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Lateral Thoracolumbar Listhesis as an Independent Predictor of Disability in Adult Scoliosis Patients: Multivariable Assessment Before and After Surgical Realignment

BACKGROUND: Lateral (ie, coronal) vertebral listhesis may contribute to disability in adult scoliosis patients.

OBJECTIVE: To assess for a correlation between lateral listhesis and disability among patients with adult scoliosis.

METHODS: This was a retrospective multi-center analysis of prospectively collected data. Patients eligible for a minimum of 2-yr follow-up and with coronal plane deformity (defined as maximum Cobb angle $\geq 20^{o}$) were included (n = 724). Outcome measures were Oswestry Disability Index (ODI) and leg pain numeric scale rating. Lateral thoracolumbar listhesis was measured as the maximum vertebral listhesis as a percent of the superior endplate across T1-L5 levels. Linear and logistic regression was utilized, as appropriate. Multivariable analyses adjusted for demographics, comorbidities, surgical invasiveness, maximum Cobb angle, and T1-PA. Minimally clinically important difference (MCID) in ODI was defined as 12.8.

RESULTS: In total, 724 adult patients were assessed. The mean baseline maximum lateral thoracolumbar listhesis was 18.3% (standard deviation 9.7%). The optimal statistical grouping for lateral listhesis was empirically determined to be none/mild (<6.7%), moderate (6.7-15.4%), and severe (≥15.4%). In multivariable analysis, listhesis of moderate and severe vs none/mild was associated with worse baseline ODI (none/mild = 33.7; moderate = 41.6; severe = 43.9; $P < .001$ for both comparisons) and leg pain NSR (none/mild = 2.9, moderate = 4.0, severe = 5.1, $P < .05$). Resolution of severe lateral listhesis to none/mild was independently associated with increased likelihood of reaching MCID in ODI at 2 yr postoperatively (odds ratio 2.1 95% confidence interval 1.2–3.7, $P = .0097$).

CONCLUSION: Lateral thoracolumbar listhesis is associated with worse baseline disability among adult scoliosis patients. Resolution of severe lateral listhesis following deformity correction was independently associated with increased likelihood of reaching MCID in ODI at 2-yr follow-up.

KEY WORDS: Adult spinal deformity, Lateral thoracolumbar listhesis, ODI, HRQOL

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Degenerative scoliosis is a common condition increasingly affecting the aging population. Fortunately, surgical intervention has been shown to significantly improve outcomes including pain, quality of life, and disability scores compared to nonoperative treatment.[1-3] Previous studies have shown that sagittal imbalance is associated with greater pain and higher Oswestry Disability Index (ODI) scores, indicating that restoration of sagittal imbalance is a critical goal for reconstructive spine surgery.[4] Anterolisthesis is one of the radiographic measures that has been correlated with persistent pain and poor functional outcomes.[5,6]

ABBREVIATIONS: MCID, Minimally clinically important difference; **ODI,** Oswestry Disability Index

Surgical management of this pathology has been shown to improve pain and functional outcomes while decreasing ODI.[7,8]

Lateral vertebral listhesis is another, albeit less well understood, metric used to assess adult scoliotic deformity. Studies have shown that lateral listhesis is associated with pain,[9,10] however, a retrospective review of 58 patients with de novo degenerative scoliosis did not find a statistically significant correlation between lateral listhesis and ODI. Additionally, lateral listhesis has been associated with nerve root compression and radiculopathy, in particular at the L4-5 level.[11,12] The full extent of listhesis may not be apparent on supine magnetic resonance imaging, and increased listhesis may change operative planning from a simple decompression to the addition of a fusion.[13]

The purpose of this study is to assess for a correlation between lateral listhesis and disability among patients with adult scoliosis. Our hypothesis is that increasing severity of lateral vertebral listhesis will be associated with increasing severity of disability, as measured by ODI. Our second hypothesis is that ODI scores will be improved following surgical realignment surgery when lateral listhesis is improved.

METHODS

Patient Sample

This study utilized a multi-center, prospectively defined database of adult spinal deformity surgery patients. Only patients with 2-yr follow-up, a coronal plane deformity, and complete baseline data were included. Coronal plane deformity was defined as a Cobb angle >20°. Institutional Review Board Approval was obtained at all participating institutions for collection and analysis of patient data, and patient consent was obtained.

Outcome Measures and Predictors

The primary outcome measure in this study was the ODI, measured at baseline, 26 wk, 1 yr, and 2 yr postoperatively. The primary independent variable was lateral vertebral listhesis, measured from standing 36-inch postero-anterior plain radiographs. Lateral listhesis was measured for both left and right sides as the distance between the superior corner of the inferior vertebrae and the ipsilateral inferior corner of the superior vertebrae, in the plane of the superior endplate of the inferior vertebrae. (Figure 1) For each PA radiograph, the maximum listhesis as a percentage of the superior endplate distance across all levels was determined. Lateral listhesis was subsequently grouped into 3 categories based on association with ODI: none/mild (<6.5%), moderate (6.5-16.6%), severe (≥16.7%). Additional covariates included baseline patient age, gender, Charlson Comorbidity Index, maximum Cobb angle, and T1-pelvic angle. For postoperative analyses, surgical invasiveness was also included as a covariate.

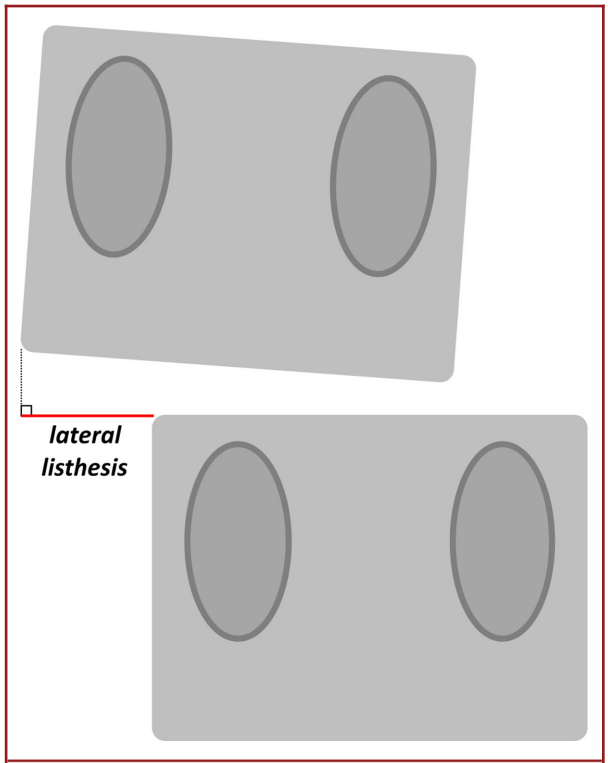

FIGURE 1. *Measurement of Lateral Listhesis: Lateral listhesis was measured for both left and right sides as the distance between the superior corner of the inferior vertebrae and the ipsilateral inferior corner of the superior vertebrae, in the plane of the superior endplate of the inferior vertebrae.*

Statistical Analysis

Statistical analysis was completed using SAS 9.4 (SAS Institute, Cary NC) and the Julia programming language, v0.6.4 (JuliaLang). The optimal statistical cutpoints for grouping lateral listhesis percentage were determined using ODI. In brief, all possible pairs of two cutpoints across the range of listhesis values were determined. For each pair of listhesis cutpoints, patients were divided into 3 groups, and a Kruskal Wallis Test between ODI across groups was performed. The optimal cutpoint pair was selected as that which minimized the *P*-value for this test. For visual simplicity, Figure 2 plots the *P*-value from the Mann Whitney U-Test between 2 groups separated by a single cutpoint, though the local minima were equivalent to the paired approach above. Analyses of baseline ODI against lateral listhesis group utilized bivariable and multivariable regression. Postoperative analyses of ODI at 26-wk, 1-yr, and 2-yr follow-up utilized multivariable mixed linear models. Logistic regression was utilized to determine the independent association of listhesis category improvement with odds of reaching a minimally clinically important difference (MCID) in ODI at 2 yr postoperatively. Statistical significance was defined as $P < .05$.

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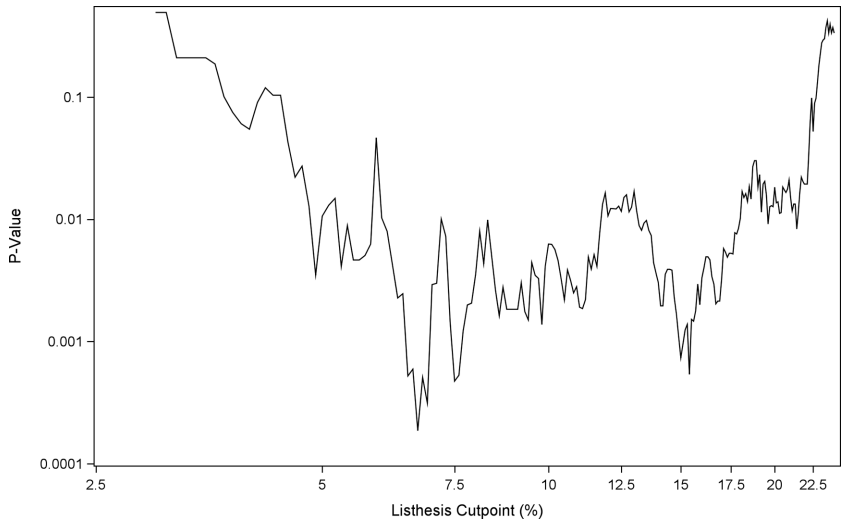


FIGURE 2. *Optimal Cutpoint Determination for Lateral Listhesis by Baseline ODI: This plot represents the p-values for serial statistical testing with variable cutpoints. Lower values represent greater statistical significance associated with a particular cutpoint. Local minima are particularly notable at ~6.7% and 15.4%.*

RESULTS

In total, 724 patients were included in this investigation. The mean age was 58.0 yr (standard deviation [SD] 15.0 yr), and 80.9% of patients were female (Table 1). The mean baseline maximum lateral listhesis was 18.3% (SD 9.7%) (5th percentile 5.7%, 25th percentile 10.4%, 50 percentile 17.3%, 75 percentile 24.0%, 95 percentile 35.9%), and the mean ODI at baseline was 42.6 (SD 18.0). In absolute measurement, this corresponded to an average 10.4 mm of baseline maximum lateral listhesis (SD 5.8mm). The majority of patients underwent posterior-only procedures (68.1%, n = 493) occurring on a single day (78%, n = 508). Lateral interbody fusion (including XLIF and LLIF) was performed for 13.1% of patients (n = 95). Additional details on surgical strategy can be found in Table 1.

The optimal grouping of baseline listhesis in association with ODI was empirically determined to be none/mild (<6.7%, 9.3% of patients), moderate (6.7-15.4%, 32.6% of patients), and severe (≥15.4%, 58.2% of patients) (Figure 2). Baseline lateral listhesis was strongly correlated with maximum coronal Cobb angle (r = 0.26, $P < .0001$).

Lateral listhesis was generally greatest at lumbar levels, specifically L3-L4 (Figure 3). At 2 yr postoperatively, 37.6% had none/mild listhesis, 44.4% exhibited moderate listhesis, and 18.1% had severe listhesis. Correspondingly, 42.9% exhibited no change or worsening in lateral listhesis category, 38.7% improved by one category (from either severe to moderate or moderate to none/mild), and 18.4% improved two categories from severe to none/mild. The mean baseline maximum coronal Cobb angle was 46.0° (SD 17.7), which decreased markedly at 2-yr follow-up (Δ 2Y – baseline 22.3°, SD 14.6).

In bivariable analysis of baseline ODI, patients with moderate vs none/mild and severe vs none/mild lateral listhesis exhibited increased disability ($P < .005$ for both comparisons). These differences persisted after adjustment in multivariable analysis (moderate vs none/mild, $\Delta = 7.9$, $P = .0006$) (severe vs none/mild, $\Delta = 10.1$, $P < .0001$) (Table 2).

Postoperatively, there were no significant differences between none/mild, moderate, and severe lateral listhesis groups at 2-yr follow-up (all $P > .05$). In multivariable analysis, change in lateral listhesis from severe to none/mild categories was independently associated with increased odds of reaching a MCID in ODI (odds ratio 2.1, $P = .0097$) (Table 3). A case example is provided in Figure 4.

DISCUSSION

There is limited data examining the impact of lateral vertebral listhesis on patient reported outcomes; however, lateral listhesis associated with adult spinal deformity is gathering increased focus.[9,11,13] Previous studies have shown that lateral listhesis is correlated with pain and radiculopathy.[9-12] Only one previous investigation was identified that evaluated the relationship between lateral listhesis and disability. This study did not detect a statistically significant relationship between the 2 variables, however their study included only 58 patients.[9] Our study encompasses a much larger sample size with 724 patients. It

TABLE 1. Descriptive Statistics

Variable	Mean/%	SD/N	Missing
Number of patients	-	724	-
Age (yr)	58.0	15.0	0
Female gender	80.9	586	0
Charlson comorbidity index			0
0	35.6	258	
1	21.8	158	
2	19.5	141	
≥3	23.1	167	
Surgical invasiveness	99.2	39.2	0
T1-pelvic angle (degrees)	21.7	13.1	0
Maximum coronal cobb angle (degrees)			
Baseline	46.0	17.7	0
Δ 2Y - BL	−22.3	14.6	192
Baseline lateral listhesis			
Maximum lateral listhesis (%)	18.3	9.7	0
Lateral listhesis category			
None/mild (<6.7%)	9.3	67	
Moderate (6.7-15.4%)	32.6	236	
Severe (≥15.4%)	58.2	421	
2-yr Lateral listhesis			
Maximum lateral listhesis (%)	10.4	7.0	192
Lateral listhesis category			
None/mild (<6.7%)	37.6	200	
Moderate (6.7-15.4%)	44.4	236	
Severe (≥15.4%)	18.1	96	
2-yr Change in lateral listhesis			192
Worsening or no change in category	42.9	228	
Severe→moderate or moderate→none/mild	38.7	206	
Severe→none/mild	18.4	98	
ODI			
Baseline	42.6	18.0	10
6 mo	27.3	17.9	430
1 yr	25.6	19.0	119
2 yr	25.2	20.1	203
2-yr ODI MCID (|Δ|12.8)	56.8	293	208
Leg pain numeric scale rating (NSR)			
Baseline	4.5	3.3	33
6 mo	1.9	2.5	442
1 yr	2.2	2.7	143
2 yr	2.2	2.7	224
Surgical characteristics			
Approach			0
Posterior only	68.1	493	
Anterior-posterior (APSF)	31.9	231	
Staged procedure	22.0	143	73
Osteotomy	67.5	488	1
Interbody fusion	61.4	444	1
ALIF	24.2	175	0
PLIF	3.5	25	0
TLIF	27.1	196	0
XLIF	13.1	95	0

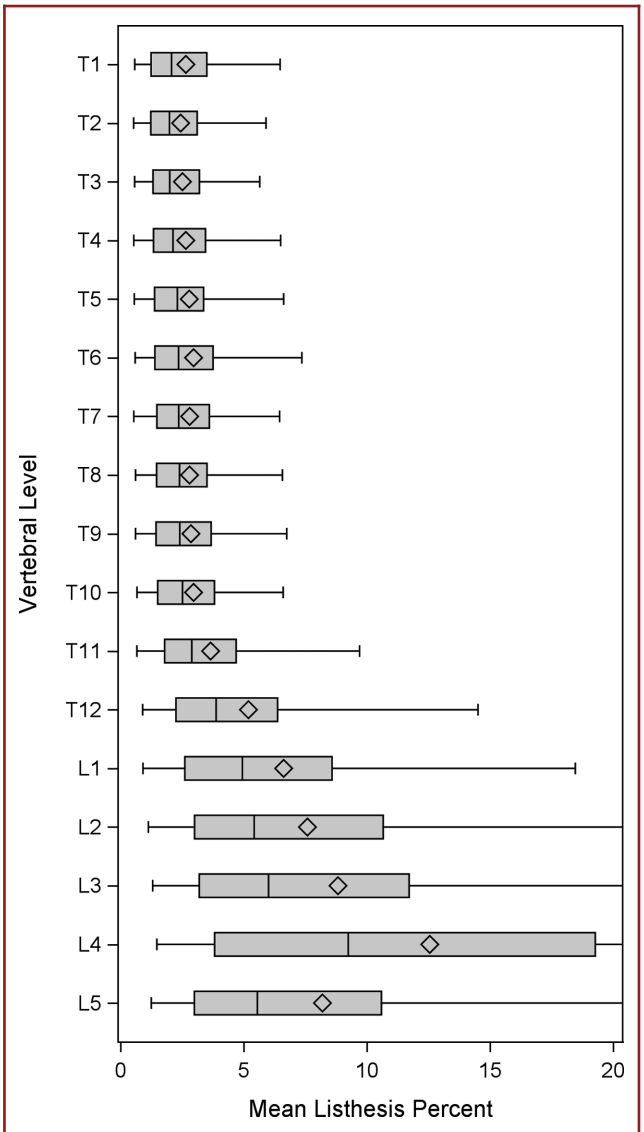


FIGURE 3. *Baseline Listhesis by Vertebral Level: Includes 5th, 25th, 50th, 75th, 95th percentiles and mean.*

is logical that a radiographic finding associated with pain and radiculopathy would also be associated with disability. This data stresses the importance of standing long-cassette (or full-body) AP radiographs for complete evaluation of the severity of disease in patients with adult scoliosis. AP radiographic data is important and relevant to clinical practice because it shows extremely valuable clinical information (global coronal alignment, standing listhesis magnitude, etc.) which can only be obtained from less expensive imaging of upright plain films compared to magnetic resonance imaging. Additionally, supine magnetic resonance imaging often underestimates the extent of

TABLE 2. Association Between Baseline Listhesis and ODI

Model type	Δ	95% CI		*P*-value
ODI				
Bivariable				
Moderate vs none/mild	7.6	2.7	12.5	.0025
Severe vs none/mild	11.0	6.4	15.7	<.0001
Severe vs moderate	3.5	0.6	6.3	.0177
Multivariable				
Moderate vs none/mild	7.9	3.4	12.4	.0006
Severe vs none/mild	10.1	5.6	14.7	<.0001
Severe vs moderate	2.2	−0.5	4.9	.1098
Leg pain NSR				
Bivariable				
Moderate vs none/mild	0.9	−0.1	1.8	.0657
Severe vs none/mild	2.0	1.1	2.9	<.0001
Severe vs moderate	1.1	0.6	1.7	<.0001
Multivariable				
Moderate vs none/mild	1.0	0.1	1.9	.0222
Severe vs none/mild	2.2	1.3	3.1	<.0001
Severe vs moderate	1.1	0.6	1.7	<.0001

TABLE 3. Association Between Change in Listhesis and 2-yr Likelihood of Achieving MCID in ODI

Model type	OR	95%CI		*P*-value
ODI				
Bivariable				
Worsening or no change in category	(ref)			
Severe→moderate or moderate→none/mild	1.2	0.8	1.8	.2950
Severe→none/mild	2.4	1.4	4.1	.0011
Multivariable				
Worsening or no change in category	(ref)			
Severe→moderate or moderate→none/mild	1.2	0.8	1.8	.4349
Severe→none/mild	2.1	1.2	3.7	.0097

lateral vertebral listhesis which can have a significant impact on operative planning.[13]

This investigation is also valuable because it showed that the disability associated with lateral vertebral listhesis can be improved as reflected by the overall improvements in ODI postsurgically in both bivariable and multivariable analyses. As expected, the difference in ODI was directionally greater for none/mild vs severe listhesis patients as compared to none/mild vs moderate listhesis patients.

Furthermore, improvement from severe to none/mild listhesis categories was independently associated with clinically significant improvement in ODI, again indicating the benefit of surgical correction of this type of coronal plane deformity. Empowered with this information, surgeons can counsel patients about the debilitating potential of lateral listhesis when identified radiographically, and can also effectively communicate about the potential benefits of surgical correction.

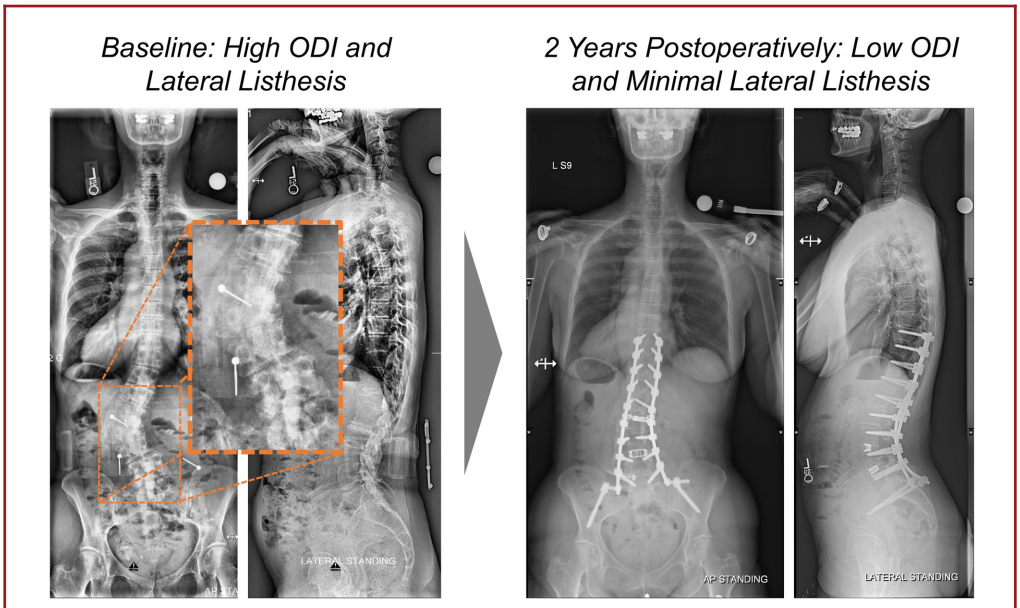
This study controlled for the degree of coronal plane deformity by including the maximum coronal Cobb angle in multivariable regression analysis. This step was critically important, as our early analyses showed that coronal plane deformity was strongly correlated with severity of lateral listhesis. Future studies may investigate the mechanisms by which angular coronal deformity and lateral listhesis are etiologically linked.

Limitations

There are several potential limitations to our study. Although the data was prospectively collected and multi-institutional, this is a retrospective review, which limits our conclusions to correlation instead of causation. Additionally, our study did not differentiate impact of vertebral rotation on the apparent coronal projection of lateral listhesis. These 2 variables are shown to be correlated,[12,14] and the amount of vertebral rotation may also contribute to disability. However, one hypothetical benefit of focusing on lateral translation over vertebral rotation is that the information can readily be obtained from plain radiographs whereas rotation is better calculated from advanced imaging. Further, while we performed multivariable analysis to reduce the influence of confounders, the possibility of unknown confounding remains. Additionally, our results indicate that improvement in lateral listhesis is associated with improved health-related quality of life independent of improvement in global sagittal and coronal alignment. Our study population, however, is one of patients specifically undergoing spinal realignment surgery. These results should not, therefore, be taken to indicate that isolated listhesis correction in the absence of intended improvement in global alignment would necessarily be associated with superior health-related quality of life. Finally, this study was not designed specifically to create a classification scheme to lateral thoracolumbar listhesis – our grouping of listhesis categories was done for statistical reasons related to assumed nonlinearity of the studied relationships. Future studies undertaking to definitively classify thoracolumbar listhesis severity into discrete groups should be conducted.

CONCLUSION

Lateral thoracolumbar listhesis of ≥6.5% of the width of the vertebral endplate is associated with worse baseline disability among adult scoliosis patients. Postoperative improvement in lateral listhesis among patients undergoing spinal deformity correction surgery may be associated with increased likelihood of patient reported outcome improvement postoperatively. Future research directions may include direct assessment of lateral listhesis pre- and postoperatively to quantify improvement.



Variable	Baseline	2 Years
ODI	50	2
Leg Pain NSR	9	5
Maximum Lateral Listhesis	21.9%	5.3%
T1PA	9°	6°
Maximum Cobb Angle	48°	23°

FIGURE 4. *Case Example: 57-yr-old female with improvement in lateral listhesis and ODI following surgical reconstruction. Close view of preoperative maximum lateral listhesis (orange dashed borders).*

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