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The Case for Operative Efficiency in Adult Spinal Deformity Surgery

Impact of Operative Time on Complications, Length of Stay, Alignment, Fusion Rates, and Patient-Reported Outcomes

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Study Design. Retrospective review of prospectively collected data.

Objective. To analyze the impact of operative room (OR) time in adult spinal deformity (ASD) surgery on patient outcomes.

Background. It is currently unknown if OR time in ASD patients matched for deformity severity and surgical invasiveness is associated with patient outcomes.

Materials and Methods. ASD patients with baseline and two-year postoperative radiographic and patient-reported outcome measures (PROM) data, undergoing a posterior-only approach for long fusion ($>$L1-Ilium) were included. Patients were grouped into short OR time ($<$40th percentile: $<$359 min) and long OR time ($>$60th percentile: $>$421 min). Groups were matched by age, baseline deformity severity, and surgical invasiveness. Demographics, radiographic, PROM data, fusion rate, and complications were compared between groups at baseline and two years follow-up.

Results. In total, 270 patients were included for analysis: the mean OR time was 286 minutes in the short OR group versus 510 minutes in the long OR group ($P<0.001$). Age, gender, percent of revision cases, surgical invasiveness, pelvic incidence minus lumbar lordosis, sagittal vertical axis, and pelvic tilt were comparable between groups ($P>0.05$). Short OR had a slightly lower body mass index than the short OR group ($P<0.001$) and decompression was more prevalent in the long OR time ($P=0.042$). Patients in the long group had greater hospital length of stay ($P=0.02$); blood loss ($P<0.001$); proportion requiring intensive care unit ($P=0.003$); higher minor complication rate ($P=0.001$); with no significant differences for major complications or revision procedures ($P>0.5$). Both groups had comparable radiographic fusion rates ($P=0.152$) and achieved improvement in sagittal alignment measures, Oswestry disability index, and Short Form-36 ($P<0.001$).

Conclusion. Shorter OR time for ASD correction is associated with a lower minor complication rate, a lower estimated blood loss, fewer intensive care unit admissions, and a shorter hospital length of stay without sacrificing alignment correction or PROMs. Maximizing operative efficiency by minimizing OR time in ASD surgery has the potential to benefit patients, surgeons, and hospital systems.

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Adult spinal deformity (ASD) encompasses a wide range of disorders altering normal spinal alignment, with a broad range of modern surgical correction techniques available.[1,2] Regardless of technique, ASD corrective surgery is associated with substantial risk of perioperative complications.[3] Risk factors for complications may be modifiable or nonmodifiable, with one potentially modifiable risk factor being prolonged operative time.

Operating room (OR) time in ASD surgery has been shown to vary widely.[4] This time may be influenced by many factors including those related to the surgeon, surgical team, institution, and the patient.[5] Prolonged OR may be linked to greater incidence of complications, longer hospital stays, higher expenses, and higher operating room resource use.[6–10] Samuel *et al*[10] examined OR time in ASD patients and reported that OR time independently increases the risk of postoperative complications in ASD patients, even after controlling for invasiveness. Although the results of this prior study are compelling, the authors utilized billing data and did not have access to radiographic data regarding deformity severity, nor were they able to track patient outcomes past 30 days.

Thus, the true independent impact of OR time on perioperative outcomes of ASD surgery remains incompletely understood. This investigation was designed to assess OR time and its effect on intraoperative and postoperative complications, postoperative patient-reported outcomes (PROMs), and spinopelvic radiographic parameters patients undergoing ASD surgery.

MATERIALS AND METHODS

Study Design

This was a retrospective cohort study examining a prospective database collected across 12 years and 13 spinal deformity centers. Institutional Review Board approval was obtained from all centers before data collection and informed consent was obtained from each patient included in the study. Inclusion criteria for this database were adults age 18 years or above and radiographic evidence of ASD, defined as coronal Cobb angle $>20\geq$, sagittal vertical axis (SVA) ≥ 5 cm, pelvic tilt (PT) $\geq 25°$, and thoracic kyphosis (TK) $\geq 60°$. Inclusion criteria for the current study were use of posterior-only approach for long fusion of at least the vertebrae from L1 to the ilium, and presence of baseline and two-year radiographic and PROMs data.

Data Collection

Participant demographic data included age, sex, body mass index (BMI), Charlson comorbidity index (CCI) and surgical procedure performed. Radiographic measurements based on coronal and sagittal full-length standing films included (i) T1 coronal balance, T1 spinopelvic inclination, and leg-length discrepancy; (ii) sacral slope, pelvic incidence (PI), PT, pelvic incidence minus lumbar lordosis (PI–LL), and SVA; and (iii) LL, TK, and cervical lordosis, along with the apex of lordosis/kyphosis. Fusion was assessed on radiographs by two fellowship-trained spine surgeons using fusion grading. Rod failure was also evaluated separately. Patient-reported outcomes included Oswestry disability index, neck disability index, Short Form-36 Physical (PCS) and mental component scores, and Scoliosis Research Society Activity, Pain, and Total scores. Intraoperative [eg, length of stay (LOS), estimated blood loss (EBL), surgical intensive care unit (SICU) placement, supplemental rod use, etc.] and postoperative (eg, implant failure, operative complications, infection, etc.) complications were also detailed at the baseline and two-year follow-up visits (minor complication and major complications defined by Carreon *et al*[11]). Excess bleeding was defined as >4 L.[12]

Groups and Statistical Analyses

Eligible participants were categorized according to their OR time (defined as the time from incision to wound closure), with those below the 40th percentile defined as having a short OR time and those above the 60th percentile as having a long OR time. Groups were subsequently propensity matched by age, baseline PI–LL mismatch, and overall surgical invasiveness, as assessed by the ASD invasiveness index. The ASD invasiveness index is calculated utilizing surgical variables including type of surgery, number of fused levels, whether or not an osteotomy or interbody fusion was implemented, and other components.[13,14] Demographic and baseline radiographic data were summarized for the short and long OR time groups and compared using χ^2 test for categorical variables and the Student *t* tests for quantitative variables.

Surgical procedure performed and intraoperative/postoperative complications were similarly analyzed. Preoperative and postoperative PROMs and radiographic spinopelvic parameters, stratified by OR time, were assessed using the Student *t* tests; preoperative to postoperative changes in PROMs and radiographic spinopelvic parameters were subsequently compared across the OR time groups using the Student *t* tests. All statistical analyses were performed using SPSS Statistics for Windows, Version 29.0 (IBM Corp., Armonk, NY) and a *P*-value for statistical significance was set at $P<0.05$ a priori.

RESULTS

Participant Characteristics

Among the 270 matched participants who met the inclusion criteria, mean OR time was 285.6 minutes (4.8 h) in the Short OR group and 510.2 minutes (8.5 h) in the long OR group ($P<0.001$) (Table 1). Short OR group had a lower BMI (27.4 vs. 29.9 kg/m^2, $P<0.001$) and CCI (1.79 vs.

TABLE 1. Baseline Patient Characteristics and Radiographic Parameters

	Short OR (N = 135)	Long OR (N = 135)	*P*
OR time (minutes)	285.61 (53.48)	510.23 (69.16)	**< 0.001**
Age (years)	64.04 (10.32)	63.73 (8.53)	0.787
Female sex	110 (82.1)	105 (77.8)	0.377
BMI	27.44 (5.31)	29.94 (6.17)	**< 0.001**
CCI	1.79 (1.64)	2.21 (1.78)	**0.040**
PT (°)	27.58 (9.46)	26.81 (10.68)	0.531
PI–LL (°)	22.24 (17.12)	21.47 (19.82)	0.733
SVA (mm)	83.01 (72.52)	95.53 (70.46)	0.152
Invasiveness	95.19 (30.84)	95.62 (29.87)	0.908
Decompression (%)	58	70	0.042
Fusion (%)	100	100	1.000
Instrumentation (%)	100	100	1.000
Distribution of UIV	–	–	0.100
Distribution of LIV	–	–	0.602
Three-column osteotomy (number of vertebras)	0.25 (0.44)	0.36 (0.51)	0.074
Smith-Peterson osteotomy (number of vertebras)	2.82 (2.8)	3.37 (3.8)	0.181
ALIF (%)	0.7	0.7	1.000
TLIF/PLIF (%)	48	40	0.339
Iliac fixation (%)	93	93	1.000
Patients with a prior spine surgery (%)	63	65	0.703
Postoperative change in PI–LL (°)	18.94 (15.4)	15.84 (15.5)	0.101
Postoperative change in PT (°)	4.13 (7.5)	3.35 (8.4)	0.423
Postoperative change in SVA (mm)	49.57 (69.8)	41.01 (70)	0.34
Postoperative change in TK (°)	18.01 (16)	16.83 (14.62)	0.526
Follow-up duration (months)	28.06 (9.20)	26.47 (5.15)	0.080

Bold values indicate statistical significance <0.05.

ALIF indicates anterior lumbar interbody fusion; BMI, body mass index; CCI, Charlson comorbidity index; LIV, lower instrumented vertebrae; OR, operating room; PI–LL, pelvic incidence minus lumbar lordosis; PLIF, posterior lumbar interbody fusion; PT, pelvic tilt; SVA, sagittal vertical axis; TK, thoracic kyphosis; TLIF, transforaminal lumbar interbody fusion; UIV, upper instrumented vertebrae.

2.21, $P = 0.040$) and a lower rate of decompression which is a component of the invasiveness index (58% vs. 70%, $P = 0.042$) than long OR group but was otherwise comparable in terms of age, sex, PT, PI–LL, SVA, the remaining components of the invasiveness index, the number of prior spine surgeries, and duration of follow-up ($P > 0.05$). After doing a multivariate regression analysis to analyze the effect of BMI and CCI on OR time, only BMI was significant explaining only a small component of operative time (correlation coefficient ß = 0.18, $P = 0.001$). Furthermore, there was no correlation between OR time and date of surgery ($P = 0.106$), and there was no difference in the date of surgery between the long and short OR time groups ($P = 0.071$).

Surgical Procedures

Patients in the short OR group less frequently underwent decompression (58.5% vs. 70.4%, $P = 0.042$) and PLIF (5.6%. vs 17.6%, $P = 0.034$), and more frequently underwent TLIF (87.3% vs. 70.6%, $P = 0.021$) (Table 2). Otherwise, there were no statistical differences in osteotomies (eg, three-column osteotomy) and interbody fusions (eg, ALIF, LLIF, AxiaLIF, etc.) performed across the two groups ($P > 0.05$).

Complications

The long OR group had a higher LOS (6.9 vs. 7.8 days, $P = 0.018$), EBL (1603.0 vs. 2487.7 mL, $P < 0.001$), and crystalloid requirement (2777.7 vs. 4562.1 mL, $P < 0.001$) (Table 3). More of long OR time patients were admitted to the ICU immediately after the procedure (65.9% vs. 82.1%, $P = 0.003$).

Furthermore, OR time when examined as a continuous variable had significant correlations with LOS ($r = 0.173$, $P < 0.001$), EBL ($r = 0.291$, $P < 0.001$), crystalloid requirement ($r = 0.460$, $P < 0.001$), and ICU admissions ($r = 0.213$, $P < 0.001$). Moreover, by doing a multivariate regression analysis, both OR time and EBL significantly contributed to LOS (ß = 0.131, $P = 0.013$, and ß = 0.155, $P = 0.003$, respectively) and ICU admission (ß = 0.159, $P = 0.002$, and ß = 0.203, $P < 0.001$, respectively).

Before discharge, there was no significant difference in the rate of minor, major, and total complications between the two groups ($P = 0.329$, 0.251, and 0.110, respectively).

TABLE 2. Surgical Procedures

	Short OR (N = 135), N (%)	Long OR (N = 135), N (%)	*P*
Decompression	79 (58.5)	95 (70.4)	**0.042**
Osteotomy	112 (83.0)	109 (81.3)	0.729
Three-column osteotomy	34 (25.2)	46 (34.1)	0.110
Interbody fusion	71 (52.6)	68 (50.4)	0.715
ALIF	1 (1.4)	1 (1.5)	1.000
PLIF	4 (5.6)	12 (17.6)	**0.034**
TLIF	62 (87.3)	48 (70.6)	**0.021**
LLIF	1 (1.4)	1 (1.5)	1.000
AxiaLIF	2 (2.8)	5 (7.4)	0.268
Other	0	1 (1.5)	0.489

Bold values indicate statistical significance < 0.05.

ALIF indicates anterior lumbar interbody fusion; PLIF, posterior lumbar interbody fusion; TLIF, transforaminal lumbar interbody fusion; TranS1, axial lumbar interbody fusion; XLIF, extreme lateral interbody fusion.

This insignificant difference was as well seen in the rate of minor, major, and total complications before 90 days postoperatively ($P = 0.261$, 0.409, and 0.244, respectively) (Table 4).

Two years postoperatively, the overall complication and reoperation rates were similar across the two groups ($P > 0.05$) (Table 5). However, more participants in the long OR group had minor complications (26.7% vs. 46.7%, $P = 0.001$), particularly operative (14.8% vs. 28.1%, $P = 0.008$) complications including dural tear (5.2% vs. 12.6%, $P = 0.032$), and excess bleeding > 4L (5.2% vs. 14.1%, $P = 0.013$).

Patient-Reported Outcome Measures

Both the short and the long OR groups noted significant improvements in their Oswestry disability index, neck disability index, Short Form-36 PCS and mental component scores, and Scoliosis Research Society Activity, Pain, and Total scores from baseline to two years postoperatively ($P < 0.05$ for all) (Table 6). However, there was no statistical difference in the change in preoperative to postoperative scores of any of these measures across the two OR groups. Their final fusion rates were also comparable (62.7% vs. 71.6%, $P = 0.119$).

Spinopelvic Parameters

Both the short and the long OR groups experienced significant improvements in their T1 spinopelvic incidence, SVA, sacral slope, PT, PI–LL, LL, TK, and apex of LL from baseline to two years postoperatively ($P < 0.05$ for all) (Table 7). There was no statistical difference in the change in preoperative to postoperative values of any of these measures across the two OR groups ($P > 0.05$).

DISCUSSION

This investigation examined operative time as an independent predictor of outcome following ASD surgery. By using propensity matching, this study controlled for deformity severity (PI–LL), age, and surgical invasiveness—all of which have been previously shown to influence OR time.[5] After matching, shorter OR time was associated with reduced EBL, hospital LOS, intravenous fluids administration, ICU utilization, and minor complications. Both groups, however, still achieved significant improvement in PROMs and spinopelvic parameters with comparable outcomes at two-year follow-up.

It is not surprising that the short OR time group experiences reduced EBL and fluid replacement as compared to the long OR time group. If not properly resuscitated, higher EBL can lead to an increased risk for organ damage, cardiovascular events, and overall mortality.[15] Other than its direct adverse events, intraoperative blood loss is also associated with increased cost, as well as the need for fluid replacement and transfusions. The latter can be associated with immunological reactions, coagulopathies, ileus, cardiac, pulmonary, or renal complications, and increase infection rate.[15–17]

In this study, prolonged OR time was also associated with a longer LOS and greater ICU utilization. These two

TABLE 3. Intraoperative Complications

	Short OR (N = 135)	Long OR (N = 135)	*P*
LOS (days) [range]	6.86 (3.31) [1–28]	7.78 (2.99) [3–22]	**0.018**
EBL (mL) [range]	1602.99 (1129.17) [50–6000]	2487.69 (1858.95) [270–12200]	**< 0.001**
Colloid (ml) [range]	880.57 (641.84) [0–6000]	958.33 (689.77) [0–13200]	0.391
Crystalloid (ml) [range]	2777.66 (1470.09) [0–2500]	4562.13 (2311.78) [0–3250]	**< 0.001**
Operative, N (%)	20 (14.8)	38 (28.1)	**0.008**
Dural tear	7 (5.2)	17 (12.6)	**0.032**
Excess bleeding	7 (5.2)	19 (14.1)	**0.013**
Pleural injury	1 (0.7)	1 (0.7)	1.000
ICU, N (%)	87 (65.9)	110 (82.1)	**0.003**

Bold values indicate statistical significance < 0.05.

EBL indicates estimated blood loss; ICU, intensive care unit; LOS, length of stay.

TABLE 4. Postoperative Complications Stratified by Time (Complications Included Cardiopulmonary, Gastrointestinal, Infections, Neurologic, Renal, Wound-Related, Musculoskeletal, and Operative)

Time	Complications, N (%)	Short OR (N = 135), N (%)	Long OR (N = 135), N (%)	*P*
Before discharge	Total	18 (13.3)	10 (7.4)	0.110
	Major	5 (3.7)	2 (1.5)	0.251
	Minor	7 (5.2)	11 (8.1)	0.329
Before 90 days	Total	25 (18.5)	18 (13.3)	0.244
	Major	15 (11.1)	11 (8.1)	0.409
	Minor	20 (14.8)	27 (20)	0.261

OR indicates operative room.

factors in contribute to the cost of care of these already costly interventions.[18–21] Our findings are similar to Basques and colleagues who showed that operative time > 310 minutes in primary lumbar fusion increased EBL and fluid replacement and transfusion. Additionally, De *et al*[22] found that prolonged OR time is linked to prolonged ventilation and reintubation, thus increasing the requirement for ICU utilization.[23] Longer OR time was also associated with an increased rate of postoperative minor complications ($P = 0.001$), but was not related to the rate of major complications. These results are supported by multiple previous studies.[1,3,24–31] Lee *et al*[25] found that OR time was the most correlated to morbidity with an odds ratio of 3.5 ($P < 0.0001$).

In a similar study to the current investigation, Samuel *et al*[10] found that OR time, but not invasiveness, increases the risk of postoperative complications in ASD patients. In that study, follow-up was limited to 30 days postoperatively, there was an absence of preoperative and postoperative PROMs and spinopelvic alignment parameters, and EBL was not assessed. Thus, our investigation builds on the previous study with longer follow-up, alignment data, and PROM data to further show that OR time truly matters in ASD surgery.

TABLE 5. Complications at Two Years Postoperatively

	Short OR (N = 135), N (%)	Long OR (N = 135), N (%)	*P*
Total	105 (77.8)	116 (85.9)	0.082
Major	40 (29.6)	43 (31.9)	0.692
Minor	36 (26.7)	63 (46.7)	**0.001**
Cardiac	3 (2.2)	5 (3.7)	0.502
Coagulopathy	7 (5.2)	4 (3.0)	0.379
Gastrointestinal	4 (3.0)	4 (3.0)	1.000
Infection	12 (8.9)	9 (6.7)	0.650
Neurologic	24 (17.8)	29 (21.5)	0.444
Pulmonary	3 (2.2)	6 (4.4)	0.336
Renal	0	1 (0.7)	0.500
Implant failure	30 (22.2)	30 (22.2)	1.000
Implant malposition	4 (3.0)	7 (5.2)	0.379
Wound	2 (1.5)	5 (3.7)	0.251
XR imbalance	36 (26.7)	39 (28.9)	0.684
Reoperation	42 (31.1)	39 (28.9)	0.690

Bold values indicate statistical significance < 0.05.
OR indicates operative room; XR, radiographic.

One important factor when assessing OR time is that some complications may not be the consequence of increased OR time, but instead may be one of the contributing factors to prolonger OR time, such as dural tears. Difficulty placing screws, a challenging decompression, and very stiff spinal deformity may also contribute to increased OR time and are difficult to quantify. Other complications potentially associated with increased OR time may be explained by the increased blood loss, fluid replacement, higher exposure to infectious agents, and the rapid decrease of antibiotics' serum concentration below the therapeutic level.[32–35] To further expand on this, Zeitlinger and colleagues reported the association between long OR time and surgical skin infections which was not mitigated by an extended postoperative antibiotic therapy.[36]

Although short-term issues such as minor complications and LOS are important, the long-term outcomes of ASD corrective surgery are paramount and are related to the improvement in PROMs, fusion rate, and radiographic parameters.[37] As there was no significant difference between the groups for improvements in fusion rates, PROM, or alignment outcomes, reducing operative duration has the potential reduce the rate of postoperative adverse events without affecting the ultimate success of the surgery.

Ongoing efforts to improve operative efficiency are warranted. Factors that may potentially help reduce OR time have been examined previously. Having an second attending surgeon on challenging cases is a logical but costly intervention which has been shown to decrease operative duration by 2.6 hours in ASD cases.[38,39] In addition, extremely complex cases can be performed preferentially by a more experienced surgeon.[38–42] Other possibly ways to

TABLE 6. Preoperative to Two Years Postoperative Changes in PROMs

	Short OR (N = 135)			Long OR (N = 135)			
	Preop	Postop	*P*	Preop	Postop	*P*	*P**
ODI	47.42 (30.50)	30.50 (18.95)	**< 0.001**	46.70 (16.09)	31.04 (19.70)	**< 0.001**	0.551
NDI	26.12 (17.00)	22.22 (15.37)	**0.040**	28.35 (18.21)	23.61 (19.14)	**0.024**	0.761
SF-36—PCS	29.67 (7.99)	38.30 (11.04)	**< 0.001**	28.62 (9.21)	37.21 (10.36)	**< 0.001**	0.973
SF-36—MCS	45.14 (14.23)	51.80 (12.25)	**< 0.001**	46.33 (13.11)	50.57 (11.57)	**< 0.001**	0.125
SRS—activity	2.74 (0.80)	3.48 (0.91)	**< 0.001**	2.70 (0.82)	3.39 (0.85)	**< 0.001**	0.580
SRS—pain	2.22 (0.68)	3.35 (1.07)	**< 0.001**	2.21 (0.86)	3.34 (1.01)	**< 0.001**	0.993
SRS—total	2.67 (0.60)	3.59 (0.80)	**< 0.001**	2.70 (0.61)	3.56 (0.72)	**< 0.001**	0.523

Bold values indicate statistical significance < 0.05.

**The Student t test comparison of the change in preoperative to postoperative PROM across the short and long OR groups.*

MCS indicates mental component score; NDI, neck disability index; ODI, Oswestry disability index; PCS, physical component score; PROM, patient-reported outcome measure; SF-36, Short Form-36; SRS, scoliosis research society.

improve efficiency include incentivizing the OR team to reduce OR/turnover time, improve preoperative equipment preparation, ensure an optimal preoperative planning to attempt to avoid intraoperative unforeseen events, and employing dedicated subspecialty staff in the OR for familiarity and accountability improvement.[43] In addition, increasing surgical efficiency may be enhanced by video feedback training for surgeons.[44]

Despite its logical message that optimizing OR time is beneficial, this study has several potential limitations. The patient population was not matched with regards to BMI, CCI, or all aspects of deformity complexity such as axial or coronal place deformity. In addition, the long OR time group had higher rates of dural tears and excessive bleeding which surely may act as confounding variables.[5] Nevertheless, the difference in rate of dural tears of only 7.4% (5.2% vs. 12.6%) between the two groups is likely not large enough to explain the 3.8 hours statistically significant difference, and bleeding increases during prolonged surgery and thus is more likely an effect rather than cause of prolonged OR time. Another potential limitation is the lack of granular data regarding tranexamic acid

TABLE 7. Preoperative to Two Years Postoperative Changes in Spinopelvic Parameters

	Short OR (N = 135)			Long OR (N = 135)			
	Preop	Postop	*P*	Preop	Postop	*P*	*P**
T1 coronal balance (°)	−2.52 (7.29)	−2.33 (5.56)	0.743	−0.18 (7.67)	−0.96 (6.20)	0.142	0.207
Leg-length discrepancy (mm)	8.08 (7.06)	7.58 (6.38)	0.486	8.01 (7.41)	8.01 (6.81)	1.000	0.579
T1 spinopelvic inclination (°)	−0.52 (6.72)	−4.74 (4.68)	**< 0.001**	1.16 (6.43)	−2.94 (5.13)	**< 0.001**	0.884
SVA (mm)	83.01 (72.52)	28.59 (53.48)	**< 0.001**	95.53 (70.46)	45.76 (51.49)	**< 0.001**	0.573
SS (°)	26.92 (11.29)	30.70 (10.34)	**< 0.001**	30.34 (12.35)	33.55 (11.23)	**< 0.001**	0.541
PT (°)	27.58 (9.46)	23.38 (9.81)	**< 0.001**	26.81 (10.68)	23.41 (10.12)	**< 0.001**	0.423
PI−LL (°)	22.23 (17.12)	3.23 (12.88)	**< 0.001**	21.47 (19.82)	5.62 (14.78)	**< 0.001**	0.101
LL (°)	32.21 (20.19)	50.82 (13.77)	**< 0.001**	35.68 (19.42)	51.40 (13.76)	**< 0.001**	0.126
TK (°)	−34.10 (19.35)	−48.47 (17.39)	**< 0.001**	−35.01 (18.44)	−46.76 (16.42)	**< 0.001**	0.185
CL (°)	12.64 (15.63)	12.44 (16.66)	0.857	11.55 (14.96)	14.00 (15.64)	**0.048**	0.111
Apex of LL†	22.62 (0.82)	22.41 (0.52)	**0.006**	22.61 (0.76)	22.47 (0.52)	**0.046**	0.338
Apex of TK†	14.88 (0.95)	15.15 (0.74)	**0.008**	15.07 (0.96)	15.10 (0.74)	0.753	0.241
Apex of CL†	4.86 (0.90)	4.81 (0.84)	0.631	4.72 (0.85)	4.58 (0.79)	0.094	0.163

Bold values indicate statistical significance < 0.05.

**The Student t test comparison of the change in preoperative to postoperative parameter across the short and long OR groups.*

†Apex refers to the vertebral level where most of the lordosis/kyphosis is localized. Cervical levels 1 to 7, thoracic levels 1 to 12, and lumbar levels 1 to 5 are represented by 1 to 7, 8 to 19, 10 to 24, respectively.

CL indicates cervical lordosis; LL, lumbar lordosis; OR, operative room; PI, pelvic incidence; PI–LL, pelvic incidence minus lumbar lordosis; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis; TK, thoracic kyphosis.

which may have varied based on the center or surgeon, and thus, contributed to differences in EBL, and similarly, decision to admit to the ICU may differ between institutions. Furthermore, fusion grading was done using plain radiographs instead of computed tomography scans or surgical exploration. Finally, it is possible that additional unmeasured confounding factors were the cause of increased OR time, including surgeon inefficiency, yet these factors are challenging to measure in a retrospective investigation with the current methodology.

CONCLUSION

Efficient surgical technique in ASD surgery leading to reduced operative time may be associated with shorter LOS, less ICU time, and reduced minor complications and does not appear to negatively affect fusion rate or alignment outcomes. Optimizing OR efficiency may reduce the rate of adverse events and increase the cost-effectiveness of the ASD surgery.

➢ Key Points

- ☐ Patients undergoing surgery for adult spinal deformity with longer operative times had longer hospital length of stay, higher estimated blood loss, increased crystalloid requirement, more intensive care unit days, and higher minor complication rates.
- ☐ Both the patients in the short and long operative time group achieved similar significant improvement in patient-reported outcome measures and radiographic spinopelvic parameters.
- ☐ Optimizing operative efficiency in adult spinal deformity surgery by decreasing operative time may decrease minor complication rates and save health care resources without compromising long-term outcomes.

References

1. Bortz CA, Pierce KE, Krol O, et al. Predictors of complication severity following adult spinal deformity surgery: smoking rate, diabetes, and osteotomy increase risk of severe adverse events. 2023;17:103–11.
2. Schwab F, Dubey A, Gamez L, et al. Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. *Spine (Phila Pa 1976)*. 2005;30:1082–5. doi:10.1097/01.brs.0000160842.43482.cd
3. Alas H, Passias PG, Brown AE, et al. Predictors of serious , preventable , and costly medical complications in a population of adult spinal deformity patients. *Spine J*. 2023;21:1559–66. doi:10.1016/j.spinee.2021.04.020
4. Scheer JK, Mundis GM, Klineberg E, et al. Postoperative recovery after adult spinal deformity surgery: comparative analysis of age in 149 patients during 2-year follow-up. *Spine (Phila Pa 1976)*. 2015;40:1505–15. doi:10.1097/BRS.0000000000001062
5. Passias PG, Poorman GW, Montes DV, et al. Predictive analytics for determining extended operative time in corrective adult spinal deformity. *Surgery*. 2022;16:291–9.
6. Wimmer C, Gluch H, Franzreb M, et al. Predisposing factors for infection in spine surgery: a survey of 850 spinal procedures. *J Spinal Disord*. 1998;11:124–8. http://www.ncbi.nlm.nih.gov/pubmed/9588468
7. Gruskay J. Complications and length of stay following spine surgery: analyzing local and national cohorts. *EliScholar – A Digit Platf Sch Publ Yale*. 2015. http://elischolar.library.yale.edu/ymtdl
8. Proietti L, Scaramuzzo L, Schiro' GR, et al. Complications in lumbar spine surgery: A retrospective analysis. *Indian J Orthop*. 2013;47:340–5. doi:10.4103/0019-5413.114909
9. Macario A. What does one minute of operating room time cost. *J Clin Anesth*. 2010;22:233–6. doi:10.1016/j.jclinane.2010.02.003
10. Samuel AM, Fu MC, Anandasivam NS, et al. After posterior fusions for adult spinal deformity, operative time is more predictive of perioperative morbidity, rather than surgical invasiveness: a need for speed? *Spine (Phila Pa 1976)*. 2017;42:1880–7. doi:10.1097/BRS.0000000000002243
11. Carreon LY, Puno RM, Dimar JR, et al. Perioperative complications of posterior lumbar decompression and arthrodesis in older adults. *J Bone Joint Surg Am*. 2003;85:2089–92. doi:10.2106/00004623-200311000-00004
12. Klineberg EO, Passias PG, Poorman GW, et al. Classifying complications: assessing adult spinal deformity 2-year surgical Outcomes. *Glob Spine J*. 2020;10:896–907. doi:10.1177/2192568220937473
13. Neuman BJ, Ailon T, Scheer JK, et al. Development and validation of a novel adult spinal deformity surgical invasiveness score: analysis of 464 patients. *Neurosurgery*. 2018;82:847–53. doi:10.1093/neuros/nyx303
14. Neuman BJ, Harris AB, Klineberg EO, et al. Defining a surgical invasiveness threshold for increased risk of a major complication following adult spinal deformity surgery. *Spine (Phila Pa 1976)*. 2021;46:931–8. doi:10.1097/BRS.0000000000003949
15. Raman T, Vasquez-montes D, Varlotta C, et al. Decision treebased modelling for identification of predictors of blood loss and transfusion requirement after adult spinal deformity surgery. *Surgery*. 2020;14:87–95.
16. Huang YH, Ou CY. Significant blood loss in lumbar fusion surgery for degenerative spine. *World Neurosurg*. 2015;84:780–5. doi:10.1016/j.wneu.2015.05.007
17. White SJW, Cheung ZB, Ye I, et al. Risk factors for perioperative blood transfusions in adult spinal deformity surgery. *World Neurosurg*. 2018:1–7. doi:10.1016/j.wneu.2018.04.152
18. Theusinger OM, Spahn DR. Perioperative blood conservation strategies for major spine surgery. *Best Pract Res Clin Anaesthesiol*. 2016;30:41–52. doi:10.1016/j.bpa.2015.11.007
19. Blanchette CM, Wang PF, Joshi AV, et al. Cost and utilization of blood transfusion associated with spinal surgeries in the United States. *Eur Spine J*. 2007;16:353–63. doi:10.1007/s00586-006-0066-3
20. Passias PG, Poorman GW, Bortz CA, et al. Predictors of adverse discharge disposition in adult spinal deformity and associated costs. *Spine J*. 2018;18:1845–52. doi:10.1016/j.spinee.2018.03.022
21. Missios S, Bekelis K. Hospitalization cost after spine surgery in the United States of America. *J Clin Neurosci*. 2015;22:1632–7. doi:10.1016/j.jocn.2015.05.005
22. Basques BA, Anandasivam NS, Webb ML, et al. Risk factors for blood transfusion with primary posterior lumbar fusion. *Spine (Phila Pa 1976)*. 2015;40:1792–7. doi:10.1097/BRS.0000000000001047
23. De R, Ramos G, Nakhla J, et al. Factors associated with prolonged ventilation and reintubation in adult spinal deformity surgery. *J Clin Neurosci*. 2017:4–7. doi:10.1016/j.jocn.2017.04.026
24. Pierce KE, Kapadia BH, Bortz C, et al. Frailty severity impacts development of hospital-acquired conditions in patients undergoing corrective surgery for adult spinal deformity. *Clin Spine Surg*. 2021;34:377–81.
25. Lee NJ, Kothari P, Kim JS, et al. Early complications and outcomes in adult spinal deformity surgery : an NSQIP study based on 5803 patients. *Global Spine J*. 2017;7:432–40. doi:10.1177/2192568217699384
26. Daley BJ, Cecil W, Clarke PC, et al. How slow is too slow? Correlation of operative time to complications: an analysis from the Tennessee Surgical Quality Collaborative. *J Am Coll Surg*. 2015;220:550–8. doi:10.1016/j.jamcollsurg.2014.12.040

27. Kim HJ, Zuckerman SL, Cerpa M, et al. Incidence and risk factors for early postoperative complications and mortality data from the National Surgical Quality Improvement Program from 2011 to 2013. *Clin Spine Surg*. 2021;34:566–74.
28. Soroceanu A, Burton DC, Oren JH, et al. Medical complications after adult spinal deformity surgery: incidence, risk factors, and clinical impact. *Spine (Phila Pa 1976)*. 2016;41:1718–23. doi:10.1097/BRS.0000000000001636
29. Yoshida G, Hasegawa T, Yamato Y, et al. Predicting Perioperative Complications in Adult Spinal Deformity Surgery Using a Simple Sliding Scale. *Spine (Phila Pa 1976)*. 2018;43:562–70. doi:10.1097/BRS.0000000000002411
30. Bortz C, Pierce KE, Brown A, et al. Frequency and implications of concurrent complications following adult spinal deformity corrective surgery. 2021;46:1155–60. doi:10.1097/BRS.0000000000004064
31. Di Capua J, Somani S, Kim JS, et al. Hospital-acquired conditions in adult spinal deformity surgery: predictors for hospital-acquired conditions and other 30-day postoperative outcomes. *Spine (Phila Pa 1976)*. 2017;42:595–602. doi:10.1097/BRS.0000000000001840
32. Procter LD, Davenport DL, Bernard AC, et al. General surgical operative duration is associated with increased risk-adjusted infectious complication rates and length of hospital stay. *J Am Coll Surg*. 2010;210:60–5.e1-2. doi:10.1016/j.jamcollsurg.2009.09.034
33. Chaudhary SB, Vives MJ, Basra SK, et al. Postoperative spinal wound infections and postprocedural diskitis. *J Spinal Cord Med*. 2007;30:441–51. doi:10.1080/10790268.2007.11753476
34. Swoboda SM, Merz C, Kostuik J, et al. Does intraoperative blood loss affect antibiotic serum and tissue concentrations. *Arch Surg*. 1996; 131:1165–71; discussion 1171-2. doi:10.1001/archsurg.1996.01430230047009
35. Polly DW, Meter JJ, Brueckner R, et al. The effect of intraoperative blood loss on serum cefazolin level in patients undergoing instrumented spinal fusion. A prospective, controlled study. *Spine (Phila Pa 1976)*. 1996;21:2363–7. doi:10.1097/00007632-199610150-00011
36. Zeitlinger L, Wilson M, Randall RL, et alPARITY Investigators. Surgical duration is independently associated with an increased risk of surgical site infection and may not be mitigated by prolonged antibiotics: secondary analysis of the PARITY trial of infection after lowerextremity endoprosthetic reconstruction for bone tumors. *J Bone Joint Surg Am*. 2023;105(Suppl 1):79–86. doi:10.2106/JBJS.23.00056
37. Diebo BG, Shah NV, Boachie-Adjei O, et al. Adult spinal deformity. *Lancet*. 2019;394:160–72. doi:10.1016/S0140-6736(19)31125-0
38. Ames CP, Barry JJ, Keshavarzi S, et al. Perioperative Outcomes and complications of pedicle subtraction osteotomy in cases with single versus two attending surgeons. *Spine Deform*. 2013;1:51–8. doi:10.1016/j.jspd.2012.10.004
39. Keefe M, Aryan HE, Errico TJ, et al. Results of the 2015 scoliosis research society approach for adult spinal deformity. *Surgery*. 2017;42:932–42. doi:10.1097/BRS.0000000000002070
40. Lau D, Deviren V, Ames CP. The impact of surgeon experience on perioperative complications and operative measures following thoracolumbar 3-column osteotomy for adult spinal deformity: overcoming the learning curve. 2020;32:207–20. doi:10.3171/2019.7.SPINE19656
41. Bourghli A, Cawley D, Novoa F, et al. 102 lumbar pedicle subtraction osteotomies: one surgeon's learning curve. *Eur Spine J*. 2018;27:652–60. doi:10.1007/s00586-018-5481-8
42. Cahill PJ, Pahys JM, Asghar J, et al. The effect of surgeon experience on outcomes of surgery for adolescent idiopathic scoliosis. *J Bone Joint Surg Am*. 2014;96:1333–9. doi:10.2106/JBJS.M.01265
43. Miller LA, Fleck MM. Team Approach: Improving Orthopaedic Operating Room Efficiency. 2023;11:1–8.
44. Casey JC, Daniels AH. CORR Synthesis: how have film review and motion analysis been used to enhance orthopaedic surgical performance. *Clin Orthop Relat Res*. 2023;481:564–79. doi:10.1097/CORR.0000000000002506