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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

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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 multilevel 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-

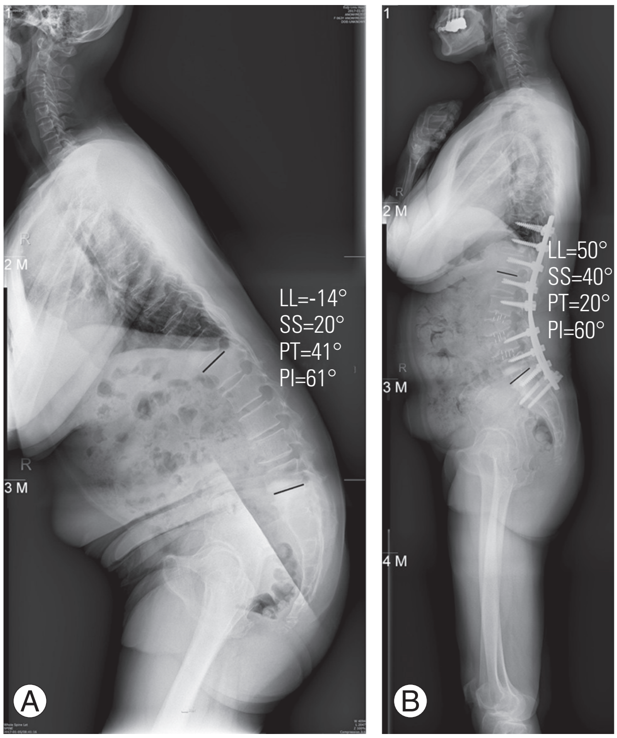

Fig. 1. A 64-year-old female patient with degenerative sagittal imbalance. **(A)** Preoperative whole-spine standing lateral images revealing LL of −14° (kyphosis). We performed a staged operation: first-stage, oblique lumbar interbody fusion (L2/3, L3/4, L4/5); second-stage, pedicle subtraction osteotomy at L3; and posterior arthrodesis from T10 to S1 with iliac screws. **(B)** Whole-spine standing lateral images 2 weeks after the second-stage operation. LL, lumbar lordosis; SS, sacral slope; PT, pelvic tilt; PI, pelvic incidence.

dure. Based on the immediate postoperative lumbar lordosis (LL) as revealed by simple radiography and MRI, the posterior fixation and correction methods (i.e., facetectomy, Ponte osteotomy, or PSO) were determined according to the amount of LL correction required as compared to the Schwab lordosis index (i.e., pelvic incidence [PI] minus LL). Most patients underwent posterior arthrodesis from the T10 to the S1 level with iliac screws (Fig. 1). S2-ilium screw or S2-alar screw was not used.

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 >25°. 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

Table 1. Demographic characteristics

Characteristic	Value
No. of patients	46
Mean age (yr)	68.9 (51 to 77)
Sex (female:male)	43:3
Bone mineral density (T-score)	-2.9 (-4.1 to 0.8)
Mean body mass index (kg/m^2)	25.4
Diagnosis	
Degenerative sagittal imbalance	29 (63)
Postoperative flat back deformity	17 (37)

Values are presented as number, number (range), or number (%).

Table 2. Overall of operation options

Operative options	Number
Fusion levels (OLIF)	138
1	2
2	4
3	32
4	8
Fusion site (OLIF)	
L1/2	7
L2/3	45
L3/4	44
L4/5	35
L5/S1	7
Posterior surgery	
Ponte osteotomy	20
Pedicle subtraction osteotomy	26

OLIF, oblique lumbar interbody fusion.

Table 3. Clinical evaluation

Complications	No. of subject (%)
Total	15 (32.6)
Severe postoperative pain	6 (13.0)
Postoperative ileus	3 (6.5)
Transient neurologic deficit	
Hip flexor weakness	4 (8.7)
Muscle power grade 2	1 (2.2)
Muscle power grade 3	3 (6.5)
Thigh pain/numbness	2 (0.4)
Permanent neurologic deficit	0
Wound infection	
Superficial	0
Deep	0
Ureteral injury	0
Sympathectomy affecting lower extremity	0
Visceral injury	0
Major vessel injury	0

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).

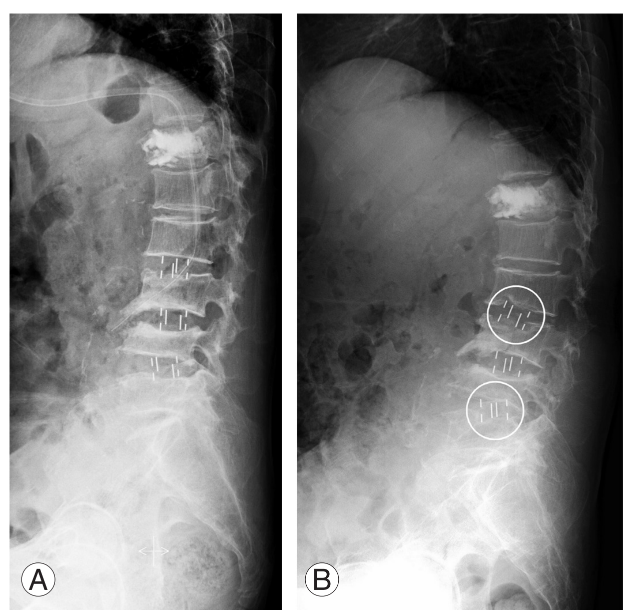

Fig. 2. A 70-year-old female patient with degenerative sagittal imbalance. We performed a staged operation; **(A)** the first stage was oblique lumbar interbody fusion (L2/3, L3/4, and L4/5). **(B)** After 1-week follow-up, supine lateral view imaging reveals that the cages of L2/3 and L4/5 were subsidence.

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).

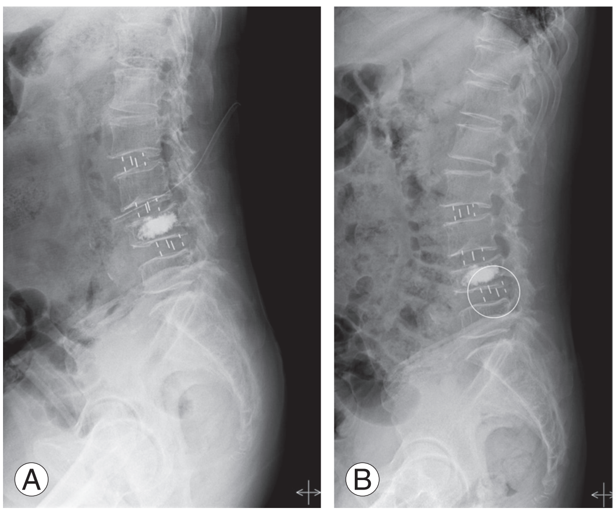

Fig. 3. A 69-year-old female patient with degenerative sagittal imbalance. We performed a staged operation; **(A)** the first stage was oblique lumbar interbody fusion (L2/3, L3/4, and L4/5). **(B)** After 1-week follow-up, supine lateral view imaging reveals that the cage of L4/5 had migrated posteriorly.

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-

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 (%).

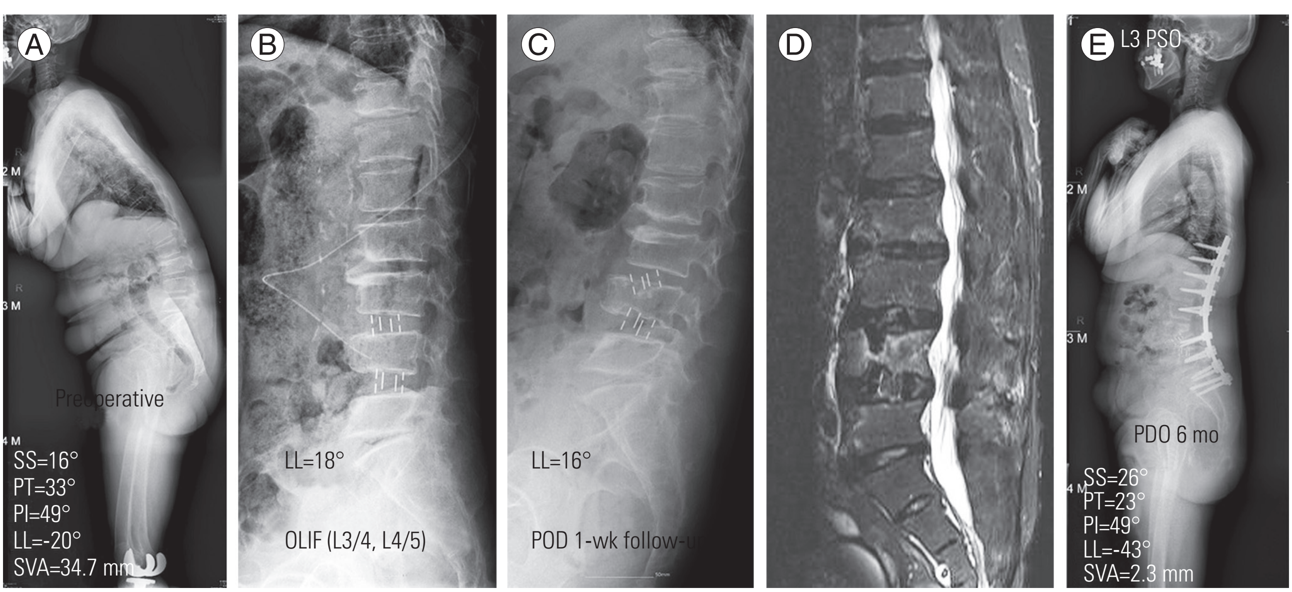

Fig. 4. A 66-year-old female patient with degenerative sagittal imbalance. **(A)** Preoperative whole-spine standing lateral imaging reveals LL of –20° (kyphosis). **(B)** First-stage operation was OLIF (L3/4 and L4/5). After 1 week, postoperative supine lateral imaging **(C)** and magnetic resonance 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.

Table 5. Radiological evaluation

Variable	End plate injury (+)	End plate injury (-)	*p*-value
Preoperative			
LL in WSSL (°)	-4.89±13.55	-4.86±10.16	0.589
LL in FELV (°)	26.6±9.49	26.7±5.48	0.613
Postoperative			
LL in magnetic resonance imaging (°)	27.45±8.55	26.42±7.09	0.061
Correction angle (°)	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).

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 migrated cage typically complain of radiating pain in the lower extremity until they receive posterior decompression 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 potentially affect the occurrence of endplate injury. Preoperative 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 between 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 associated with the approach; hence, a thorough minimally invasive 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 complained 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 neurological deficits, including hip flexor weakness or thigh pain/numbness, were the most focused issue. OLIF preserved 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 permanent neurological deficit, there were no permanent neurological deficits due to OLIF.

The treatment strategy for ASD along with sagittal imbalance is challenging. To achieve sufficient lordosis correction and stability (reduced pseudarthrosis), various 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 effective and safe interbody fusion method. Most previous studies reviewed D/XLIF-related complications, with only a few studies focusing on OLIF. These studies only highlighted OLIF from a positive perspective, with no precautions 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) resulted 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 spontaneously 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, surgeons 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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References

1. O'Boynick CP, Kurd MF, Darden BV 2nd, Vaccaro AR, Fehlings MG. Timing of surgery in thoracolumbar trauma: is early intervention safe? Neurosurg Focus 2014;37:E7.
2. Bridwell KH, Baldus C, Berven S, et al. Changes in radiographic and clinical outcomes with primary treatment adult spinal deformity surgeries from two years to three- to five-years follow-up. Spine (Phila Pa 1976) 2010;35:1849-54.
3. Carreon LY, Glassman SD, Howard J. Fusion and nonsurgical treatment for symptomatic lumbar degenerative disease: a systematic review of Oswestry Disability Index and MOS Short Form-36 outcomes. Spine J 2008;8:747-55.
4. Weinstein JN, Lurie JD, Tosteson TD, et al. Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. N Engl J Med 2007;356:2257-70.
5. Smith JS, Lafage V, Shaffrey CI, et al. Outcomes of operative and nonoperative treatment for adult spinal deformity: a prospective, multicenter, propensity-matched cohort assessment with minimum 2-year follow-up. Neurosurgery 2016;78:851-61.
6. McCarthy I, O'Brien M, Ames C, et al. Incremental cost-effectiveness of adult spinal deformity surgery: observed quality-adjusted life years with surgery compared with predicted quality-adjusted life years without surgery. Neurosurg Focus 2014;36:E3.
7. Sciubba DM, Scheer JK, Yurter A, et al. Patients with spinal deformity over the age of 75: a retrospective analysis of operative versus non-operative management. Eur Spine J 2016;25:2433-41.
8. Smith JS, Shaffrey CI, Klineberg E, et al. Complication rates associated with 3-column osteotomy in 82 adult spinal deformity patients: retrospective review of a prospectively collected multicenter consecutive series with 2-year follow-up. J Neurosurg Spine 2017;27:444-57.
9. Anand N, Kong C, Fessler RG. A staged protocol for circumferential minimally invasive surgical correction of adult spinal deformity. Neurosurgery 2017;81:733-9.
10. Strom RG, Bae J, Mizutani J, Valone F 3rd, Ames CP, Deviren V. Lateral interbody fusion combined with open posterior surgery for adult spinal deformity. J Neurosurg Spine 2016;25:697-705.
11. Davis TT, Hynes RA, Fung DA, et al. Retroperitoneal oblique corridor to the L2-S1 intervertebral discs in the lateral position: an anatomic study. J Neurosurg Spine 2014;21:785-93.
12. Silvestre C, Mac-Thiong JM, Hilmi R, Roussouly P. Complications and morbidities of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lumbar interbody fusion in 179 patients. Asian Spine J 2012;6:89-97.
13. Molinares DM, Davis TT, Fung DA. Retroperitoneal oblique corridor to the L2-S1 intervertebral discs: an MRI study. J Neurosurg Spine 2016;24:248-55.
14. Ohtori S, Orita S, Yamauchi K, et al. Mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for lumbar spinal degeneration disease. Yonsei Med J 2015;56:1051-9.
15. Schwab F, Ungar B, Blondel B, et al. Scoliosis Research Society-Schwab adult spinal deformity classification: a validation study. Spine (Phila Pa 1976) 2012;37:1077-82.
16. Manwaring JC, Bach K, Ahmadian AA, Deukmedjian AR, Smith DA, Uribe JS. Management of sagittal balance in adult spinal deformity with minimally invasive anterolateral lumbar interbody fusion: a preliminary radiographic study. J Neurosurg Spine 2014;20:515-22.
17. Phan K, Maharaj M, Assem Y, Mobbs RJ. Review of early clinical results and complications associated with oblique lumbar interbody fusion (OLIF). J Clin Neurosci 2016;31:23-9.
18. Abe K, Orita S, Mannoji C, et al. Perioperative complications in 155 patients who underwent oblique lateral interbody fusion surgery: perspectives and

indications from a retrospective, multicenter survey. Spine (Phila Pa 1976) 2017;42:55-62.
19. Park HY, Ha KY, Kim YH, et al. Minimally invasive lateral lumbar interbody fusion for adult spinal deformity: clinical and radiological efficacy with minimum two years follow-up. Spine (Phila Pa 1976) 2018;43:E813-21.
20. Fujibayashi S, Kawakami N, Asazuma T, et al. Complications associated with lateral interbody fusion: nationwide survey of 2998 cases during the first 2 years of its use in Japan. Spine (Phila Pa 1976) 2017;42:1478-84.
21. Joseph JR, Smith BW, La Marca F, Park P. Comparison of complication rates of minimally invasive transforaminal lumbar interbody fusion and lateral lumbar interbody fusion: a systematic review of the literature. Neurosurg Focus 2015;39:E4.