Precautions for Combined Anterior and Posterior Long-Level Fusion for Adult Spinal Deformity: Perioperative Surgical Complications Related to the Anterior Procedure (Oblique Lumbar Interbody Fusion)

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**Study Design:** Retrospective, single-center study.

**Purpose:** We aimed to determine the perioperative complications of oblique lumbar interbody fusion (OLIF) as a first-stage procedure in combined anterior and posterior operation for adult spinal deformity (ASD) along with sagittal imbalance. Specifically, we aimed to identify the radiological and clinical types of perioperative surgical complications and the factors affecting these complications.

**Overview of Literature:** OLIF has recently gained popularity, and there are several reports of good outcomes and only a few of complications with OLIF; however, a few studies have focused on the perioperative surgical complications of ASD along with sagittal imbalance.

**Methods:** The perioperative period was a 1-week interval between the anterior and posterior procedures. All patients underwent simple radiography and magnetic resonance imaging preoperatively and postoperatively. Cage placement was evaluated for displacement (i.e., subsidence and migration) and vertebral body fracture. Clinical patient complaints were evaluated perioperatively. Student t-test was used for data analysis.

**Results:** A total of 46 patients were included, totaling 138 fusion segments. A week after OLIF, 14 patients/33 segments (30.4%/23.9%) demonstrated endplate injury-associated cage placement change. Subsidence was the most common cage placement-related complication. As compared with patients without endplate injury, those with endplate injuries showed significantly larger correction angles and a higher proportion of them had larger height cages than the disk height in the full-extension lateral view. Although 32.6% of the patients experienced perioperative clinical complications, they were relatively minor and transient. The most common complication was severe postoperative pain (Visual Analog Scale score of >7), and hip flexor weakness spontaneously resolved within 1 week.

**Conclusions:** OLIF yielded more than expected endplate injuries from treatment modalities for ASD along with sagittal imbalance. Therefore, surgeons should be cautious about endplate injury during OLIF procedures. It is difficult to accomplish lordosis correction via OLIF alone; therefore, surgeons should not attempt this impractical correction goal and insert an immoderate cage.

**Keywords:** Adult spinal deformity; Oblique lumbar interbody fusion; Complications; Endplate injury
Introduction

The incidence of adult spinal deformity (ASD) continues to increase with an increase in the aging population. Recently, operative treatments for ASD have increased with an increase in the emphasis on the quality of life and improvement in surgical techniques. In addition, several previous studies have reported good outcomes for operative treatment [1-7]. However, among the ASDs, especially in cases with concurrent sagittal imbalance, different aspects of these treatment strategies are needed. In these cases, a large lordosis correction angle with long-level fusion is necessary to restore the sagittal balance. Unlike the general operative treatment for ASD (i.e., the conventional open approach), pedicle subtraction osteotomy (PSO), a procedure that is used for large lordosis correction, revealed high complication rates of up to 78% [8], including massive bleeding, neurological deficits, or pseudarthrosis. In an effort to avoid tree column osteotomy (e.g., PSO) as well as to restore the sagittal balance with fewer surgical complications, combined anterior-posterior-staged operation was performed by several surgeons [9,10]. Therefore, combined anterior-posterior-staged operation is the current trend for operative treatment for ASD along with degenerative sagittal imbalance.

Lumbar interbody fusion is a popular anterior procedure. Davis et al. [11] investigated the retroperitoneal oblique corridor to the L2 to S1 intervertebral space and concluded that the oblique corridor may avoid complications associated with the anatomic structures with the use of anterior or other lateral approaches. Silvestre et al. [12] and Molinares et al. [13] also reported the safety of approaches via the oblique corridor; the main difference between these two approaches was regarding splitting of the psoas muscles. Recently, oblique lumbar interbody fusion (OLIF) has gained popularity, with several reports showing good outcomes and only a few complications with this technique. However, most of the previous studies on OLIF were about short-level fusion or degenerative spinal diseases, such as spondylolisthesis or degenerative lumbar scoliosis. Only a few studies have investigated the complications and limitations of OLIF, and even fewer studies have focused on the perioperative surgical complications of ASD along with sagittal imbalance that require multi-level interbody fusion and long-level posterior arthrodesis.

Therefore, through this study, we aimed to determine the perioperative complications of OLIF as a first-stage procedure of combined anterior and posterior operation for ASD along with sagittal imbalance. Particularly, we attempted to answer the following questions: (1) from a radiological and clinical perspective, what types of perioperative surgical complications occur and (2) what factors affect these complications?

Materials and Methods

1. Patients

The Institutional Review Board approved this study (EUH IRB file no., 2018-02-007), and all patients that declared an interest and were eligible were enrolled after providing informed consent.

This retrospective analysis investigated perioperative surgical complications of OLIF (as a first-stage procedure) before the posterior second-stage procedure. We retrospectively reviewed the patients' medical records and relevant data obtained from April 2015 to July 2017. The study inclusion criteria were as follows: (1) degenerative sagittal imbalance and (2) postoperative flat back deformity. Patients who had spinal tumor(s), infection(s), ankylosing spondylitis, and/or acute vertebral fracture(s) of the thoracic and lumbar spine were excluded. Patients were evaluated with simple radiography and magnetic resonance imaging (MRI). The surgical indication was based on clinical symptoms and radiological parameters. The perioperative period was defined as a 1-week interval between the anterior and posterior procedures.

2. Operative procedure

The operation was performed by one surgeon in two stages, within an interval of 1 week. For the first procedure (i.e., the anterior approach), all patients underwent OLIF (OLIF25 Clydesdale Spinal System; Medtronic Sofamor Danek, Minneapolis, MN, USA). OLIF was conducted using a left-sided approach in all patients. The most proximal level to the distal level of OLIF was L1–2 to L5–S1, respectively. According to the patient's condition, the fusion level was determined from 1 level to 4 levels. Simple radiography and MRI were performed within 1 week of the first procedure, and indirect neural decompression was evaluated on the MRI scans after OLIF to determine the level of decompression for the second posterior proce-
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3. Clinical evaluation

Patient complaints were evaluated during the 1-week perioperative period. The ileus was defined as the appearance of small bowel gas on the abdominal simple radiograph, and severe postoperative pain was defined as a Visual Analog Scale (VAS) score of >7 after postoperative day 3. New onsets of motor weakness or sensory deficit postoperatively were classified as neurological deficits; if symptoms spontaneously resolved within 1 week, these symptoms were considered to be transient.

4. Radiological evaluation

All patients underwent preoperative and postoperative simple radiography and MRI. Simple radiography involved obtaining whole-spine standing anteroposterior/lateral (WSSA/L), supine anteroposterior/lateral, and full-extension lateral view (FELV) images. WSSA/L imaging followed the Spinal Deformity Study Group method: (1) fists-on-clavicle position or cross-arm position for the upper extremities and (2) full extension of the hip and knee joints. FELV imaging was completed in a translateral position while the patient’s back was fully extended by placing relatively hard pillows under the patient’s back. Radiological measurements were conducted with m-view (Infinitt Healthcare Co., Seoul, Korea) on the hospital’s picture archiving and communication system. Radiological evaluations compared the Cobb angle to the results of patients’ preoperative and postoperative simple radiographs and MRI scans. The sagittal vertical axis (SVA), pelvic tilt (PT), sacral slope (SS), thoracic kyphosis, and LL were measured. PI (SS plus PT) and the Schwab lordosis index (PI minus LL) were also calculated. Sagittal imbalance was defined as an SVA of >5 cm and a PT of >25º. Lastly, cage placement was evaluated. Change in the cage placement was considered to indicate endplate injury. Cage placement-related injuries included displacement of the cage (i.e., subsidence and migration) and vertebral body fracture.

5. Statistical analysis

We categorized the perioperative complications of OLIF based on the radiological and clinical evaluations. The incidence of each complication was analyzed. For radiological complications, differences between patients without and with an endplate injury were assessed using the Student t-test. IBM SPSS software ver. 22.0 (IBM Corp., Armonk, NY, USA) was used to perform statistical analysis. All p<0.05 were considered to be statistically significant.

Results

A total of 46 patients were found eligible for inclusion in this study; Table 1 presents the patient characteristics. Moreover, this study comprised 138 fusion segments, and...
most patients underwent OLIF at the L2/3, L3/4, and L4/5 levels (Table 2).

During the clinical evaluation, although 32.6% of patients experienced perioperative complications, these complications were relatively minor and transient. The most common complication was severe postoperative pain, and hip flexor weakness spontaneously resolved within 1 week (Table 3).

One week after OLIF, 14 patients/33 segments experienced endplate injury-associated cage placement change. Subsidence of the cage was the most common cage placement-related complication (Fig. 2). Posterior migration and vertebral body fracture occurred in only one patient/one segment (Figs. 3, 4 and Table 4).

In the radiological evaluation, all LL cases were found to be similar, irrespective of the incidence of endplate injury. As compared to patients without endplate injury,
those with endplate injury showed a significantly larger correction angle \( (p=0.003) \). Moreover, as compared to patients without endplate injury, a significantly greater proportion of patients with endplate injury showed larger height cages than disk height in FELV \( (p<0.001) \) (Table 5).

**Table 4. Endplate injury associated cage placement change**

| Variable                        | Patients (n=46) | Segments (n=138) |
|---------------------------------|-----------------|------------------|
| Total                           | 14 (30.4)       | 33 (23.9)        |
| Cage displacement               | 13 (28.3)       | 32 (23.2)        |
| Subsidence                      | 12 (26.1)       | 31 (22.5)        |
| Posterior migration             | 1 (2.1)         | 1 (0.7)          |
| Vertebral body fracture         | 1 (2.1)         | 1 (0.7)          |

Values are presented as number (%).

**Discussion**

The treatment of ASD along with sagittal imbalance requires different aspects of the treatment strategy, and long-level arthrodesis is necessary to achieve large correction angles. The traditional treatment modality is a posterior-only operation, such as Smith-Petersen osteotomy or PSO; however, these operations result in several complications, including excessive blood loss, neurological deficit, and pseudoarthrosis \([14,15]\). To minimize these complications and perform less-invasive approaches, minimally invasive fusions, such as lateral lumbar interbody fusion (LLIF) and OLIF, are increasingly utilized \([16]\). The current trend for operative treatment of ASD along with sagittal imbal-

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**Fig. 3.** A 69-year-old female patient with degenerative sagittal imbalance. We performed a staged operation; (A) the first stage was oblique lumbar interbody fusion (L2/3, L3/4, and L4/5). (B) After 1-week follow-up, supine lateral view imaging reveals that the cage of L4/5 had migrated posteriorly.

**Fig. 4.** A 66-year-old female patient with degenerative sagittal imbalance. (A) Preoperative whole-spine standing lateral imaging reveals LL of \(-20^\circ\) (kyphosis). (B) First-stage operation was OLIF (L3/4 and L4/5). After 1 week, postoperative supine lateral imaging (C) and magnetic resonance imaging scan (D) reveal the vertically fractured L4 vertebral body. The second stage was PSO at L3 and posterior arthrodesis from T10 to S1 with iliac screws. (E) Postoperative whole-spine standing lateral imaging 2 weeks after the second-stage operation shows well-maintained lordosis although the L4 vertebral body was fractured. SS, sacral slope; PT, pelvic tilt; PI, pelvic incidence; LL, lumbar lordosis; SVA, sagittal vertical axis; OLIF, oblique lumbar interbody fusion; POD, postoperative day; PSO, pedicle subtraction osteotomy.
ance is combined anterior-posterior-staged operation. Various anterior lumbar interbody fusion (ALIF) procedures have been developed to overcome the disadvantages of various anterior instrumentation techniques. Nowadays, OLIF is considered as the solution to the caveats of both ALIF and LLIF techniques, and several previous studies on OLIF have shown improved clinical and radiological outcomes. However, these studies focused mainly on the strengths of OLIF, performed OLIF frequently, and reported good outcomes from short-level fusion; there are only a few studies about the complications of OLIF [17,18]. To the best of our knowledge, the present study is the first to examine perioperative surgical complications of ASD along with sagittal imbalance that required correction using multi-level interbody fusion and long-level posterior arthrodesis.

The patients’ characteristics of our study included different disease entities and multi-level fusions of OLIF. The most common diagnosis was degenerative sagittal imbalance, and patients showed poor bone quality (bone mineral density T-score, −2.9; range, −4.1 to 0.8). Moreover, unlike other previous studies that included fusions of fewer than 3 levels [18-20], most patients in our study underwent OLIF of more than 3 levels at L2/3, L3/4, L4/5, and L5/S1.

For the radiological evaluation, endplate injury was the most important complication. When performing an anterior- and posterior-staged operation, the interval between the two procedures is usually 1 week [19]. In general, the purpose of OLIF for degenerative spinal disease is indirect decompression; however, as a first-stage procedure, the purpose of OLIF for ASD along with sagittal imbalance would be anterior support to increased union rate and lordosis correction assistance. Herein, the total incidence of endplate injury was 23.9%. Other studies have reported an 18.7% incidence of cage subsidence from OLIF and a 10.8%–58.2% incidence of cage subsidence from direct/extreme lateral interbody fusion (D/XLIF) [18,21]. Therefore, the total incidence of endplate injury in our study was somewhat higher than that reported in other studies. During the OLIF procedure, although we prepared the endplate and carefully selected the cage size, we speculated that multi-level fusion (>3 levels) and the attempt to achieve greater lordosis correction were likely causes for the relatively higher incidence of endplate injury. Considering the results of our study and that of other studies, endplate injury occurred frequently, especially following multi-level fusions via OLIF; thus, surgeons should pay attention to the possibility of endplate injury.

It is unknown whether endplate injury-associated cage placement change is a meaningful complication of OLIF. To the best of our knowledge, no studies have investigated the effect of cage subsidence on the stability or the correction angle; however, endplate injury could lead to anterior support failure that causes pseudarthrosis or lordosis correction failure. Such studies would require great attention under special circumstances, such as vertebral body fracture (one segment) or posterior migration (one segment). Vertebral body fracture could affect the stability or generate local kyphosis. Patients with a posteriorly

| Table 5. Radiological evaluation |
|--------------------------------|
| Variable | End plate injury (+) | End plate injury (-) | p-value |
| Preoperative | | | |
| LL in WSSL (º) | -4.89±13.55 | -4.86±10.16 | 0.589 |
| LL in FELV (º) | 26.6±9.49 | 26.7±5.48 | 0.613 |
| Postoperative | | | |
| LL in magnetic resonance imaging (º) | 27.45±8.55 | 26.42±7.09 | 0.061 |
| Correction angle (º) | 33.5±5.07 | 27.5±5.31 | 0.003* |
| Cage usage | | | |
| Mean disc height in FELV (mm) | 10.4±2.42 | 11.2±3.55 | 0.098 |
| Mean cage height (mm) | 11.9±2.54 | 11.0±1.74 | 0.108 |
| Bigger than FELV (segment) | 18 (90) | 6 (5) | <0.001* |

Values are presented as mean±standard deviation or number (%). LL, lumbar lordosis; WSSL, whole-spine standing lateral; FELV, full extension lateral view. *p<0.05 (statistically significant).
migrated cage typically complain of radiating pain in the lower extremity until they receive posterior decompres-
sion during the posterior second-stage procedure. Under
these circumstances, if an endplate injury occurs, cage
placement change should occur during an early stage.
Therefore, during the perioperative period, surgeons need
to carefully evaluate the cage placement.

Table 4 provides multiple clues for factors that poten-
tially affect the occurrence of endplate injury. Preopera-
tive or postoperative LL was not significantly different
between patients without and with endplate injury, but
the correction angle was significantly different between
these patients. In terms of cage usage, there were no be-
tween group differences in the mean disk height in FELV
and mean cage height. However, in patients with endplate
injury, the mean cage height was significantly greater than
the mean disk height in FELV ($p=0.033$). Furthermore, a
greater proportion (90%) of patients with endplate injury
had larger-sized cages than disk height in FELV, whereas
only 5% of the patients without endplate injury had larger
cages. Therefore, we speculated that the risk of endplate
injuries increased when cages were over-corrected as
compared to the disk height in FELV. When the surgeon
used a larger cage to achieve greater lordosis correction,
aggressive reaming of endplates and over-distraction
could have occurred. Hence, the surgeon should carefully
prepare the endplate. Osteoporotic bone quality, older
age, and technical issues could also be the reasons for the
occurrence of endplate injury. Technically, preparing the
endplates without injury was extremely difficult because
several patients with ASD along with sagittal imbalance
had wedge-shaped disk spaces as a result of degenerative
changes.

In the clinical evaluation, 32.6% of patients experienced
complications. Most clinical complications were associat-
ed with the approach; hence, a thorough minimally inva-
sive mini-open approach should be performed. Although
complications were minor and transient, the incidence
was much higher than expected. Despite OLIF being
a minimally invasive operation, 13% of patients com-
plained of severe postoperative pain (VAS score $>7$). This
incidence of severe postoperative pain was higher than
anticipated, which indicates that careful and appropriate
postoperative pain control are necessary. Transient neu-
rological deficits, including hip flexor weakness or thigh
pain/numbness, were the most focused issue. OLIF pre-
served the psoas muscles; however, these muscles could
be easily injured by traction. In fact, 9.1% of patients in
this study developed a transient neurological deficit. This
incidence of transient neurological deficit caused by OLIF
was not better than that due to D/XLIF (9.4%) reported in
other studies [21]. However, while D/XLIF caused perma-
nent neurological deficit, there were no permanent neuro-
logical deficits due to OLIF.

The treatment strategy for ASD along with sagittal
imbalance is challenging. To achieve sufficient lordosis
correction and stability (reduced pseudarthrosis), vari-
ous attempts were made. Presently, combined anterior-
posterior-staged operation has gained popularity as a
reasonable solution for previous concerns. OLIF was
recently introduced and has gained popularity as an ef-
ectic and safe interbody fusion method. Most previous
studies reviewed D/XLIF-related complications, with only
a few studies focusing on OLIF. These studies only high-
lighted OLIF from a positive perspective, with no precau-
tions or limitations about its usage and with good patient
outcomes. Therefore, we planned this study to verify these
findings when OLIF was applied as a treatment for ASD
along with sagittal imbalance. As suspected, OLIF had
a relatively high radiological and clinical complication
rates. In the radiological evaluation, patient factors (such
as older age and osteoporotic bone quality), and, more
importantly, a surgical factor (such as endplate injury) re-
sulted in a high complication rate. When surgeons select
a cage, they should consider the premeasured disk height
and preparation of the instrument intraoperatively. If a
larger-sized cage can fit, many surgeons tend to select the
larger cage to achieve greater lordosis. However, during a
procedure preparation, endplate damage can occur easily
because of osteoporotic bone quality. Thus, immoderate
cage insertion could result in perioperative complications,
although clinical complications were not severe and sponta-
naneously revolved within 1 week.

Conclusions

In conclusion, OLIF resulted in a higher occurrence of
endplate injury than expected in the treatment of ASD
along with sagittal imbalance. Thus, surgeons should be
cautious of endplate injury during OLIF. It is difficult to
achieve lordosis correction via OLIF alone; therefore, sur-
geons should not attempt this impractical correction goal
and insert an immoderate cage accordingly. Therefore, we
suggest that surgeons select the appropriately sized cage
and carefully prepare the endplate in an effort to reduce the possibility of endplate injury and to plan proper correction, including osteotomy, if achieving a greater correction angle is necessary.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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