

Benchmark Values for Construct Survival and Complications by Type of ASD Surgery

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Structured Abstract

Objective: Provide benchmarks for the rates of complications by type of surgery performed

Study Design: Prospective multicenter database

Background: We have previously examined overall construct survival and complication rates for ASD surgery. However, the relationship between type of surgery and construct survival warrants more detailed assessment.

Methods: Eight surgical scenarios were defined based on the levels treated, previous fusion status (primary [P] vs. revision [R]), and 3-column osteotomy use [3CO]: Short Lumbar fusion, LT-Pelvis with 5-12 levels treated (P, R or 3CO), UT-Pelvis with \leq 13 levels treated (P, R or 3CO), and Thoracic to Lumbar fusion without pelvic fixation, representing 92.4% of the case in the cohort. Complication rates for each type were calculated and Kaplan Meier curves with multivariate Cox regression analysis was used to evaluate the effect of the case characteristics on construct survival rate, while controlling for patient profile.

Results: 1073 of 1494 patients eligible for 2-year follow-up (71.8%) were captured. Survival curves for major complications (with or without reoperation), while controlling for demographics differed significantly among surgical types ($p < 0.001$). Fusion procedures short of the pelvis had the best survival rate, while UT-Pelvis with 3CO had the worst survival rate. Longer fusions and more invasive operations were associated with lower 2-year complication-free survival, however there were no significant associations between type of surgery and renal, cardiac, infection, wound, gastrointestinal, pulmonary, implant malposition or neurologic complications (all $p > 0.5$).

Conclusion: This study suggests that there is an inherent increased risk of complication for some types of ASD surgery independent of patient profile. The results of this paper can be used to produce a surgery-adjusted benchmark for ASD surgery with regard to complications and survival. Such a tool can have very impactful applications for surgical decision making and more informed patient counseling.

Key Points (3-5):

- Eight surgical scenarios, based on levels treated, previous fusion status (Primary vs. Revision), and 3-column osteotomy, accounted for 92.4% of cases in a multicenter database.
- Survival curves for major complications (with or without reoperation), adjusted for demographics, varied significantly across surgical types.
- Fusion procedures excluding the pelvis demonstrated the highest survival rate, whereas UT-Pelvis with 3-column osteotomy showed the lowest survival rate.
- Longer fusions and more invasive procedures correlated with decreased 2-year complication-free survival. However, no significant associations were found between surgery type and complications such as renal, cardiac, infection, wound, gastrointestinal, pulmonary, implant malposition, or neurologic complications.

Key Words (max 5):

1. ASD Surgery
2. Complications
3. Kaplan Meier analysis
4. Cox regression analysis
5. Adult Spinal deformity Benchmark

Introduction

Adult spinal deformity (ASD) is a condition that is frequently underestimated in terms of its prevalence, severity, and health impact. The literature has shown that ASD affects as many as 68% of healthy adults over the age of 65¹. Disability from ASD is often significant. Recent studies have demonstrated that patients with ASD face markedly greater disability than the general population, and that the degree of disability associated with ASD is comparable to that of heart disease, rheumatoid arthritis, and diabetes².

ASD surgery is associated with high rates of complications. Moreover, these complications are frequently significant in both severity and cost. Smith et. al reported that ASD surgery has an overall complication rate of 69.8%, with nearly 30% of patients experiencing a complication requiring reoperation³. Notable and impactful complications that have occurred frequently in prior studies include neurological complications, implant failure, radiographic imbalance, and operative complications⁴.

In addition to their effects on patients' physical and mental wellness, complications following ASD surgery can have negative financial repercussions. The average direct cost of surgical revision in ASD surgery has been reported to be between \$29,593 and \$86,673. Average costs for neurologic complications, medical complications, instrument failure, and pseudarthrosis were found to be \$29,561, \$26,622, \$66,838, and \$76,695, respectively. Notably, patients who have multiple postoperative complications may face costs in excess of one million dollars⁵.

As ASD surgery becomes more common and more costly, the need for a nuanced understanding of its associated risks grows. In reality, "ASD surgery" is an umbrella term that encompasses numerous surgical operations of varying severity, invasiveness, and extensiveness. We have previously examined overall complication rates for ASD surgery, however more detailed analysis of the relationship between complication rate and type of surgery is needed.

It is the intent of the authors that the results of this analysis may be used as a surgery-adjusted benchmark for complication rates and construct survival associated with the different types of ASD surgery.

Methods

Sample

Patient data were derived from a 20-center North American ASD database. Included patients were those 18 years of age or older who presented with at least one of the following: scoliosis $\geq 20^\circ$, sagittal vertical axis (SVA) ≥ 5 cm, pelvic tilt (PT) $\geq 25^\circ$, or thoracic kyphosis $\geq 60^\circ$. Data were collected between 2008 and 2019 via mail and in-person visits. Postoperative complication data were collected via standard questionnaire in the perioperative period and during post-surgical follow-up visits, or whenever the participating clinician became aware of a specific instance of a complication. Complications were classified by severity as one of the following: adverse event (AE), minor, major, or major with reoperation.⁶ Each site received IRB approval to collect and use de-identified patient data for this purpose, and each patient gave informed consent for long-term data to be collected and analyzed. Data were submitted to a central site for analysis.

Participating clinicians were orthopaedic or neurological surgeons who specialize in treatment of ASD patients. All decisions regarding each patient's care, including surgical decision making, radiographic and pathologic interpretation, and the use of devices or instruments were at the discretion of the treating surgeon.

Data

The following demographic data were collected for each patient: age, sex, body mass index (BMI), American Society of Anesthesiologists score (ASA), Charlson comorbidity index (CCI), and prior surgical history. Health-related quality of life (HRQOL) data included: Oswestry Disability Index (ODI)⁷, Short Form 36 (SF-36)⁸, and the Scoliosis Research Society-22r (SRS-22r)^{9,10}. Prior studies have established values for minimum clinically important difference (MCID) in spine surgery, and these values were utilized for the analysis of the 2-year postoperative HRQOL data^{11,12}

Radiographic data were assessed based on full-length, free-standing lateral and anteroposterior X-rays performed prior to surgery and at the 2-year follow-up visit. Independent readers used Spineview (ENSAM Laboratory of Biomechanics)¹³ to evaluate all images, and the SRS-Schwab classification criteria were used to describe each patient's spinal deformity¹⁴.

Perioperative data collected included: estimated blood loss (EBL), length of stay (LOS), International Spine Study Group (ISSG) invasiveness score¹⁵, and admission to an intensive care unit (ICU) (yes or no). Surgical data on the number of vertebral levels treated and the use of decompression, interbody fusion, and/or three-column osteotomy (3CO) were also recorded.

Definition of Surgical Type

Surgical type was defined based upon the number of levels treated, the positions of the upper- and lower instrumented vertebrae (UIV and LIV, respectively), the use of 3CO, and the presence of previous spinal fusion. The application of these categorization criteria to the sample resulted in the eight surgical scenarios shown in **Figure 1**: short lumbar, thoracic to lumbar, upper thoracic to pelvis (with 3CO, primary, and revision subtypes) and lower thoracic to pelvis (with 3CO, primary, and revision subtypes).

Analysis

Time to first complication (survival) was analyzed using both univariate and multivariate approaches. Univariate Kaplan-Meier analysis was used to examine survival for each surgical type and execute pairwise comparisons between types. Multivariate Cox regression analysis was utilized to compare surgical types while controlling for patient characteristics (age, ASA, baseline frailty, BMI, and Date of Surgery - DOS). All analysis was conducted using SPSS version 26.0 (IBM Corporation) at an alpha level of 0.05.

Results

Cohort

1,073 (71.8%) of the 1,494 eligible patients completed the minimum required follow-up. The mean age was 60 years (± 14 ranging from 18 to 87) and the cohort was 76.3% women and 88.2% White. Average BMI was $28.1 \text{ kg/m}^2 \pm 6.0$. Median CCI was 2, median pre-operative modified frailty index was 3.3, and median follow-up time was 25 months. 50.5% of the cohort had undergone previous spine surgery. Pain and disability were prevalent (**Table 1**), with 59.3% of patients having an ODI score above 40. The median preoperative back pain score was 8. In terms of SRS classification, 40.8% of patients had no major coronal curvature (Type N), 31.9% had lumbar scoliosis (Type L), and 23.2% had a double major curve (Type D). 64.6% of patients presented with a PI-LL modifier at + or ++, 66.8% had a PT modifier at + or ++, and 59.3% had an SVA modifier at + or ++.

Surgical Data

98.9% of patients in the cohort underwent posterior fixation, 10.3% of which was performed minimally invasively. 79.8% had sacroiliac fixation. Details of the surgical procedures performed are summarized in **Table 2**. Median EBL was 1300 cc, and 65.1% of patients were admitted to the ICU postoperatively. 13.9% of these patients stayed in intensive care for more than 48 hours. The median LOS was 7 days.

Type of Surgery

90% of the surgeries performed in this cohort fit into one of the eight aforementioned surgical scenarios. 123 patients (11.5%) underwent short lumbar surgery and 133 (12.4%) had surgery between thoracic and lumbar spines. 443 patients (41.3%) were in the lower thoracic to pelvis (5-12 levels) group. 283 of these (26.4%) were primary, 76 (7.1%) were revision, and 84 (7.8%) were treated with a 3CO, most commonly located at L3 (N=38 45.2%), L4 (N=27 32.1%), or L2 (N=11 13.1%). 282 patients (26.3%) underwent surgery extending from the upper-thoracic spine to the pelvis (≥ 13 levels treated). Of these, 158 (14.7%) were primary, 46 (4.3%) were revision, and 78 (7.3%) were treated with a 3CO (L3 [N=27,34.6%], L2 [N=15, 19.2%], L4 [N=15, 19.2%] and T8-T12 [N=16, 20.5%]). 92 patients (8.6%) had surgery of some variety that did not fit into these categories. Details of surgical procedure and in-hospital metrics can be found in **Table 3**.

2-Year Outcomes

There were significant improvements in HRQOL measures (paired tests all $p < 0.001$). The percentages of patients reaching at least 1 MCID at 2 years were as follows: 49.8% for ODI, 54.8% for SF36-PCS, 62% for SRS-22r Activity, 66.4% for SRS-22r Pain, and 63.1% for SRS-22r Appearance. There were also significant changes in alignment following surgery. After two years, 71.5% of patients had no major coronal curves (Type N), 42.4% of patients improved PI-LL modifier by ≥ 1 grade, 25.7% improved PT modifier by ≥ 1 grade, and 33.5% improved SVA modifier by ≥ 1 grade.

700 patients (65.2%) experienced at least one complication before the two-year follow-up visit. Excluding adverse events, this number drops to 58%. 423 patients (39.4%) had at least one major complication, and 241 (22.5%) required reoperation.

Pre-operative data by Surgical Type

Comparison of demographic information demonstrated some significant differences between the different types of surgery (**Table 04**). Patients in the Thoracic to Lumbar group were significantly younger than those in other groups with lower CCI and BMI (all $p < 0.001$). By design, significant difference was found in location of previous UIV and LIV, with Upper Th. to Pelvis revision and 3CO having the largest rate of existing fusion extended to pelvis. Pre-operative SRS Classification was significantly different also, with the largest rate of type D curve for Primary Upper Th. to pelvis and Thoracic to Lumbar patients (52.5% and 44.4% respectively). Lower Th. to Pelvis with 3CO had the lowest rate of SVA modifier at 0 (7.2%), while Thoracic to Lumbar had the highest (82.7%). Outside of Thoracic to Lumbar, all other types of surgery had a mean ODI above 40 points, a mean PCS below 32 points, and a median VAS between 7 and 8 (**Table 04**)

2-Year Outcomes by Surgical Type

Comparison of complication rates among types of ASD surgery showed significant differences (Chi-Square all $p < 0.001$) (**Table 05**). Comparison of the rates of patients reaching MCID also showed significant differences across surgery type (Chi square all $p < 0.05$), except for SRS-22 Mental Score ($p = 0.83$) (**Table 05**).

Kaplan Meier Survival analysis

Kaplan-Meier survival analysis using log-rank demonstrated significant differences in time to first event among the different surgical types (**Figure 02**). Short lumbar (1) and thoracic to lumbar (2) demonstrated similar survival curves (pairwise comparison $p > 0.1$) and significantly different behavior than fusion to the pelvis (3 to 8) (all pairwise $p < 0.05$). Within the fusion to the pelvis group, pairwise comparisons showed a significant difference between lower-thoracic to the pelvis (revision (7) and primary (6)) ($p = 0.049$), and between upper-thoracic to the pelvis Primary (3) ($p = 0.006$) and 3CO (5) ($p = 0.020$) for time to first complication (including AE). Similarly, for complications excluding AEs, a significant difference between lower-thoracic to pelvis Revision (7) and upper-thoracic to pelvis Primary (3) ($p = 0.039$) and 3CO (5) ($p = 0.030$) was observed.

For major complications (**Figure 3 Left**), there was no significant difference between Short Lumbar (1) and Thoracic to Lumbar (2) ($p = 0.30$) survival curves, but there were

significant differences among all other curves (all $p < 0.05$) except Upper Th. to Pelvis Revision (4) vs Short Lumbar (1) ($p=0.052$).

Significant differences in survival curves between Upper Th. to Pelvis 3CO (5) and Lower Th. to Pelvis, Primary (6) ($p < 0.001$) and Revision (7) ($p=0.010$), were observed, with the latter two having significantly higher survival rates than the upper thoracic to pelvis 3CO type. Similarly, the Lower Th. to Pelvis Primary (6) type demonstrated significantly higher survival than Upper Th. to Pelvis Primary (3) ($p=0.031$).

For major complications leading to reoperation (**Figure 3 Middle**), there were no significant differences between Short Lumbar (1) and Lower Th. to Pelvis Primary (6) ($p=0.41$), Upper Th. to Pelvis Revision (4) ($p=0.56$) or Thoracic to Lumbar (2) ($p=0.98$). Additionally, there were no significant differences between fusion to pelvis surgery (all $p < 0.05$) except for Lower Th. to Pelvis Primary (6) versus Upper Th. to Pelvis Primary (3) ($p=0.003$) and Upper Th. to Pelvis 3CO (5) ($p=0.02$).

For minor complications (**Figure 3 Right**), there were no significant differences between surgical types.

Cox Regression analysis

Cox regression controlling for age, ASA, frailty index, BMI, and DOS showed a significant difference between short lumbar (1) and all other surgical types (**Figure 4 Left**). Short lumbar demonstrated a significantly lower complication rate than all other types ($p < 0.05$).

Similar analysis excluding the short lumbar group (1) revealed no significant difference in overall complication rate while controlling for patient profile ($p=0.112$) or in overall complication rate excluding AEs ($p=0.120$) among surgical types, nor were there significant differences in time to first complication leading to reoperation ($p=0.170$) or time to first minor complication ($p=0.770$).

Stratification by complication severity showed that there was a significant difference in the rate of major complications ($p < 0.001$), with thoracic to lumbar (2) and upper thoracic to pelvis with 3CO (5) groups having drastically different survival curves ($p=0.003$ and $p=0.005$, respectively) than all other surgical types (**Figure 4 Right**).

Discussion

These results demonstrate that type of ASD surgery is an independent risk factor for major complications. Certain surgical types involve marked differences in their inherent risk for major complications. For thoracolumbar operations, this risk is lower than that of other types. For surgery extending from the upper-thoracic spine to the pelvis, utilizing 3CO, this risk is higher than that of other types. This study has shown that longer and more invasive surgery is associated with an increased rate of major complication at two years when controlling for patient characteristics and provides benchmark rates.

This study also shows that complications occur at different times for different surgical types. We see that for the longer and more invasive operations, complications appear much more quickly than for the shorter types of surgery such as short lumbar or thoracic to lumbar (Figure 4 Left). This is especially evident when looking at the timing of major complications (Figure 4 Right). These findings expand on those presented by Lafage et al. who showed that two-thirds of patients undergoing ASD surgery experience complications of some type within two years, with operative complications occurring most commonly within the first month.¹⁶

As a group, shorter operations within the lumbar spine or between thoracic and lumbar spines showed considerably lower risk for complications and complications excluding AEs than did longer operations involving fusion to the pelvis. This is indicative of a baseline difference in risk between ASD operations of notably different lengths and degrees of invasiveness.

While perhaps somewhat intuitive to those who regularly treat ASD, these results are a necessary point of reference and a demonstration of the degree to which complication rates can vary among the most common surgical procedures in the field. It is also intuitive that inappropriate surgery could lead to premature failure or an unnecessary escalation in invasiveness, both of which diminish the likelihood of the surgery being cost-effective. Adult spinal deformities exhibit significant variability in terms of radiographic presentation¹⁷, patient characteristics¹⁸, and concurrent conditions^{19,20}, making it challenging to define the appropriate surgical approach without significantly reducing the boundaries of this study's validity.

Outside of the implications for patient education and preoperative shared decision making, these results demonstrate some clinically applicable trends that are useful for assessing outcomes and quality of care following ASD operations. Most notably, these results highlight the

likelihood of reoperation associated with the use of three column osteotomy. In both surgical type groups that included 3CO, about one third of patient had revision surgery at some point within two years (28.6% in the lower Th. to Pelvis group and 30.8% in the Upper Th. to Pelvis group), which is in line with previous reported results²¹. When it comes to timing, our study showed that these reoperations happened sooner in patients in the Upper Th. to Pelvis with 3CO group. Furthermore, it is useful to note that in different surgical types, complications appear and plateau at different times, but in all cases, complications continue to develop over time²². In particular we demonstrated that major complications appeared more quickly and continued to appear for the longer operations, but occurred less frequently in the initial postoperative period and continued to appear more gradually in the shorter surgical types. Our results not only provide a baseline benchmark based on surgical type, but also offer a resource upon which surgeons can build a profile of expected complications and their likely timing based on the characteristics of a potential or previously completed spinal deformity operation. They may also be use to help further estimate the resource utilization and cost effectiveness specific to each type of surgery performed as adverse event an reoperation have been previously identified as major factor affecting these results^{23,24}.

These results support previous observations by Bortz et al. who found that extended operative time and fusion of nine or more levels were strong predictors of co-occurring complications²⁵. Our findings also align with Smith et al.'s 2016 study on complication rates which found that use of 3CO was associated with higher complication rates²⁶. Generally speaking, it has been established previously that surgical approach and degree of invasiveness are important determinants of complication rate in ASD surgery. For example, Uribe et al. demonstrated in their comparison of open, hybrid, and minimally invasive approaches to ASD correction that less invasive surgical techniques led to fewer complications. Our study supports and expands on these findings by analyzing complications associated with the most common surgical approaches to ASD treatment at a much higher level of specificity²⁶

Our study was limited by the fact that complications were grouped into relatively broad categories, preventing a more detailed analysis of exactly what complications occurred and their associations with surgical type. While this inhibited the examination of individual complications, it allowed for greater generalizability in our results. We were further limited by the length of the

follow-up period. At only two years follow-up, we are likely not capturing the full scope of complications that occur following ASD surgery. Repeat studies examining complication rates in the long term may be needed to fully understand the course of postsurgical complications and outcome longevity. Finally, we did not assess the appropriateness of the surgical strategy employed. Rather, this study assumes that the right operation was performed based on each patient's characteristics. While determining what operation is most appropriate can sometime be challenging, assuming of the correct surgical decision represents the general trend in Adult Spinal Deformity patient treatment. A larger cohort of patients is needed to further determine which type of surgery or surgeries result in superior outcomes for a given patient profile.

Conclusion

Discussions of complication rates in ASD surgery are less useful absent the understanding of the significant variability that exists in complication and construct survival rates for the different surgical operations that exist under the ASD umbrella. When it comes to postoperative complications, specificity matters. We have demonstrated herein that not all ASD operations are created equal in terms of their associated frequency and severity of postoperative complications. A more nuanced grasp of this topic is important in a field that continues to expand so dynamically.

To that end, the results of this study can be used as a surgery-adjusted benchmark for complication rates associated with the most common types of operations that take place for the treatment of ASD. Such a tool has clinically impactful applications for surgeon decision making, patient counseling, and quality of care metrics. Additionally, having reference data for expected complications specific to surgical type has the potential to be significantly important for spine surgeons in the near future as our healthcare infrastructure moves toward bundled payment systems in an effort to increase efficiency, accountability, and quality of care.

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Figure 1: Definition of surgical cases type based upon the number of levels fused, the position of the upper- and lower-most instrumented vertebrae, revision status, and the use of three-column osteotomy.

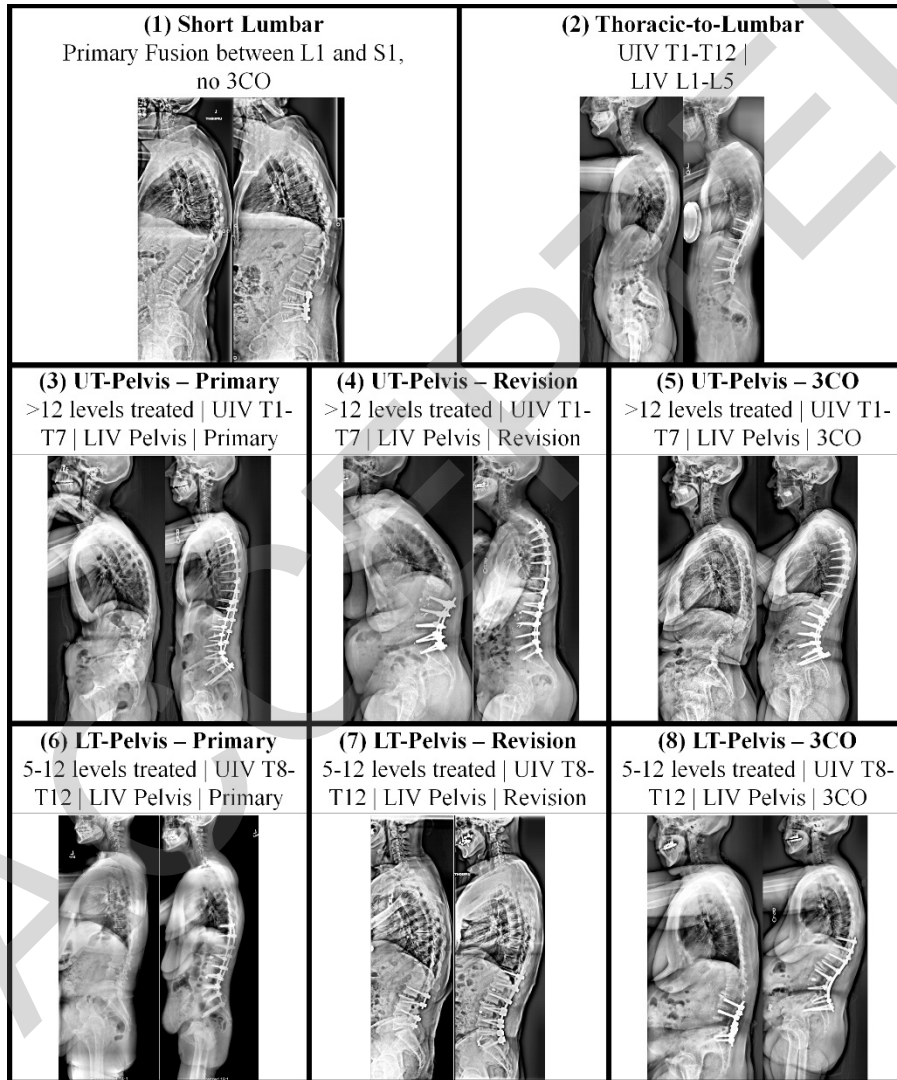


Figure 2: Survival function for the number of days until first overall complication for each surgical type.

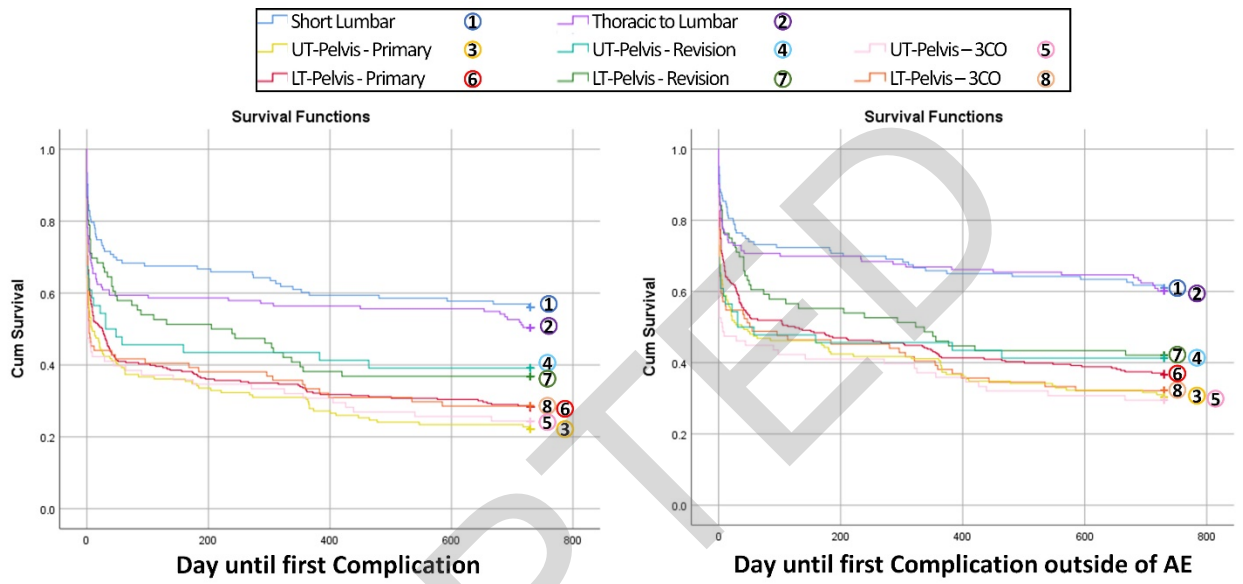


Figure 3: Kaplan Meier survival curves until first major complication (left), major complication requiring a reoperation (middle) and minor (left) complications across the different types of surgery performed.

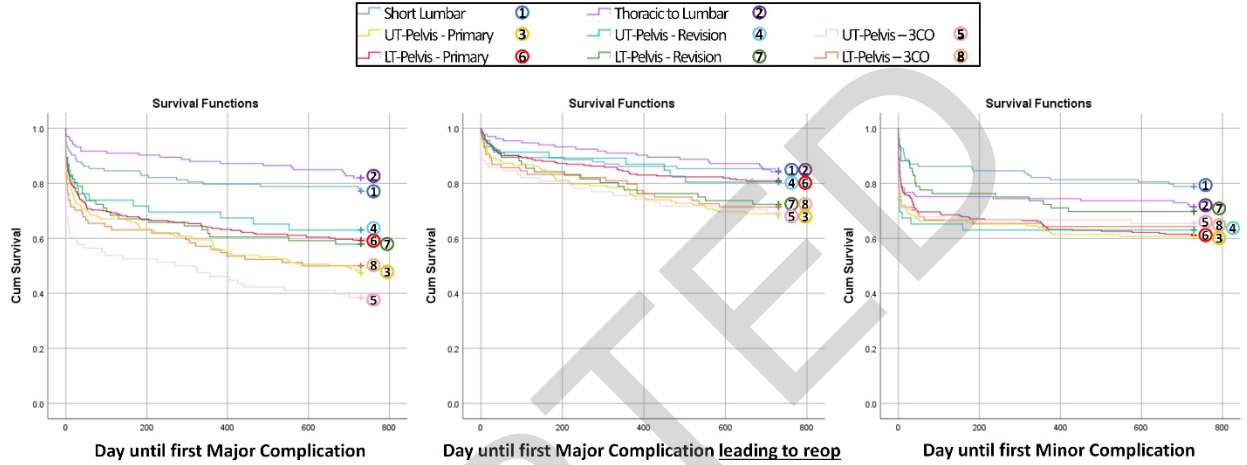


Figure 4: Cox regression analysis survival curves showing days until first complication (left) or until first major complication (right) across the different types of surgery.

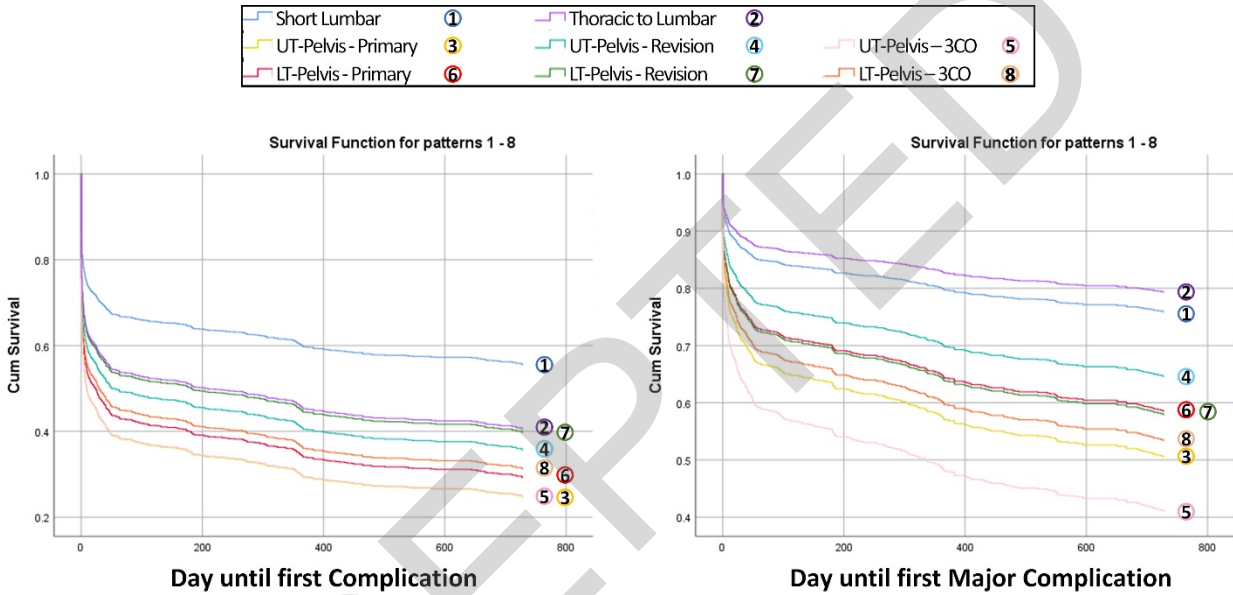


Table 1: Pre-operative health related quality of life (HRQOL) score for the entire cohort. HRQOL included NRS back and leg pain, ODI, SF-36 PCS and MCS scores, SRS-22 domains and total scores

	MEAN ± STD	MEDIAN (25TH TO 75TH)
NRS BACK PAIN	7.2 ± 2.2	8 (6 to 9)
NSR LEG PAIN	4.8 ± 3.3	5 (2 to 8)
ODI	44.5 ± 17.2	44.0 (34.0 to 56.0)
SF36 - PCS	31.0 ± 9.6	29.7 (24.4 to 36.6)
SF36 - MCS	45.6 ± 13.4	46.4 (35.9 to 56.8)
SRS22- ACTIVITY	2.85 ± 0.87	2.80 (2.20 to 3.40)
SRS22 - PAIN	2.35 ± 0.82	2.23 (1.80 to 2.80)
SRS22- APPEARANCE	2.42 ± 0.73	2.40 (1.80 to 3.00)
SRS22- MENTAL	3.44 ± 0.89	3.55 (2.80 to 4.20)
SRS22 - TOTAL	2.77 ± 0.63	2.77 (2.32 to 3.18)

Table 2: Surgical procedure performed among the cohort, including number of level fused, osteotomies, direct decompression use of interbody fusion as well as the approach and the invasiveness index score as described by Neuman et al. ¹⁵

ASA Grade	I / II: 56.7% ; III / IV: 43.2%
# levels treated	9 levels (8 to 14)
	10.9% 1 to 4 levels treated
	59.6% 5 to 12 levels treated
	29.4% 13 or more level treated
Osteotomy	760 (70.8%)
3-Column Osteotomy	191 (17.8%)
Direct decompression	630 (58.9%)
Interbody Fusion	689 (65.2%)
ALIF	271 (25.3%)
P/TLIF	331 (30.9%)
LLIF	172 (16.0%)
Invasiveness Index	83.5 (62.2 to 111.3)

Table 3: Details of surgical procedures (upper- and lower-most Instrumented vertebra, mean number of level treated, rate of direct decompression, rate of interbody fusion [IBF] used and approach, median number of osteotomies used, median invasiveness index) and in-hospital metrics (median estimated blood loss [EBL], intensive care unit(ICU) stay and extended ICU stay, length of stay [LOS]) by type of surgery performed.

	Upper Vertebra	Lower Vertebra	Level treated	Direct Decomp.	BF	IBF	Osteo	Invasi. Index	BL	ICU	OS
Short Lumbar (N=123)	2: 27.6%	1: 39.8%	S		BF: 94.3%	I					
	1: 24.4%	5: 33.3%	L		LIF: 39.0%	A	(0 to 0)	5.7 (33.2 to 58.9)	38 (100 to 725)	1.1%	(3 to 7)
	3: 24.4%	Lium: 17.9%	I +/- 2	3.7%	/TLIF: 26.8%	P					
					LIF: 49.6%	L				.6%	
Lower Thor. to Pelvis Primary (N=283)	10: 61.1%	Lium: 91.5%	I		BF: 75.9%	I					
	11: 21.2%	T			LIF: 31.8%	A	(0 to 6)	8.7 (64.5 to 96.3)	300 (750 to 1975)	5.7%	(5 to 9)
	9: 11.3%	T	+/- 1	2.0%	/TLIF: 41.3%	P					
					LIF: 14.8%	L				2.7%	
Lower Thor. to Pelvis Revision (N=76)	10: 47.4%	Lium: 81.6%	I		BF: 61.8%	I					
	11: 19.7%	T	+/- 1	3.7%	LIF: 18.4%	A	(0 to 4)	4.1 (58.4 to 97.3)	300 (650 to 2050)	7.1%	(5 to 8)
	9: 19.7%	T			/TLIF: 38.2%	P				3.2%	

Table 4: Details of demographic (Age, BMI, Charlson Comorbidity Index [CCI] and Sex (% Female)), location of previous fusion, pre-operative SRS Classification (Type, and 3 sagittal modifiers) and pre-operative Health Related Quality of Life (HRQOL: Back Pain VAS, Oswestry Disability Index [ODI], SF36 Physical Component Score [PCS] and SRS22 Total Score)

	Demographic	Previous Fusion Location	Previous Fusion Level	SRS Type	SRS PI-LL	SRS SVA	SRS PT	SRS RQOL	HRQOL
Thoracic Lumbar (N=123)	Age: 66.9±12			: 85 (69.1%)	: 45 (36.6%)	: 54 (44.6%)	: 39 (31.7%)	0	Back Pain: 7 (6 to 9)
	MI: 29.3±6.1	None: 100%	None: 100%	: 2 (1.6%)	: 38 (30.9%)	: 42 (34.7%)	: 49 (39.8%)	0	ODI: 46.8±14.1
	CCI: 2 (1 to 3)			: 28 (22.8%)	: 40 (32.5%)	: 25 (20.7%)	: 35 (28.5%)	0	PCS: 30.1±7.2
	Sex (F): 84 (68.3%)			: 8 (6.5%)					SRS22: 2.8±0.6
Lower Thoracic to Primary (N=283)	Age: 64.8±9			: 106 (37.5%)	: 88 (31.1%)	: 120 (42.7%)	: 87 (30.7%)	0	Back Pain: 8 (6 to 9)
	MI: 28.1±5.4	None: 100%	None: 100%	: 3 (1.1%)	: 85 (30%)	: 108 (38.4%)	: 124 (43.8%)	0	ODI: 45.8±14.6
	CCI: 2 (1 to 3)			: 144 (50.9%)	: 110 (38.9%)	: 53 (18.9%)	: 72 (25.4%)	0	PCS: 29.5±8.1
	Sex (F): 220 (78.3%)			: 30 (10.6%)					SRS22: 2.8±0.6
Lower Thoracic	Age: 66.3±7.6	L3: 36.8%	L1: 40.8%	S: 54 (71.1%)	S: 12 (15.8%)	S: 19 (25%)	S: 21 (27.6%)	0	Back Pain: 7.5 (6 to 9)

Pelvis: Revision (N=76)	Age:	B	L	L	T	+	+	O	
	MI:	29±5.6	2: 23.7%	5: 34.2%	: 1 (1.3%)	: 19 (25%)	: 20 (26.3%)	: 32 (42.1%)	DI: 52.6±14.4
	CI:	2 (1 to 3)	L	L	: 16 (21.1%)	+	+	+	P
	Sex (F):	56 (74.7%)	4: 17.1%	4: 13.2%	: 5 (6.6%)	+	+	+	CS: 28±7.4 RS22: 2.6±0.6
Lower Th. to Pelvis: 3CO (N=84)	Age:	A	N	N	N	0	0	Ba	
	MI:	64.6±10.2	one: 28.6%	one: 28.6%	: 58 (69%)	: 2 (2.4%)	: 6 (7.2%)	: 6 (7.1%)	ck Pain: 8 (7.5 to 9)
	CI:	2 (0.25 to 3)	L	L	: 16 (19%)	+	+	+	P
	Sex (F):	52 (61.9%)	3: 15.5%	5: 20.2%	L : 7 (8.3%)	+	+	+	CS: 27.5±7.7 RS22: 2.5±0.7
Upper Th. to Pelvis: Primary (N=158)	Age:	A	N	N	N	0	0	Ba	
	MI:	63.2±8.7	one: 100%	one: 100%	: 11 (7%)	: 59 (37.3%)	: 63 (39.9%)	: 46 (29.1%)	ck Pain: 8 (6 to 9)
	CI:	2 (1 to 3)	L	L	: 60 (38%)	+	+	+	P
	Sex (F):	134 (84.8%)	3: 15.5%	5: 20.2%	L : 7 (8.3%)	+	+	+	CS: 31±9.1 RS22: 2.7±0.6
Upper Th. to	Age:	A	T	S	N	0	0	Ba	
	MI:	60.8±12.7	10: 15.2%	1: 34.8%	: 22 (47.8%)	: 13 (28.3%)	: 8 (18.2%)	: 11 (23.9%)	ck Pain: 8 (7 to 9)
	CI:	2 (1 to 3)	L	L	: 60 (38%)	+	+	+	P
	Sex (F):	134 (84.8%)	3: 15.5%	5: 20.2%	L : 7 (8.3%)	+	+	+	CS: 31±9.1 RS22: 2.7±0.6

Revision (N=46)	MI: 29.3±7.4	L 3: 15.2%	ium 19.6%	: 2 (4.3%)	: 9 (19.6%)	+ : 13 (29.5%)	: 16 (34.8%)	DI: 51.1±14.9
	CI: 2 (1 to 4)	L 2: 13.0%	L 4: 19.6%	: 10 (21.7%)	+ : 24 (52.2%)	+ : 23 (52.3%)	+ : 19 (41.3%)	CS: 27.9±8.4
	Sex (F): 39 (84.8%)	L 4: 13.0%	L 5: 17.4%	: 12 (26.1%)				RS22: 2.6±0.6
Upper Th. to Pelvis: 3CO (N=78)	Age: 62.5±9.9	one: 35.9%	one: 35.9%	: 33 (42.3%)	: 6 (7.7%)	0 : 11 (14.9%)	: 12 (15.4%)	Back Pain: 8 (6 to 9)
	MI: 28.9±5.6	10: 11.5%	ium: 25.6%	: 1 (1.3%)	: 22 (28.2%)	+ : 15 (20.3%)	: 22 (28.2%)	DI: 48.6±19.5
	CI: 1 (0.75 to 3)	L 1: 9%	S 1: 14.1%	: 24 (30.8%)	+ : 50 (64.1%)	+ : 48 (64.9%)	+ : 44 (56.4%)	CS: 28.8±10.4
	Sex (F): 60 (76.9%)			: 20 (25.6%)				RS22: 2.6±0.7
Thoracic to Lumbar (N=133)	Age: 38.4±14.6			: 25 (18.8%)	: 115 (86.5%)	0 : 110 (82.7%)	: 101 (75.9%)	Back Pain: 7 (5 to 8)
	MI: 25.1±6.1	one: 91.0%	one: 91.0%	: 23 (17.3%)	: 11 (8.3%)	+ : 17 (12.8%)	: 25 (18.8%)	DI: 29.3±18
	CI: 0 (0 to 1)			: 26 (19.5%)	+ : 7 (5.3%)	+ : 6 (4.5%)	+ : 7 (5.3%)	CS: 40.4±10.7
	Sex (F): 96 (72.2%)			: 59 (44.4%)				RS22: 3.1±0.7

Table 5: Rate of complication by type of surgery, stratified by type of complication (Surgical vs Medical) and severity (requiring a reoperation, Major, Minor). Rate of patients reaching an 2-year MCID stratified by type of surgery performed.

		Thoracic to Lumbar	Lower Th. to Pelvis			Upper Th. to Pelvis			Thoracic to Lumbar	T
			Primary	Revision	CO	Primary	Revision	CO		
Complication	Any		7	6		7	6		4	
	Complication (w AE)	3.9%	1.7%	3.2%	1.4%	7.8%	0.9%	5.6%	9.6%	
	Medical		6	5		6	5		3	
	Surgical	9.0%	3.3%	7.9%	7.9%	9.6%	8.7%	0.5%	9.8%	
	Reop		2	1		3	2		1	
	Major (no reop)	0.3%	1.9%	4.5%	0.2%	2.3%	3.9%	1.8%	7.3%	
	Minor		5	5		5	5		3	
		2.5%	4.1%	1.3%	9.5%	7.0%	0.0%	5.4%	0.8%	
2-year MCID	ODI MCID?		1	2		3	1		1	
	SF36-PCS MCID?	5.4%	9.1%	7.6%	8.6%	1.6%	9.6%	0.8%	5.8%	
	SRS22 Activity MCID?		2	1		3	2		4	
	SRS22 Pain MCID?	0.1%	5.8%	8.4%	1.0%	2.3%	6.1%	1.0%	0.5%	
	Appeal. MCID?		3	3		3	3		2	
	Mental MCID?	1.1%	8.9%	0.3%	5.7%	9.2%	7.0%	4.6%	8.6%	
			5	4		6	4		3	
		9.6%	9.2%	8.6%	4.4%	1.3%	3.5%	5.4%	7.7%	
		6	5		6	5		4		
	1.0%	8.4%	0.0%	9.5%	7.9%	1.2%	6.2%	6.4%		
		6	6		7	7		5		
	5.2%	9.3%	7.6%	1.7%	1.2%	2.1%	9.3%	0.8%		
		7	6		7	6		5		
	3.2%	7.8%	7.6%	0.4%	5.2%	2.8%	9.3%	6.3%		
		6	5		8	6		8		
	1.8%	4.3%	2.9%	8.0%	0.4%	9.8%	7.3%	0.2%		
		4	4		4	3		3		
	8.4%	2.8%	2.6%	5.7%	5.1%	7.2%	4.0%	9.7%		