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Cantilever Transforaminal Lumbar Interbody Fusion for Upper Lumbar Degenerative Diseases (Minimum 2 Years Follow Up)

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Purpose: To evaluate the clinical outcomes of cantilever transforaminal lumbar interbody fusion (c-TLIF) for upper lumbar diseases. **Materials and Methods:** Seventeen patients (11 males, 6 females; mean ± SD age: 62 ± 14 years) who underwent c-TLIF using kidney type spacers between 2002 and 2008 were retrospectively evaluated, at a mean follow-up of 44.1 ± 12.3 months (2 year minimum). The primary diseases studied were disc herniation, ossification of posterior longitudinal ligament (OPLL), degenerative scoliosis, lumbar spinal canal stenosis, spondylolisthesis, and degeneration of adjacent disc after operation. Fusion areas were L1-L2 (5 patients), L2-L3 (9 patients), L1-L3 (1 patient), and L2-L4 (2 patients). Operation time, blood loss, complications, Japanese Orthopaedic Association (JOA) score for back pain, bone union, sagittal alignment change of fusion level, and degeneration of adjacent disc were evaluated. **Results:** JOA score improved significantly after surgery, from 12 ± 2 to 23 ± 3 points ($p < 0.01$). We also observed significant improvement in sagittal alignment of the fusion levels, from - 1.0 ± 7.4 to 5.2 ± 6.1 degrees ($p < 0.01$). Bony fusion was obtained in all cases. One patient experienced a subcutaneous infection, which was cured by irrigation. At the final follow-up, three patients showed degenerative changes in adjacent discs, and one showed corrective loss of fusion level. **Conclusion:** c-TLIF is a safe procedure, providing satisfactory results for patients with upper lumbar degenerative diseases.

Key Words: Transforaminal lumbar interbody fusion, upper lumbar spine, lumbar degenerative diseases, sagittal alignment, clinical outcome

INTRODUCTION

Upper lumbar disc herniation at the L1/2, L2/3, and L3/4 levels have been reported to constitute no more than 5% of all disc herniations.[1-3] Although the anterior approach has been used classically for patients with upper lumbar degenerative disease, the development of spinal instrumentation has enabled effective use of the posterior approach. Posterior lumbar interbody fusion (PLIF) has become a popular surgical procedure for patients with degenerative lumbar diseases, as it enables both interbody fusion and posterior decompression.[4-6] Because the PLIF procedure

partially preserves the facet joint, requiring retraction of the dural sac in order to insert an interbody graft and/or spacers anteriorly, there is a possible risk for dural or nerve root injury.[7] In upper lumbar lesions, the distance between the two pars interarticularis is short, the interlaminar space in all dimensions is small, and the inferior border of the lamina usually overhangs the disc space to a great extent. Therefore, PLIF carries a higher risk of nerve-related complications in upper lumbar lesions. In contrast, anterior procedures have advantages, in that a complete discectomy is possible without retracting the dura. Anterior procedures, however, also have disadvantages, including the difficulty of reconstruction of the lordosis and the risk of blood vessel injuries. Therefore, at present, the optimal surgical approach for upper lumbar lesions, anterior or posterior, is still unclear.[8]

A modified PLIF technique, called transforaminal lumbar interbody fusion (TLIF), was first introduced in 1982.[9] Because the bone graft can be inserted far laterally, the TLIF technique can be safely indicated for interbody fusion of the upper lumbar spine. Moreover, TLIF can be performed at any lumbar level below L1, because it avoids significant retraction of the dura and conus medullaris.[10,11] The cantilever TLIF procedure (c-TLIF) is similar, using a specifically designed kidney-type spacer.[12] In c-TLIF, the kidney-shaped allograft/spacer/cage is inserted into the anterior column and the autologous bone in the middle column. This procedure is advantageous in that it restores sagittal alignment using only a uni-portal for spacer insertion.[12]

Beginning in 2002, we have been utilizing c-TLIF for upper lumbar degenerative diseases, including degenerative spondylolisthesis, spinal canal stenosis, and intervertebral disc herniation and degeneration of the adjacent disc after surgery. In this study, we evaluate the clinical outcomes of the c-TLIF procedure for patients with upper lumbar degenerative diseases.

MATERIALS AND METHODS

Operative indications

Operative indications for upper lumbar c-TLIF included: 1) Failure of conservative therapy, including physical therapy and epidural injections. 2) Back pain caused by instability of the upper lumbar lesion. 3) Sagittal imbalance (local kyphosis or scoliosis) of the thoraco-lumbar junction to the upper lumbar lesion. 4) Activity of the patient.

Patients

We retrospectively evaluated the outcomes for 17 patients (11 males, 6 females; mean ± SD age, 61.9 ± 14.4 years) with upper lumbar degenerative diseases who underwent c-TLIF from 2002 to 2008. Average follow-up was 44.1 ± 12.3 months (2 year minimum). The primary diseases we studied were disc herniation (4 patients), OPLL of lumbar (1 patient), degenerative scoliosis (3 patients), degeneration of adjacent disc after surgery (2 patients), lumbar spinal canal stenosis (6 patients), and spondylolisthesis (1 patient). The fusion areas were L1-L2 (5 patients), L2-L3 (9 patients), L1-L3 (1 patient) and L2-L4 (2 patients)(Table 1).

Operative procedures

Intervertebral fusion was performed using autogenous bone grafts from the lamina, spinosus process and iliac bone and intervertebral spacers. We used lordotic-shaped IBS® spacers (Ortho Development Company, Salt Lake City, Utah, USA), ranging in height from 7 mm to 13 mm. The spacers were inserted while the interspinous space was distracted. Distraction of disc space and regaining disc space height restores the height of the neural foramen, improves foraminal narrowing, and decreases foraminal stenosis. Indirectly, central stenosis may be relieved if it is caused by infolding of the ligamentum flavum or by annular compression.[13]

Nine patients underwent dural decompression by flavectomy and partial laminectomy. In 8 patients, the ligamentum flavum and lamina were preserved and the dural tube was not exposed. In all patients, the interbody spacer was first inserted and then minced bone graft impacted into the residual interbody spacer laterally while the interspinous space was spread. Thus, the dural tube was not retracted at all. Whenever a kidney-shaped IBS spacer was used, a unilateral facetectomy was performed to provide a portal for insertion, with the inserted side selected on the basis of preoperative symptoms. If a disc herniation or foraminal stenosis was present and predominantly one-sided, that side was chosen.[14] If preoperative lower extremity symptoms were bilateral, the open wedge side, based on anterior-posterior plain X-ray film, was chosen for spacer insertion. In upper lumbar lesions, if adequate unilateral total facetectomy was performed followed by distraction of the intraspinosus space, sufficient exposure for an insertion portal of the kidney-shaped IBS spacer was obtained, as in lower lumbar lesions. It was important to take special care in identifying and securing exiting nerve roots, which are more likely to interfere with the spacer insertion portal of

Table 1. Characteristics and Clinical Courses of the Study Patients

Case	Sex	Age at operation	Follow-up period (months)	Diagnosis*	TLIF procedures						
					Level	Instrumentation used	Disc spacer used	Spacer height (mm)	Blood loss (g)	Op. time (min)	Canal decompression
1	F	67	84	AD	L2-3	TSRH	IBS	10	450	315	-
2	M	41	68	DH	L1-2	Xia	IBS	11	250	162	Hemilaminectomy
3	F	54	63	DH	L1-2	ST360	IBS	9	950	209	Hemilaminectomy
4	M	63	57	OPLL	L1-2	ST360	IBS	11	431	180	Laminectomy
5	M	56	51	SCS	L1-3	ST360	IBS	9.11	1425	266	Hemilaminectomy
6	F	78	49	AD	L2-3	ST360	IBS	7	125	222	Hemilaminectomy
7	M	69	48	DS	L2-3	ST360	IBS	9	152	116	-
8	M	91	48	DS	L2-3	M8	IBS	11	553	145	-
9	F	27	43	DH	L2-3	Ti Alloy	IBS	11	130	201	Hemilaminectomy
10	M	70	42	SL	L1-2	M8	IBS	13	302	148	-
11	M	57	36	DS	L2-3	Java	IBS	11	130	143	-
12	F	83	32	SCS	L2-3	Legacy	IBS	10	600	223	Hemilaminectomy
13	M	35	29	DH	L1-2	Legacy	IBS	11	460	233	-
14	M	74	28	SCS	L2-3	USS II	IBS	8	460	200	Hemilaminectomy
15	M	70	24	SCS	L2-3	Blackstone	IBS	10	220	210	-
16	M	41	24	SCS	L2-4	TSRH	IBS	10.12	1200	360	Laminectomy
17	F	77	24	SCS	L2-4	Legacy	IBS	7.9	480	223	-
Mean ± SD		61.9 ± 14.4	44.1 ± 12.3m						489.3 ± 253.5	209 ± 44.5	

TLIF, transforaminal lumbar interbody fusion; AD, adjacent disc degeneration after spinal operation; DH, disc herniation; OPLL, ossification of ligamentum flavum; SCS, spinal canal stenosis; DS, degenerative scoliosis; SL, spondylolisthesis.
*Diagnosis.

the TLIF procedure in the upper lumbar lesion. If sufficient exposure for the spacer insertion portal was not obtained by facetectomy, we performed a partial flavectomy and applied minimum medial retraction of the dural tube in a limited number of cases.

Evaluation of clinical outcomes

Operation time and blood loss

The operation time and the amount of blood loss were measured as markers of the surgical invasiveness of the TLIF procedure.

Japanese Orthopaedic Association score (JOA score) for back pain

The Japanese Orthopaedic Association score (JOA score) for back pain (Table 2) was measured preoperatively, after 6 months and at final follow-up. The full score is 29 points (29 points means no physical synptoms), based on three subjective symptoms (9 points), three clinical signs (6 points), and seven activities of daily living (14 points)(Table 2). The full score indicate full activities of daily living without any symptoms.

Radiographical evaluation

The segmental lordosis angle of the fused area and lumbar lordosis angle (L1 superior end plate to S1 superior end plate)[15] were evaluated using lateral plain radiograms. Bony union was evaluated using sagittal reconstruction images of computed tomograms (CT). Degenerative change in adjacent discs was evaluated using lateral plain radiograms and magnetic resonance imaging (MRI).

Complications

Intraoperative and postoperative complications were analyzed.

Statistical analysis

Statistical comparisons of JOA score and lordotic angle of the fusion area were compared using the non-parametric Friedman test followed by the Wilcoxon signed-rank test. All data are shown as mean ± standard deviation. *p* values

Table 2. The Japanese Orthopaedic Association's Evaluation System for Lower Back Pain Syndrome (JOA Score)

	Symptoms and signs	Evaluation and score		
I	Subjective symptoms			
	Lower back pain	None		3
		Occasional mild pain		2
		Occasional severe pain		1
		Continuous severe pain		0
	Leg pain and / or tingling	None		3
		Occasional slight symptoms		2
		Occasional severe symptoms		1
		Continuous severe symptoms		0
	Gait	Normal		3
		Able to walk farther than 500 m although it results in symptoms		2
		Unable to walk farther than 500 m		1
		Unable to walk farther than 100 m		0
II	Clinical signs			
	Straight-leg-raising test	Normal		2
		30 - 70º		1
		Less than 30º		0
	Sensory disturbance	None		2
		Slight disturbance (not subjective)		1
		Marked disturbance		0
	Motor disturbance	Normal		2
		Slight weakness (MMT 4)		1
		Marked weakness (MMT 3 to 0)		0
III	Restriction of ADL	Severe	Moderate	None
	Turn over while lying	0	1	2
	Standing	0	1	2
	Washing	0	1	2
	Leaning forwards	0	1	2
	Sitting (about 1 hour)	0	1	2
	Lifting or holding heavy objective	0	1	2
	Walking	0	1	2
IV	Urinary bladder function	Normal	0	
		Mild dysuria	- 3	
		Severe dysuria	- 6	

ADL, activities of daily living; MMT, manual muscle testing. Maximum score 29

of less than 0.05 were considered significant.

RESULTS

Operation time and blood loss

The mean ± SD operation time was 209 ± 46 minutes (range: 116 to 360 minutes), and the mean ± SD intraoperative blood loss was 489 ± 254 grams (range: 125 to 1,425 grams)(Table 1). One patient experienced intraoperative bleeding from a rupture of a hypertrophied epidural varix, resulting in a relatively large blood loss of 1,425 grams (Table 1).

Japanese orthopaedic association score (JOA Score) for back pain

Compared with the preoperative JOA score, this parameter was significantly higher 6 months post-operation ($p <$ 0.01). 15 patients maintained a higher JOA score until final follow-up, but two patients' scores improved for six months but had decreased at final follow-up because of adjacent

Table 3. Clinical Outcomes of the Study Patients

Case	JOA score			Fusion level lordosis angle			Lumbar lordosis angle			Hony busion	Complications
	Pre op.	Post op 6 m	Final	Pre op.	Post op 6 m	Final	Pre op.	Post op 6 m	Final		
1	9	14	14	0	4	3.7	10	12.5	12.5	Yes	
2	15	29	27	5	6	6	44.6	51.2	52.5	Yes	Degeneration of adjecent disc
3	19	27	27	- 23	- 18.3	-18.6	8.8	12	12	Yes	
4	16	24	26	8	13	13	8.3	10	10	Yes	Minor infection
5	16	26	27	1.2	1.8	1.4	17	23	22	Yes	
6	14	23	23	- 15.7	- 1.8	- 2.8	6.6	8	8	Yes	
7	13	23	23	- 6	4.6	4.5	38	42	41.1	Yes	
8	13	26	23	0	2.2	2.4	22	26	26	Yes	Degeneration of adjecent disc
9	15	24	28	4	5	5	35	40	40	Yes	
10	11	19	19	-13	10.3	10.2	20	22	22	Yes	
11	12	18	22	5	4.4	4.4	26	27	27	Yes	
12	6	17	17	18.6	22.2	22.2	42.9	44.7	44	Yes	
13	7	27	27	- 8	- 3	- 8	19.4	24.7	22.6	Yes	Correction loss of fusion level
14	14	29	29	8	12.1	12.9	32.4	35.8	36.8	Yes	Degeneraion of adjecent disc
15	14	19	19	- 0.5	5.6	5.2	33.7	37	37.4	Yes	
16	8	29	29	7.2	13.3	13.3	30.6	35.7	34	Yes	
17	13	17	17	0	14	14	10.6	30	30	Yes	
Mean ± SD	12.6 ± 2.7	23 ± 4	23.4 ± 3.9	-1.0 ± 7.4	5.6 ± 6.1	5.2 ± 6.1	23.4 ± 10.8	28.3 ± 10.6	28.1 ± 1 0.7		
Paired t-test		*	*		*	*		*	*		

*$p < 0.01$ (compared to the pre operative values).

disc degenerative changes (Table 3).

Radiographical evaluation

Lordosis angle of the fused area

Preoperatively, most patients showed decreased lumbar lordosis and local kyphosis or flat back. Six months after surgery, the segmental lordosis angle of the fused area was significantly higher ($p < 0.01$). Lumbar lordosis angle also increased significantly ($p < 0.01$). In all patients, lordosis was maintained until the final follow-up period, except for one patient who showed correction loss at final follow-up. However, the clinical symptoms of this patient did not worsen (Table 3).

Bony union

Bony union was achieved in all patients and all disc spaces at final follow-up (Table 3).

Adjacent disc degeneration

Adjacent disc degeneration was observed in three patients. One experienced upper adjacent disc level instability, one experienced lower adjacent disc herniation, and one experienced upper adjacent disc height decrease. In two patients, the degeneration was symptomatic, resulting in decreases in total JOA score. In one patient, the degeneration was asymptomatic (Table 3).

Complications

• Intraoperative complications

Dural injury or neurological damage was not observed in any of the patients. One patient experienced a relatively large amount of bleeding due to a hypertrophied epidural varix.

• Postoperative complications

One patient experienced a subcutaneous infection, which was cured by irrigation (Table 3).

• Clinical case presentation (Case 2, a 41-year old man)

Enhanced MRI (magnetic resonance imaging) showed a ring enhanced mass (Fig. 1) an extruding herniation at L1-L2, and compressed dura on the left side. His preoperative JOA score was 15 points. At first, we considered the indications of a simple discectomy. His flexion-extension radio-

graph showed no remarkable instability. Retrospectively, this was partly because of his severe back pain, which restricted his lumbar segmental motion. Intraoperatively, grasping and gently lifting spinous process of L1 and L2 using Kocher klamp revealed remarkable instability at L1/2, suggesting disc fusion. In addition, removal of the disc herniation at L1/2 using curved punches required a unilateral facetectomy. Otherwise, we would have needed to retract the dural tube at the level of conus medullalis, which has the potential to cause neurological complications. Therefore, TLIF using the kidney-shaped spacer via unilateral facetectomy provided sufficient exposure for the removal of the disc herniation and good fix at the L1/2 segment. Following c-TLIF (with left side hemilaminectomy) at L1-L2 (Fig. 2A and B), his symptoms improved dramatically. One year after surgery, his complaint was completely resolved, and his JOA score was 29 points. Post-operative MRI revealed an absence of disc herniation and decompression of the dura (Fig. 2C). Three years after surgery, however, his back pain and numbness and pain of the left lower extremity reappeared. The MRI at that time revealed a lower degenerative change in the adjacent disc (L3/4 disc herniation). His JOA score at that time was 27/29.

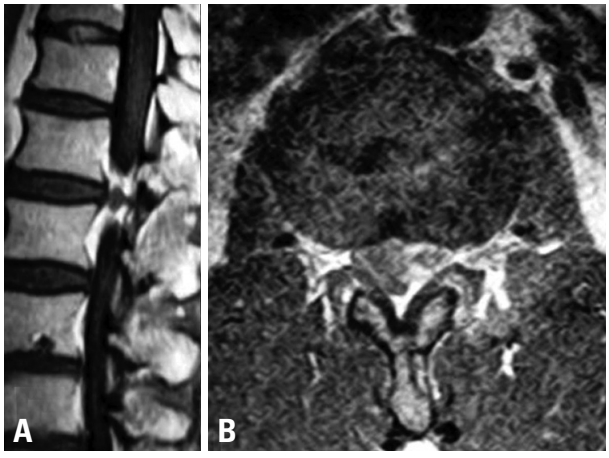

Fig. 1. Preoperative enhanced MRI (A: sagittal, B: axial), showing a ring enhanced mass at the L1-L2 level.

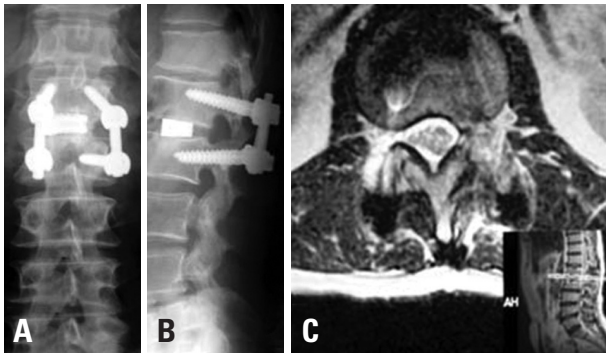

Fig. 2. Postoperative X-P (A: anterior-posterior, B: lateral) showing good sagittal alignment. Postoperative MRI (C), showing sufficient decompression of the dural tube.

DISCUSSION

Overall results of c-TLIF for upper lumbar spinal pathologies

The results presented here show that the c-TLIF procedure using intradiscal spacers provides satisfactory clinical outcomes for patients with upper lumbar pathologies. Significant improvements in subjective and objective findings, as well as activity in daily life, were observed at final follow-up. Bony union was achieved in all patients and all disc spaces at final follow-up, and there were significant increases in the lordosis angle of the fused segment. It is important to note that, although lumbar interbody fusion with intervertebral spacers and autogenious bone graft was performed on the upper lumbar spine, no iatrogenic injury of neural elements was seen in any of these patients.

Decompression for the spinal canal

Because the c-TLIF is performed via the posterior approach, this procedure allows surgeons to perform decompression of the posterior element in any fashion. In cases of central disc herniation, the conventional PLIF procedure may not provide sufficient working portals for the insertion of punches at the upper lumbar levels. In c-TLIF, however, the unilateral facet is removed and the working portal is secured, allowing for the safe removal of centrally protruding discs with curved punches. Some of our patients were treated with hemilaminectomy or total laminectomy to achieve adequate decompression of the dura, thus ameliorating neurological symptoms in all patients.

Restoration of sagittal alignment in the upper lumbar spine

We found that c-TLIF significantly increased both the total lumbar lordosis angle and the lordosis angle of the fusion levels in all patients and maintained lordosis in 16 of 17 patients. Previous results have indicated the importance of restoring sagittal alignment in degenerative diseases of the upper lumbar spine.[8] When the intervertebral disc of the upper lumbar spine is degenerated or herniated, thoracolumbar kyphosis is likely to be modulated. This pathological condition can lead to a relatively unsatisfactory outcome in posterior decompression surgery for the upper lumbar spine.[8]

Importantly, in c-TLIF, the removal of the unilateral facet can allow for insertion of relatively large intervertebral spacers posteriorly, without any damage to neural structures. The excellent outcomes observed in our patients may have been partly due to successful restoration of sagittal alignment of the lumbar spine. One patient (No. 13), however, showed a correction loss in the sagittal alignment of the fused area. This may have been due to the central location of the spacer, resulting in its subsidence.

Surgical invasiveness of c-TLIF for upper lumbar lesions

Earlier studies have reported that TLIF is less invasive than conventional techniques, as evidenced by shorter operating time, less blood loss, shorter hospital stay, and lower incidence of complications.[10,16] We found that operation time and blood loss were slightly higher than previously reported.[10] This may have been due to a learning curve difference; although TLIF can be easily mastered, there is a learning curve.[14] In the present study, the operations were performed by several surgeons, who differed in their experience with the c-TLIF procedure. Second, while the box-type or cylindrically-shaped spacers used for conventional TLIF techniques are inserted in one direction, the kidney-shaped spacers in c-TLIF are inserted in a combination maneuver while striking and rotating a handle attached to the spacer.[17] This suggests that c-TLIF is somewhat technically demanding. In addition, the c-TLIF procedures for upper lumbar lesions were performed more meticulously and slowly than at the cauda equine level. Therefore, advancements in learning curve should reduce the surgical invasiveness of this procedure.

Comparison with other procedures

The TLIF procedure may be a useful alternative to traditional procedures, including ALIF and PLIF, for the lumbar spine.[10,16,18,19] Our results also suggest several potential advantages and disadvantages of c-TLIF procedure for pathological conditions of the upper lumbar spine. The advantages include: 1) Both posterior decompression and interbody fusion can be performed in a single stage. 2) Intervertebral spacer and graft insertion is performed by unilateral resection of the facet. 3) Since the insertion portal is wide enough, even in the upper lumbar spine, the spinal canal area need not be explored for spacer insertion.[13,20] 4) Using a spacer of sufficient height and pedicle screw systems, reestablishment of normal alignment is possible. Disadvantages include: 1) The procedure is technically demanding. 2) The unilateral facet has to be resected, leaving less bony contact area between two vertebral levels. This may be a fatal weakness in cases of hardware removal due to postoperative infection. 3) Similar to other spinal fusion procedures, there are risks to the adjacent disc levels.

Limitations of the present study

Our study had several limitations, including its retrospective design, the relatively small study population, and the absence of a control group. Additionally, the postoperative follow-up period may not be long enough to fully assess the risks of complications to adjacent disc levels.[21,22] Future prospective trials should compare c-TLIF with conventional anterior lumbar interbody fusion for upper lumbar lesions.

In conclusion, retrospective analysis of the clinical outcomes of the c-TLIF procedure for patients with upper lumbar degenerative diseases showed that c-TLIF provided satisfactory amelioration of clinical symptoms, sagittal alignment, and solid bony union, without any neurological complications.

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