



Original Article

Age, body mass index, and osteoporosis are more predictive than imaging for adjacent-segment reoperation after lumbar fusion

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ABSTRACT

Background: Adjacent-segment disease (ASD) is a well-described long-term complication after lumbar fusion. There is a lack of consensus about the risk factors for development of ASD, but identifying them could improve surgical outcomes. Our goal was to analyze the effect of patient characteristics and radiographic parameters on the development of symptomatic ASD requiring revision surgery after posterior lumbar fusion.

Methods: In this retrospective cohort study, we identified patients who underwent lumbar fusion surgery and revision surgery from May 2012 to November 2018 using an institutional lumbar fusion registry. Patients having both pre- and post-operative upright radiographs were included in the study. Revision surgeries for which the index operation was performed at an outside hospital were excluded from analysis. Univariate analysis was conducted on candidate variables, and variables with $P < 0.2$ were selected for multivariate logistic regression.

Results: Of the 106 patients identified, 21 required reoperation (29 months average follow-up). Age >65 years (OR 4.14, 95% CI 1.46–11.76, $P = 0.008$), body mass index (BMI) >34 (OR 1.13, 95% CI 1.04–1.23, $P = 0.004$), and osteoporosis (OR 1.38–142.42, $P = 0.03$) were independent predictors of reoperation in the multivariate analysis. Increased facet diastasis at fusion levels (OR 0.60, 95% CI 0.42–0.85, $P = 0.004$) was associated with reduced reoperation rates. Change in segmental LL at the index operation level, rostral and caudal facet diastasis, vacuum discs, and T2 hyperintensity in the facets were not predictors of reoperation.

Conclusion: Age >65 , BMI >34 , and osteoporosis were independent predictors of adjacent-segment reoperation after lumbar spinal fusion.

Keywords: Adjacent segment disease, Fusion, Imaging, Lumbar lordosis, Reoperation, Spine

INTRODUCTION

Lumbar instrumented fusion is a common procedure for the treatment of a variety of degenerative spinal disorders including lumbar spondylolisthesis and is supported by multiple guidelines.^[2,7,9,18,24,25,30] Numerous factors are involved in the decision to perform a lumbar fusion, including patient characteristics, imaging features, and diagnosis. Over the past decade, the use of lumbar fusion has increased by 32.1%, with the greatest increase being for spondylolisthesis.^[17]

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Current surgical techniques are highly effective in achieving improved patient outcomes with high rates of bony fusion, up to 90–95%.^[31] Initial satisfactory outcomes can be achieved with lumbar fusion, but reoperation is sometimes required for the delayed development of adjacent-level disease.^[12,22]

Adjacent-segment degeneration is defined based on degenerative changes seen at adjacent segments on radiological imaging, whereas adjacent-segment disease (ASD) requires both radiologic degeneration and clinical symptoms.^[26] The reported incidence of ASD after lumbar fusion ranges from 3.9% to 14%.^[1,26] The incidence based on radiological imaging is even higher, ranging from 5% to 92%.^[10,13,23,26,27]

The exact pathogenesis of ASD is yet to be elucidated. Numerous patient, radiographic, and clinical risk factors have been published, but most lack consensus. Factors reported in the literature include age, female sex, osteoporosis, posterior interbody fusion, fusion length, pre-existing adjacent-level disc degeneration, sagittal alignment, and lumbar stenosis.^[20] The objective of this study was to analyze risk factors for the development of ASD using data from a single-institution spine registry to compare patients who developed it after lumbar fusion with those who did not.

MATERIALS AND METHODS

Study design

An institutional review board approved retrospective single-center study was performed using the lumbar fusion registry at our institution to identify patients who underwent index lumbar fusion surgery with instrumentation and their revision surgery here from May 2012 to November 2018. Patients older than 18 years of age who underwent 1st-time lumbar fusion and had pre- and postoperative upright lumbar radiographs were included in the study. Patients who lacked pre- or post-operative radiographs or who underwent revision surgeries for which the index operation was performed at an outside hospital were excluded from the study. Patients who fit these criteria but did not require revision for ASD were used for comparison.

Variables and outcomes

Candidate variables obtained from patient records included sex, age, diagnosis of osteoporosis, number of levels fused, pre- and post-operative segmental lordosis at the index fusion level and adjacent segments, preoperative T2 signal hyperintense signal in the facets, preoperative facet diastasis (the maximum distance between the inferior articular process and the superior articular process for a given joint measured in millimeters), preoperative disc space height, pre- and postoperative lumbar lordosis (LL), amount of disc

space distraction if interbody placed, change in pre- versus post-operative segmental lordosis at the fusion levels, history of trauma, and body mass index (BMI).

Age >65 years was considered elderly. For BMI, we used the standard accepted medical definition to classify patients: overweight (BMI 25–29.9), mild obesity (30–34.9), moderate obesity (35–39.9), and severe obesity (≥ 40).^[4] Segmental and regional lordosis were measured using the Cobb method.^[5]

Statistical analysis

Univariate analysis was conducted on candidate variables. Candidate variables with $P < 0.2$ were selected for multivariate logistic regression. Data were analyzed using standard SPSS statistical software 25 (IBM Corp, Armonk, New York, USA). Mean values for continuous variables were compared using *t*-test whereas categorical variables were compared using Chi-squared. $P < 0.05$ was deemed statistically significant.

RESULTS

Participants

A total of 106 patients who underwent lumbar fusion and met the inclusion criteria for the study were identified. Of these, 21 (19.8%) required revision surgery. The average length of follow-up was 29 months after the index operation.

Descriptive data

The mean age was 60.2 years for the non-ASD group (no revision surgery) and 67.1 years for the ASD group ($P = 0.02$) [Table 1]. The majority of operations were single-level fusions, and there was no significant difference in reoperation rate based on number of levels in the index fusion ($P = 0.11$) [Table 1]. The spine levels fused ranged from L2 through S1, with the most common fusion level being L4-L5 [Table 2]. A significantly higher percentage of the ASD group were >65 years ($\chi^2=7.88$; $P = 0.05$). Overall, 59.4% of the patients were female and 40.6% were male, but sex was not correlated with reoperation rate ($P = 0.80$). The mean BMIs of the non-ASD and ASD group were 29.65 and 33.89, respectively ($P = 0.003$). When BMI was categorized into two groups, BMI >34 or BMI <34, patients with BMI >34 were significantly more likely to require reoperation ($\chi^2=11.2$, $P = 0.02$). Osteoporotic patients were also found to be significantly more likely to require reoperation ($P = 0.005$).

Radiographic data

The radiographic characteristics of patients with and without ASD after posterior lumbar fusion are shown in

Table 1: Characteristics of patients with and without ASD after posterior lumbar fusion.

Patient characteristic	Non-ASD (n=85)	ASD (n=21)	P value
Age in years, mean (SD)	60.2 (12.25)	67.1 (9.8)	0.02
Age >65 years, n (%)	32 (37.6)	15 (71.45)	0.05
Sex, n (%)			0.8
Male	35 (41.2)	8 (38.1)	
Female	50 (58.8)	13 (61.9)	
BMI in Kg/m ² , mean (SD)	29.65 (5.5)	33.9 (6.1)	0.003
BMI<34, n (%)	68 (80)	13 (61.9)	
BMI>34, n (%)	17 (20)	8 (38.1)	
Osteoporosis, n (%)	1 (1.2)	3 (14.3)	0.005
Posterolateral fusion, n (%)	12 (14.1)	7 (33.3)	
PLIF, n (%)	64 (75.3)	14 (66.7)	
TLIF, n (%)	9 (10.6)	0 (0)	
Spinal levels fused, n (%)			0.11
1 spinal level	60 (70.6)	12 (57.1)	
2 spinal levels	22 (25.9)	5 (23.8)	
>2 spinal levels	3 (3.5)	4 (19)	
Duration of follow-up (months)	26.3	40.6	

ASD: Adjacent-segment disease, BMI: Body mass index, PLIF: Posterior lumbar interbody fusion, SD: Standard deviation, TLIF: Transforaminal lumbar interbody fusion

Table 2: Characteristics of the lumbar spine levels with instrumented fusion.

Levels instrumented	Number of surgeries (%)
L5-S1	18 (17)
L4-5	43 (40.6)
L4-S1	18 (17)
L3-4	6 (5.7)
L3-5	10 (9.4)
L3-S1	4 (3.8)
Others (L2-3, L2-L4, L2-L5, L1-L5)	7 (6.7)

Tables 3 and 4. On radiographic imaging, preoperative LL demonstrated mean values of 52.9° and 48.23° for the non-ASD and the ASD group, respectively, whereas postoperative mean LL was 50.86 and 48.88, respectively [Table 3]. These values showed that surgery had little effect on the postoperative lordosis for those patients and, unsurprisingly, there was no statistical difference between the groups.

Intervertebral disc space height measurements did not differ significantly between the two groups, either before or after surgery, suggesting that this study lacked any power to detect whether intervertebral disc height was a predictor or not [Table 3]. On the other hand, the average preoperative facet diastasis was 3.27 mm in the non-ASD group and 1.86 mm in the study group ($P = 0.03$), indicating a significant difference

Table 3: Radiographic characteristics of patients with and without ASD after posterior lumbar fusion.

Radiographic characteristic	Non-ASD (n=85)	ASD (n=21)	P value
Preop LL (degrees)	52.9	48.23	0.29
Postop LL (degrees)	50.86	48.88	0.61
Preop segmental LL (degrees)	21.82	20.08	0.52
Postop segmental LL (degrees)	19.41	19.62	0.93
Change in segmental LL (degrees)	2.42	0.44	1
Rostral preop segmental LL (degrees)	19.01	15.93	0.15
Rostral postop segmental LL (degrees)	19.84	17.82	0.29
Change in rostral segmental LL (degrees)	0.84	1.89	0.63
Preop disc space (mm)	11.52	11.04	0.79
Postop disc space (mm)	14.85	14.23	0.71
Change in disc space (mm)	-2.61	-3.24	0.62
Rostral adjacent preop disc space (mm)	11.8	10.76	0.26
Rostral adjacent postop disc space (mm)	12.73	11.94	0.52
Change in rostral segment disc space (mm)	-0.12	-1.18	0.32
Caudal adjacent preop disc space (mm)	7.81	5.67	0.11
Caudal adjacent postop disc space (mm)	8.52	6.09	0.11
Change in caudal segment disc space (mm)	-0.71	-0.42	0.56
Preop facet diastasis (mm)	3.27	1.86	0.03
Rostral preop facet diastasis (mm)	1.48	1	0.16
Caudal preop facet diastasis (mm)	1.07	1.11	0.92

ASD: Adjacent segment disease, LL: Lumbar lordosis

between the groups [Table 3]. Other measures of facet diastasis were not significantly different preoperatively.

Segmental lordosis

For index-level segmental lordosis, the mean pre- and post-operative values were only marginally different between patients who required reoperation and those who did not ($P > 0.05$ for both). Unsurprisingly, change in segmental lordosis was not statistically significant. Comparing those whose segmental lordosis remained the same and those who had a decrease versus patients who had an increase in segmental lordosis, there was no statistically significant difference in reoperation rates ($P = 0.47$). When comparing the rostral adjacent segment pre- and post-operative

segmental lordosis, there was no statistically significant difference between the two groups. The change in segmental lordosis between both groups was also not statistically significant. When categorized into same versus decrease versus increase in segmental lordosis, there was again no statistically significant difference in reoperation rates ($P = 0.63$). Caudal pre- and post-operative segmental lordosis was not significantly different between the two groups with $P = 0.08$ and $P = 0.03$, respectively. Again, when the difference in caudal pre- and post-operative segmental lordosis is categorized into same versus decrease versus increase in lordosis, univariate analysis showed no statistically significant difference, with $P = 0.12$ [Table 3].

Predictors

Variables with $P < 0.2$ were used in the binary logistic regression analysis [Table 5]. Age >65 years (OR 4.14, 95% CI 1.46–11.76, $P = 0.008$), BMI >34 (OR 1.93, 95% CI 1.26–2.99, $P = 0.02$), increased facet diastasis at fusion levels (OR 0.60, 95% CI 0.42–0.85, $P = 0.004$), and osteoporosis (OR 14, 95% CI 1.38–142.42, $P = 0.03$) were all independent predictors of reoperation in the multivariate analysis. Change in segmental LL at the index operation level, rostral and caudal facet diastasis, vacuum discs, and T2 hyperintensity in the facets were not predictors of reoperation.

Table 4: Radiographic characteristics of patients with and without ASD after posterior lumbar fusion.

Radiographic characteristic	P value
Rostral vacuum disc	0.008
Caudal vacuum disc	0.71
T2 facet hyperintensity	0.53
Rostral T2 facet hyperintensity	0.58
Caudal T2 facet hyperintensity	0.24

ASD: Adjacent-segment disease

Table 5: Multivariate logistic regression of variables involved in ASD.

Variable	Odds ratio	95% confidence interval	P value
Age	4.14	1.46–11.76	0.008
Osteoporosis	14	1.38–142.42	0.03
BMI	1.93	1.25–2.99	0.003
Caudal preop segmental LL	0.912	0.82–1.01	0.085
Caudal post segmental LL	0.9	0.81–0.99	0.04
Caudal preop disc space	0.87	0.75–1.02	0.08
Caudal postop disc space	0.88	0.77–1.01	0.08
Preop facet diastasis	0.6	0.42–0.85	0.004
Rostral preop facet diastasis	0.74	0.49–1.13	0.163

ASD: Adjacent-segment disease, BMI: Body mass index, LL: Lumbar lordosis

DISCUSSION

In this study, we retrospectively reviewed our institutional lumbar fusion registry and identified 106 patients who met inclusion criteria to investigate predictors of ASD. Our main aim was to assess clinical and radiographic risk factors that contributed to the development of ASD. According to our results, age >65 years, BMI >34 , and osteoporosis were independent predictors of reoperation whereas radiographic measurements and changes were not overall predictors of reoperation.

There was no statistically significant difference in the pre- and post-operative LL in either group [Table 1]. These values indicate surgery had no significant impact on lordotic angle. Bagheri *et al.*^[3] reported an increased risk of ASD with decreased postoperative LL. Their study found a significant difference in preoperative LL between the two groups, which was not found in our study. However, similar to our study, the mean LL was lower in patients with ASD. Further studies such as the meta-analysis conducted by Phan *et al.* and a review of the literature conducted by Saavedra-Pozo *et al.* showed that the lower preoperative LL was associated with increased risk of ASD.^[21,26] Numerous other studies all reported no significant difference in pre- and post-operative LL between the non-ASD and ASD group.^[28,29,32] Because this study was not focused on correction of LL, and the differences in LL from pre- to post-operative were minimal, it is unlikely that this study was powered to detect the significance of the lower LL on risk of reoperation for ASD. Furthermore, we did not have pelvic incidence data on these patients and so it would be impossible to know whether any patients had suboptimal postoperative LL or not.

Evaluation of segmental LL in our study found that the mean angles were similar in the non-ASD and ASD groups, with no significant change in pre- and post-operative segmental LL. Similarly, there was no significant difference in rostral segmental lordosis between the two groups, although there was a significant difference in the caudal postoperative segmental lordosis between the two groups, with the mean segmental LL higher in non-ASD group and less likelihood of reoperation with a higher segmental LL. However, on multivariate analysis, this did not turn out to be an independent predictor of reoperation.

There was no statistically significant change in disc space height at the level of surgery, or at the rostral and caudal adjacent levels. Although the caudal pre- and post-operative disc space measurements fulfilled our criteria for inclusion in the logistic regression, they were not significant predictors in that analysis. Similarly, Makino *et al.*^[15] measured preoperative intervertebral disc space height at L3-L4 and L4-L5 and found no significant difference between groups. Postoperative intervertebral disc space height was not

measured in their study. Another interesting finding in our study that was contrary to our expectation was that facet diastasis at the level of surgery was significantly higher in the non-ASD group. This was associated with a decreased likelihood of reoperation. However, rostral and caudal facet diastasis were not significant predictors. Rostral vacuum disc showed a statistically significant difference between the two groups, but could not be included in the logistic regression because of the small sample size ($n = 6$).

According to our multivariate analysis, age >65 years was associated with an increased risk of developing ASD requiring surgery. The literature suggests mixed results on the role of age in predicting ASD in general. Several studies indicate age as a risk factor,^[1,9,11,14] but others have found no association of age with development of ASD.^[29,32] Furthermore, a study by Maragkos *et al.*^[16] found a lower incidence of ASD in older patients. They hinted that older patients are less active, which results in less degeneration. They suggested that surgeons are reluctant to perform revision surgery in older patients.

BMI is an objective measure that can be followed in relation to formation of ASD. Higher BMI results in increased stress on the lumbar spine, which can accelerate disc degeneration caused by the increased burden to absorb the loading forces.^[6] Our results demonstrate that BMI of >34 is associated with an increased risk of ASD. Similar to age, the results of the literature vary regarding the importance of BMI; some studies show no association^[8,32] whereas other studies corroborate our findings.^[3,9,11,19,29]

We found that osteoporosis was associated with an increased risk of reoperation, which is consistent with findings seen by Hashimoto *et al.*^[11] This is not surprising as the poor bone quality in osteoporotic patients can result in accelerated degeneration. However, there are a few studies that report no association of ASD with osteoporosis.^[3,32] The contradictory data may be a result of a difference in the degree of osteoporosis in patients in the different studies. Surgeons may also be less likely to offer reoperation to patients with osteoporosis because of the concern of instrumentation failure.

Limitations

This was a retrospective single-institution study with a small number of patients that had reoperation and thus had the inherent limitations of that study type. This may limit the generalizability of the findings. Data were unavailable in some patients, and some data points were not collected because of either loss of data or poor image quality. The length of follow-up was shorter in the non-ASD group, which may be a potential source of bias, as longer follow-up generally results in higher reoperation rates because of the natural history of lumbar degenerative disease. The accuracy of measurement

of angles and disc space may have been compromised if a slight movement led to a change in measured values. We were unable to carry out analysis on pelvic parameters because the imaging studies did not include the femoral heads.

CONCLUSION

In this study, we retrospectively reviewed 106 patients who underwent lumbar fusion, of which 21 (19.8%) of the patients required revision surgery for the treatment of ASD. We found that age >65, BMI >34, and osteoporosis were independent predictors of ASD leading to reoperation.

Ethical approval

This study was completed under ethical guidelines and was approved by the institutional review board.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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