



Impact of surgical treatment on lipid metabolism in patients with lumbar spinal disorders: Prospective observational study

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Abstract

Purpose It is still unclear how lumbar spinal surgery affects the lipid metabolism of patients with lumbar spinal disorders (LSDs) such as lumbar spinal canal stenosis and lumbar disk herniation. The present study aimed to assess the impact of lumbar spinal surgery on lipid metabolism in patients with LSDs and clarify the factors associated with changes in visceral fat (VF) accumulation before and after lumbar spinal surgery.

Methods Consecutive patients with lumbar spinal surgery for LSDs were prospectively included. Abdominal computed tomography images and blood examination of the participants were evaluated before surgery and at 6 months and 1 year after surgery. The cross-sectional VF area (VFA) was measured at the level of the navel using computed tomography images. Blood examination items included triglycerides and high-density lipoprotein (HDL).

Results The study enrolled a total of 138 patients. Female patients with LSDs had significantly increased VFA and serum triglyceride levels after lumbar spinal surgery. On multivariable analysis, the group with > 100 cm² of preoperative VFA and a postoperative decrease in VFA had a significantly worse preoperative walking ability based on the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (relative risk 2.1; 95% confidence intervals 1.1–4.1).

Conclusions The present study demonstrated that patients with LSDs did not necessarily improve their lipid metabolism after lumbar spinal surgery. Instead, female patients with LSDs had significantly deteriorated lipid metabolism after lumbar spinal surgery. Finally, a worse preoperative walking ability was associated with the improvement in excess VF accumulation after lumbar spinal surgery.

Keywords High-density lipoprotein · Japanese Orthopaedic Association Back Pain Evaluation Questionnaire · Lumbar spinal disorders · Lumbar spinal canal stenosis · Lumbar disk herniation · Lumbar spinal surgery · Metabolic syndrome · Visceral fat · Triglycerides · Walking ability

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Introduction

Lumbar spinal disorders (LSDs) such as lumbar spinal canal stenosis and lumbar disk herniation are globally common musculoskeletal conditions. With societal aging, the number of patients with LSDs has increased [1]. LSDs are involved in mobility reduction and social life decline because of low back pain, leg pain, motor weakness, and sensory disturbances of lower extremities, and intermittent claudication [2, 3]. In addition, older patients with LSDs were prescribed multiple medications because of multiple comorbidities [4–6]. Among comorbidities, metabolic syndrome was reported as a disorder in which lumbar spinal canal stenosis is potentially involved [7]. Decreasing physical activity due to lumbar spinal stenosis was speculated to mediate the incidence of metabolic syndrome [7].

According to guidelines [8, 9], those with visceral fat (VF) accumulation accompanied by any two of dyslipidemia, hypertension, and diabetes mellitus (DM) are diagnosed with metabolic syndrome. VF accumulation can be defined as the cross-sectional area of viscous adipose tissue measured at the level of the navel using computed tomography (CT) ≥ 100 cm² [9]. Serum levels of triglycerides, high-density lipoprotein (HDL), and fasting plasma glucose are parameters commonly used for dyslipidemia and type 2 DM, respectively [8, 9]. Lifestyle guidance including exercise is the first line of treatment for metabolic syndrome [8, 9].

Although conservative therapy is recommended as the first-line treatment for LSDs according to the guidelines, it should not be continued unnecessarily in cases with severe and long-standing symptoms due to polypharmacy and medical costs as well as treatment resistance to surgery [2, 3, 6, 10]. In surgery for LSDs, the 2-year outcomes of surgery have been reported to be better than conservative therapy, although the choice of decompression alone or combination of decompression and fusion should be considered depending on the case [10]. In general, lumbar spinal surgery for patients with LSDs has shown efficacy on pain, motor function, social life, psychology, and healthy life expectancy [11–16]; however, it is still unclear how lumbar spinal surgery affects the lipid metabolism of patients with LSDs. Thus, this study primarily aimed to assess the impact of lumbar spinal surgery on lipid metabolism by measuring pre- and postoperative VF accumulation and serum levels of triglycerides and HDL in patients with lumbar spinal surgery for LSDs. The secondary aim was to clarify the factors associated with changes in lipid metabolism before and after lumbar spinal surgery.

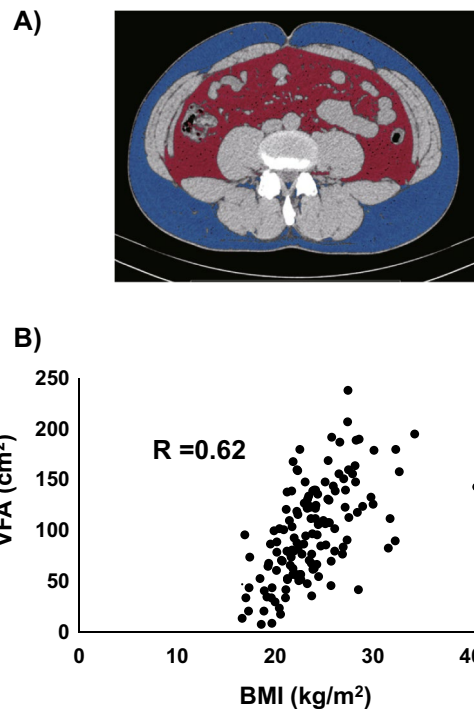


Fig. 1 Calculation of visceral fat area (VFA). **A** Computed tomography image of the VFA (red) at the level of the navel. **B** Correlation between body mass index (BMI) and VFA. R, correlation coefficient

Materials and methods

Study participants

We prospectively enrolled the patients aged ≥ 30 years who were scheduled to undergo surgical treatment for LSDs at a single hospital between April 2021 and March 2022. The follow-up period was 1 year. LSDs included lumbar spinal canal stenosis, lumbar degenerative spondylolisthesis, lumbar spondylolytic spondylolisthesis, and lumbar disk herniation. Lumbar spinal surgery was indicated for patients with apparent symptoms and who had no efficacy of conservative therapy [2, 3, 10]. The diagnosis of LSDs was confirmed by magnetic resonance imaging, CT, or myelography. Degenerative lumbar scoliosis was defined as a Cobb angle $\geq 10^\circ$. Lumbar spinal fusion was basically recommended for patients with lumbar degenerative spondylolisthesis and spondylolytic spondylolisthesis. Patients with an upper instrumented level of thoracic spine or lower instrumented level of the pelvis were excluded.

Data collection

Spinal CT images of participants were examined before surgery and at 6 months and 1 year after surgery. The

cross-sectional VF area (VFA) at the level of the navel on CT images was calculated using Vitrea (Canon Medical Systems Corporation, Tochigi, Japan) (Fig. 1A). Because one of the criteria for metabolic syndrome is $VFA \geq 100 \text{ cm}^2$ [9], we used 100 cm^2 of VFA on CT as the cut-off value for grouping in this study. Blood examination of each participant was also performed before surgery, and at 6 months and 1 year after surgery. Blood examination items included triglycerides and HDL. The participants completed the following clinical outcome assessments before surgery, and at 6 months and 1 year after surgery: the Zurich Claudication Questionnaire (ZCQ) and the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ). The following patient data were collected: age; sex; body mass index (BMI); duration of conservative therapy before surgery; medical history, including DM, hypertension, dyslipidemia, and degenerative lumbar scoliosis; and perioperative factors including surgical procedures, surgical time, and surgical blood loss. Surgical treatment was considered effective in each domain of the JOABPEQ according to a previous study [17].

CT examinations

All CT examinations were performed as spinal CT examinations, which were covered entire abdomen from diaphragm to pelvis and reconstructed as spinal CT with bone algorithm and bone window setting and abdominal CT with abdominal window setting. CT data were obtained with a 64-detector row CT scanner (Revolution Maxima; GE Healthcare, Chicago, IL, USA). CT examinations were conducted as unenhanced CT with helical scanning using the following parameters: $64 \times 0.625 \text{ mm}$ collimation, auto mA with image noise, 120 kVp, 0.516 beam pitch, 0.7 s gantry rotation time, 512×512 matrix, and 320-mm field of view. All CT data were then reconstructed with the filtered back projection or hybrid iterative reconstruction (ASIR-V⁴, GE) methods in contiguous section thickness of 5 mm and used for generating the lung reconstruction kernel as a soft tissue kernel (GE). All CT examinations were performed with breath-holding at end expiration.

Statistical analyses

Data among groups were compared using the chi-squared test, Wilcoxon signed-rank test, or Kruskal–Wallis test as appropriate. Correlations between BMI and VFA were evaluated by Spearman correlation coefficients. We constructed a Poisson regression model to explore the factors, including age, sex, BMI, medical history including hypertension, dyslipidemia, and diabetes mellitus, surgical procedure, and preoperative score in 5 domains of JOABPEQ, associated

with changes in visceral fat accumulation before and after lumbar spinal surgery. Considering that Poisson regression model have the advantage to estimate direct relative risk [18], it was selected to directly estimate relative risk, which adjusted for age and sex, for preoperative $VFA \geq 100 \text{ cm}^2$ and 1-year postoperative decrease of VFA. In this model, the JOABPEQ scores were categorized in tertiles to account for the number of samples according to a previous study [6]. Poisson regression was performed using the STATA16 software (Stata Corporation, College Station, TX, USA). *P* values < 0.05 to indicate statistical significance.

Results

The study enrolled a total of 138 patients. Table 1 summarizes the characteristics of participants, and Table 2 shows the preoperative and 6-month and 1-year postoperative ZCQ scores including symptom severity and physical function and JOABPEQ scores. The 6-month and 1-year postoperative ZCQ and JOABPEQ scores were significantly improved compared with the baseline data in all domains (Table 2).

First, to examine the association between VFA and BMI, we calculated the correlation coefficient between preoperative VFA and preoperative BMI for participants and found a correlation coefficient of 0.62, indicating a moderate correlation (Fig. 1B). Table 3 shows preoperative and 6-month and

Table 1 Baseline Characteristics

Patients	<i>n</i> = 138
Gender	Male: 75, female: 63
Age (years)	62.4 ± 14.2
BMI (kg/m ²)	23.8 ± 3.8
<i>Duration of conservative therapy before surgery</i>	
< 6 months	67 (48.6%)
> = 6 months, < 1 year	34 (24.6%)
> = 1 year, < 3 year	16 (11.6%)
> = 3 years	19 (13.8%)
Unclear	2 (1.4%)
<i>Medical history</i>	
Diabetes mellitus	16 (11.6%)
Hypertension	52 (37.7%)
Dyslipidemia	39 (28.3%)
Degenerative lumbar scoliosis	18 (13.0%)
<i>Surgical procedure</i>	
Decompression alone	81 (58.7%)
Fusion alone	9 (6.5%)
Decompression + fusion	48 (34.8%)
Surgical time (min)	82.3 ± 54.1
Surgical blood loss (ml)	46.5 ± 74.3

BMI body mass index

Table 2 Valuables of patient reported outcome at baseline and follow-up after surgery ($n = 138$)

	Median (25–75% tile)			<i>p</i> value*	
	Preoperation	6POM	1POY	preoperation versus 6POM	preoperation versus 1POY
<i>ZCQ</i>					
Symptom severity	3.3 (2.9–3.7)	1.9 (1.0–2.4)	1.7 (0.9–2.3)	<0.001	<0.001
Physical function	2.8 (2.2–3.2)	0.8 (0.5–1.5)	0.5 (0–1.5)	<0.001	<0.001
<i>JOABPEQ</i>					
Pain disorder	43 (14–71)	100 (71–100)	100 (86–100)	<0.001	<0.001
Lumbar function	50 (25–75)	83 (67–100)	92 (83–100)	<0.001	<0.001
Walking ability	21 (0–43)	100 (64–100)	100 (71–100)	<0.001	<0.001
Social life	35 (22–51)	78 (57–100)	78 (58–100)	<0.001	<0.001
Psychological disorder	44 (32–53)	67 (53–80)	68 (53–82)	<0.001	<0.001

ZCQ Zurich Claudication Questionnaire, *JOABPEQ* JOA Back Pain Evaluation Questionnaire

*Wilcoxon signed-rank test

Table 3 Visceral fat area on CT and serum levels of triglyceride and high-density lipoprotein cholesterol at baseline and follow-up after surgery ($n = 138$)

	Preoperation	6POM	1POY	<i>p</i> value*	
				Preoperation versus 6POM	Preoperation versus 1POY
<i>CT</i>					
Visceral fat area (cm ²)					
Whole ($n = 138$)	99.5 ± 47.2	100.6 ± 51.1	104.0 ± 53.6	0.342	0.08
Men ($n = 75$)	110.3 ± 47.7	108.5 ± 53.6	114.3 ± 57.3	0.663	0.655
Women ($n = 63$)	85.6 ± 43.1	89.5 ± 45.9	91.7 ± 46.5	0.024	0.012
<i>Laboratory data</i>					
Triglyceride (mg/dl)					
Whole ($n = 138$)	137.0 ± 79.8	144.4 ± 80.6	142.6 ± 70.7	0.074	0.09
Men ($n = 75$)	138.0 ± 80.1	141.8 ± 84.6	138.3 ± 67.8	0.629	0.545
Women ($n = 63$)	135.7 ± 80.0	148.1 ± 76.1	147.6 ± 74.2	0.028	0.048
HDL (mg/dl)					
Whole ($n = 138$)	63.1 ± 16.4	62.8 ± 16.2	61.8 ± 15.6	0.731	0.185
Men ($n = 75$)	60.0 ± 15.5	59.0 ± 15.5	57.8 ± 14.4	0.39	0.63
Women ($n = 63$)	67.1 ± 16.7	67.7 ± 15.7	66.6 ± 15.8	0.723	0.92

HDL high-density lipoprotein cholesterol

*Wilcoxon signed-rank test

1-year postoperative data for VFA on CT and serum levels of triglycerides and HDL in blood examination. VFA tended to increase after surgery as a whole (Table 3). No significant changes were seen in men; however, significant changes were seen in women 6 months and 1 year after surgery compared with before surgery (Table 3). In blood examination, triglyceride levels also tended to increase after surgery as a whole (Table 3). While men showed no significant changes, women showed significant changes 6 months and 1 year after surgery compared with before surgery (Table 3). Meanwhile, HDL levels tended to decrease both as a whole and by sex; however, none of these changes were significant (Table 3).

When the participants were divided into two groups based on whether VFA increased or decreased 1 year after

surgery, each group included 55.8% ($n = 77$) and 44.2% ($n = 61$) of the patients, respectively. Figure 2 shows the percentage of the four groups that were further divided based on whether the preoperative VFA was greater or less than 100 cm²; group A, postoperative increase in VFA and preoperative VFA < 100 cm²; group B, postoperative increase in VFA and preoperative VFA ≥ 100 cm²; group C, postoperative decrease in VFA and preoperative VFA < 100 cm²; group D, postoperative decrease in VFA and preoperative VFA ≥ 100 cm² (Fig. 2). In the present study, we examined whether the preoperative JOABPEQ scores for each domain differed among these four groups (Table 4). However, no significant difference in the preoperative score of each JOABPEQ domain was found among the four groups

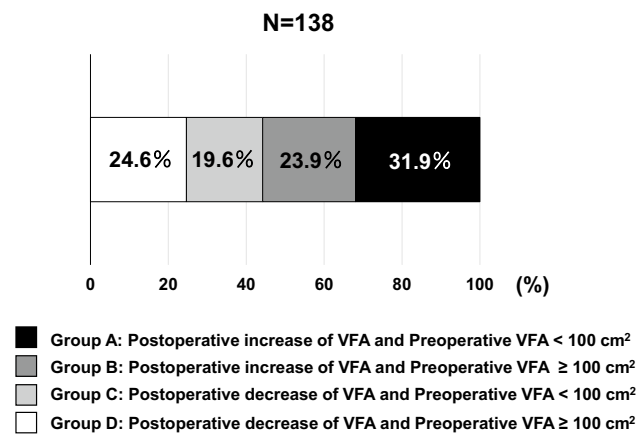


Fig. 2 Distribution of the four groups

(Table 4). Then, the frequency of effective cases of surgical treatment in each domain for JOABPEQ was compared among the four groups (Fig. 3). However, they also showed no significant differences among the four groups (Fig. 3). Next, the participants were divided into two groups based on whether surgery was effective or ineffective in each domain of the JOABPEQ, and the frequency of postoperative VFA increase or decrease was compared between the two groups (Fig. 4). In this analysis, there were no significant differences in the frequency of postoperative VFA increase or decrease between the two groups in all domains.

Finally, to identify the characteristics of those with a preoperative VFA ≥ 100 cm² and a decrease in VFA 1 year after surgery, we used a Poisson regression model to examine the factors associated with this group. After adjusting for age and sex, a lower score in the walking ability of preoperative JOABPEQ was associated with an increased risk of this group (RR 2.1; 95% CI 1.1–4.1) (Table 5).

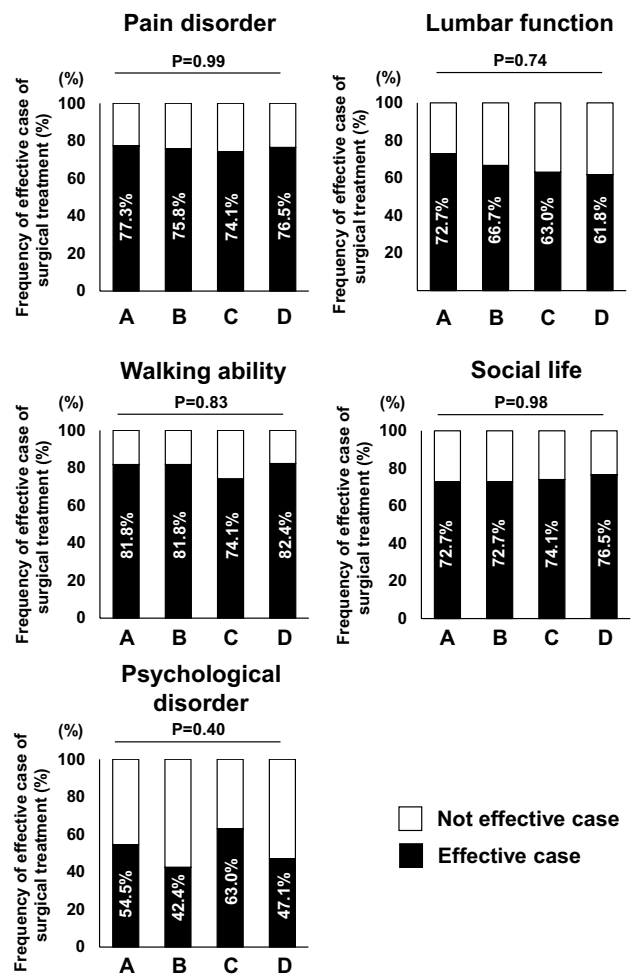


Fig. 3 Comparison of the frequency of effective cases of surgical treatment among the four groups. Group A, postoperative increase in the visceral fat area (VFA) and reoperative VFA < 100 cm² (n = 44); group B, postoperative increase in the VFA and preoperative VFA ≥ 100 cm² (n = 33); group C, postoperative decrease in the VFA and preoperative VFA < 100 cm² (n = 27); and group D, postoperative decrease in the VFA and preoperative VFA ≥ 100 cm² (n = 34)

Table 4 Comparison of preoperative scores of each domain for JOABPEQ among four groups

	Postoperative increase		Postoperative decrease		p value*
	Group A VFA < 100 cm ² (n = 44)	Group BVFA > = 100 cm ² (n = 33)	Group CVFA < 100 cm ² (n = 27)	Group DVFA > = 100 cm ² (n = 34)	
Pain disorder	43 (14–71)	30 (0–71)	43 (14–57)	43 (29–71)	0.47
Lumbar function	50 (40–77)	50 (42–75)	58 (42–83)	50 (33–83)	0.848
Walking ability	40 (12–57)	43 (14–43)	29 (21–64)	25 (7–48)	0.547
Social life	45 (32–51)	32 (22–51)	46 (31–51)	45 (26–51)	0.455
Psychological disorder	46 (34–51)	45 (36–53)	39 (34–51)	43 (36–59)	0.788

JOABPEQ Japanese Orthopaedic Association Back Pain Evaluation Questionnaire

*Kruskal–Wallis test

Discussion

This study followed the lipid metabolism of patients with LSDs who underwent lumbar spinal surgery. Overall, patients with LSDs tended to have increased VFA and increased triglyceride and decreased HDL levels on blood examination after lumbar spinal surgery, indicating that the lipid metabolism of patients with LSDs tended to deteriorate after lumbar spinal surgery. In particular, female patients with LSDs had significantly increased VFA and increased serum levels of triglycerides after lumbar spinal surgery. The multivariable analysis showed that the group with $> 100 \text{ cm}^2$ of preoperative VFA and a postoperative decrease in VFA had significantly worse preoperative walking ability.

Considering that lumbar spinal surgery improves motor function weakness and impaired social life in patients with LSDs [11, 12, 14], the lipid metabolism of patients with LSDs may have improved. Meanwhile, considering that improvement in psychological disorders could lead to increased appetite [19], lumbar spinal surgery has the potential to deteriorate lipid metabolism as psychological disorders improved [15]. The results of this study indicated that lipid metabolism in patients with LSDs tends to deteriorate with lumbar spinal surgery. Separate analyses for men and women showed that this was true for women. Because women were reported to have a less daily exercise [20], lipid metabolism in female patients with LSDs may more strongly reflect improved psychological impairment than improvements in motor function following lumbar spinal surgery than male patients with LSDs. However, patients with LSDs who are not diagnosed with metabolic syndrome or obesity do not need to improve their lipid metabolism after lumbar spinal surgery. Therefore, most importantly, LSD patients with a preoperative diagnosis of metabolic syndrome or obesity will have their lipid metabolism improved by lumbar spinal surgery. In this study, we attempted to identify associated factors using multivariable analysis, with a preoperative VFA of $\geq 100 \text{ cm}^2$ and a decrease in postoperative VFA as objective variables. On multivariable analysis, a lower walking ability before lumbar spinal surgery was associated with VFA improvement. Given that LSD patients with lower walking ability before lumbar surgery are more likely to cause metabolic syndrome because of decreased physical activity and that such patients may have improved lipid metabolism because of improved walking ability following lumbar spinal surgery, these results are to some extent consistent with our clinical impression. Conversely, our results also indicate that lumbar surgery alone does not improve the lipid metabolism of patients with LSDs. According to the previous study [21], patients who underwent total knee replacement for knee osteoarthritis, another common musculoskeletal degenerative disease, showed no change in the

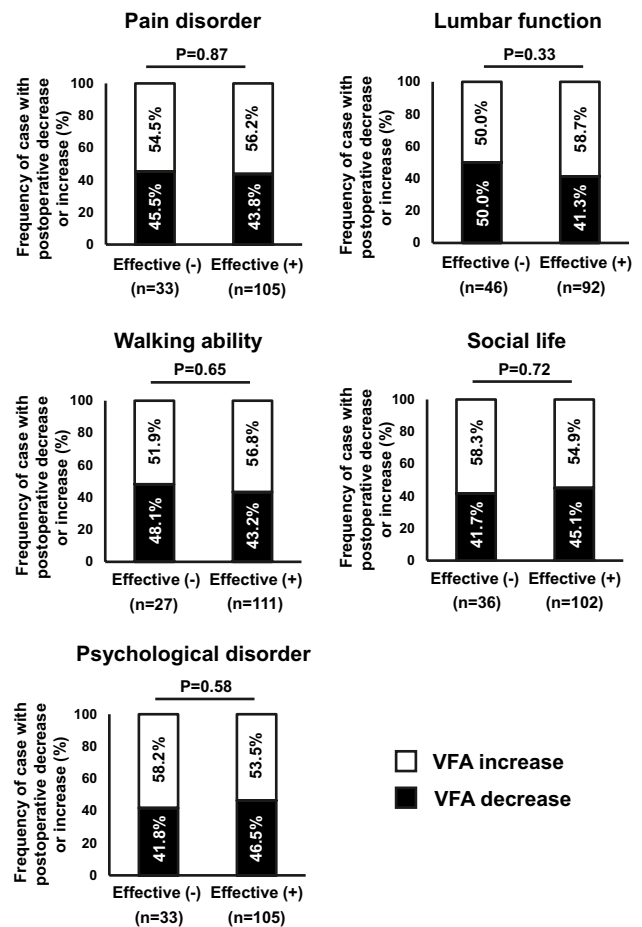


Fig. 4 Comparison of the frequency of postoperative visceral fat area (VFA) increase or decrease between the two groups based on whether surgery was effective or ineffective in each domain of Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ)

frequency of metabolic syndrome 2 years postoperatively. These findings may suggest the importance of postoperative lifestyle guidance for the improvement of lipid metabolism in patients with musculoskeletal degenerative diseases. Regarding clinical research, the results of this study were not conclusive because the study participants did not receive uniform postoperative lifestyle guidance, including exercise. To accurately assess changes in lipid metabolism after lumbar spinal surgery in patients with LSDs, all patients with LSDs should receive the similar postoperative lifestyle guidance.

This study had several limitations. First, the number of participants is limited. A larger sample is needed to gain a more comprehensive understanding of lipid metabolism in patients with surgical LSDs. In particular, multivariable analysis for identifying factors involved in VFA improvement may yield more meaningful results if conducted in a larger number of patients. Second, this study did not

Table 5 Poisson regression model of a preoperative visceral fat area $\geq 100 \text{ cm}^2$ and a decrease in visceral fat area 1 year after surgery

	No. of participants	No. of outcome	Incidence (%)	<i>p</i> value by chi-square test	Age & sex-adjusted relative risk (RR)	95% confidence interval (CI)	<i>p</i> value
Age							
< 50	32	6	18.8	0.11	Reference		
50–64	38	11	29.0		1.6	(0.7–3.9)	0.29
65–74	36	13	36.1		1.9	(0.8–4.4)	0.13
> 74	32	4	12.5		0.8	(0.3–2.8)	0.78
Sex							
Women	63	10	15.9	0.03	Reference		
Men	75	24	32.0		1.8	(0.9–3.4)	0.10
BMI (kg/m²)							
< 25.0	93	19	20.4	0.10	Reference		
≥ 25.0	45	15	33.3		1.5	(0.8–2.6)	0.16
Hypertension							
No	86	18	20.9	0.19	Reference		
Yes	52	16	30.8		1.5	(0.8–2.7)	0.22
Dyslipidemia							
No	99	22	22.2	0.29	Reference		
Yes	39	12	30.8		1.7	(1.0–3.2)	0.06
Diabetes mellitus							
No	122	30	24.6	0.97	Reference		
Yes	16	4	25.0		1.0	(0.4–2.6)	0.99
Surgical procedure							
Decompression alone	81	22	27.2	0.41	Reference		
Fusion	57	12	21.1		0.7	(0.4–1.2)	0.18
JOABPEQ							
Pain disorder							
Tertile1 (score < 29)	42	6	14.4	0.17	0.5	(0.2–1.1)	0.08
Tertile2	46	13	28.3		0.9	(0.5–1.7)	0.83
Tertile3 (score > 43)	50	15	30.0		Reference		
Lumbar function							
Tertile1 (score < 42)	35	10	28.6	0.76	1.2	(0.6–2.4)	0.58
Tertile2	51	11	21.6		1.0	(0.5–1.9)	0.91
Tertile3 (score > 67)	52	13	25.0		Reference		
Walking ability							
Tertile1 (score < 21)	42	15	35.7	0.12	2.1	(1.1–4.1)	0.02
Tertile2	36	8	22.2		1.1	(0.5–2.5)	0.74
Tertile3 (score > 36)	60	11	18.3		Reference		
Social life							
Tertile1 (score < 32)	44	12	27.3	0.50	1.4	(0.6–2.9)	0.43
Tertile2	46	13	28.3		1.4	(0.7–2.9)	0.33
Tertile3 (score > 49)	48	9	18.8		Reference		
Psychological disorder							
Tertile1 (score < 39)	45	10	22.2	0.66	1.0	(0.5–2.1)	0.98
Tertile2	44	13	29.6		1.4	(0.7–2.7)	0.32
Tertile3 (score > 48)	49	11	22.5		Reference		

include patients with LSDs receiving conservative therapy as a control group. VF has been reported to likely increase with age because of a decrease in muscle mass

and a decrease in basal metabolic rate with age [22, 23]. Thus, whether our findings are specific to lumbar spinal surgery remains unclear. Third, the follow-up duration of

1 year was insufficient to assess the impact of lumbar spinal surgery on lipid metabolism. In the longer term, the impact of lumbar surgery on lipid metabolism in patients with LSDs may be different. Fourth, given that metabolic syndrome is more likely to occur in middle-aged individuals than in older people [24, 25] and that a significant relationship between lumbar spinal canal stenosis and metabolic syndrome has been observed in people aged < 65 years [7], this study should have focused primarily on those aged < 65 years. Fifth, this study only analyzed VFA on CT images and serum triglyceride and HDL levels in blood examination and did not examine metabolic syndrome based on diagnostic criteria. Finally, we have not examined potential variations in exercise levels or dietary habits that could underlie the observed changes in VFA and serum triglycerides levels in female patients after surgery. The absence of evaluation of these variables was one of limitations in this study. To the best of our knowledge, however, this is the first prospective study to assess lipid metabolism in patients with LSDs who underwent surgery. This study could provide useful information for both physicians and surgeons.

In conclusion, the results of this study demonstrated that patients with LSDs did not necessarily have improved lipid metabolism after lumbar spinal surgery. Instead, female patients with LSDs had significantly deteriorated the status after lumbar spinal surgery. Finally, the multi-variable analysis indicated that a worse preoperative walking ability was associated with the improvement in excess VF accumulation after lumbar spinal surgery.

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Declarations

Conflict of interest None of the authors has any potential conflict of interest.

Ethical approval This study enrolled only patients who agreed to participate in the study after being informed about risk of radiation exposure from CT as well as the study protocol approved by the ethics committee of our institution (approval number, 2020–02). All participants individually provided written informed consent. All study methods were conducted in accordance with the guidelines set out in the Declaration of Helsinki.

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