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Re-operation After Long-Segment Fusions for Adult Spinal Deformity: The Impact of Extending the Construct Below the Lumbar Spine

BACKGROUND: Deciding where to end a long-segment fusion for adult spinal deformity (ASD) may be a challenge, particularly in the absence of an abnormality at L5/S1. Some suggest prophylactic extension of the construct to the sacrum and/or ilium (S/I) to protect against distal junctional failure, while others support terminating in the lower lumbar spine to preserve motion.

OBJECTIVE: To compare the risk of re-operation after long-segment fusions for ASD that ends at L4 or L5 (L4/5) vs S/I.

METHODS: A multicenter database of patients treated for ASD by circumferential minimally invasive surgery or hybrid surgical technique was screened for individuals with long fusions (≥4 vertebral levels) ending at L4 or below and with at least 2 yr of follow-up. Multivariate regression modeling was used to compare surgical morbidity between the L4/5 and S/I groups, and Cox proportional hazard modeling was used to compare risk of re-operation.

RESULTS: There were 45 subjects with fusion to L4/5 and 71 to S/I. Over a 32-mo median follow-up, 41 re-operations were performed; 6 were for distal junctional failure. In those with normal or mild degeneration at L5/S1, fusion to S/I afforded no significant change in re-operative risk (hazard ratio = 1.18 [95% confidence interval: 0.53-2.62], $P = .682$). In those undergoing circumferential minimally invasive surgery correction, fusion to S/I was associated with significantly greater blood loss (499.6 cc, $P < .001$) and surgical time (97.5 min, $P = .04$).

CONCLUSION: In the setting of a normal or mildly degenerated L5/S1 disc space, fusion to the sacrum/ilium did not significantly change the risk of requiring a re-operation after a long-segment fusion for ASD.

KEY WORDS: Distal junctional failure, Adjacent segment degeneration, Adult spinal deformity, Reoperation, Spine

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Surgical management of adult spinal deformity (ASD) is associated with improvements in multiple clinical and radiographic domains.[1] However, the operations are often technically challenging and carry a substantial risk of complications.[2] Furthermore, the rates of revision surgery have been reported to exceed 30%.[3-5] This has compelled clinicians to incorporate strategies to mitigate the likelihood of requiring a subsequent operation.

One such strategy is to extend any long-segment fusion construct involving the lower lumbar spine down to the sacrum or further yet to the ilium. Accepted indications for this include lumbosacral instability, advanced degeneration at L5/S1 or deformity involving the lumbosacral junction. However, in the setting of a relatively normal appearing lumbosacral junction, this practice is controversial.[6,7]

ABBREVIATIONS: ASD, adult spinal deformity; **CI,** confidence interval; **cMIS,** circumferential minimally invasive surgery; **DJF,** distal junctional failure; **EBL,** estimated blood loss; **HR,** hazard ratio; **HYB,** hybrid technique; **LL,** lumbar lordosis; **L4/5,** fusion terminated at L4 or L5; **LLIF,** lateral lumbar interbody fusion; **PI,** pelvic incidence; **rhBMP,** recombinant human bone morphogenetic protein; **S/I,** fusion terminated at the sacrum and/or ilium; **SVA,** sagittal vertical axis

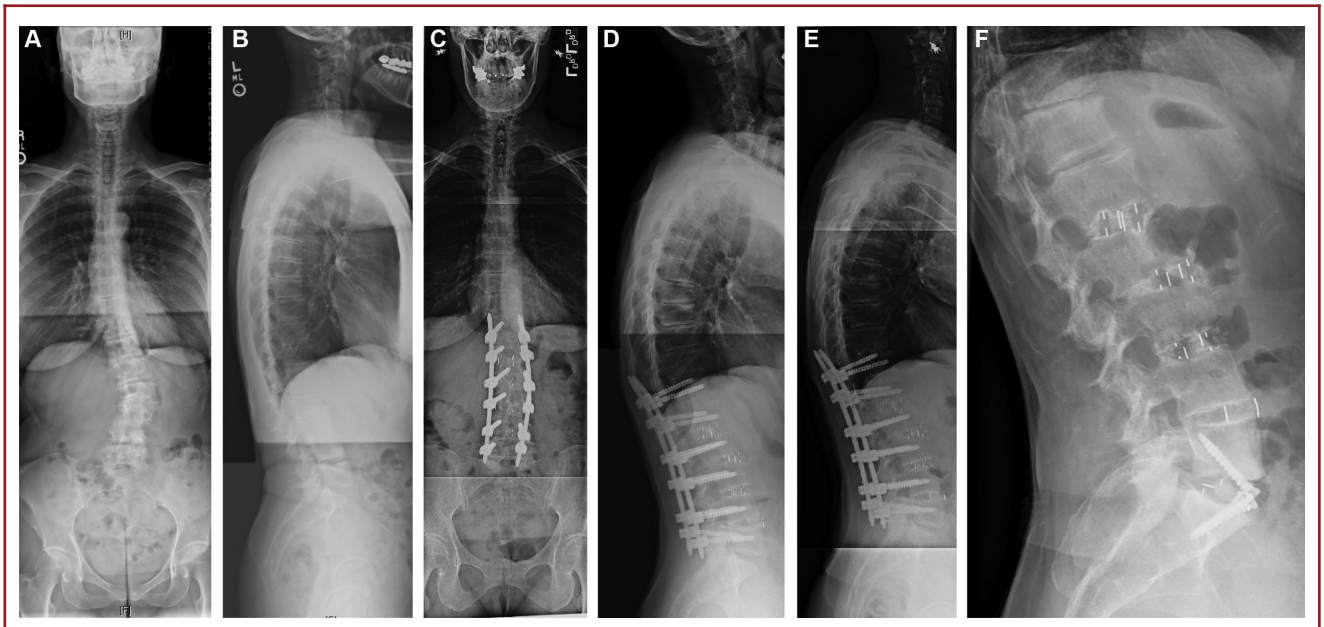

FIGURE 1. *Illustrative case of a 59-yr-old female who underwent surgical intervention for ASD by cMIS technique to treat intractable back pain.* **A**, *Standing preoperative anteroposterior and* **B**, *lateral plain film radiographs. Her index operation included LLIF performed at each intervertebral level between L1 and L5 and posterior percutaneous instrumentation from T12 to L5.* **C**, *Standing anteroposterior and* **D**, *lateral plain film radiographs after the index operation.* **E**, *At 3 yr following her index operation she returned with disc space degeneration at L5/S1 and bilateral L5 radiculopathy from L5/S1 neural foraminal stenosis.* **F**, *She underwent an anterior lumbar interbody fusion at L5/S1 to relieve the foraminal steonsis which was successful in relieving her symptoms. The posterior instrumentation was removed as well, at the request of the patient.*

Proponents of prophylactic extension suggest that the multiple fused segments immediately adjacent to the lumbosacral junction places substantial stress on that level and may lead to degeneration and a need for revision (Figure 1).[8] Conversely, others suggest that ending the fusion construct in the lower lumbar spine preserves additional motion segments and may in fact reduce the likelihood of requiring a revision surgery.[9] Only a few studies have addressed this important association.[10] The available data are from relatively small, single center cohort series using traditional open surgical approaches and thus, the controversy persists.[11,12] The aim of this investigation is to compare the risk of re-operation between patients with ASD who had a fusion construct terminated at L4 or L5 and those extended to the sacrum and/or ilium during the index operation using a large multicenter, multisurgeon database.

METHODS

Study Design

We performed a time to event analysis on a cohort of patients undergoing corrective surgery for ASD. Criteria for inclusion were as follows: (1) older than 18 yr of age, (2) a 2-yr minimum follow-up, (3) 4 or more vertebral levels fused, (4) the lowest instrumented vertebral level at or below L4, and (5) at least 1 of the following parameters on 36-in long-cassette standing scoliosis radiographs: lumbar scoliosis $\geq 20^{\circ}$, sagittal vertical axis (SVA) > 5 cm, pelvic tilt $> 20^{\circ}$, or a pelvic incidence (PI) and lumbar lordosis (LL) mismatch $> 10^{\circ}$. Ten institutions and 11 surgeons participated. Institutional review board approval for the study was obtained at each participating site, and consent was obtained from each participating subject.

Group Definitions

Patients were dichotomized by the lowest instrumented vertebral level. The first group included those with a construct ending at L4 or L5 (L4/5) and the second group with the construct extended to the sacrum and/or the ilium (S/I). The decision of where to terminate the construct was at the discretion of the primary surgeon.

Each group was substratified by the preoperative status of the L5/S1 disc space. The degree of preoperative L5/S1 disc space degeneration was assessed on a lateral lumbosacral radiograph and graded from 0 to 3, using the modified Weiner Grade system (Table 1).[11,13] In accordance with the methodology of Edwards et al,[11] disc spaces with a grade of 0 or 1 were considered relatively healthy while those with a grade of 2 or 3 were considered to be substantially degenerated.

Surgical Technique

Surgical correction of the ASD was performed with either circumferential minimally invasive surgery (cMIS) or hybrid technique (HYB). Those in the cMIS group had stand-alone multilevel lateral lumbar interbody fusion (LLIF), an LLIF followed by percutaneous pedicle screw instrumentation, or a combination of LLIF and minimally invasive

TABLE 1. Modified Weiner Grading System for L5/S1 Disc Space Degeneration[11,13]

Grade[a]	Description	Characteristics[b]
0	No degeneration	Normal disc height, no spur formation, no eburnation, no listhesis, no gas.
1	Mild degeneration	Less than 25% disc space narrowing, small spur formation, minimal eburnation, no listhesis, and no gas.
2	Moderate degeneration	25%–75% disc space narrowing, moderate spur formation, moderate eburnation, listhesis of 3 mm or more, and no gas.
3	Advanced degeneration	Greater than 75% disc space narrowing, large spur formation, marked eburnation, listhesis of 5 mm or more, and gas present.

[a]Grade assigned based on the presence of the most severe characteristic.
[b]Characteristics are assessed on lateral X-ray of the lumbosacral region.

transforaminal lumbar interbody fusion with percutaneous pedicle screw instrumentation. None of the cMIS patients had an osteotomy. Patients in the HYB group had initial multilevel LLIF and then a posterior approach that included open segmental instrumentation and fusion with osteotomies or facet resection where indicated.[14]

Clinical Outcomes

Back and leg pain were quantified by the visual analog scale and disability by the Oswestry Disability Index. Each was measured at preoperative assessment and compared with the last postoperative visit.[15] Other recorded outcomes included surgical specific factors such as operative time, estimated blood loss (EBL), and duration of hospital stay. The time between each re-operation and the index surgery was recorded, as was the indication for re-operation.

Radiographic Outcomes

Preoperative and postoperative radiographic parameters were compared based on 36-in long-cassette standing scoliosis radiographs. The degree of scoliosis was determined using the coronal Cobb angle of the lumbar spine. The SVA was calculated as the distance from the C7 plumb line to the posterosuperior aspect of S1. Pelvic tilt was measured as the angle of a vertical line subtended by a line drawn from the center of the femoral head to the midpoint of the superior S1 endplate. PI was calculated as the angle subtended by a line drawn from the center of the femoral head to the midpoint of the superior S1 endplate. LL was the angle between a line parallel to the superior endplate of L1 and another parallel to the superior endplate of S1. The pelvic incidence – lumbar lordosis mismatch (PI-LL) was the difference between PI and LL. These measurements are summarized in Figure 2.

Statistical Methodology

Raw data are presented using descriptive statistics, continuous variables as means with standard deviations and dichotomous data as frequencies and percentages. Group comparisons of continuous data were conducted using unpaired t-statistic testing and comparisons of categorical data were made by the Chi-square analysis. Time to event data is presented using Kaplan-Meier plots. The comparative risk of re-operation between the L4/5 and S/I groups was determined using a multivariate Cox proportional hazard regression model. Re-operative risk was adjusted for group differences in age, body mass index, smoking status, surgical technique, and SVA. The assessment was limited to those with a healthy (modified Weiner grade 0 and 1) L5/S1 disc space to capture meaningful clinical equipoise. Multivariate linear regression modeling was employed to determine differences in mean operative time, EBL, and duration of postoperative hospital stay. The alpha level

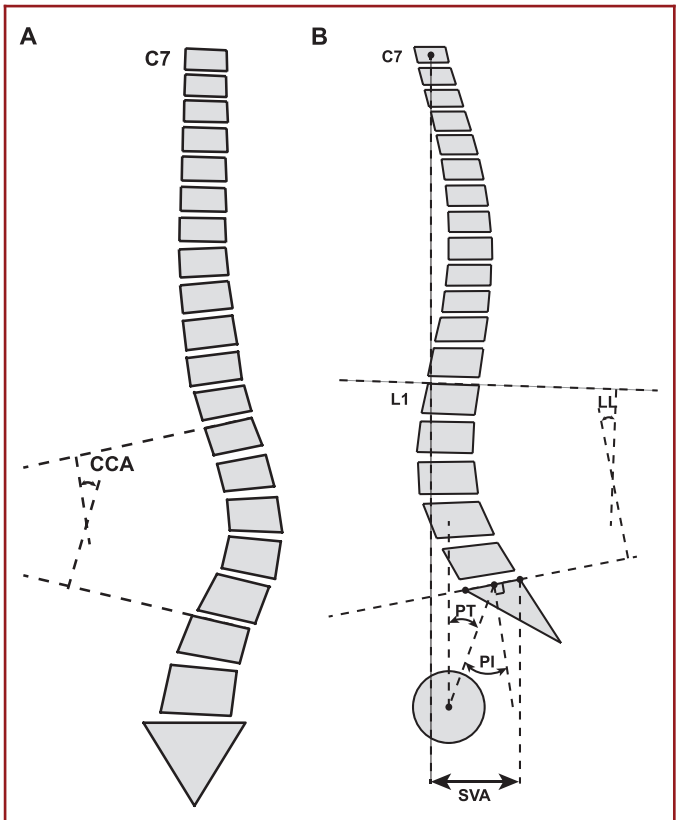

FIGURE 2. *Illustrated measurements of radiographic parameters from 36-in long-cassette standing scoliosis radiographs.* **A**, *Coronal parameters.* **B**, *Sagittal and pelvic parameters. CCA, coronal Cobb angle; SVA, sagittal vertical axis; PT, pelvic tilt; PI, pelvic incidence; LL, lumbar lordosis.*

TABLE 2. Comparison of Baseline Patient Characteristics and Surgical Details

	L4/5 (n = 45)	S/I (n = 71)	*P* value
Age ± SD (years)	60.9 ± 12.9	59.5 ± 12.7	.293
Female (%)	34 (75.6)	57 (80.3)	.546
Current smoker (%)	2 (4.4)	5 (7.0)	.567
Body mass index ± SD (kg/m^2)	27.5 ± 5.4	27.2 ± 6.0	.635
Surgical technique			
cMIS (%)	28 (62.2)	33 (46.5)	.098
HYB (%)	17 (37.8)	38 (53.5)	.098
L4 and L5 interbody fusion technique			
None (%)	11 (24.4)	9 (12.7)	.104
ALIF (%)	0 (0.0)	7 (9.9)	.029
TLIF (%)	7 (15.6)	6 (8.5)	.238
LLIF (%)	27 (60.0)	49 (69.0)	.320
L5 and S1 interbody fusion technique			
None (%)	45 (100)	20 (28.2)	-
ALIF (%)	0 (0.0)	9 (12.7)	-
TLIF (%)	0 (0.0)	42 (59.2)	-
LLIF (%)	0 (0.0)	0 (0.0)	-
Fixation to the Ilium			
Sacral-alar iliac screws	0 (0.0)	2 (2.8)	-
Traditional iliac screws	0 (0.0)	35 (49.3)	-
Mean number of levels instrumented ± SD	6.0 ± 3.0	8.5 ± 3.9	<.001
Mean postoperative follow-up ± SD (months)	33.0 ± 9.8	35.0 ± 10.5	.286

L4/5, fusion terminated at L4 or L5; S/I, fusion terminated at the sacrum and/or ilium; cMIS, complete minimally invasive surgical technique; HYB, hybrid surgical technique; ALIF, anterior lumbar interbody fusion; TLIF, transforaminal lumbar interbody fusion; LLIF, lateral lumbar interbody fusion.

for accepting statistical significance was set at 0.05. All analyses were performed using SPSS software (IBM Inc, Armonk, New York).

RESULTS

Patient Demographics and Surgical Details

One hundred and sixteen patients from the multicenter database met our inclusion criteria. Baseline patient demographics are presented in Table 2. A total of 45 (38.8%) patients had fusion stopped at L4 or L5, while 71 (61.2%) included the sacrum and/or ilium (Figure 3). The status of the L5/S1 disc space was nearly evenly split in the S/I group with 49.3% having a grade of 0 or 1 and 50.7% with grade 2 or 3. In contrast, the majority (82.2%) in the L4/5 group had a grade 0 or 1 disc space. The most common technique for interbody fusion at L4/5 was LLIF in both groups, while the most frequent method for interbody fusion at L5/S1 in the S/I group was transforaminal lumbar interbody fusion. Furthermore, 52.1% of those in the S/I group had fixation to the ilium (Table 2).

Surgical Outcomes

There were no significant differences between groups on preoperative radiographic measures of spinal deformity, nor were there significant differences on these measures postoperatively (Table 3). Notably, those in the S/I group had 1.8 cm more preoperative SVA. Patients in the S/I group had significantly more preoperative back pain and leg pain but postoperative differences were not significantly different. Those in the cMIS group who underwent fusion to the S/I had significantly greater EBL and operative time but there were no significant differences in those undergoing HYB surgery (Table 4).

Re-operations

Over a 32-mo median follow-up, 41 re-operations occurred (Table 5). Failure of fixation or pseudarthosis was the most common indication and was the reason for re-operation in 13 (11.2%) cases. This was followed by proximal junctional failure, which was the indication for re-operation in 11 (9.5%). Three (2.6%) individuals had 2 separate operations after the index surgery. No one had more than 2 re-operations. The 1- and 2-yr probabilities of requiring a re-operation were 17.2% (95% confidence interval [CI]: 11.5, 25.4) and 25.9% (95% CI: 18.9, 34.9), respectively. Six (5.2%) individuals had re-operations performed for distal junctional failure (DJF). In 1 case, the failure was at L4/5 while in the other 5 instances it occurred at L5/S1. The earliest occurrence of DJF was at 12 mo and the latest at 47 mo. The 1- and 2-yr probability of requiring a re-operation specifically for DJF were 1.0% (95% CI: 0.2, 7.1) and 3.3% (95% CI: 1.1, 9.8), respectively.

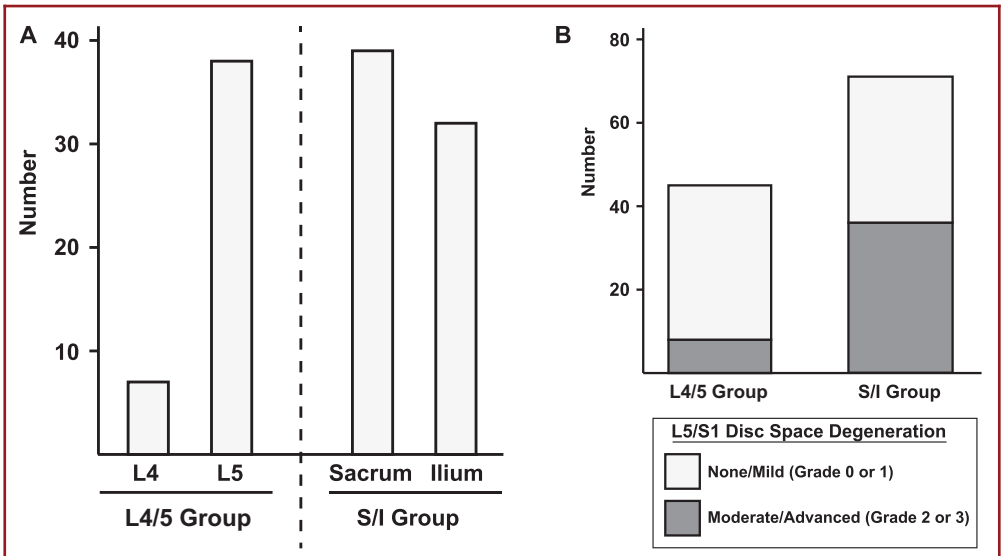

FIGURE 3. *Cohort distributions.* **A**, *Stratified by lowest instrumented vertebral level during the index operation (dichotomized at the L5/S1 junction).* **B**, *Stratified by preoperative L5/S1 disc space status. Fusion terminated at L4 or L5 (L4/5); fusion terminated at the sacrum and/or ilium (S/I).*

TABLE 3. Preoperative and Postoperative Comparison of Radiographic Measures of Deformity and Clinical Measures of Disability and Pain

Parameter	Preoperative L4/5	Preoperative S/I	*P* value	Postoperative L4/5	Postoperative S/I	*P* value
CCA ± SD (degrees)	39.8 ± 14.1	40.8 ± 18.3	.867	14.7 ± 23.9	17.1 ± 20.8	.241
SVA (mm)	40.7 ± 49.2	58.5 ± 60.0	.152	42.6 ± 56.9	45.0 ± 60.1	.733
PT ± SD (degrees)	24.3 ±10.9	25.0 ± 10.5	.878	24.8 ± 11.4	23.7 ± 9.8	.667
PI ± SD (degrees)	54.9 ± 13.3	53.9 ± 12.9	.883	55.6 ± 13.0	54.2 ± 12.3	.768
LL ± SD (degrees)	38.3 ± 13.3	34.5 ± 17.9	.305	43.6 ± 12.5	43.4 ± 14.2	.851
LL – PI ± SD (degrees)	16.5 ± 15.1	19.4 ± 17.0	.596	11.8 ± 17.6	11.1 ± 14.2	.984
ODI ± SD	51.0 ± 18.0	52.3 ± 17.4	.7	35.0 ± 16.7	31.4 ± 20.8	.217
Back pain ± SD (VAS)	6.2 ± 2.1	7.3 ± 2.2	.003	3.7 ± 2.7	4.0 ± 2.9	.662
Leg pain ± SD (VAS)	4.5 ± 3.0	5.7 ± 3.2	.048	2.6 ± 3.0	2.7 ± 2.9	.699

L4/5, fusion terminated at L4 or L5; S/I , fusion terminated at the sacrum and/or ilium; CCA, maximum coronal Cobb angle; SVA, sagittal vertical axis; PT, pelvic tilt; PI, pelvic incidence; LL, lumbar lordosis; LL – PI, pelvic incidence – lumbar lordosis mismatch; ODI, Oswestry Disability Index; VAS, visual analogue scale.

The risk of re-operation was not significantly different between those in the L4/5 and S/I group when considering subjects with a healthy (modified Weiner grade 0 or 1) L5/S1 disc were (hazard ratio [HR] = 1.21 [95% CI: 0.51-2.85], $P = .664$). The descriptive Kaplan-Meier curve may be found in Figure 4. A meaningful comparison could not be conducted on those with advanced degeneration at L5/S1 because only 8 subjects in the L4/5 group had a preoperative modified Weiner grade of 2 higher.

DISCUSSION

ASD is a highly complex clinical condition, and the controversy surrounding surgical management is commensurate. The decision regarding were to terminate a long-segment fusion is often problematic.[6] Accepted indications for arthrodesis to the sacrum and/or ilium are generally considered to be (1) lumbosacral instability due to spondylolysis or a prior decompression, (2) spinal deformity involving the lumbosacral junction, and (3) advanced degeneration at L5/S1.[6,7] In the absence of these indications, the discourse pertaining to the optimal level at which to end a fusion persists.

A primary concern with termination proximal to the sacrum is the potential for subsequent disc degeneration at L5/S1, leading to increasingly positive sagittal balance, pain, and possibly another surgery. In a study conducted by Kuhns et al,[8] 69% of patients with long-segment fusions to L5 for ASD had evidence

TABLE 4. Between-Group Comparisons of Postoperative Length of Stay, Surgical Blood Loss, andOperative Time

	Unadjusted mean L4/5 ± SD	Unadjusted mean S/I ± SD	Adjusted mean difference[a] (95% CI)	*P* value
LOS (days)				
cMIS	7.7 ± 5.4	8.4 ± 3.6	−1.04 (−3.53, 1.45)	.406
HYB	9.2 ± 3.3	10.8 ± 5.5	−1.40 (-4.47, 1.67)	.365
EBL (cc)				
cMIS	399.1 ± 292.0	844.7 ± 612.6	−499.64 (−756.43, −242.84)	<.001
HYB	1280.0 ± 894.9	1787.1 ± 1268.6	−441.15 (−1166.01, 283.71)	.227
Operative time (minutes)				
cMIS	430.9 ± 162.1	530.1 ± 208.5	−97.52 (−189.65, −5.38)	.038
HYB	673.5 ± 186.5	701.2 ± 250.5	−44.93 (−189.47, 99.61)	.535

L4/5, fusion terminated at L4 or L5; S/I, fusion terminated at the sacrum and/or ilium; cMIS, complete minimally invasive surgical technique; HYB, hybrid surgical technique; LOS, length of stay; EBL, estimated blood loss.
[a]Adjusted for baseline differences between groups.

TABLE 5. Indications for Re-operation, Stratified by Lowest Instrumented Vertebral Level and Preoperative Status of L5/S1 Disc Space

		L5/S1 grade 0 or 1		L5/S1 grade 2 or 3	
Indication for re-operation	Total n = 116	L4/5 n = 37	S/I n = 35	L4/5 n = 8	S/I n = 36
Infection (%)	4 (3.4)	1 (2.7)	1 (2.9)	–	2 (5.6)
Neurological change (%)	6 (5.2)	1 (2.7)	3 (8.6)	–	2 (5.6)
Distal junctional failure (%)	6 (5.2)	5 (13.5)	–	1 (18.2)	–
Proximal junctional failure (%)	11 (9.5)	3 (8.1)	7 (20.0)	–	1 (2.8)
Fixation failure/pseudarthrosis (%)	13 (11.2)	3 (8.1)	3 (8.6)	2 (25.0)	5 (13.9)
Bowel/bladder injury (%)	1 (0.9)	–	–	–	1 (2.8)
Total re-operations	41	13	14	3	11

L4/5, fusion terminated at L4 or L5; S/I, fusion terminated at the sacrum and/or ilium.

of advanced L5/S1 degeneration and 23% required subsequent surgery to extend the construct to the sacrum, over a minimum 5-yr follow-up. A comprehensive systematic review of distal adjacent segment pathology after long thoracolumbar fusion found that the risk of developing new symptoms is approximately 18% to 20% during a period of 9 yr and most require re-operation.[16] Moreover, the expansive cancellous anatomy of the L5 pedicles may elevate the risk of fixation failure at this level. Kyphotic decompensation and sagittal imbalance may ensue if this occurs.[17] While fusion to the S/I affords protection in these regards, it is not without its own problems that may necessitate re-operation. The lumbosacral junction is a site of high mechanical demand and fusion is associated with a notable risk of pseudarthrosis and sacral instrumentation failure.[9] These occurrences may be reduced by anterior interbody arthrodesis and iliac fixation,[18] but again this may raise the risk profile. Iliac screws may become symptomatic from prominence or motion in many cases and re-operation may be needed for removal.[19,20]

Despite these complexities, few studies have directly compared the outcomes. The evidence that is available arises from those undergoing traditional open surgical techniques and is limited by relatively small sample sizes at single centers.[10] Edwards et al[11] matched 27 patients with fusion to L5 to 12 patients with fusion to the sacrum at a single institution. All patients had a relatively healthy L5/S1 disc space (modified Weiner grade 0 or 1). They found that patients with fusions that stopped at L5 had inferior sagittal balance compared to the group fused to the S/I, but had significantly fewer surgical procedures and fewer major complications over a mean follow-up period of 4.8 yr (minimum 2 yr). This provides quality long-term outcome data but caution should be used when interpreting these results because small differences in the cohort of 12 patients with fusion to the S/I could change the results substantially. Another retrospective analysis of 45 adult patients undergoing long-segment fusion in a single center reported no significant association between re-operation rates and the extent of distal fusion (L5 vs S/I) with a minimum follow-up of 2 yr.[12] A recent systematic review of the topic, which included both of these studies and 1 other, concluded that risk of re-operation is not consistently affected by the lowest instrumented vertebral level (L5 vs S/I).[10]

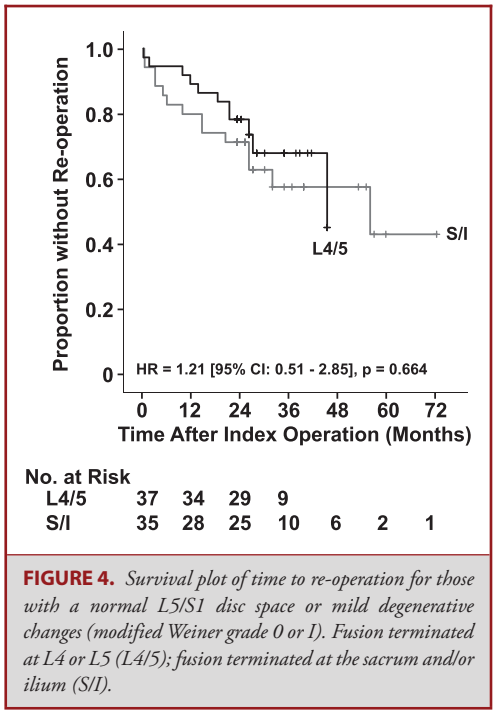

FIGURE 4. *Survival plot of time to re-operation for those with a normal L5/S1 disc space or mild degenerative changes (modified Weiner grade 0 or I). Fusion terminated at L4 or L5 (L4/5); fusion terminated at the sacrum and/or ilium (S/I).*

The results from our analysis lend further support to this notion that prophylactic extension to the S/I may not reduce the risk of re-operation. There was no significant difference in the need for re-operation between the L4/5 and S/I groups when L5/S1 disc space was relatively healthy. The overall proportion of patients requiring at least one re-operation was 32.8%. Of these, a relatively small proportion (14.6%) of the re-operations were done for DJF. Notably, while the risk of re-operation was unchanged, those undergoing cMIS who were fused to the S/I had significantly greater EBL and surgical time. These results are likely to be more generalizable than those previously available, owing to the large number of patients and multicenter/multisurgeon nature of the database. The time to event data allowed for an estimation of the time-based risk of re-operation that is adjusted for between-group differences. Furthermore, we were able to control for the preoperative status of the L5/S1 disc space and by doing so, limit the analysis to those subjects where clinical equipoise remains.

Limitations

Notwithstanding these strengths, the findings are subject to some limitations. It should be recognized that the median follow-up time of 32 mo may bias the results toward early surgical indications for revision and away from indications generally associated with a longer period of follow-up.[3] The data collection pertaining to the timing and indication of re-operations relied on surgeon self-reporting, which is subject to ascertainment bias. All procedures were performed by surgeons specialized in the management of ASD and thus, generalizability to those less experienced may be limited. We did not have data on the status of the L5/S1 facet joints which may have influenced surgical decision making and is a potential confounding factor. We also were unable to study specific factors that may mitigate the need for revision for certain indications. Examples of this include (1) the use of recombinant human bone morphogenetic protein (rhBMP) to potentially decrease the rates of pseudarthrosis,[21] (2) sacral alar-iliac screws rather than the traditional iliac wing screws,[22] (3) the impact of interbody fusion at an adjacent level, and (4) the degree of forward sagittal imbalance and the degree of L5/S1 disc degeneration that is acceptable to avoid fusion below the lumbar spine.

The number of specific considerations is proportionate to the highly complex nature of the pathology. In order to properly evaluate the impact of specific details on the rates of revision, large prospective studies with high degrees of detailed documentation and long periods of follow-up will be needed, but this will challenge feasibility. We provide instead an overall comparison of the association between the extent of distal fusion and the need for subsequent revision surgery in a diverse cohort of patients undergoing long-segment fusions by cMIS or HYB techniques at centers specialized in the management of ASD. There are numerous reasons why a revision surgery may be required after the initial correction. Individual patient characteristic must be carefully evaluated and as surgical techniques continue to evolve the progression may favor one approach over the other and surgeons should be well apprised of their own personal outcomes.

CONCLUSION

The decision of where to stop a long-segment fusion for ASD can be a perplexing problem, especially in the absence of abnormality at the lumbosacral junction. This multicenter data suggest that extending a long-segment fusion for ASD to the S/I does not significantly change the risk of requiring a re-operation when the L5/S1 disc space is relatively normal and the decision making is at the discretion of a surgeon experienced in the treatment of ASD. This should give surgeons pause before reflexively extending the construct to the S/I, but greater follow-up will be needed to see if this holds over the long term.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

This is a report from the minimally invasive spine surgery (MIS) branch of the International Spine Study Group (ISSG) reviewing their results of 116 patients treated for adult spinal deformity (ASD) from 10 different centers using complete MIS (cMIS) or hybrid (HYB) surgery. The end point of surgery was to determine the risk for reoperation due to distal segment failure stratifying it to the most caudal instrumented level (L4/5 vs sacrum/ilium). Although the surgical decision was at the discretion of the individual surgeons, the patients were substratified according to modified Wiener Grade of L5/S1 disc space for this study.

Back and leg pain were quantified by the visual analog scale (VAS) and disability by the Oswestry Disability Index (ODI). All the standard measurements were done from 36-inch standing x-rays and demographic, operative, hospitalization data were included. Fourty-five (38.8%) patients in L4/5 group and 71 (61.2%) in SI group. Most patients had good disc space grade (Wiener Grade 0 or 1) at L5/S1 in L4/5 group while it was evenly divided in the SI group. Surgical outcomes were similar in both groups in respect to functional and radiographic results except a few minor differences in operative time and estimated blood loss.

Forty-one patients needed reoperations for different reasons during their follow-up. Pseudarthrosis or instrumentation failure was the main reason for reoperation (13 patients - 13.2%). Eleven patients (9.5%) had proximal junctional kyphosis related problems. Three patients had 2 more operations after the index procedure. No one needed more than 2 reoperations. Six (5.2%) patients were reoperated for DJF. The 1- and 2-year probability of requiring a re-operation specifically for DJF were 1.0% [95% CI: 0.2, 7.1] and 3.3% [95% CI: 1.1, 9.8] respectively. Ultimately, the authors concluded that there is not an advantage to extend to S/I levels in cases with minimally degenerated L5/S1 disc space in cMIS/HYB treated ASD cases.

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Distal fixation in adult thoracolumbar spinal deformity surgery is crucial. Multiple studies have shown premature failure, pseudoarthrosis and loss of sagittal balance when long fusions (greater than 4 levels) are performed without supplemental iliac fixation (iliac screws, S2AI screws).[1,2,3]

This study is important because it demonstrated that one does not have to prophylactically treat L5-S1 in cases of no degeneration or mild degeneration of L5-S1. However, in the cohort that included L5-S1, only 52.1% of cases included iliac fixation. Overall, the authors found that 14.6% of patients needed reoperation for distal junctional failure. The reoperation rate of L5-S1 cohort was not different from the cohort fused to L5. However, one may postulate that a difference in reoperation for distal failure may have been found if all L5-S1 patients received iliac fixation.

Differences in blood loss and operative time were also see when stopping at L5-S1 as opposed to L4-5. It is also important to note that most patients received TLIF at L5-S1. Increased blood loss has been associated with TLIF[4] as has a lack of improvement in sagittal balance.[5] While no differences were seen in the SVA between the cohorts, perhaps increased use of anterior lumbar interbody fusion at L5-S1 would have resulted in less blood loss and statistically improved sagittal balance when compared to the L4-5 cohort.

Overall, this paper reinforces the notion that inclusion of the L5-S1 segment may be tailored to the individual patient needs (advanced degeneration, neuroforaminal stenosis at L5-S1, or spondylolisthesis) without unacceptably high failure rates when stopping at L5 as opposed to S1.

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