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Preoperative dorsal disc height is a predictor of indirect decompression effect through oblique lateral interbody fusion in lumbar degenerative stenosis

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Abstract

The extent of indirect decompression after oblique lateral interbody fusion (OLIF) is one of the most important factors in deciding the strategy. To assess the radiographical predictors of the effect of indirect decompression in patients with lumbar degenerative spondylosis by OLIF. Thirty-two consecutive patients who underwent OLIF at 58 lumbar disc levels were enrolled in this study. The radiographic measurements included central disc height (cDH), dorsal disc height (dDH), right/left foraminal height in sagittal plane computed tomography (CT), and cross-sectional dural sac antero-posterior diameter (CDSD) in axial plane CT. All patients were followed up for 1 year after surgery. All CT parameters (cDH, dDH, CDSD, right foraminal height [RFH], and left foraminal height [LFH]) significantly increased after OLIF ($P < .0001$). The mean raised height difference was 4.3, 3.4, 3.4, and 2.6 mm for cDH, dDH, RFH, and LFH, respectively. The mean CDSD increase was 1.4 mm. The median values of post/pre-operation (change rates) were 1.5 times in cDH, 1.9 times in dDH, and 1.2 times in CDSD, RFH, and LFH. RFH and LFH change rates were related with both cDH and dDH change rates, while the CDSD change rate was only associated with the dDH change rate ($P = .0206$*) but not with cDH ($P = .2061$). There was a significant negative relationship between the CDSD change rate and preoperative dDH ($P = .0311$*, $R^2 = 0.0817$) but not with preoperative cDH ($P = .4864$). OLIF should be avoided for patients with preserved high dDH.

Abbreviations: cDH = central disc height, CDSD = cross-sectional dural sac antero-posterior diameter, CS3 = cage subsidence over 3 mm, CT = computed tomography, dDH = dorsal disc height, LLIF = lateral lumbar interbody fusion, MRI = magnetic resonance imaging, OLIF = oblique lateral interbody fusion.

Keywords: dorsal disc height, endplate injury, indirect decompression, lumbar degenerative spondylosis, oblique lateral interbody fusion

1. Introduction

Currently, oblique lateral interbody fusion (OLIF) is widely used and has become a familiar operation for spine surgeons. OLIF is used to reconstruct the intervertebral space by inserting a wider and larger cage than that used in the posterior approach. Furthermore, OLIF is fundamentally aimed at indirect decompression by ligamentotaxis without direct decompression, such as that observed in laminectomy. The extent of indirect decompression after OLIF is 1 of the most important factors in deciding the strategy for lumbar spinal stenosis, lumbar foraminal stenosis, and/or lumbar degenerative spondylolisthesis. Posterior direct decompression and fusion is usually selected for cases in which posterior bony lesions are observed, such as in facet hypertrophy and ossification of the ligamentum flavum. Except for such cases, minimally invasive OLIF is preferred as it involves less muscle damage, bone removal, and blood loss than that observed with the posterior approach. However, it has not been clearly established in which cases direct decompression can be avoided. Thus, we assessed the radiographical predictors of the effect of indirect decompression in patients with lumbar degenerative spondylosis to select the most adequate surgical procedure.

2. Materials and Methods

This study was retrospectively performed in a single institute. Thirty-two consecutive patients (mean age: 69.4 years; 9 men and 28 women) with lumbar degenerative spondylosis who underwent OLIF with simultaneous or staged percutaneous pedicle screw fixation at 58 lumbar disc levels were enrolled in this study. The exclusion criteria included infection, absence of foraminal or spinal stenosis with simple unstable pathology and preexisting direct-decompressed lumbar levels.

All patients underwent magnetic resonance imaging (MRI), computed tomography (CT), and plain radiography. The radiographic measurements included central disc height (cDH),

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dorsal disc height (dDH), and right/left foraminal height in sagittal plane CT, and cross-sectional dural sac antero-posterior diameter (CDSD) in axial plane CT, along with the corrected angle (local kyphotic angle; local coronal angle) between the fused lumbar level on plain radiographs. Dural sac expansion was examined qualitatively through MRI by a single surgeon to determine whether additional direct decompression should be performed. Immediately after surgery, all patients underwent CT to detect vertebral endplate injury and vertebral body fracture and were followed up for 1 year after surgery with CT to assess bone cyst formation, adjacent segmental diseases, and complete fusion. In particular, any degree of endplate injury, such as modest cortical discontinuity, was considered. Cage subsidence on follow-up CT was defined as a subsidence >3 mm cage subsidence over 3 mm (CS3) under the endplate. All parameters were measured before and after OLIF, and differences between preoperative and postoperative parameters were also assessed. Statistical analyses, including chi-square test and linear and logistic regression analyses, were performed using the JMP 8 software (SAS Campus Drive, North Carolina, United States).

2.1. Surgical procedure

During surgery, the patient was placed in the right lateral decubitus position with the left side up. The left hip was straightened to minimize tension in the psoas muscle. Then, a skin incision was made 6 cm ventral to the ventral aspect of the vertebra, which was marked under fluoroscopy, and 4 cm away from the iliac crest line. After skin incision, the external and internal oblique fasciae were dissected bluntly. Our access was via the extra-transverse fascia, and the transverse fascia was preserved until the psoas muscle was reached to decrease the possibility of peritoneal and sympathetic nerve injuries. This was followed by cutting of the anterior belly of the psoas fascia. After visualization of the anterior aspect of the disc space, discectomy with release of annulus fibrosus and curettage of the endplate were performed. Careful attention was paid to avoid endplate injury during this procedure, which can be a major contributor to the loss of the indirect decompression effect. An appropriate 6-degree angled cage containing mixed iliac and prosthetic bone was placed slightly ventral to the midline. Percutaneous pedicle fixation with mild compression and reduction force during final fastening was performed in the prone position.

The informed consent has been obtained from all patients involved in our research. The institutional review board of Otaru General Hospital approved this study.

3. Results

The patients' demographic data are shown in Table 1. Among the 32 patients, 21 had unstable degenerative spondylolisthesis, 5 had stable spinal stenosis, 6 had degenerative scoliosis, and 2 had osteoporotic vertebral fracture.

Single segment fusion was performed in 11 (34%) patients, double segments in 16 (50%), and triple segments in 5 (16%). With regard to bone fragility, 7 (22%) patients had osteoporosis, 3 (9%) patients underwent hemodialysis, and 2 (6%) patients were administered daily steroids over the years. Teriparatide or romosozumab was administered to 11 (34%) patients before and after OLIF surgery to avoid late phase complications.

Visual Analogue Scale of leg decreased from 64 to 16 after surgery. Approach-related physical complications are shown in Table 2. Five patients (16%) developed complications, including peritoneum breaches in 2 patients (1 was perceived during operation and sutured) and hematomas in the psoas major in 3 patients, who were all asymptomatic. Notably, left anterior thigh pain occurred in 22 (69%) patients immediately after surgery; however, most of the cases were reversible and in remission by a median of 6 days after the surgery. Two patients (6%) had permanent thigh sensory loss that did not hinder their daily lives. There was a positive relationship between the Meyerding grade of spondylolisthesis and left anterior thigh pain immediately after OLIF (P = .0373). No life-threatening or severe functional deterioration such as perforations in major vessels, the ureter, or the intestines or motor paresis were observed.

Table 1

Patient demographic data.

Patient demographic factor		n = 32	%
Mean age		69.4	8.7(SD)
Sex	Male	9	28
	Female	23	72
Level	L4/5	10	31
	L3/4	1	3
	L3/4/5	14	44
	L2/3/4	2	6
	L2/3/4/5	5	16
# of operated levels		1.8	
Meyerding grade	0	11	32
	1	20	65
	2	1	3
Instability		24	75
Bone fragility		12	38
	Osteoporosis	7	22
	Hemodialysis	3	9
	Steroid	2	6
Teriparatide usage		11	34

Table 2

Approach-related physical complications.

Physical complication		n	%
Anterior thigh pain (immediately after surgery)		22	69
	Days until remission	6	Median
	Motor weakness (permanent)	0	0
	Sensory loss (permanent)	2	6
Peritoneum injury		1	3
Psoas major hematoma		3	9
Mean change of local angle	Sagittal balance	3	3
	Coronal balance	1.8	0.5

The radiographical assessment is shown in Table 3. Fifteen (26%) of the 58 operated lumbar disc levels exhibited vertebral body sclerosis due to spondylosis or fracture before surgery.

Intraoperative endplate injury and vertebral body fractures related to manipulation of the dilator and cage insertion were identified on CT immediately after surgery in 19 (33%) and 4 (7%) levels, respectively. Two (3%) of the 4 fracture cases underwent additional extending fixation surgery and balloon kyphoplasty, respectively. Qualitative MRI analysis after surgery showed that the extent of indirect decompression was poor in 4 (15%) levels, mild in 12 (44%), and good in 11 (41%) out of the 27 spinal stenotic levels. (Fig. 1)

Qualitative MRI analysis of dural sac expansion after surgery was performed for the most stenotic level of each patient. Therefore, of the 27 spinal stenotic disc levels evaluated by a single surgeon, 4 (15%), 12 (44%), and 11 (41%) disks showed poor, intermediate, and good results, respectively. A comparison between postoperative and preoperative CT parameters related to indirect decompression is shown in Table 4.

All CT parameters (cDH, dDH, CDSD, right foraminal height [RFH], and left foraminal height [LFH]) significantly increased after OLIF (P < .0001). The mean height increase was 4.3, 3.4, 3.4, and 2.6 mm for cDH, dDH, RFH, and LFH,

Table 3

Radiographical assessment.

		n = 58	%
Endplate injury		19	33
Existing vertebral body sclerosis		15	26
Vertebral body fracture		4	7
Bone cyst formation		13	22
Subsidence of cage		18	31
Screw loosening		15	29
Complete fusion		12	27
Adjacent segmental diseases (fracture, stenosis)		7	14
MRI qualitative assessment	Grade		
	0	4	7
	1	12	21
	2	11	19
	3	31	53

MRI = magnetic resonance imaging.

respectively. The mean increase in CDSD was 1.4 mm. The median change rates (post-operation value divided by pre-operation value) were 1.5 times in cDH, 1.9 times in dDH, and 1.2 times in CDSD, RFH, and LFH. Additionally, RFH and LFH change rates were correlated to both cDH and dDH change rates, while CDSD change rate was associated with dDH change rate (P = .0206*) but not with cDH (P = .2061). As prognostic factors, preoperative cDH and dDH were assessed. There was a significant negative relationship between the CDSD change rate and preoperative dDH (P = .0311*, R^2 = 0.0817) but not with preoperative cDH (P = .4864). For lumbar spinal stenosis cases, which included 27 disc levels, logistic regression analysis showed that the preoperative dDH cutoff value to attain more than 1.2 times the CDSD change rate was 4.1 mm (P = .0040*, AUC 0.0817). The mean corrected local angle was 3.0 ± 6.9° for local kyphotic angle and 1.8 ± 2.8° for local coronal angle. Follow-up CT revealed CS3 in 18 (31%) levels, bone cyst formation in 13 (22%) levels, and radiographical adjacent segmental stenosis in 5 (9%) levels.

There were 2 patients (6.3%) underwent additional laminectomy for direct compression due to small CDSD change (1.0 and 1.1, respectively) rates associated with poor improvement of symptoms. Their pre/post-operative dDH and change rates were 5.3/6.3 mm, 1.19 and 5.6/7.8, 1.39, respectively.

Patients with bone fragility, including osteoporosis, hemodialysis, and daily steroid usage, did not experience endplate injury or vertebral body fracture during surgery (P = .4613 and 0.4871, respectively), while their existing vertebral body sclerosis decreased significantly (P = .0085*), and they tended to have low incidence of CS3 (P = .0852). Moreover, patients with endplate injury showed significantly increased frequency of bone cysts along the endplates during the follow-up period (P = .0198*) and increased distances of cage subsidence (P = .0004*).

4. Discussion

In recent years, lateral lumbar interbody fusion (LLIF), including OLIF and extreme lateral interbody fusion, has gained popularity among spine surgeons. Hynes et al reported that the overall complication rate in their OLIF 25–51 series was 11.7%, which included cage subsidence (4.4%).[1] Segmental lordosis correction with OLIF is as efficient as that seen with other interbody approaches, such as anterior lumbar interbody fusion, transforaminal lumbar interbody fusion, and extreme lateral interbody fusion, and it is superior to posterior approaches in disc height reconstruction.[2] Fujibayashi et al reported that OLIF 25 achieved significant dural sac expansion and that it significantly raised foraminal height.[3] Significantly reduced thickness of the ligamentum flavum after surgery through the OLIF approach plays an important role in improving the spinal canal area for indirect decompression.[4] Notably, an additional posterior direct decompression group showed a statistically lower cage height minus preoperative disc height (5.3 mm) compared with that observed in a non-decompression group.[5] These results are consistent with our findings that elevated disc height contributes to the expansion of the dural sac. However, it is difficult to predict the adequacy of indirect decompression prior to LLIF, and some studies have used intraoperative CT myelography to determine whether they should add further direct decompression.[6,7] In our study, the reconstruction of the dDH was more essential than that of the cDH. Preoperative lower dDH (<4.1 mm) can be a prognostic radiographical factor for effective cross-sectional dural sac expansion. Conversely, an evident preserved disc height level should be avoided when performing LLIF.

The expansion of the preoperative dural sac cross-sectional area has been indicated before[3]; thus, mild spinal canal stenosis before OLIF would not expand markedly after surgery, which is similar to that seen with direct decompression surgery. In addition, a systematic review concluded that bony stenosis appears as an absolute contraindication for the anterior approach, which leads to incomplete decompression of the central canal and lateral recess.[8]

Previous studies have reported no relationship between cage location and the extent of dural sac expansion.[9] The anterior location of the cage resulted in improved segmental lordosis. The posterior location of the cage should not be used as it leads to contralateral root or dural sac compression. Moreover, a larger angled cage helps in the correction of sagittal lordosis; however, this posterior inclined cage could reduce the effect of restoration of the dDH. For decompression of the neural tract, the dDH should be the focus of attention.

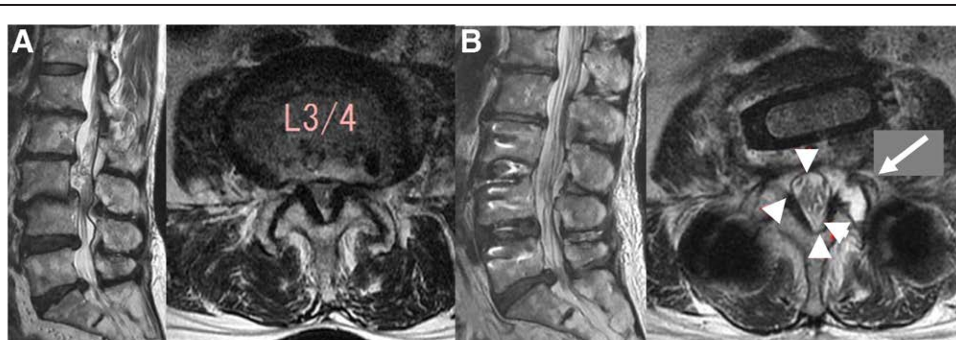

Figure 1. A example of typical MRI findings of patients who underwent OLIF surgery. (A) (pre-operative), and (B) (post-operative). Arrowhead; indirectly decompressed and widened spinal canal. White arrow; a large facet gap is shown. MRI = magnetic resonance imaging, OLIF = oblique lateral interbody fusion.

Table 4

Computed tomography parameters of operated lumbar level.

	Pre	Post	Post – Pre	Post/Pre
Mean value				
Central disc height (mm)	7	11.3	4.3	3.1
Dorsal disc height (mm)	3.6	7	3.4	7.5
Cross-sectional diameter (mm)	8.8	10.2	1.4	1.2
Foraminal height (Rt)	14.3	17.7	3.4	1.3
Foraminal height (Lt)	15.3	17.8	2.6	1.2
Median value				
Central disc height (mm)	7.8	11.5	3.7	1.5
Dorsal disc height (mm)	3.7	7.2	3.5	1.9
Cross-sectional diameter (mm)	8.4	9.8	1.4	1.2
Foraminal height (Rt)	15	17.8	2.8	1.2
Foraminal height (Lt)	16	18	2	1.2

Pre = presurgery, post = postsurgery.

To maintain the effect of indirect decompression, intraoperative endplate injury should be avoided. In our study, endplate injury was significantly correlated with the occurrence of cage subsidence and bone cyst formation 3 months after surgery. Satake et al reported that intraoperative and late-onset endplate injuries occurred in 16.8% and 11.4% of cases, respectively.[10] They also reported that cage subsidence was identified in 28.3% of the operated disc level. Moreover, patients with late-onset endplate injury demonstrated a significantly lower fusion rate than those of patients with intraoperative injury and individuals in a no injury control group; however, the fusion rate did not significantly affect clinical outcomes. Thus, endplate injury or cage subsidence does not always correlate with poor clinical outcomes, but severe subsidence causes subsequent clinical problems with a reduction in the effect of indirect decompression. Conversely, there was a significant negative relationship between existing vertebral sclerosis and endplate injury.

In cases of adult spinal deformity, Beng et al reported that the effect of indirect decompression with OLIF was influenced by preoperative lumbar lordosis in adult spinal deformity surgery,[11] especially in a group with >20° lordosis. This indicates difficulty in expanding the spinal canal only by indirect decompression in the severe kyphotic lumbar spine.

4.1. Limitations

This study had small number of patients whose spinal canal was decompressed insufficiently and added direct decompression to improve their symptoms, which resulted in less information of clinical outcomes.

5. Conclusions

Appropriate levels of indirect decompression through OLIF can be achieved if suitable cases are selected before surgery. The anterior location of the OLIF cage is recommended to avoid an opponent root injury. According to our study, raising the dDH is key to obtaining the effect of indirect decompression through OLIF. As endplate injury during cage preparation at the intervertebral disc can lead to bone cysts and cage subsidence, which diminish the effects of indirect decompression, more attention should be paid on manipulation of dilators and cage trials than on transforaminal lumbar interbody fusion with direct decompression. Patients with existing vertebral body sclerosis had lower incidence of endplate injury during surgery. Preoperative lower dDH (<4.1 mm) can be a prognostic radiographical factor for effective cross-sectional dural sac expansion. When the dDH is sufficiently preserved (high dDH) in patients with lumbar spinal stenosis, OLIF should be avoided, and a posterior approach should be selected to achieve sufficient neural decompression.

Author contributions

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