452–e458.
14. Iwata T, Miyamoto K, Hioki A, et al. Morphologic changes in contralateral lumbar foramen in unilateral cantilever transforaminal lumbar interbody fusion using kidney-type intervertebral spacers. *J Spinal Disord Tech* 2015; 28: E270–E276.
15. Cho PG, Park SH, Kim KN, et al. A morphometric analysis of contralateral neural foramen in TLIF. *Eur Spine J* 2015; 24: 783–790.
16. Chen YL, Lai OJ, Wang Y, et al. The biomechanical study of a modified lumbar interbody fusion-crenel lateral interbody fusion (CLIF): a three-dimensional finite-element analysis. *Comput Methods Biomech Biomed Engin* 2020; 23: 548–555.