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

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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

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
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. 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.

A modified PLIF technique, called transforaminal lumbar interbody fusion (TLIF), was first introduced in 1982. 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. The cantilever TLIF procedure (c-TLIF) is similar, using a specifically designed kidney-type spacer. 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.

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, spinous 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.

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. 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 intraspinous 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
Radiographical evaluation
The segmental lordosis angle of the fused area and lumbar lordosis angle (L1 superior end plate to S1 superior end plate) 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 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 symptoms), 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.

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 ± 4.1, 44.1 ± 12.3m, 489.3 ± 209, ± 253.5 ± 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.
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
experienced lower adjacent disc herniation, and one experi-
enced 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 as-
ymptomatic (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).

Table 3. Clinical Outcomes of the Study Patients

| Case | JOA score | Fusion level lordosis angle | Lumbar lordosis angle | Bony union | Complications |
|------|-----------|-----------------------------|-----------------------|------------|---------------|
|      | Pre op.   | Post op 6 m | Final | Pre op. | Post op 6 m | Final | Pre op. | Post op 6 m | Final | Degeneration of adjacent disc |
| 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                        |
| 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                        |
| 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                        |
| 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                        |
| 14   | 14        | 29           | 29    | 8       | 12.1        | 12.9  | 32.4    | 35.8        | 36.8    | Yes                        |
| 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 ± 3.9 | -1.0 ± 7.4 | 6.1 ± 6.1 | 23.4 ± 10.8 | 28.3 ± 10.6 | 28.1 ± 10.7 |

Paired t-test

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

Radiographical evaluation

Lordosis angle of the fused area
Preoperatively, most patients showed decreased lumbar lor-
dosis and local kyphosis or flat back. Six months after sur-
gery, the segmental lordosis angle of the fused area was sig-
nificantly 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. How-
ever, 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 experi-
enced 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 as-
ymptomatic (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 indica-
tions of a simple discectomy. His flexion-extension radio-

Mean

± SD
change in the adjacent disc (L3/4 disc herniation). His JOA score at that time was 27/29.

**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 autogenous 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. 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.
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 cylinderically-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.\(^{12,20}\) 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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