Is the Goutallier grade of multifidus fat infiltration associated with adjacent-segment degeneration after lumbar spinal fusion?

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OBJECTIVE The aim of this study was to investigate whether fat infiltration of the lumbar multifidus (LM) muscle affects revision surgery rates for adjacent-segment degeneration (ASD) after L4–5 transforaminal lumbar interbody fusion (TLIF) for degenerative spondylolisthesis.

METHODS A total of 178 patients undergoing single-level L4–5 TLIF for spondylolisthesis (2006 to 2016) were retrospectively analyzed. Inclusion criteria were a minimum 2-year follow-up, preoperative MR images and radiographs, and single-level L4–5 TLIF for degenerative spondylolisthesis. Twenty-three patients underwent revision surgery for ASD during the follow-up. Another 23 patients without ASD were matched with the patients with ASD. Demographic data, Roussouly curvature type, and spinopelvic parameter data were collected. The fat infiltration of the LM muscle (L3, L4, and L5) was evaluated on preoperative MRI using the Goutallier classification system.

RESULTS A total of 46 patients were evaluated. There were no differences in age, sex, BMI, or spinopelvic parameters with regard to patients with and those without ASD ($p > 0.05$). Fat infiltration of the LM was significantly greater in the patients with ASD than in those without ASD ($p = 0.029$). Fat infiltration was most significant at L3 in patients with ASD than in patients without ASD ($p = 0.017$). At L4 and L5, there was an increasing trend of fat infiltration in the patients with ASD than in those without ASD, but the difference was not statistically significant ($p = 0.354$ for L4 and $p = 0.077$ for L5).

CONCLUSIONS Fat infiltration of the LM may be associated with ASD after L4–5 TLIF for spondylolisthesis. Fat infiltration at L3 may also be associated with ASD at L3–4 after L4–5 TLIF.

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KEYWORDS lumbar multifidus; fat infiltration; Goutallier classification; adjacent-segment degeneration; transforaminal lumbar interbody fusion; TLIF; spondylolisthesis; degenerative

THE lumbar multifidus (LM) muscles are important for providing lumbar stability; they act as dynamic stabilizers of the lumbar spine by reinforcing lumbar lordosis and resisting lumbar flexion.^{1,2} It has been hypothesized that dysfunction of the low-back muscles can result from fat infiltration of the LM,³ reflecting muscle atrophy and degeneration.⁴ Whole-body imaging studies have shown that the LM muscles in spine patients have significant levels of muscle loss and fatty atrophic changes compared with healthy controls.^{4–7} Fat infiltration in the LM is also strongly associated with low-back pain in adults.^{7,8} Low-back pain can not only lead to dysfunction but also result in fat infiltration of the LM muscle as a consequence of muscular atrophy due to underuse.³ De-

generative conditions of the spine may not only involve the discs and facets but also the paraspinal musculature,⁴ and degeneration of the discs and facets may also precipitate paraspinal muscle degeneration.^{4,9}

Fat infiltration of the LM muscle has historically been evaluated using MRI.^{10–12} Studies have shown that MRI of the LM muscles in patients with low-back pain reveals a significantly higher fat content than that found in asymptomatic controls.¹⁰ The Goutallier classification system, first reported in 1994, is a grading system that classifies muscles in the shoulder by the amount of fat within it.¹³ However, this classification system has been used to quantify the degree of fat infiltration in the lumbar paraspinal muscles.^{11,12} Battaglia et al. investigated the reliability of

ABBREVIATIONS ASD = adjacent-segment degeneration; CSA = cross-sectional area; LM = lumbar multifidus; TLIF = transforaminal lumbar interbody fusion.

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the Goutallier classification system for grading muscle fatty degeneration in the LM muscle using MRI, and they showed that this system was reliable in grading LM muscle fat infiltration.¹¹ In addition, the amount of fat infiltration graded according to the Goutallier classification has been shown to be associated with disc degeneration.¹²

We hypothesize that fat infiltration of the LM muscle may be associated with adjacent-segment degeneration (ASD) after lumbar fusion. We evaluated revision surgery rates for ASD in patients undergoing single-level L4–5 TLIF for spondylolisthesis and the correlation with fat infiltration by the Goutallier classification.

Methods

Sample Collection

A total of 178 patients who underwent single-level transforaminal lumbar interbody fusion (TLIF) for L4–5 spondylolisthesis at the University of California, San Francisco, from 2006 to 2016, were retrospectively analyzed after receiving institutional approval. Inclusion criteria were a minimum 2-year follow-up, single-level L4–5 TLIF for degenerative spondylolisthesis (including lysis), preoperative MRI clear enough to grade fat infiltration, and preoperative 3-foot standing radiographs to evaluate the Roussouly curvature type and spinopelvic parameters. Exclusion criteria were tumor, infection, fusion of > 1 level, non-TLIF fusions, scoliosis of more than 10°, and TLIF at fusion levels other than L4–5. Patients were also excluded if their adjacent segment exhibited severe preoperative degeneration with $\geq 50\%$ of disc height loss, 3 mm or greater listhesis at L3–4, 5° or more of angulation on flexion and extension radiographs, or grade III or higher Pfirrmann degeneration on sagittal T2-weighted MRI.¹⁴

Goutallier Classification

Routine preoperative MR images were obtained. Images were positioned from the midsagittal plane tangentially to the posterior caudal corner of the upper vertebral body and perpendicularly to the surface of the lumbar muscles as illustrated in Fig. 1. Fat infiltration at the three lower segments (L3, L4, and L5) was evaluated preoperatively on axial T1-weighted MR images by three investigators using the Goutallier classification.^{12,13} One attending spine surgeon and two clinical researchers were fully trained on the Goutallier classification method, and they were allocated cases at random without knowledge of whether the patient had ASD. The grades of the LM muscle were defined as follows: grade 0, no intramuscular fat; grade 1, some fatty streaks present; grade 2, fat is evident but less than muscle tissue; grade 3, the amount of fat is equal to the amount of muscle; and grade 4, more fat than muscle tissue (Fig. 2).

Spinopelvic Parameters

Three-foot standing lateral radiographs were obtained preoperatively, immediately postoperatively, and at the last clinical follow-up. Radiographic analyses included measurements of pelvic incidence, sacral slope, pelvic tilt, lumbar lordosis, and pelvic incidence minus lumbar lordosis mismatch. After the ASD cohort was identified,

FIG. 1. Sagittal correlation of the location of the axial LM measurements.

spinopelvic parameters were measured. Because spinopelvic parameters have been associated with ASD, controls with the same spinopelvic parameters were identified as the control group. An equal number of patients without ASD and the same spinopelvic parameters were chosen as the control group.

Surgical Technique

After prone positioning, the spine is exposed, and the surgical level is confirmed with imaging. Pedicle screws are placed either with stereotactic navigation or by fluoroscopy-guided insertion. A total facetectomy is then performed, usually on the most severely stenotic side, and Kambin's triangle is accessed. Disc preparation is performed, and endplate cartilage is removed. A cage of an appropriate size (expandable titanium, static titanium, or static polyetheretherketone) is filled with the surgeon's choice of graft (local autograft, iliac crest autograft, al-

FIG. 2. Goutallier classification of fat infiltration of the LM muscle (outlined in white) on axial T1-weighted MR images. The grades were as follows: grade 0, no intramuscular fat; grade 1, some fat streaks present; grade 2, fat is evident but less than muscle tissue; grade 3, the amount of fat is equal to the amount of muscle; grade 4, more fat than muscle tissue.

lograft, or bone morphogenetic protein), and graft material is placed into the disc space itself. The cage is placed under fluoroscopic guidance, the rods and set screws are placed, graft material is placed laterally for posterolateral fusion, and the wound is closed in layers.

Statistical Analysis

The data were analyzed using SPSS (version 17.0, SPSS Inc.). Data are reported as means with standard deviations. Comparison between continuous values of two groups was done using independent-samples t-tests. Categorical variables were compared using Fisher's exact test. Statistical significance was noted with $p < 0.05$.

Results

Of the 178 patients, 23 patients underwent revision surgery for ASD by the last follow-up after TLIF. Twenty-three patients without ASD were matched by spinopelvic parameters and used as controls. A total of 46 patients were evaluated (18 males and 28 females, mean age 61.41 ± 10.46 years). The mean follow-up was 40.01 ± 18.42 months (range 24–131 months). Of the entire cohort of 178 patients, 23 patients (12.92%) underwent revision surgery for ASD in the follow-up period, with 13 patients (7.3%) undergoing revision at L3–4, 4 patients (2.25%) at L5–S1, and 6 patients (3.37%) at both L3–4 and L5–S1. There were no differences in age, sex, BMI, Roussouly type, and spinopelvic parameters with regard to patients with and without ASD ($p > 0.05$; Table 1).

ASD and non-ASD patients were then subdivided, and the total number of levels within each Goutallier grade from L3 to L5 was calculated. Goutallier grade 1

TABLE 1. Patient demographics

	ASD (n = 23)	No ASD (n = 23)	p Value
Mean age, yrs	63.45 ± 9.0	59.36 ± 11.92	0.210
F/M sex	12:11	16:7	0.365
Mean BMI	29.01 ± 5.31	27.41 ± 6.38	0.391
Goutallier classification (no. of levels)			0.029*
Grade 0	0	3	
Grade 1	13	19	
Grade 2	38	37	
Grade 3	12	10	
Grade 4	6	0	
Mean spinopelvic parameters, °			
PI	59.09 ± 10.86	58.36 ± 10.82	0.825
PT	21.27 ± 7.99	22.32 ± 7.43	0.655
SS	37.82 ± 8.94	36.04 ± 9.24	0.521
LL	56.41 ± 11.56	51.18 ± 12.69	0.161
PI-LL	9.36 ± 8.62	10.09 ± 9.03	0.786
Roussouly classification			
Type 1	1	1	
Type 2	11	11	
Type 3	6	6	
Type 4	5	5	

LL = lumbar lordosis; PI = pelvic incidence; PI-LL = PI minus LL; PT = pelvic tilt; SS = sagittal slope.

Values represent the number of patients or mean $\pm$ SD unless stated otherwise.

* $p < 0.05$.

TABLE 2. Goutallier grades of the LM muscle from L3 to L5 in patients with (n = 23) and patients without (n = 23) ASD

	No. of Levels					p Value
	Grade 0	Grade 1	Grade 2	Grade 3	Grade 4	
L3						
ASD	0	6	16	1	0	0.017*
No ASD	3	12	7	1	0	
Total	3	18	23	2	0	
L4						
ASD	0	5	11	6	1	0.354
No ASD	0	6	15	2	0	
Total	0	11	26	8	1	
L5						
ASD	0	2	11	5	5	0.077
No ASD	0	1	15	7	0	
Total	0	3	26	12	5	

* p < 0.05, Fisher's exact test.

was observed at L3 and L5 levels with and without ASD, respectively; grade 2 was observed in 38 and 37 levels, respectively; grade 3 was observed in 12 and 10 levels, respectively; and grade 4 was observed in 6 and 0 levels, respectively ($p = 0.029$) (Table 1). For grade 0, there were 3 patients without ASD, but there were no grade 0 patients with ASD. The inter- and intrarater reliability were calculated as 0.800 and 0.834, respectively.

When subdivided by level, fat infiltration was more significant at L3 in patients with ASD than in patients without ASD ($p = 0.017$). At L4 and L5, the difference was not statistically significant ($p = 0.354$ for L4 and $p = 0.077$ for L5) (Table 2).

Discussion

Paraspinal muscle degeneration progresses with age and includes a reduction in muscle size and infiltration of fatty degeneration within the muscle.⁴ There is a growing body of evidence showing an association between paraspinal muscle degeneration and lumbar spine issues.^{1,5,6,8,15} Recently, studies have suggested that both the paraspinal muscle cross-sectional area (CSA) and fat infiltration are associated with low-back pain, radiculopathy, and spinal stenosis.^{7,15–17} However, other studies have shown the opposite result: that muscle CSA was not associated with spinal degeneration.^{6,18} Some reports have noted that fat infiltration is a better reflection of muscle degeneration compared with the CSA.^{15,19} Other studies have reported that paraspinal muscle damage during lumbar surgery may be one of the most important factors that causes atrophy or fat infiltration of the muscles.^{20,21} In addition, studies have validated the measurement of LM muscle fat infiltration as seen on MRI using the Goutallier classification system, reflecting that this is a reliable system to grade LM fatty degeneration.^{11,12}

We found that LM fat infiltration at L3 to L5 was greater in ASD patients than in patients without ASD ($p = 0.029$) (Table 1). Another interesting point is that the

fat infiltration was more significant at L3 in patients with ASD than in those without ASD ($p = 0.017$) (Table 2). The results indicate that fat infiltration of the LM may contribute to ASD after L4–5 TLIF for spondylolisthesis, especially at L3–4. We found that revision surgery for ASD at the upper adjacent segment (L3–4) was nearly 3 times that of the lower adjacent segment (L5–S1). This finding suggests that the cephalad level is at higher risk for ASD, which is consistent with previous reports.^{24,25} The reason may be that there is increased stress at the cephalad adjacent segment because the L5–S1 ligamentous complex is very tough and strong.²⁶ The increased fat infiltration of the LM at L3 may be another reason.²⁷ The higher incidence of L3–4 ASD is consistent with the increased fat infiltration of the LM muscles at L3 ($p < 0.05$), but this correlation was not seen with fat infiltration of the L5 LM muscle and ASD ($p > 0.05$).

There are a few studies that have investigated the association of spinal disorders and fat infiltration of the LM, erector spinae (ES), and psoas muscles.^{4,18,28} Fat infiltration of both the LM and ES was associated with reduced intervertebral disc height and an increased risk of Modic changes. Unlike the fat infiltration of the posterior paraspinal muscles, fatty degeneration in the psoas was minimal.⁴ In particular, Teichtahl et al. reported that the high fat content of the ES was significantly associated with Modic changes.¹⁸ Moreover, a large number of studies have demonstrated that fat infiltration in the LM muscles is strongly associated with low-back and leg pain or poor functional performance of the lumbar spine.^{5,7,8,17,18,27} Taken together, the findings suggest that fat infiltration of the LM muscle is associated with spinal pathology, and it may be a contributing factor to ASD after fusion surgery.⁸

With regard to cohort matching, the initial parameters chosen to perform the matching were spinopelvic parameters. The main reason spinopelvic parameters were chosen as the main factors for matching is that previous studies have shown that spinopelvic mismatch is associated with ASD.^{22,23} Thus, these were the main control variables that we thought were critical to avoid having a significant confounder for ASD. After patients with matched spinopelvic parameters were identified, baseline demographics such as age, sex, and BMI were analyzed, and they were not found to be statistically different. Thus, not only were spinopelvic parameters matched, but also there were no significant differences between age, sex, and BMI. Although there was a difference in the absolute numbers with regard to sex, the statistical calculation of the differences between cohorts revealed a p value of 0.365. Thus, there was not a statistically significant difference between the two groups with regard to sex. Although older literature suggested that women are more likely than men to develop ASD, a major confounder in those studies was most likely poor bone quality and not necessarily sex per se. For instance, Etebar and Cahill²⁹ reported higher rates of “next segment” degeneration in postmenopausal women; however, they also included the fact that more than 50% were on bisphosphonates, indicating poor bone health as a confounder in their findings. In addition, more recent studies with more rigorous statistical analyses have shown that sex is generally not a risk factor for ASD.³⁰ With re-

gard to the clinical relevance of this information, patient counseling about the understanding and awareness of the increased fatty infiltration can be implemented as a potential prognostic indicator of needing revision surgery. In the future, if the exact cause of fatty infiltration can be elucidated (deconditioning of the musculature, metabolic syndrome from high fructose consumption, or other underlying metabolic disorder), then an intervention such as physical therapy or dietary changes could be implemented to potentially mitigate the risk of progression.

There are some limitations to this study. The results presented should be considered cautiously because of the small sample size. Although there were 178 patients with a minimum 2-year follow-up, the small number of patients with ASD limits the analytical power of the results. Furthermore, the present study was a single-center retrospective study, and the MRI evaluation only focused on the levels of L3 to L5; the upper lumbar musculature was not evaluated. Thus, other factors could account for the variation on paravertebral muscle fat infiltration. However, we tried to make the two comparison groups as homogeneous as possible, matching for spinopelvic parameters, limiting the surgery type to only L4–5 TLIF, and limiting the diagnosis to only degenerative spondylolisthesis at L4–5. Moreover, we focused on evaluating the fat infiltration of the LM muscle and not the CSA of the muscles. The CSA may be another important factor that was not considered in this study, because previous studies have reported that fat infiltration, not muscle CSA, was associated with pain, disability, and structural abnormalities in the lumbar spine.¹⁸ Another potential limitation is that paraspinal muscular fat infiltration may be a sign of underlying myopathy. Because of the rare diagnosis of primary myopathy, we were not able to delineate patients who had actual myopathies. Another factor that was not addressed in this study is whether or not adjacent-segment facet violation occurred with pedicle screw placement. However, the historical way to assess for superior facet violation is by grading pedicular screw placement according to the method of Gertzbein and Robbins.³¹ This analysis, however, is performed using a postoperative CT scan, and, unfortunately, not all patients had postoperative CT scans, precluding this analysis. However, all TLIFs were performed by surgeons with more than 15 years of experience each, and, hopefully, the knowledge of avoiding the superior facet would have minimized this incidence. Another limitation to this study is the lack of consideration of other factors that are associated with ASD. Although we had excluded preexisting degenerative cases by MRI, other factors that were not accounted for may also have contributed to ASD. Additional studies are necessary to improve our understanding of the association between paraspinal fat infiltration and ASD or other spinal disorders.

Conclusions

In patients who underwent revision surgery for ASD after L4–5 TLIF for degenerative spondylolisthesis, fat infiltration of the LM muscle was more significant compared with patients without ASD. Fat infiltration of the LM muscle may be associated with ASD after L4–5 TLIF

for spondylolisthesis. Fat infiltration at L3 may also be associated with ASD at L3–4 after L4–5 TLIF.

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Conception and design: Chou. Acquisition of data: Duan, Guinn, Rivera. Analysis and interpretation of data: Duan. Drafting the article: Duan. Critically revising the article: Mummaneni, Berven, Chou. Reviewed submitted version of manuscript: Mummaneni, Berven. Approved the final version of the manuscript on behalf of all authors: Duan. Administrative/technical/material support: Mummaneni, Guinn, Rivera, Berven. Study supervision: Chou.

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