Korean J Neurotrauma. 2022 Oct;18(2):287-295
https://doi.org/10.13004/kjnt.2022.18.e42
pISSN 2234-8999·eISSN 2288-2243

KJNT

Clinical Article

Check for updates

Importance of Surgical Order for Minimizing Vascular Injury During the L5-S1 Approach in Multilevel Oblique Lateral Interbody Fusion Surgery

Ju-Sung Jang [1], Myeong Jin Ko [1], Young-Seok Lee [1], Seung Won Park [2], and Seong Hyun Wui [2]

[1]Department of Neurosurgery, College of Medicine, Chung-Ang University Hospital, Seoul, Korea
[2]Department of Neurosurgery, College of Medicine, Chung-Ang University Gwangmyeong Hospital, Gwangmyeong, Korea

Received: Jun 10, 2022
Revised: Aug 11, 2022
Accepted: Aug 13, 2022
Published online: Sep 15, 2022

Address for correspondence:
Myeong Jin Ko
Department of Neurosurgery, College of Medicine, Chung-Ang University Hospital, 102 Heukseok-ro, Dongjak-gu, Seoul 06973, Korea.
Email: nerve0731@cau.ac.kr

ORCID iDs
Ju-Sung Jang
https://orcid.org/0000-0002-8853-604X
Myeong Jin Ko
https://orcid.org/0000-0002-1850-7753
Young-Seok Lee
https://orcid.org/0000-0002-6881-812X

Conflict of Interest
The authors have no financial conflicts of interest.

ABSTRACT

Objective: In oblique lateral interbody fusion (OLIF) surgery at the L5-S1 level (OLIF51), anatomical complexity and the possibility of vascular injury during retraction of the common iliac vein (CIV) make the surgery challenging. We radiologically evaluated patients who underwent OLIF surgery to determine approaches that can make OLIF51 surgery easier during multilevel OLIF.
Methods: We retrospectively analyzed 275 consecutive patients who underwent OLIF surgery between September 2014 and December 2019. The distance between the left and right CIVs (dCIV) was measured using an axial image at the L5 lower endplate level, and the height of the iliocaval junction (hCIV) was measured from the L5 lower endplate to the iliocaval junction in the sagittal image. The sum of anterior disc height of each level (sADH) was calculated.
Results: Eighty-two patients (33 males and 49 females) were enrolled. The number of three- (L2-3-4-5), two- (L3-4-5), and one-level (L4-5) fusions was 13, 21, and 48, respectively. Changes between the pre- and postoperative sADH, dCIV, and hCIV values were 17.1±4.7, 7.7±3.5, and 13.1±4.7 mm in three-level fusion; 10.6±4.1, 5.6±3.7, and 7.0±3.1 in two-level fusion; and 4.3±2.5, 3.3±2.7, and 3.0±2.0 mm in one-level fusion, respectively. As the number of surgical levels increased, the changes in sADH, dCIV, and hCIV significantly increased.
Conclusions: The dCIV and hCIV values increased when the upper segment underwent surgery before OLIF51 during multilevel OLIF.

Keywords: Spinal fusion; Minimally invasive surgical procedures; Lumbosacral region

INTRODUCTION

Oblique lateral interbody fusion (OLIF) is a minimally invasive surgical technique that can fuse the L2 to S1 vertebrae in a single position.[13] Many studies have reported the clinical and radiological results of L2-5 OLIF (OLIF25) and L5-S1 OLIF (OLIF51), and they are known to have excellent outcomes in correcting lumbar lordosis.[8,10,11,13]

In recent years, with an increasingly aging society, the use of short- and long-level fusion surgery is increasing. In addition, the importance of lumbar lordosis correction for shortand long-level fusion surgery is increasing. In particular, lordosis correction of the lower lumbar region (L4-5-S1) is the most important part.[1,5,14] In this regard, OLIF surgery is advantageous in correcting the lower lumbar angle. However, especially in the case of OLIF51, the possibility of vascular injury during retraction of the common iliac vein (CIV) as well as the anatomical complexity make it difficult for the operator to attempt OLIF51.[10] Several studies have reported preoperative radiological evaluation to reduce vascular injury during OLIF51 surgery[2,3]; however, no study has evaluated the OLIF51 approach by assessing vascular shape changes during multilevel spinal fusion surgery.

We radiologically evaluated patients who underwent OLIF surgery to determine how to simplify OLIF51 surgery during multilevel OLIF surgery.

MATERIALS AND METHODS

Study participants

This study was approved by the Institutional Review Board of Chung-Ang University Hospital (2101-001-19347). We retrospectively analyzed 275 consecutive patients who underwent OLIF surgery performed by two surgeons (SWP and MJK) between September 2014 and December 2019 in Chung-Ang university hospital. Patients with acute traumatic fracture, spinal metastasis, infection, and a history of previous lumbar fusion surgery were excluded. Considering the possibility of postoperative anatomical change due to CIV retraction during the L5-S1 approach, patients who underwent OLIF51 were also excluded.

Surgical technique

The surgical technique for OLIF25 has been published previously.[6] Briefly, patients were positioned in the right lateral decubitus position under general anesthesia. Using C-arm imaging, a 4–5 cm oblique skin incision was made from the anterior margin of the target disc. The external oblique, internal oblique, and transverse abdominis muscles were split along directions of muscle fibers. The target disc was approached anteriorly through the retroperitoneal space, and a cage (Clydesdale; Medtronic, Minneapolis, MN, USA) packed with a demineralized bone matrix (Grafton; Medtronic, Minneapolis, MN, USA) was inserted using an orthogonal maneuver after the disc was removed. In case of multilevel surgery, the operation was performed from the lowest disc and proceeded upward by the same way as mentioned herein.

Radiologic evaluation for anterior space at the L5-S1 disc level

The distance between the left and right CIVs (dCIV) and the height of the iliocaval junction (hCIV), which is known to be related to vascular injury, were measured.[2] The dCIV was measured using an axial image at the L5 lower endplate level, and the hCIV was measured from the L5 lower endplate to the iliocaval junction in the sagittal image (**FIGURE 1**). The anterior disc height (ADH) is the distance between the lower endplate of the upper vertebra and the upper endplate of the lower vertebra of the operated segment; the ADH per segment (sum of anterior disc heights of each level; sADH) was summed.

All radiologic factors were measured from computed tomography (CT) images taken pre- and postoperatively. The measurements were undertaken by three independent examiners (2 spine surgeons and 1 neurosurgical resident) twice at 1-week intervals.

https://doi.org/10.13004/kjnt.2022.18.e42

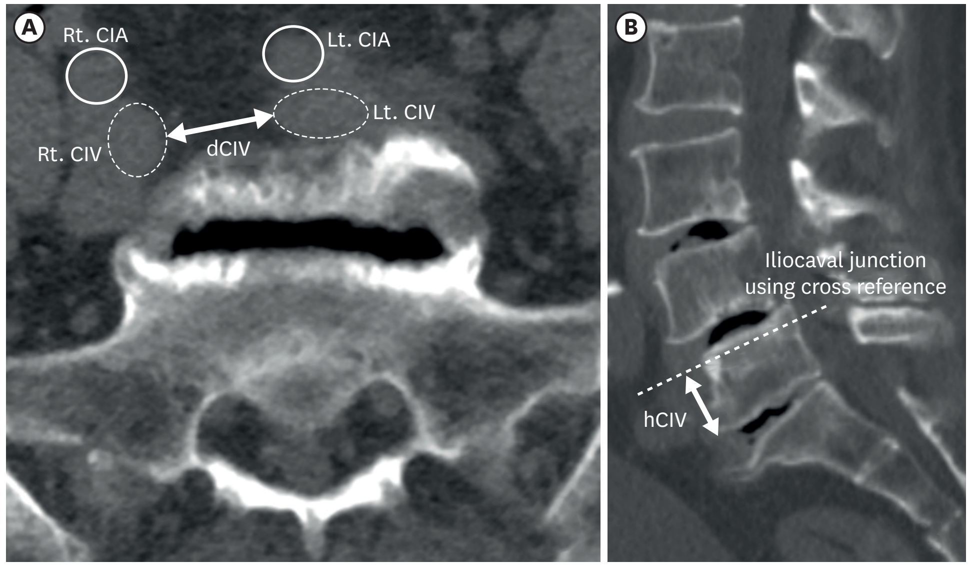


FIGURE 1. Measurements of dCIV and hCIV.
dCIV and hCIV were measured on the preoperative and postoperative non-enhance spine CT. CIA (white solid line circle) could be easily identified because it looks round, and the oval-shaped CIV (white dotted line circle) is observed behind the CIA. The distance between the left and right CIVs was measured using an axial image at the L5 lower endplate level and designated as dCIV (2-way arrow) (A). The hCIV (2-way arrow) was measured from the L5 lower endplate to the iliocaval junction in the sagittal image by using cross reference line (white dotted line) (B).
dCIV: distance between the right and left common iliac vein, hCIV: height of the iliocaval junction, CT: computed tomography, CIA: common iliac artery.

Statistical analysis

Pre- and postoperative radiological values were compared using the Wilcoxon signed-rank test in each fusion level and the Kruskal-Wallis test among fusion levels. Cage height and angle were compared using the Kruskal-Wallis test. Post hoc testing was conducted using the Mann-Whitney *U* test for factors that were found to be significant in the Kruskal-Wallis test. For all analyses, $p<0.05$ was considered statistically significant. The intraclass correlation coefficient (ICC) values were graded using previously described semiquantitative criteria (0.90–1.0: excellent, 0.70–0.89: good, 0.50–0.0.69: fair/moderate, 0.25–0.49: low, and 0.0–0.24: poor).

RESULTS

The average age of the 82 (33 male and 49 female) enrolled patients was 65.5±7.5 (range: 45–77) years. The number of total fusion levels was 129, and the primary diagnosis of each fusion level was central canal stenosis in 59 (45.7%), foraminal stenosis in 33 (25.6%), degenerative spondylolisthesis in 23 (17.8%), and intervertebral disc herniation in 14 (10.9%). The number of three- (L2-3-4-5), two- (L3-4-5), and one-level (L4-5) fusions were 13, 21, and 48, respectively.

The mean height and angle of the used cages were 13.4±0.8 mm and 10.6°±1.3° in three-level fusion, 13.2±0.8 mm and 10.9°±1.4° in two-level fusion, and 13.5±1.1 mm and 11.9°±2.3° in one-level fusion, respectively, and the differences were not significant (p=0.156 and p=0.064, respectively; **TABLE 1**).

https://doi.org/10.13004/kjnt.2022.18.e42

TABLE 1. Patient characteristics

Characteristics	Values	p-values
Number of patients	82	-
Age (yr)	65.5±7.5	-
Sex ratio (male:female)	33:49	-
Number of total fusion level	129	-
3 levels fusion (L2-3-4-5)	13	
2 levels fusion (L3-4-5)	21	
1 level fusion (L4-5)	48	
Diagnosis of each level		-
Central canal stenosis	59 (45.7%)	
Foraminal stenosis	33 (25.6%)	
Degenerative spondylolisthesis	23 (17.8%)	
Intervertebral disc herniation	14 (10.9%)	
Cage height (mm)		0.156
3 levels fusion	13.4±0.8	
2 levels fusion	13.2±0.8	
1 level fusion	13.5±1.1	
Cage angle (°)		0.064
3 levels fusion	10.6±1.3	
2 levels fusion	10.9±1.4	
1 level fusion	11.9±2.3	

Changes in ADH, dCIV, and hCIV

Preoperative sADHs were 24.5±5.6, 17.2±5.2, and 9.9±2.7 mm in three-, two-, and one-level fusions, respectively, which were significantly increased postoperatively to 41.7±2.5 (p=0.001), 27.8±2.4 (p<0.001), and 14.2±1.6 mm (p<0.001), respectively.

The preoperative dCIVs were 33.3±9.3, 29.1±10.2, and 29.2±10.6 mm in three-, two-, and one-level fusions, respectively. The postoperative dCIVs were significantly increased to 41.0±9.1 (p=0.001), 34.6±9.0 (p<0.001), and 32.5±10.0 mm (p<0.001) in three-, two-, and one-level fusions, respectively.

The preoperative hCIVs were 36.6±10.9, 36.9±9.7, and 38.5±11.8 mm in three-, two-, and one-level fusions, respectively, which were significantly postoperatively increased to 49.7±11.4 (p=0.001), 43.9±9.8 (p<0.001), and 41.5±11.7 (p<0.001), respectively, in three-, two-, and one-level fusions (**TABLE 2**).

The intra-observer and inter-observer ICCs were 0.85–0.92 and 0.78–0.86, respectively (**TABLE 3**).

TABLE 2. Pre- and postoperative radiologic measurements in each fusion level

Variables	Preop	Postop	p-value
Three-level fusion			
sADH (mm)	24.5±5.6	41.7±2.5	0.001
dCIV (mm)	33.3±9.3	41.0±9.1	0.001
hCIV (mm)	36.6±10.9	49.7±11.4	0.001
Two-level fusion			
sADH (mm)	17.2±5.2	27.8±2.4	<0.001
dCIV (mm)	29.1±10.2	34.6±9.0	<0.001
hCIV (mm)	36.9±9.7	43.9±9.8	<0.001
One-level fusion			
sADH (mm)	9.9±2.7	14.2±1.6	<0.001
dCIV (mm)	29.2±10.6	32.5±10.0	<0.001
hCIV (mm)	38.5±11.8	41.5±11.7	<0.001

Preop: preoperative value, Postop: postoperative value, sADH: sum of anterior disc heights of each level, dCIV: distance between right and left common iliac vein, hCIV: height of the iliocaval junction.

https://doi.org/10.13004/kjnt.2022.18.e42

TABLE 3. Strength of agreement of inter- and intra-observer analysis for parameters

Variables	Intra-observer ICC	Inter-observer ICC
ADH	0.92	0.86
dCIV	0.85	0.82
hCIV	0.87	0.78

ICC: intraclass correlation coefficient, ADH: anterior disc height, dCIV: distance between right and left common iliac vein, hCIV: height of the iliocaval junction.

Changes between the pre- and postoperative sADH, dCIV, and hCIV values were 17.1±4.7, 7.7±3.5, and 13.1±4.7 mm for three-level fusion, 10.6±4.1, 5.6±3.7, and 7.0±3.1 for two-level fusion, and 4.3±2.5, 3.3±2.7, and 3.0±2.0 mm for one-level fusion, respectively (**FIGURE 2**). As the number of surgical levels increased, the changes in the sADH, dCIV, and hCIV also significantly increased ($p<0.001$; **FIGURE 3**).

DISCUSSION

In multilevel spinal fusion surgery, correction of lumbar lordosis is an important factor related to patients' postoperative quality of life; in particular, the importance of lower lumbar lordosis correction is emphasized.[5,14] OLIF25 and OLIF51 are widely used minimally invasive

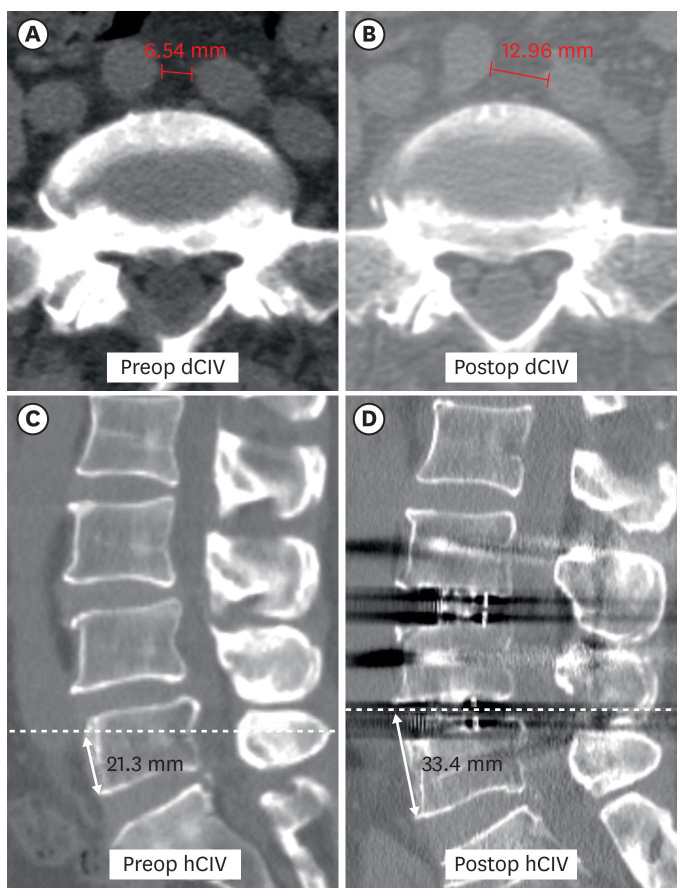
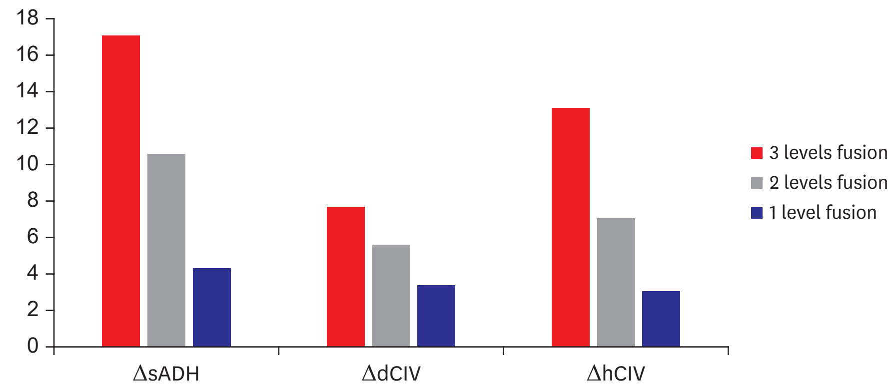


FIGURE 2. Pre- and postoperative changes on CT images.
In one-level fusion surgery, dCIV was increased from 6.54 mm preoperatively (A) to 12.96 mm postoperatively (B). In two-levels fusion surgery, hCIV was increased from 21.3 mm preoperatively (C) to 33.4 mm postoperatively (D).
CT: computed tomography, dCIV: distance between the right and left common iliac vein, hCIV: height of the iliocaval junction, Preop: preoperative, Postop: postoperative.

https://doi.org/10.13004/kjnt.2022.18.e42

KJNT



	3 levels fusion	2 levels fusion	1 level fusion	*p*-values
ΔsADH (mm)	17.1±4.7	10.6±4.1	4.3±2.5	<0.001
ΔdCIV (mm)	7.7±3.5	5.6±3.7	3.3±2.7	<0.001
ΔhCIV (mm)	13.1±4.7	7.0±3.1	3.0±2.0	<0.001

FIGURE 3. Changes (Δ, postoperative value-preoperative value) in sADH, dCIV, hCIV.
As the number of surgical segments increased, the left and right CIV distances widened significantly, and the height of CIV bifurcation increased.
sADH: sum of anterior disc heights of each level, dCIV: distance between the right and left common iliac vein, hCIV: height of the iliocaval junction, CIV: common iliac vein.

spinal fusion techniques that are reportedly superior to conventional surgical techniques for correcting lumbar lordosis.[4,8,11]

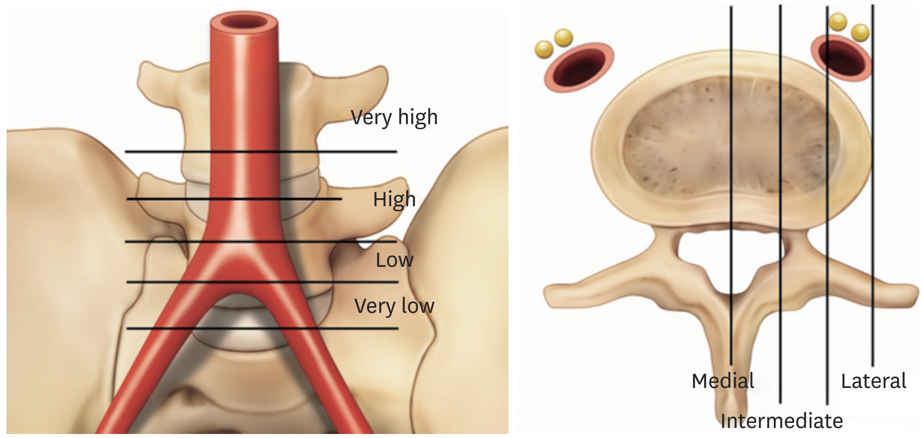
OLIF enables lumbar fusion surgery from the L2 to the S1 vertebrae in a single position, and OLIF51 is excellent for lordosis correction of the L5-S1 segments.[8,9,11] However, the risk of vascular injury, which may occur while performing OLIF51, is high due to the need to retract the left CIV while approaching the disc space and the anatomical complexity.[3,13]

The incidence of CIV injury during anterolateral surgical approaches was found to be 8.6%–11.5%, and risk factors for CIV injury included a low iliocaval junction, narrow CIV bifurcation, insufficient perivascular fat tissue, and vascular anomaly.[2,3]

Capellades et al.[2] classified patients into the following 12 groups: based on hCIV (very high, high, low, and very low) and based on dCIV (medial, intermediate, and lateral). The 5 groups of them (high/medial, low/medial, very low/medial, very low/intermediate, and very low/lateral) were reported that there was a risk of vascular injury due to the required CIV manipulation.[2] On using this subgroup classification in our study dataset, we found that there were 3 (23.1%), 6 (28.6%), and 11 (22.9%) patients with preoperative vascular injury risks in the three-, two-, and one-level fusion groups, respectively. There was a significant postoperative reduction in the number of patients with vascular injury risks from 3 to 1 (7.7%, $p=0.035$), from 6 to 3 (14.3%, $p=0.023$), and from 11 to 8 (16.7%, $p<0.001$) patients in the three-, two-, and one-level fusion groups, respectively (**FIGURE 4**).

Chung et al.[3] reported that the probability of vascular injury was increased when the amount of perivascular fat tissue was low. In this study, since perivascular fat tissue was not measured, it was impossible to directly confirm whether the increment of the postoperative dCIV and hCIV was associated with the amount of perivascular fat tissue. However, we did find that the dCIV and hCIV increased in all patients who underwent OLIF25; this suggests

https://doi.org/10.13004/kjnt.2022.18.e42



Very high/medial	Very high/intermediate	Very high/lateral
High/medial	High/intermediate	High/lateral
Low/medial	Low/intermediate	Low/lateral
Very low/medial	Very low/intermediate	Very low/lateral

	Preop (risk N/total N)	Postop (risk N/total N)	*p*-values
3 levels fusion	3/13 (23.1%)	1/13 (7.7%)	0.035
2 levels fusion	6/21 (28.6%)	3/21 (14.3%)	0.023
1 level fusion	11/48 (22.9%)	8/48 (16.7%)	<0.001

FIGURE 4. Changes in vascular injury risk of the L5-S1 approach according to Capellades et al.[2]
According to Capellades et al.,[2] the 5 subgroups marked in gray (high/medial, low/medial, very low/medial, very low/intermediate, and very low/lateral) had risks of vascular injury because CIV manipulation was required. When our study results were subjected to the above subgroup classification, the risk of vascular injury was significantly reduced after all types of fusion surgery.
The illustration is newly drawn and attached.
CIV: common iliac vein, Preop: preoperative, Postop: postoperative, N: number.

that considering the degree of CIV adhesion related to the amount of perivascular fat tissue is not necessary in patients with degenerative spinal disorders.

The results of previous studies have shown that a relatively taller cage could be inserted using lateral approaches, including OLIF, compared with that using posterior approaches, thus increasing the postoperative disc height significantly.[7,12] In our study, as in previous studies, the sADH increased with the surgical level, and it was confirmed that the dCIV and hCIV also increased with the sADH. When OLIF was performed at the L4-5 level, the dCIV and hCIV increased by 11.3% and 8.1%, respectively, as compared with their preoperative values. When OLIF was performed at the L3-4-5 level, the dCIV and hCIV increased by 19.2% and 19.0%, respectively, from their preoperative values. When OLIF was performed at the L2-3-4-5 level, the dCIV and hCIV increased by 23.1% and 35.8%, respectively, from their preoperative values. Therefore, it is expected that the risk of CIV injury during OLIF51 could be reduced if OLIF is performed on the upper segments and finally on the L5-S1.

Since the CT images were taken with the patient in the supine position, the vascular structure may appear different in the right lateral decubitus position, which is the patient position during the OLIF surgery. CT images taken with the patient in the right lateral decubitus position could better reflect the actual vascular structure during OLIF. However, since our

https://doi.org/10.13004/kjnt.2022.18.e42

study is retrospective in nature and since most CT scans are performed with the patient in the supine position in clinical settings, it may be more reasonable to establish a surgical plan based on the CT images taken in the supine position.

The present study is retrospective study with relatively small volume. Therefore, a larger-prospective multicenter study is necessary to provide more verified information. Additionally, it is expected that the results of our study will be more clearly verified if the intraoperative CT scan is used to investigate changes of CIV during surgery.

CONCLUSION

The dCIV and hCIV increased if surgery was performed on the upper segment first before OLIF51 was undertaken during multilevel OLIF surgery. It is expected that it will be helpful if these points were considered when planning the surgery.

REFERENCES

1. Barrey C, Roussouly P, Le Huec JC, D'Acunzi G, Perrin G. Compensatory mechanisms contributing to keep the sagittal balance of the spine. **Eur Spine J** 22 Suppl **6**:S834-S841, 2013
PUBMED | CROSSREF
2. Capellades J, Pellisé F, Rovira A, Grivé E, Pedraza S, Villanueva C. Magnetic resonance anatomic study of iliocava junction and left iliac vein positions related to L5-S1 disc. **Spine (Phila Pa 1976) 25**:1695-1700, 2000
PUBMED | CROSSREF
3. Chung NS, Jeon CH, Lee HD, Kweon HJ. Preoperative evaluation of left common iliac vein in oblique lateral interbody fusion at L5-S1. **Eur Spine J 26**:2797-2803, 2017
PUBMED | CROSSREF
4. Costanzo G, Zoccali C, Maykowski P, Walter CM, Skoch J, Baaj AA. The role of minimally invasive lateral lumbar interbody fusion in sagittal balance correction and spinal deformity. **Eur Spine J** 23 Suppl **6**:699-704, 2014
PUBMED | CROSSREF
5. Hyun SJ, Han S, Kim YB, Kim YJ, Kang GB, Cheong JY. Predictive formula of ideal lumbar lordosis and lower lumbar lordosis determined by individual pelvic incidence in asymptomatic elderly population. **Eur Spine J 28**:1906-1913, 2019
PUBMED | CROSSREF
6. Ko MJ, Park SW, Kim YB. Effect of cage in radiological differences between direct and oblique lateral interbody fusion techniques. **J Korean Neurosurg Soc 62**:432-441, 2019
PUBMED | CROSSREF
7. Ko MJ, Park SW, Kim YB. Correction of spondylolisthesis by lateral lumbar interbody fusion compared with transforaminal lumbar interbody fusion at L4-5. **J Korean Neurosurg Soc 62**:422-431, 2019
PUBMED | CROSSREF
8. Li R, Li X, Zhou H, Jiang W. Development and application of oblique lumbar interbody fusion. **Orthop Surg 12**:355-365, 2020
PUBMED | CROSSREF
9. Mun HY, Ko MJ, Kim YB, Park SW. Usefulness of oblique lateral interbody fusion at L5-S1 level compared to transforaminal lumbar interbody fusion. **J Korean Neurosurg Soc 63**:723-729, 2020
PUBMED | CROSSREF
10. Orita S, Shiga Y, Inage K, Eguchi Y, Maki S, Furuya T, et al. Technical and conceptual review on the L5-S1 oblique lateral interbody fusion surgery (OLIF51). **Spine Surg Relat Res 5**:1-9, 2020
PUBMED | CROSSREF
11. Park SW, Ko MJ, Kim YB, Le Huec JC. Correction of marked sagittal deformity with circumferential minimally invasive surgery using oblique lateral interbody fusion in adult spinal deformity. **J Orthop Surg 15**:13, 2020
PUBMED | CROSSREF

https://doi.org/10.13004/kjnt.2022.18.e42

12. Shimizu T, Fujibayashi S, Otsuki B, Murata K, Matsuda S. Indirect decompression via oblique lateral interbody fusion for severe degenerative lumbar spinal stenosis: a comparative study with direct decompression transforaminal/posterior lumbar interbody fusion. **Spine J 21**:963-971, 2021
PUBMED | CROSSREF
13. Woods KR, Billys JB, Hynes RA. Technical description of oblique lateral interbody fusion at L1-L5 (OLIF25) and at L5-S1 (OLIF51) and evaluation of complication and fusion rates. **Spine J 17**:545-553, 2017
PUBMED | CROSSREF
14. Yilgor C, Sogunmez N, Boissiere L, Yavuz Y, Obeid I, Kleinstück F, et al. Global alignment and proportion (GAP) score: development and validation of a new method of analyzing spinopelvic alignment to predict mechanical complications after adult spinal deformity surgery. **J Bone Joint Surg Am 99**:1661-1672, 2017
PUBMED | CROSSREF