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Predictors of Operative Duration in Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis: A Retrospective Cohort Study

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ABSTRACT

Background: Accurate prediction of operative duration is necessary for efficient operating room scheduling, minimizing cancellations, shortening waitlists, better risk stratification, and effective preoperative counseling. Prolonged operative duration is also associated with negative patient outcomes. Posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS) is typically a lengthy surgical procedure with variable operative duration. The purpose of this study is to identify patient-, procedure-, and surgeon-specific variables that influence the operative duration in PSF for AIS and determine its impact on early postoperative outcomes.

Methods: Hospital records of 150 AIS patients who underwent PSF at a single center were retrospectively reviewed. Various patient-, procedure-, and surgeon-specific variables—deemed to be possibly affecting the operative duration—were analyzed. A multivariate regression model was used to identify independent predictors of operative duration. The association between operative duration and early postoperative outcome measures was determined.

Results: The final model obtained from the multivariate regression analysis included the following factors: experience of the chief surgeon ($\beta = -0.36$), Cobb angle of the major structural curve ($\beta = 0.35$), number of screws inserted ($\beta = 0.28$), coronal deformity angular ratio ($\beta = 0.20$), and apical vertebral rotation ($\beta = -0.21$ to 0.03). The model could explain 44% of the variability in the operative duration ($R^2 = 0.44$). The operative duration had a significant correlation with estimated blood loss, need for perioperative blood transfusion, and length of hospital stay.

Conclusions: A set of variables that predict the variability in operative duration during PSF for AIS was identified, with the experience of the chief surgeon and the severity of the curve being the strongest predictors.

Clinical Relevance: The results of this study emphasize the need for each hospital and surgical team to identify predictors of operative duration in their setup in order to better anticipate prolonged operative duration.

Level of Evidence: 3.

Other and Special Categories

Keywords: AIS, idiopathic scoliosis, operative duration, scoliosis, surgical time

INTRODUCTION

Operating rooms (ORs) are one of the most resource-intensive and profitable components of a hospital system. Access to surgical care varies widely across the world with most publicly funded health care systems being marred by long surgical waitlists and a high incidence of surgical cancellations. It is very much in the interest of all the stakeholders—the policymakers, the health care providers as well as the patients—that the OR time is utilized in the best possible manner. Being able to accurately predict the duration of a surgical procedure is critical to prepare an optimal OR schedule. Failure to do so may lead to either overbooked surgical lists eventually culminating into postponement or cancellation of several surgical procedures scheduled for the day, or an underbooked OR causing underutilization of a scarce resource and eroding the cost-effectiveness of the same for the health care system.[1] Ineffective use of the OR ultimately leads to prolonged surgical waitlists. In the case of scoliosis, this can lead to increasing curve severity and larger stiffer curves, which need surgery of a greater magnitude to achieve correction.[2] The average waiting time for scoliosis surgery is approximately 6 months in the United Kingdom and almost twice as long in Canada—both being developed countries that have publicly funded health care systems.[3,4] While similar data for developing countries are lacking, this period is expected to be a lot more considering the staggering population and the limited number of centers where scoliosis correction surgeries are performed. The current COVID-19 pandemic has thrown surgical services across the globe into disarray with all nonessential elective surgery, which includes scoliosis correction, being canceled in most health care systems. An unprecedented number of surgical procedures have been deferred, creating a huge backlog of patients planned for surgery. The postpandemic phase will need effective delivery of surgical care to address this backlog—the backbone of which will be a robust system of surgical scheduling that ensures optimal utilization of the OR time.

Across various surgical disciplines, increased operative duration has been found to be associated with negative postoperative outcomes.[5–7] There is growing evidence that prolonged surgical duration adversely impacts several components of a patient's surgical outcome after spine surgery. These include the rate of both medical and surgical complications, unplanned readmissions, reoperations, mortality, superficial surgical site infection (SSI), wound dehiscence, blood loss, need for postoperative blood transfusion, and occurrence of venous thromboembolism.[8–10] This importance of operative duration is reflected in its inclusion as a component of the World Health Organization Surgical Safety Checklist, which mandates that anticipated operative duration must be a part of the communication between the surgeon, anesthesiologist, and the OR staff prior to the commencement of the surgical procedure. The ability to correctly estimate the operative duration also helps in risk stratification, guides resource allocation, and allows better preoperative counseling of the patients' relatives prior to scoliosis correction surgery.

There is considerable variability in operative duration, particularly, in a relatively lengthy surgery like posterior arthrodesis for scoliosis; this variability is on account of distinct patient-, procedure-, and surgeon-specific factors. Surgeons' estimates of the operative duration have been found to be poorly predictive in previous studies.[1] While some factors, such as male sex, body mass index (BMI), number of screws used, need for osteotomy, severity of the curvature, and experience of the surgeon, have been separately found to correlate with operative duration in scoliosis correction surgery,[11–14] there is a lack of a comprehensive study focusing on all possible factors that can predict surgical duration in posterior spinal fusion (PSF) for idiopathic scoliosis. The objective of our study was to identify the factors that predict the variability in operative duration in PSF for adolescent idiopathic scoliosis (AIS). In addition, the operative duration was correlated with early postoperative outcome measures, such as the need for postoperative transfusion, need for postoperative intensive care unit (ICU) stay, length of hospital stay (LOS), SSI, and postoperative complications within 30 days from surgery.

METHODS

After prior approval of the Institutional Ethics Committee and with the due informed consent of the patients or their guardians, the hospital records and imaging of 150 AIS patients operated at a single center between January 2014 and January 2020 were retrospectively analyzed. All included patients had undergone deformity correction and instrumented spinal fusion by a posterior-only approach using a pedicle screw construct in a single sitting. Patients with a history of prior surgery, who had a simultaneous procedure on the spinal cord (such as detethering of a low-lying tethered cord) in the same sitting, or those who had a supplemental anterior procedure were excluded. All the surgeries were performed by a single chief surgeon, though the assistants did vary.

For this study, operative duration was defined as the time elapsed between the skin incision and wound closure. This was the primary outcome measure or the dependent variable. The independent variables were a set of patient-, procedure-, and surgeon-specific factors that were deemed to be possibly affecting the operative duration. These included the following: (1) patient-specific factors: age at the time of surgery, sex, BMI, Cobb angle of the major structural curve, flexibility index of the major structural curve, coronal deformity angular ratio (C-DAR; DAR is a unitless number that denotes the severity of the deformity and is calculated as the Cobb angle of the biggest scoliotic curve divided by the vertebral levels involved in the curve), total DAR (T-DAR, sum of coronal and sagittal DAR, in the event that there is an added kyphotic component in the deformity as well), thoracic sagittal profile (thoracic kyphosis, TK), lumbar sagittal profile (lumbar lordosis, LL), axial rotation (Nash and Moe grade), and the Lenke curve type (Type 1–6); (2) procedure-specific factors: number of levels fused, number of screws inserted, and the type of osteotomy used (classified as per the Schwab's anatomical spinal osteotomy classification),[15] and (3) surgeon-specific factors: experience of the chief surgeon (years spent as an attending consultant) and number of assistants and experience of the first assistant (months spent after entering into postgraduate training). Furthermore, early postoperative outcome measures (need for postoperative blood transfusion, need for ICU stay or postoperative mechanical ventilation, SSI, LOS, and postoperative complications within 30 days from surgery) were also noted. The postoperative complications were graded in accordance with the grading previously described by Rampersaud et al.[16]

Statistical analysis was performed using Stata 15 software (StataCorp Inc, TX, USA). Descriptive statistics were presented as mean (±SD), median (first and third quartiles) or frequency/percentage as applicable. Association between operative duration and continuous independent variables was assessed using Pearson's correlation/Spearman's rank correlation, while 1-way analysis of variance (ANOVA) was used for categorical independent variables. A P value of <0.05 was considered to be statistically significant. For multivariate analysis, a model-building exercise using backward stepwise regression was performed with the probability of removal of model terms set at 0.20. We forced age and sex as terms that had to be included in the model. The final model was evaluated for collinearity and interaction. For each of the predictive factors included in the model, regression coefficients (including the standardized regression coefficients, β) and 95% confidence limits were calculated. The standardized coefficient allowed us to compare the relative strength of various predictors within the model. We also studied the association between operative duration and early postoperative outcome measures using the 1-way ANOVA for categorical variables and Pearson's correlation for continuous variables.

RESULTS

The study population comprises 150 AIS patients, which included 61 men and 89 women. The mean age was 15.8 ± 3.8 years, and the mean BMI was 21.1 ± 2.3. The distribution of the scoliotic curves as per the Lenke classification was as follows: Type 1 = 90 (60%), Type 2 = 2 (1.3%), Type 3 = 23 (15.3%), Type 5 = 23 (15.4%), and Type 6 = 12 (8%). The mean preoperative Cobb angle of the major structural curve was 64.7° ± 13.6°, which was corrected to a mean postoperative Cobb angle of 18.7°± 8.3° after surgery, representing a 71% correction. The mean number of levels fused during PSF was 11.8 ± 2.1, whereas the mean number of screws inserted per procedure was 17.6 ± 3.4. The mean operative duration per patient was 236 ± 63 minutes, and the mean estimated blood loss (EBL) was 655 ± 127 cc (20.4% of estimated blood volume). The descriptive statistics of the various patient-, procedure-, and surgeon-specific independent variables used in the study along with the results of the bivariate correlation analysis with operative duration, which was the primary outcome measure, is given in Table 1. There was a significant positive correlation between operative duration and the severity of curve (coronal Cobb angle), axial rotation of apical vertebra, number of fused levels, and the number of screws inserted, whereas a significant negative correlation was noted between operative duration and the flexibility index of the major structural curve as well as the experience of the chief surgeon. The final model obtained from the multivariate regression analysis included the following factors (listed in order of the relative strength of prediction): experience of the chief surgeon (β = −0.36), Cobb angle of the major structural curve (β = 0.35), number of screws inserted (β = 0.28), C-DAR (β = 0.20), and the axial rotation of apical vertebra (β = −0.20 to 0.03) (Table 2). The model could explain 44% of the variability in the operative duration (R^2 = 0.44). Using the results of the analysis, the following formula was developed to predict the operative duration in AIS patients undergoing PSF:

Operative duration (minutes) = C + [1.5 × Cobb angle (degrees)] − [22.3 × experience of the chief surgeon (years)] + [2.2 × C-DAR] + [6.2 × number of screws inserted]+ N

C and N are constants. C = 184 for men, and 166 for women. N varies according to the axial rotation of the apical vertebra (N = 0, for Nash and Moe Grade 1; N= (−32), for Nash and Moe Grade 2; N = 5, for Nash and Moe Grade 3, and N = 6 for Nash and Moe Grade 4).

The mean postoperative LOS was 5.7 ± 2.1 days; 98/150 (65%) patients required perioperative blood transfusion. The rate of SSI in the study population was 4.6% (7/150), whereas 31/150 (21%) patients required postoperative ICU stay/mechanical ventilation. A total of 29 postoperative complications were seen in 25 patients (16%), a majority of them (19/29) were graded as "minor" complications as per the classification proposed by Rampersaud et al.[16] In addition to a significant positive correlation with the EBL, operative duration was also found to significantly correlate with the LOS and the need for perioperative blood transfusion—patients with longer operative times required more blood transfusions and had a longer hospital stay after surgery; however, there was no impact on the rate of SSI, need for postoperative ICU stay/mechanical ventilation, or the rate of early (<30 days) postoperative complications.

DISCUSSION

In the context of mounting administrative, societal, and political pressures on surgical services, identifying the predictors of operative duration for a surgical

Table 1. Descriptive statistics of various factors and their correlation with operative duration by bivariate analysis.

Factors	Summary Statistics[a]	Operative Duration, min[b], mean ± SD	Association with Operative Duration
Patient-specific factors			
Age, y	15.8 ± 3.8	-	0.08 (0.39)[c]
Sex			0.83 (0.10)[d]
M	42 (32%)	243 ± 68	
F	88 (68%)	231 ± 66	
BMI	21.1 ± 2.3	-	0.08 (0.39)[c]
Cobb angle (of the major structural curve)	64.7° ± 13.6°	-	0.38 (0.0001)[c]
Flexibility index (of the major structural curve) (%)	23.9 ± 12.8	-	−0.21 (0.02)[c]
C-DAR	8.7 ± 2.1	-	0.13 (0.15)[c]
T-DAR	10.3 ± 4.4	-	0.09 (0.32)[c]
Thoracic kyphosis	32.3° ± 14.6°	-	0.12 (0.19)[c]
Lumbar lordosis	49.2° ± 14.8°	-	0.10 (0.26)[c]
Axial rotation (Nash and Moe grade)			3.62 (0.01)[d]
1	14 (9.3%)	228 ± 68	
2	68 (45.3%)	219 ± 62	
3	43 (28.7%)	261 ± 83	
4	25 (16.7%)	263 ± 64	
Lenke curve type			0.78 (0.50)[d]
1	90 (60%)	232 ± 68	
2	2 (1.3%)	212 ± 57	
3	23 (15.3%)	258 ± 65	
4	0	-	
5	23 (15.3%)	216 ± 68	
6	12 (8%)	248 ± 56	
Procedure-specific factors			
Number of levels fused	11.8 ± 2.1	-	0.29 (0.003)[c]
Number of screws inserted	17.6 ± 3.4	-	0.33 (0.008)[c]
Type of osteotomy used			0.14 (0.18)[d]
1	118 (78.7%)	235 ± 72	
2	25 (16.7%)	229 ± 52	
3	5 (3.3%)	254 ± 81	
4	2 (1.3%)	264 ± 32	
Surgeon-specific factors			
Experience of the chief surgeon (y)	6.1 (4.9, 7)	-	−0.36 (0.001)[e]
Experience of the first assistant (mo)	39 (26, 58)	-	−0.21 (0.08)[e]
Number of assistants	3 (2, 3)	-	−0.12 (0.11)[e]

Abbreviations: BMI, body mass index; C-DAR, coronal deformity angular ratio; T-DAR, total deformity angular ratio.
[a]Mean ± SD for continuous variables with normal distribution, median (first quartile, third quartile) for continuous variables with non-normal distribution, frequency/percentage for categorical variables.
[b]Mentioned separately for each group for categorical variables only.
[c]Pearson's correlation was used for continuous variables with a normal distribution. Figure in cells denotes the Pearson's correlation coefficient *"r"* with *P* value in brackets.
[d]1-way analysis of variance used for categorical variables. Figure in cells denotes the "*F*" value with *P* value in brackets.
[e]Spearman's rank correlation was used for continuous variables with non-normal distribution. Figure in cells denotes the Spearman's rank correlation coefficient 'ρ (rho)' with *P* value in brackets.

procedure has 2 important implications, as follows: (1) maximizing the OR efficiency by minimizing overutilization or underutilization of OR time with indirect benefits in terms of reducing the number of postponed or canceled surgical procedures, and the waiting list time and (2) guides resource allocation and risk stratification, which in turn allows for better preoperative counseling. In most hospitals, the estimation of operative duration is

Table 2. Significant predictors of operative duration obtained from multivariate regression analysis.

Parameter	Regression Coefficient	Standardized Coefficient (β)	95% CI	*P* value
Experience of the chief surgeon	−22.3	−0.36	−32.39)–(to −12.23	<0.0001
Cobb angle of the major structural curve	1.5	0.35	0.61–2.52	0.001
Number of screws inserted	6.2	0.28	2.21–10.45	0.002
C-DAR	2.2	0.20	0.24–4.62	0.045
Apical vertebral rotation (Nash and Moe Grade)[a]				
2	−32.2	−0.21	−78.2 to 12.4	0.10
3	5.3	0.03	−42.9 to 53.2	0.08
4	6.4	0.03	−46.4 to 60.2	0.08

Abbreviations: C-DAR = coronal deformity angular ratio; CI = confidence interval.
Final model: $n = 150$; $R^2 = 0.44$; $P < 0.0001$.
[a]Nash and Moe Grade 1 was taken as a reference.

arbitrary and is generally based on the surgeon's routine estimate for a given surgical procedure or the historical times for the same procedure taken as a reference by the anesthesiologist or the OR manager. However, if the predictors of operative duration for a given surgical procedure in a particular OR setup are known, it would be possible to make a more accurate prediction of operative duration for each individual patient rather than making an average prediction for all the patients undergoing the same surgical procedure.[1] Prolonged operative duration has also been shown to impact multiple indices that form a part of a patient's early postoperative outcome in scoliosis surgery. In a retrospective study of 1691 patients who underwent posterior arthrodesis for AIS, Minhas et al reported that a total operating time exceeding 300 minutes was an independent risk factor for the requirement of perioperative blood transfusion.[17] Dupuis et al reported a multivariate logistic regression model that predicted the risk of homologous blood transfusion after scoliosis surgery with 92.3% accuracy, surgery lasting more than 255 minutes was an independent predictor.[18] While studies focusing solely on pediatric spinal deformities have yielded conflicting evidence regarding the impact of operative duration on the rate of SSI, there is robust evidence that prolonged operative duration increases the risk of SSI following spine surgery for degenerative spine disorders and adult spinal deformity.[9,19] In a prospective cohort of 702 surgically treated AIS patients, Carreon et al reported a non-neurological complication rate of 15.4%, where increased operative blood loss and prolonged surgery time were noted as risk factors.[20] In another study, scoliosis patients with a prolonged operative duration were more likely to have multiple complications after surgery rather than a single complication.[21]

A comprehensive assessment for predictive factors that influence the operative duration in posterior arthrodesis for AIS is lacking. Various studies have only explored the impact of individual variables on outcomes in scoliosis surgery, with some of them reporting a correlation with operative duration. Obesity has been found to correlate with operative duration in scoliosis correction surgery; AIS patients who were obese (BMI percentile > 85) were found to have a significantly longer operative time (324 ± 78 minutes vs 293 ± 55 minutes) than those who were not obese (BMI percentile < 85).[11] Miyanji et al reported that a larger curve in scoliosis patients was also associated with a longer operative time. For every 10° increase in Cobb angle, there was an increase of 78 minutes in the operative time.[22] In another study, AIS patients with a preoperative curve magnitude >70° were found to have a significantly longer operative time (median 6.5 hours vs 5 hours) when compared to those with a Cobb angle <70°.[23] Recently, studies have also focused on surgeon-specific factors impacting outcomes of scoliosis surgery. In a multicentre prospective study that included 165 AIS patients, young surgeons with an experience <5 years had significantly longer operating times (458 minutes vs 265 minutes) than surgeons with more than 5 years of experience. Ryu et al quantitatively expressed the learning curve for scoliosis surgery in terms of gains made in operative duration—till the surgeon's experience reached 23 to 25 cases, the operative duration showed a decreasing trend; after this, it stabilized.[24] In a multicentric study, Talathi et al noted that irrespective of whether the surgery was assisted by an orthopedic/neurosurgery resident or a fellow, the operative duration did not differ significantly, concluding that the experience of the first assistant did not impact the operative duration in scoliosis surgery.[25] Involvement of dual attending surgeons as compared to a single attending surgeon in scoliosis correction surgery has also been demonstrated to shorten the operative duration in AIS patients.[26] Another aspect that has been reported to influence the operative duration is the deployment of a specialized spine team that includes dedicated OR technicians and nurses, in addition to the surgeons. Miyanji et al reported a mean reduction of 53 minutes in operative duration after the institution of a specialized Pediatric Spine Surgical Team in the OR.[27] Similar findings were also noted by Murgai et al with the surgical time increasing by 27 minutes when <60% dedicated spine technicians or nurses were available in the OR team.[28] Significant predictors of operative duration in surgery for AIS were identified using a multivariate linear regression model by Heller et al. Cobb angle, osteotomy use, male sex, number of screws, Lenke 3 curve type, and the surgeon performing the procedure were the variables included in the final model that accounted for 56% of the variance in the operative duration.[13] Three different surgeons performed the surgeries in this study with the surgeon performing the surgery being the strongest predictor of the operative duration. Other surgeon-specific factors, such as the experience of the surgeons, the experience of the first assistant, and the number of assistants, were not included as variables. The authors also quantified osteotomy use as the percentage of patients in whom an osteotomy was performed, rather than grading the osteotomy in terms of invasiveness. A correlation of the operative duration with early postoperative outcomes was also not established in this study.

In our study, all the surgeries were performed by a single chief surgeon. The experience of the chief surgeon, Cobb angle of the major structural curve, number of screws inserted, C-DAR, and the axial rotation of the apical vertebra were identified as significant predictors of operative duration in the final multivariate regression model that accounted for 44% of the variability in operative duration in our study population—among these, experience of the chief surgeon was the strongest predictor as quantified by the standardized regression coefficient (β). The establishment of an independent correlation between the severity of the major structural curve and operative duration in our study corroborates the findings of previous studies.[14,22,23] The severity of the curve would also have factored in an increased curve stiffness (flexibility index) and the need for more extensive release (osteotomy use). While the number of levels fused and flexibility index of the major structural curve bore a positive correlation with the operative duration on bivariate analysis, these variables did not feature in the final model obtained from multivariate regression analysis. This is likely because these variables were already factored in with the number of screws used as an independent predictor in the final model. Previous studies[22,24] have reported that screw insertion accounts for 30% to 38% of the total operative duration in posterior arthrodesis for AIS. In comparison, exposure/dissection takes 10% to 15% of the total operative duration. Multiple studies have reported that low implant density pedicle screw constructs fare just as well as high-density pedicle screw constructs in terms of coronal and sagittal curve correction and the incidence of postoperative complications.[29,30] The implant density in our study was ~75%; lowering this implant density could also have shortened the operative duration in addition to the obvious benefits in terms of cost savings. Axial rotation of the apical vertebra has been previously reported to be associated with pedicle dysmorphia.[31,32] Increased apical vertebral rotation is associated with morphological pedicle types that are more difficult to cannulate, which can slow down a surgeon who is cautious of avoiding screw malposition at this step. Among the surgeon-specific factors, the experience of the chief surgeon was an independent predictor of operative duration in our study, corroborating the findings of Cahill et al.[12] While the chief surgeon was fellowship-trained in pediatric spinal deformity and had a substantial experience in performing surgery for degenerative lumbar and cervical disorders independently, the role of a chief surgeon in pediatric spinal deformity cases was donned just around the beginning of the recruitment period for this study. This suggests that at least in the early part of a surgeon's career, operative duration is significantly affected by experience. Contrary to the experience of the chief surgeon, neither the experience of the first assistant nor the number of assistants impacted the operative duration in our study. Talathi et al have previously reflected on similar findings in their study and noted that surgeons appeared to be adept at delegating responsibility to the assistants in accordance with their skill and level of expertise, and the level of participation of the assistant may differ under the supervisory role of the surgeon.[25] Being an academic institute without a dedicated spine fellowship program under our department, the residents who assisted the surgical procedures were rotated between different orthopedic subspecialties, such as joint arthroplasty, sports medicine, and musculoskeletal oncology. The operative duration correlated with the EBL, the need for postoperative blood transfusion, and LOS in our study, while it did not correlate with the need for ICU stay, rate of SSI, or rate of postoperative complications. This is likely because these outcome measures are multifactorial in nature and due consideration has to be given to the patient's comorbidities and anesthetic concerns, which were not assessed in this study. The small sample size and a retrospective study design remain the major limitations of our study. While every effort was made to include as many relevant variables as possible, this was limited by the availability of information from the hospital records. Intraoperative factors unknown to us could have influenced the operative duration—these can only be identified in a study with a prospective study design. With the advent of big data analysis and integration of artificial intelligence into health care, it is expected that hitherto "unknown" factors that influence the operative duration would also be identified, allowing for a more accurate estimation of operative duration. An important factor that we could not assess was the impact of a dedicated spine team, including the OR technician, radiographer, and nursing staff. However, the results of this study emphasize the need for each hospital and surgical team to identify the predictors of operative duration in their setup, so that prolonged operative duration can be better anticipated.

CONCLUSION

Our study led us to the development of a multivariate regression model that could explain 44% of the variability in operative duration. Among the variables included in the model, the experience of the chief surgeon and the severity of the curve were the strongest predictors of operative duration. Identification of such predictors is even more relevant in a lengthy and "high-stakes" surgical procedure, such as PSF for AIS where there is great variability in operative duration and increased risk of perioperative complications. The practical implications of this study—better planning of OR schedules and preoperative counseling of patients for potential negative outcomes associated with prolonged surgery—may be better realized if patients are recruited from multiple centers in a prospective study design.

REFERENCES

1. Eijkemans MJC, van Houdenhoven M, Nguyen T, Boersma E, Steyerberg EW, Kazemier G. Predicting the unpredictable: a new prediction model for operating room times using individual characteristics and the surgeon's estimate. *Anesthesiology*. 2010;112(1):41–49. doi:10.1097/ALN.0b013e3181c294c2

2. Ahn H, Kreder H, Mahomed N, Beaton D, Wright JG. Empirically derived maximal acceptable wait time for surgery to treat adolescent idiopathic scoliosis. *CMAJ*. 2011;183(9):E565-70. doi:10.1503/cmaj.101511

3. Clark S. Waiting times for scoliosis surgery. *Lancet*. 2008;371(9606):10–11. doi:10.1016/S0140-6736(08)60047-1

4. Dabke HV, Jones DAS, Ahuja S, Howes J, Davies PR. Should scoliosis patients be kept on a waiting list. *Eur Spine J*. 2005;14(Suppl 1):S7.

5. Procter LD, Davenport DL, Bernard AC, Zwischenberger JB. General surgical operative duration is associated with increased risk-adjusted infectious complication rates and length of hospital stay. *J Am Coll Surg*. 2010;210(1):60–65. doi:10.1016/j.jamcollsurg.2009.09.034

6. Rambachan A, Mioton LM, Saha S, Fine N, Kim JYS. The impact of surgical duration on plastic surgery outcomes. *Eur J Plast Surg*. 2013;36(11):707–714. doi:10.1007/s00238-013-0851-2

7. Daley BJ, Cecil W, Clarke PC, Cofer JB, Guillamondegui OD. 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(4):550–558. doi:10.1016/j.jamcollsurg.2014.12.040

8. Kim BD, Hsu WK, De Oliveira GS, Saha S, Kim JYS. Operative duration as an independent risk factor for postoperative complications in single-level lumbar fusion: an analysis of 4588 surgical cases. *Spine (Phila Pa 1976)*. 2014;39(6):510–520. doi:10.1097/BRS.0000000000000163

9. Puffer RC, Murphy M, Maloney P, et al. Increased total anesthetic time leads to higher rates of surgical site infections in spinal fusions. *Spine (Phila Pa 1976)*. 2017;42(11):E687–E690. doi:10.1097/BRS.0000000000001920

10. Hersey AE, Durand WM, Eltorai AEM, DePasse JM, Daniels AH. Longer operative time in elderly patients undergoing posterior lumbar fusion is independently associated with increased complication rate. *Global Spine J*. 2019;9(2):179–184. doi:10.1177/2192568218789117

11. Hardesty CK, Poe-Kochert C, Son-Hing JP, Thompson GH. Obesity negatively affects spinal surgery in idiopathic scoliosis. *Clin Orthop Relat Res*. 2013;471(4):1230–1235. doi:10.1007/s11999-012-2696-6

12. 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(16):1333–1339. doi:10.2106/JBJS.M.01265

13. Heller A, Melvani R, Thome A, Leamon J, Schwend RM. Predictors of variability in the length of surgery of posterior instrumented arthrodesis in patients with adolescent idiopathic scoliosis. *J Pediatr Orthop B*. 2016;25(3):258–262. doi:10.1097/BPB.0000000000000274

14. Nugent M, Tarrant RC, Queally JM, Sheeran P, Moore DP, Kiely PJ. Influence of curve magnitude and other variables on operative time, blood loss and transfusion requirements in adolescent idiopathic scoliosis. *Ir J Med Sci*. 2016;185(2):513–520. doi:10.1007/s11845-015-1306-5

15. Schwab F, Blondel B, Chay E, et al. The comprehensive anatomical spinal osteotomy classification. *Neurosurgery*. 2014;74(1):112–120. doi:10.1227/NEU.0000000000000182o

16. Rampersaud YR, Moro ERP, Neary MA, et al. Intraoperative adverse events and related postoperative complications in spine surgery: implications for enhancing patient safety founded on evidence-based protocols. *Spine (Phila Pa 1976)*. 2006;31(13):1503–1510. doi:10.1097/01.brs.0000220652.39970.c2

17. Minhas SV, Chow I, Bosco J, Otsuka NY. Assessing the rates, predictors, and complications of blood transfusion volume in posterior arthrodesis for adolescent idiopathic scoliosis. *Spine (Phila Pa 1976)*. 2015;40(18):1422–1430. doi:10.1097/BRS.0000000000001019

18. Dupuis C, Michelet D, Hilly J, et al. Predictive factors for homologous transfusion during paediatric scoliosis surgery. *Anaesth Crit Care Pain Med*. 2015;34(6):327–332. doi:10.1016/j.accpm.2015.04.003

19. Glotzbecker MP, Riedel MD, Vitale MG, et al. What's the evidence? Systematic literature review of risk factors and preventive strategies for surgical site infection following pediatric spine surgery. *J Pediatr Orthop*. 2013;33(5):479–487. doi:10.1097/BPO.0b013e318285c507

20. Carreon LY, Puno RM, Lenke LG, et al. Non-neurologic complications following surgery for adolescent idiopathic scoliosis. *J Bone Joint Surg Am*. 2007;89(11):2427–2432. doi:10.2106/JBJS.F.00995

21. Hod-Feins R, Abu-Kishk I, Eshel G, Barr Y, Anekstein Y, Mirovsky Y. Risk factors affecting the immediate postoperative course in pediatric scoliosis surgery. *Spine (Phila Pa 1976)*. 2007;32(21):2355–2360. doi:10.1097/BRS.0b013e3181558393

22. Miyanji F, Slobogean GP, Samdani AF, et al. Is larger scoliosis curve magnitude associated with increased perioperative health-care resource utilization? A multicenter analysis of 325 adolescent idiopathic scoliosis curves. *J Bone Joint Surg Am*. 2012;94(9):809–813. doi:10.2106/JBJS.J.01682

23. Tarrant RC, Queally JM, O'Loughlin PF, Sheeran P, Moore DP, Kiely PJ. Preoperative curves of greater magnitude (>70°) in adolescent idiopathic scoliosis are associated with increased surgical complexity, higher cost of surgical treatment and a delayed return to function. *Ir J Med Sci*. 2016;185(2):463–471. doi:10.1007/s11845-015-1391-5

24. Ryu KJ, Suh SW, Kim HW, Lee DH, Yoon Y, Hwang JH. Quantitative analysis of a spinal surgeon's learning curve for scoliosis surgery. *Bone Joint J*. 2016;98-B(5):679–685. doi:10.1302/0301-620X.98B5.36356

25. Talathi NS, Flynn JM, Pahys JM, et al. The effect of the level of training of the first assistant on the outcomes of adolescent

idiopathic scoliosis surgery. *The Journal of Bone and Joint Surgery*. 2019;101(6):e23. doi:10.2106/JBJS.18.00018

26. Chan CYW, Kwan MK. Perioperative outcome in posterior spinal fusion for adolescent idiopathic scoliosis: a prospective study comparing single versus two attending surgeons strategy. *Spine (Phila Pa 1976)*. 2016;41(11):E694–E699. doi:10.1097/BRS.0000000000001349

27. Miyanji F, Greer B, Desai S, et al. Improving quality and safety in paediatric spinal surgery: the team approach. *Bone Joint J*. 2018;100-B(4):493–498. doi:10.1302/0301-620X.100B4.BJJ-2017-1202.R1

28. Murgai RR, Andras LM, Nielsen E, Scott G, Gould H, Skaggs DL. Dedicated spine nurses and scrub technicians improve intraoperative efficiency of surgery for adolescent idiopathic scoliosis. *Spine Deform*. 2020;8(2):171–176. doi:10.1007/s43390-020-00037-0

29. Quan GMY, Gibson MJ. Correction of main thoracic adolescent idiopathic scoliosis using pedicle screw instrumentation: does higher implant density improve correction? *Spine (Phila Pa 1976)*. 2010;35(5):562–567. doi:10.1097/BRS.0b013e3181b4af34

30. Bharucha NJ, Lonner BS, Auerbach JD, Kean KE, Trobisch PD. Low-density versus high-density thoracic pedicle screw constructs in adolescent idiopathic scoliosis: do more screws lead to a better outcome? *Spine J*. 2013;13(4):375–381. doi:10.1016/j.spinee.2012.05.029

31. Czerwein J, Thornhill B, Amaral T, Wollowick A, Sharan A, Sarwahi V. P93. Does CT based pedicle morphology correlate with degree of curve rotation grade or level of apex? *Spine J*. 2008;8(5):145S-146S. doi:10.1016/j.spinee.2008.06.735

32. Sarwahi V, Amaral T, Wendolowski S, et al. MRIs are less accurate tools for the most critically worrisome pedicles compared to CT scans. *Spine Deform*. 2016;4(6):400–406. doi:10.1016/j.jspd.2016.08.002

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