Radiological Assessment of Damage to the Iliopsoas Muscle by the Oblique Lateral Interbody Fusion Approach

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Abstract:

Introduction: There are several reports about invasive muscle injury during posterior spinal surgery. However, few reports have evaluated the association between the clinical symptoms and changes in the physical properties of the psoas major after oblique lateral interbody fusion (OLIF). Therefore, the current study aimed to investigate the relationship between the clinical symptoms and changes in the psoas major muscle before and after OLIF.

Methods: Twenty-seven patients who underwent single-level OLIF following the diagnosis of degenerative lumbar disease were included in the study. The cross-sectional areas (CSAs) of the psoas major on the approaching and contralateral sides were measured in the axial computed tomography view of the surgical intervertebral space preoperatively and postoperatively at 1 week and 3, 6, and 12 months. The preoperative and postoperative changes in the CSAs were compared. Muscle degeneration was evaluated using axial magnetic resonance images at the same level as that in the CSA evaluation preoperatively and at 12 months postoperatively. Additionally, the relationship between these parameters and postoperative lower limb symptoms was investigated.

Results: Significant swelling of the psoas major on the approach side was observed 1 week postoperatively ($p < 0.05$). No postoperative muscle degeneration was observed. Three cases of paresthesia in the front of the thigh were observed, but no association was found with changes in CSA in any of the cases.

Conclusions: The OLIF approach caused swelling of the psoas major 1 week postoperatively with no more muscle degeneration in the mid-term. Although numbness of the lower limbs was found in some cases, no association was found with changes in CSA. Our study findings suggest that the OLIF approach causes temporary injury or swelling of the psoas major, but the long-term damage to the muscle is not significant.

Keywords:

Oblique lateral interbody fusion, psoas major muscle, degenerative lumbar disease, lumbar spinal surgery, computed tomography values, muscle injury

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Introduction

Oblique lateral interbody fusion (OLIF) has been attracting attention as one of the minimally invasive anterior lumbar interbody fusion procedures with the potential capability of achieving effective indirect neural decompression[1)]. OLIF is very useful in cases where anterior reconstruction or reoperation is necessary after posterior spinal surgery[2)]. Ap-

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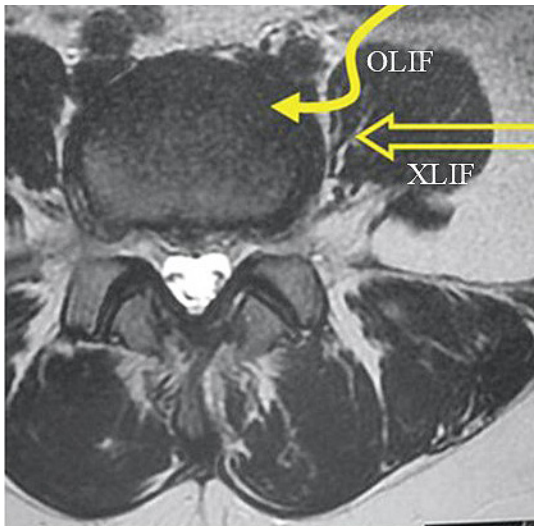

Figure 1. OLIF and XLIF approaches. OLIF, oblique lateral interbody fusion; XLIF, extreme lateral interbody fusion

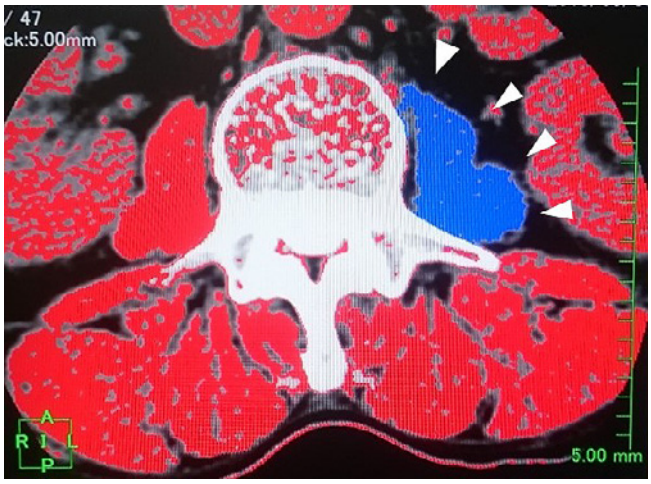

Figure 2. The red part indicates the muscle area that was manually extracted with the CT value, and the blue part surrounded by arrowheads indicates the psoas major. CT, computed tomography

proaching the anterior lateral part of the intervertebral disc through the oblique lateral corridor in front of the psoas major of the lumbar vertebrae has been reported to cause less damage to the psoas major than that with extreme lateral interbody fusion (XLIF), its counterpart psoas-splitting procedure[3,4].

There are several reports about invasive muscle injury during posterior spinal surgery. For instance, the conventional posterior lumbar interbody fusion procedure caused more multifidus degeneration and postoperative low back pain than minimally invasive procedures such as percutaneous pedicle screw fixation[5,6]. These studies imply that dysfunction of the multifidus caused by surgical invasion is associated with low back pain[7]. However, few reports have evaluated the association between the clinical symptoms and changes in the physical properties of the psoas major after OLIF. Considering that postoperative numbness occurs in the thigh on the approach side after OLIF in some clinical cases, the issue regarding surgical invasion of the psoas major should be investigated[8].

The purpose of the current study was to investigate the relationship between the clinical symptoms and changes in the psoas major before and after OLIF.

Materials and Methods

Patients and surgical strategy

Twenty-seven patients who underwent single-level OLIF under the diagnosis of degenerative lumbar disease between November 2013 and April 2015 in our facility were included in the study. Patients who underwent multiple OLIF procedures and revision using the anterior approach were excluded from the study.

This case-control study was approved by the ethics committee of our institution. All participants were informed about the purpose of the study, received information about the study, and provided consent.

The operation was performed by two spinal surgeons at our institution. OLIF was performed as follows. Through a small skin incision (6 cm) in the left abdominal wall, we bluntly entered the retroperitoneal space. We identified and prepared the anterior lateral aspect of the lumbar spine and the medial border of the psoas (Fig. 1). The psoas was retracted laterally and the disk space was isolated. Incision of the anterolateral annulus was followed by subtotal discectomy and further preparation of the graft bed. An intervertebral cage (Clydesdale Spinal System; Medtronic, Minneapolis, MN, USA) filled with bone graft from the iliac bone was used. Subsequently, posterior fixation was performed in all patients. Open pedicle screws or percutaneous pedicle screws were also used in all patients[9-11].

Assessment of the muscle volume of the psoas major

To evaluate perioperative changes in the OLIF procedure, cross-sectional areas (CSAs) of the psoas major were evaluated. Muscle analysis was performed using a software on a dedicated offline workstation (Virtual Place Raijin; AZE Ltd., Tokyo, Japan) that enabled us to extract the region of interest using computed tomography (CT) values and to measure the CSA[12]. The range of CT values was set to 30 to 80 HU to determine the muscle tissue and select part of the psoas major (Fig. 2)[13]. CSAs of the psoas major muscle on the approach and contralateral sides were measured using the axial CT view at the level of the surgical intervertebral space preoperatively and postoperatively at 1 week and 3, 6, and 12 months. In addition, in order to reduce the amount of exposure as much as possible, CT images were taken only for the slice of ±3 cm to be analyzed at 1 week, and 3 and 6 months postoperatively.

Table 1. Fujibayashi's Classification.

Grade	0	1	2	3
Fat degeneration	nothing	<50%	>50%	>50%
Muscle atrophy	-	-	-	+

Table 2. Demographic Data.

No. patients	27
Age, mean (range), yr	57.5±18.34 (14-82)
Gender (Male/Female)	14/13
Diagnosis	
Lumbar spinal stenosis	13 (49%)
Lumbar spondylolisthesis	9 (33%)
Lumbar spondylolytic spondylolisthesis	3 (11%)
Discogenic pain	2 (7%)
Surgical intervertebral space	
L1/2	1 (4%)
L3/4	9 (33%)
L4/5	17 (63%)
Operation time, min	94.05±31.83
Estimated blood loss, mL	57.3±64.8

Assessment of the muscle property of the psoas major

Muscle degeneration was evaluated using axial magnetic resonance T2-weighted images at the same level as that used in the CSA evaluation before and 12 months postoperatively. Additionally, the progression of fat degeneration was evaluated using Fujibayashi's classification, which classifies this variable by the rate of fat degeneration in the muscle (Table 1)[14].

Clinical outcome

In all patients, a 100-mm visual analog scale (VAS) was used to assess leg pain preoperatively and 12 months postoperatively. There were some patients with temporary postoperative lower limb symptoms owing to OLIF. Therefore, to evaluate the relationship between complications after OLIF and the change in the muscle property of the psoas major, patients with postoperative lower limb neural symptoms and lower limb pain were evaluated. Additionally, the relationship between change in the CSA of the psoas major at 1 week postoperatively and postoperative lower limb pain according to the VAS score was analyzed.

Statistical analysis

The intra- and inter-rater reliability of measurement value of CSA were evaluated three times by two independent analysis performed preoperatively and 1 week postoperatively using the intraclass correlation coefficients. We evaluated the mean ratio of the CSAs of the psoas major on the approach sides to the contralateral sides (CSA ratio) in each period using the Steel-Dwass test. The difference between the preoperative and 1-week postoperative CSAs of the psoas major on each side was evaluated using the Wilcoxon signed-rank test, while the correlations of the CSA ratio were evaluated using the non-parametric Spearman's rho (ρ) correlation coefficient. In addition, in order to evaluate the factors for the change in the CSAs of the psoas major, the operation time, estimated blood loss at the time of anterior surgery, and the CSA ratio 1 week postoperatively were evaluated by multiple regression analysis. Furthermore, correlations between the CSA ratio at 1 week postoperatively and lower limb pain at 12 months postoperatively were evaluated using the non-parametric Spearman's rho (ρ) correlation coefficient. Statistical significance was set at a p-value < 0.05. All statistical analyses were performed using JMP® 13 software (SAS Institute Inc., Cary, NC, USA). All data are reported as means ± standard deviations, unless otherwise indicated.

Table 3. Intra- and Inter-rater Reliability of the CSA Measurement.

	before		1 week	
	Rater 1	Rater 2	Rater 1	Rater 2
Intra-rater ICC	0.98	0.96	0.98	0.97
Inter-rater ICC	0.97		0.96	

Results

Patient demographics

Fourteen men and 13 women with a mean age of 57.5 ± 18.34 years (range, 14-82 years) were included in the study. The diagnoses included lumbar spinal stenosis, lumbar spondylolisthesis, lumbar spondylolytic spondylolisthesis, and discogenic pain. The surgical intervertebral spaces were L1/2 in 1 patient, L3/4 in 9 patients, and L4/5 in 17 patients. We used a left-side approach in all patients. For the surgical findings, the operation time was 94.05 ± 31.83 min, and the estimated blood loss was 57.3 ± 64.8 mL for the anterior surgery (Table 2).

Muscle volume of the psoas major

The CSA measurement demonstrated high precision with intraclass correlation coefficients for both intra-rater (0.96-0.98) and inter-rater (0.96-0.97) reliability (Table 3). The mean CSA ratios in each period were 1.08 ± 0.21 preoperatively and 1.25 ± 0.24 at 1 week postoperatively, 1.05 ± 0.08 at 3 months postoperatively, 1.02 ± 0.10 at 6 months postoperatively, and 1.05 ± 0.16 at 12 months postoperatively; the CSA ratio at 1 week postoperatively was significantly higher than that in the other periods ($p < 0.05$) (Fig. 3). A significant difference was seen in the change in psoas major preoperatively and at 1 week postoperatively with the mean CSAs of the psoas major at 814 ± 412 and 893 ± 362 mm^2, respectively, on the approach side ($p < 0.01$). However, there was no significant difference in the contralateral

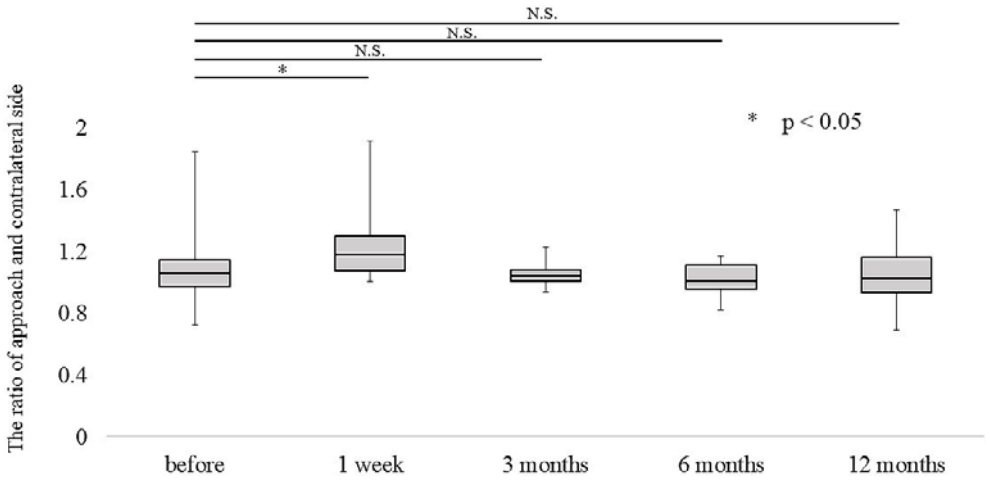

Figure 3. Mean ratios of the CSAs of the psoas major on the approach and contralateral sides preoperatively and postoperatively at 1 week and 3, 6, and 12 months. CSAs, cross-sectional areas; N.S., not significant

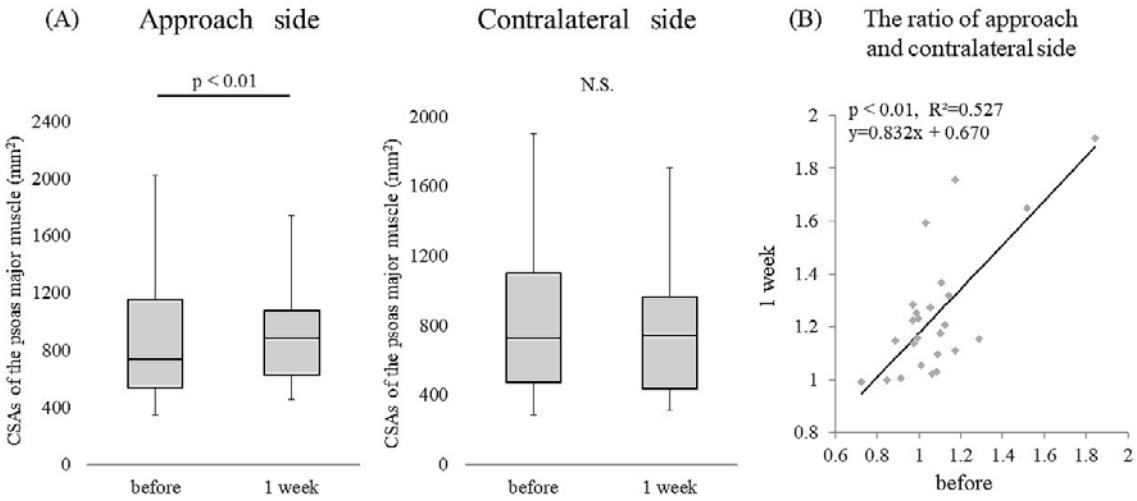

Figure 4. (A) Difference in the CSAs of the psoas major on the approach and contralateral sides between preoperatively and 1 week postoperatively. (B) Correlations of the ratios of the CSAs of the psoas major on the approach to contralateral sides between preoperatively and 1 week postoperatively. CSAs, cross-sectional areas; N.S., not significant

side because the CSAs of the muscle were 795 ± 444 mm^2 preoperatively and 754 ± 377 mm^2 1 week postoperatively (Fig. 4A). A strong correlation was found between the CSA ratios preoperatively and 1 week postoperatively (r^2 = 0.527, $p < 0.01$) (Fig. 4B).

Multivariate analysis of the relationships between surgical findings and change in the CSAs of the psoas major are shown in Table 4. In multiple regression analysis, the CSA ratio 1 week postoperatively positively correlated with the operation time during the anterior surgery.

Muscle property of the psoas major

The degeneration of the postoperative psoas major at 12 months postoperatively was grade 0 according to Fujibayashi's classification in all patients; therefore, no postoperative fat degeneration was observed.

Clinical outcome

Regarding postoperative lower limb neurological symptoms, three patients had paresthesia of the anterior thigh (3/27 11.1%) with no motor deficit of the iliopsoas, and the symptom resolved within 2 to 3 weeks. There was no correlation between the CSA ratio at 1 week postoperatively and postoperative lower limb pain (Fig. 5).

Discussion

Our radiological assessment regarding the postoperative change in the psoas major showed that the CSAs on the approaching side were significantly increased 1 week postoperatively, and the mean CSA ratio was significantly increased at 1 week postoperatively compared to those in the

Table 4. Multiple Linear Regression Analysis of Surgical Findings.

Independent variables	Regression Coefficient	95% CI	P-value	R^2
			0.041*	0.401
Intercept			<0.001	
Operation time	0.0051	0.0013; 0.0088	0.014	
Estimated blood loss	−0.0011	−0.0033; 0.0012	0.319	

*analysis of variance of this model.

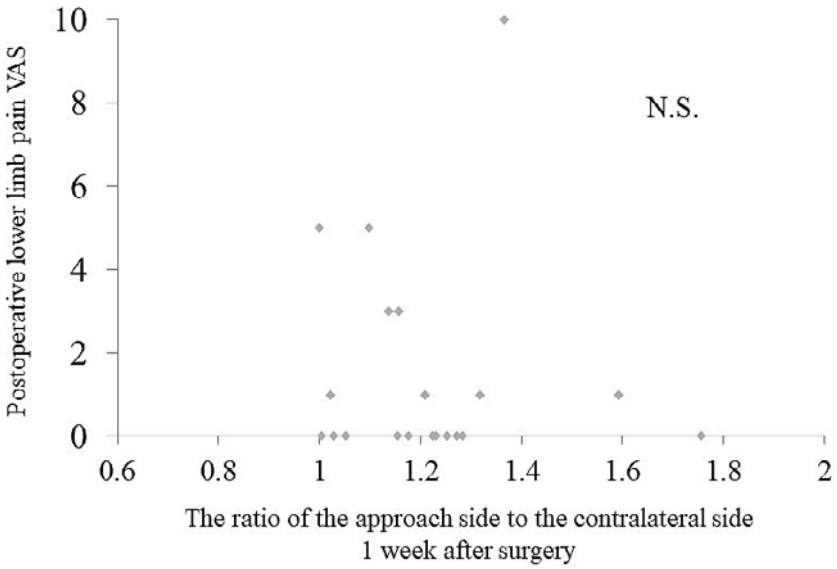

Figure 5. Correlations between the postoperative lower limb pain according to the VAS score and the ratio of CSAs of the psoas major on the approach to contralateral sides. VAS, visual analog scale; CSAs, cross-sectional areas; N.S., not significant

Table 5. Postoperative Lower Limb Symptoms Using the LLIF Approach.

	year	approach	Lower limb symptoms	
			Patients (/total)	Incidence (%)
Tohmeh AG et al	2011	XLIF	28/102	27.5
Abe K et al	2016	OLIF	21/155	13.1
Kim JS et al	2016	OLIF	6/29	20.6
Current study	2018	OLIF	3/27	11.1

other periods. In addition, the change in CSA ratio affected the operation time during the anterior surgery, and no postoperative degeneration of the psoas major was observed after OLIF. Although numbness of the lower limbs was found in some cases, spontaneous recovery was seen at an early stage, and no correlation between the change in the psoas major and lower limb pain was found.

Regarding the factors that increased the CSA by 1 week postoperatively, the CT value of the clotted blood ranged from 40 to 70 HU[15], and we considered that swelling of the psoas major or hematoma occurred owing to surgical manipulation. These kinds of radiological changes have been discussed in previous studies. Regarding the disorder of the paraspinal muscle by surgical manipulation during spinal surgery, Kawaguchi et al., Styf et al., and Stevens et al. reported that the use of retractors can cause ischemic muscle degeneration[16-18]. Herein, the CSA increased only 1 week postoperatively compared to that in the preoperative period, and improved 3 months postoperatively. Additionally, degeneration of the psoas major did not occur 1 year postoperatively. Although the differences in running and blood circulation of the multifidus and psoas major must be considered as the operation time affected the increase in CSA, we assumed that this condition might be the result of temporary postoperative swelling caused by intraoperative muscle retraction, suggesting that the OLIF approach has a minimal effect on the psoas major.

Sometimes, transient neurological symptoms occur in the thigh on the approaching side after lateral lumbar interbody fusion (Table 5). Tohmeh et al. reported that patients experienced transient postoperative iliopsoas weakness (27.5%) and upper medial thigh sensory loss (17.6%) after undergoing the XLIF approach[19]. Abe et al. and Kim et al. also reported temporary postoperative muscle weakness or numbness on the approach side when using the OLIF approach[8,20]. Similarly, in the current study, 11.1% of the patients experi-

enced postoperative thigh numbness. Although it was not related to postoperative lower limb pain and swelling of the psoas major immediately after surgery, the nerve root in the psoas major and symptoms could be caused by the degree of damage to the muscle by surgical manipulation. No report has investigated the damage of the psoas major in XLIF. However, similar neurological symptoms occur in XLIF, and the effect of damage to the psoas major was considered.

There were some limitations to the current study. First, as not only the psoas major was identified by the CT value, we could not completely exclude other tissues with the same range of CT values, such as those with hematoma. Second, as the pathological evaluation for the psoas major was difficult, the degeneration of the muscle was only evaluated using magnetic resonance imaging. Furthermore, the number of cases was small. As there were few cases of postoperative lower limb symptoms in the entry side immediately after surgery, we could not compare the patients with postoperative lower limb symptoms and those without symptoms. Further studies are warranted in the future.

Conclusion

We evaluated the relationship between clinical symptoms and changes in the psoas major before and after OLIF. The OLIF approach causes swelling of the psoas major 1 week postoperatively with no more muscle degeneration in the mid-term. Moreover, although numbness of the lower limbs was found in some cases, no association was found with changes in CSA. Our study findings suggest that the OLIF approach causes temporary injury or swelling of the psoas major, but the long-term damage to the muscle is not significant.

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Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Informed Consent: Informed consent was obtained by all participants in this study.

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