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ORIGINAL ARTICLE

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

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Abstract
Background Surgical procedures to correct larger curve magnitudes >70° in patients with adolescent idiopathic scoliosis (AIS) are still common; despite their increased complexity, limited research has assessed the effect of preoperative curve severity on outcomes.
Aim This study aimed to examine the impact of preoperative curves >70° vs. those ≤70° on perioperative, functional and financial outcomes in patients with AIS undergoing posterior spinal fusion (PSF).
Methods Seventy seven eligible AIS patients who underwent PSF were prospectively followed-up, until return to preoperative function was reported. Preoperative curves >70° vs. ≤70° were analysed in relation to surgical duration, estimated blood loss, perioperative complications, length of hospitalisation, return to function and cost of surgical treatment per patient.
Results Severe preoperative curves >70°, identified in 21 patients (27.3 %), were associated with significantly longer surgical duration (median 6.5 vs. 5 h, $p = 0.001$) and increased blood loss (median 1250 vs. 1000 ml, $p = 0.005$)—these patients were 2.1 times more likely to receive a perioperative blood product transfusion (Relative Risk 2.1, CI 1.4–2.7, $p = 0.004$). Curves >70° were also associated with a significantly delayed return to school/college, and an increased cost of surgical treatment (€33,730 vs. €28,620, $p < 0.0001$).
Conclusion Surgeons can expect a longer surgical duration, greater intraoperative blood loss and double the blood product transfusion risk when performing PSF procedures on AIS patients with curves greater than 70° vs. those ≤70°. Surgical correction for curves >70°, often as a result of lengthy surgical waiting lists, also incurs added expense and results in a partial delay in early functional recovery.

Keywords Adolescent idiopathic scoliosis · Large deformity magnitude · Posterior spinal fusion · Perioperative outcomes · Functional outcomes · Cost of surgical treatment · Surgical waiting times

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Introduction

Adolescent idiopathic scoliosis (AIS) is a three dimensional spinal deformity characterised by thoracic and lumbar scoliosis, relative thoracic hypokyphosis and rotation of the spine in otherwise healthy children at, or around puberty. Curve progression, or increasing deformity, is influenced by several factors including curve magnitude, peak growth velocity, curve phenotype, gender and patient maturity (age at diagnosis, menarchal status and the amount of skeletal growth remaining) [1]. When conservative treatment measures fail, surgery is often necessary; its primary goal is to halt curve progression and achieve a balanced spine with maximum permanent correction of the deformity [2]. Primary curves with a Cobb angle greater than 45°–50° are indications for surgery [2], however, procedures to correct curves greater than 70° (United States [3]; Turkey [4]) and greater than 90° (Poland [5]; United States [6]) are still common, particularly in health-care systems where wait-times for assessment and surgery allow deterioration. Rapid curve progression during phases of rapid growth can occur while patients wait for treatment [7], increasing the likelihood of longer operative time, increased hospital stay and additional surgeries such as anterior release and staged posterior correction, as well as other complications such as excessive intraoperative blood loss, neurologic deficits or inadequate curve correction [7, 8].

As the Cobb angle increases, AIS patients' health-related quality of life scores, in domains such as pain, self-image and function, tend to decrease [9, 10]. From a respiratory perspective, preoperative Cobb angles exceeding 70° have been associated with impaired pre- [11] and postoperative [12] pulmonary function. Relatively large deformities including curves >70° [13], >90° [6], between 70° and 100° [3] and curves >100° [5] in AIS patients have been assessed with regard to safety and surgical efficacy in achieving an optimal correction. However, no study, of which the current investigators are aware has yet reported on the perioperative and financial outcomes associated with curves >70° vs. ≤70° specifically, after instrumented posterior spinal deformity correction and fusion (PSF). The fact that cost-effectiveness is becoming an important criterion within health service management, particularly within spinal surgery, increases the need to quantify and analyse costs of surgical treatment in relation to deformity magnitude [14, 15]. In addition, a better understanding of complications, or issues, associated with surgical treatment of more severe deformity will benefit surgeons in treatment planning and risk assessment.

The primary aim of the current study was to investigate the impact of severe preoperative curves (>70°) vs. those ≤70° on perioperative complexity (i.e. blood loss, surgical duration, perioperative complication rates and length of hospital stay). Secondary aims included investigating the impact of curve severity on timing of return to postoperative function, financial cost and surgical waiting times.

Methods

Study design and patient selection

Between January 2010 and April 2012, 77 consecutive patients undergoing PSF for AIS at two Dublin tertiary centres [Our Lady's Children's Hospital (OLCHC; public hospital) and the Blackrock Clinic (BRC; private hospital)] were enrolled in this prospective study [16]. The study was approved by the hospitals' respective ethics committees prior to commencement. Inclusion criteria included a diagnosis of AIS, treatment with one-stage PSF and normal ambulatory and functional motor capabilities. Exclusion criteria included a history of prior spine surgery, anterior fusion and complex co-morbidities that might confound outcomes including neurological, cardiac, metabolic, endocrine and psychiatric disorders. From the 78 consecutive AIS patients who underwent spinal fusion during the study period, one case was excluded due to a diagnosis of hypothyroidism; the remaining 77 cases successfully completed follow-up. The majority of procedures ($n = 68$; 88 %) were carried out by the senior author (PJK); nine procedures were carried out by the second senior author (DPM). In both hospitals, the same perioperative protocol was in place in terms of perioperative analgesia, postoperative transfusion and the use of tranexamic acid. In addition, both centres employ the same physiotherapy protocol, which has been discussed in detail in a previous study [16].

Primary outcome

The primary outcome assessed was impact of preoperative curve magnitude >70° vs. ≤70° on perioperative complexity as defined by key perioperative parameters including: intraoperative blood loss, surgical duration, perioperative complications and length of hospital stay. Data on intra-surgical factors (surgical duration and estimated blood loss), length of hospital stay, perioperative (i.e. intra and post) complications as well as hospital readmission incidence were collected from medical charts and operative records. The definition of a perioperative complication in the current study was broad and inclusive, incorporating adverse events occurring within 30 days of surgery. Major complications included adverse events necessitating a longer hospital/intensive care stay or requiring further medical and surgical interventions including pneumothorax requiring chest drain insertion, and respiratory failure. All events with transient detrimental effect including medical adverse events or surgical complications with limited need for further intervention were deemed 'minor' including perioperative blood product transfusion, superficial wound ooze or infection, ileus, pneumonia and respiratory or urinary tract infections.

Immediate preoperative and serial postoperative radiographs were measured using the Cobb method; data on preoperative primary curve angle, number of fused vertebrae, degree of thoracic and lumbar correction as well as percent thoracic and lumbar curve correction were documented.

Baseline socio-demographic data (age at surgery, gender and race), preoperative co-morbidities, weight and height on admission, were collected from medical charts and hospital admission assessments.

Secondary outcome

The secondary outcomes assessed were the relationship of preoperative Cobb angle with (1) postoperative return to function (school/college, physical activity and return to a normal sleeping pattern), (2) estimated in-hospital cost of surgical treatment and (3) surgical waiting time.

Follow-up was performed by the study coordinator (RCT) via telephone interviews with parents and when indicated, the adolescent, every 6–8 weeks from the 6 weeks postoperative check-up using a structured questionnaire, until return to all functional activity outcomes under analysis was reported [16]. Data were prospectively collected on timing of return to: (1) a normal sleeping pattern uninterrupted by pain, as per the preoperative habitual pattern, (2) school/college part-time (i.e. half-days) and full-time (i.e. full days), (3) part-time physical activity, defined as low impact, non-contact, non-competitive recreational physical activity greater than walking (e.g. gentle swimming, yoga and jogging) as well as unrestricted physical activity, including competitive athletic activity and contact sports. If non-return to any of the functional outcomes under analysis was reported during the first-year after surgery, patients were followed up to a minimum of 18 months; the authors were prepared to follow-up patients to 2 years, if required.

An estimated hospital-specific cost of surgery per patient was performed based on key selected health-care resource outcomes including cost of intensive care and in-patient room (per 24 h), theatre time (per hour), number of instrumented pedicle screws/rods used, blood product transfusions (per unit), radiographs, parenteral nutrition use and daily blood profiles analysed. The selected in-hospital health-care costs incurred over the study period were provided by the respective finance departments of Our Lady's Children's Hospital and the Blackrock Clinic. The surgical waiting time for each patient, defined as the time the patient was placed on the surgical list to the time of surgery, was retrospectively collected from the respective hospitals electronic patient admission system.

Statistical analysis

Data were analysed using the Statistical Package for Social Sciences, Version 19.0 (SPSS® Inc, Chicago, IL). Data are summarised as number of observations or percentages, means ± standard deviations (SD) or medians with interquartile ranges (IQR). Relationships between categorical variables were examined using cross-tabulations and the Chi-squared statistics test. For continuous normally distributed data, the Independent t test was performed; Mann–Whitney U test was used for non-parametric data. Spearman's correlation coefficient (r_s) was used to assess the relationship between non-parametric continuous variables. Binary logistic regression was used to determine the variables independently associated with curves >70°. The relative risk (RR) and 95 % confidence intervals (CI) were calculated for each predictor factor in the final model. Statistical significance was set at $p < 0.05$.

Results

The mean follow-up time of the 77 eligible patients who underwent PSF using all pedicle screw instrumentation was 12.8 months (SD 5.7). The mean age at surgery was 15.04 years (SD 1.89) (Table 1). An equal proportion of patients attended each included hospital [OLCHC; $n = 39$ patients (50.6 %)].

The mean preoperative primary Cobb angle was 62.3° (SD 13.2). Severe curves (>70°) were noted in 21 patients (27.3 %) (three of these patients had curves >90°). Preoperative curves between 40° and 70° were identified in 55 patients (71.4 %); one patient had a curve of 35°.

A major perioperative complication was identified in four cases (5.2 %) including, pneumothorax ($n = 2$), superior mesenteric artery syndrome ($n = 1$) and type I respiratory failure ($n = 1$). Almost half the sample received a blood product transfusion (46.8 %).

Primary outcome

In the univariate analysis, preoperative curves >70° were associated with significantly greater intraoperative blood loss (median 1250 vs. 1000 ml, $p = 0.005$), longer surgical duration (median 6.5 vs. 5 h, $p = 0.001$), an increased minor perioperative complication rate (90.5 vs. 67.9 %, $p = 0.044$) as well as blood product transfusion requirement (Table 2). No significant difference was detected between the two curve severity groups with respect to major perioperative complication rate ($p = 0.57$), length of hospital stay ($p = 0.498$), hospital readmission incidence ($p = 0.423$) or demographic

Table 1 Characteristics of the cohort ($N = 77$)

Age at surgery (yrs), mean (SD)	15.04 (1.89)
Female, *n* (%)	72 (93.5)
Caucasian, *n* (%)	76 (98.7)
Most prevalent preoperative co-morbidity, *n* (%)	
Asthma	14 (18.2)
Preoperative primary Cobb angle (°), mean (SD)	62.3 (13.2)
Preoperative curve severity category (°), *n* (%)	
40–70[a]	56 (72.7)
>70–80	12 (15.6)
>80[b]	9 (11.7)
No. of fused vertebrae, median (IQR)	12 (10–13)
Surgical duration (hrs), median (IQR)	5.5 (4.3–7)
Estimated intraoperative blood loss (ml), median (IQR)	1012 (791–1400)
Perioperative allogeneic RBC transfusion, *n* (%)	33 (42.9)
Overall minor perioperative complication rate, *n* (%)	57 (74)
Minor perioperative complications, *n* (%)	
Gastrointestinal (ileus)	7 (9.1)
Respiratory-related[c]	16 (20.8)
Electrolyte imbalance requiring supplementation	14 (18.2)
Perioperative blood product transfusion[d]	36 (46.8)
Superficial wound infection	5 (6.5)
Overall major perioperative complication rate, *n* (%)	4 (5.2)
Major perioperative complications, *n* (%)	
Pneumothorax requiring chest drain insertion	2 (2.6)
SMA syndrome	1 (1.3)
Type 1 respiratory failure	1 (1.3)
Weight on admission (kg), mean (SD)	52 (10.8)
Length of hospital stay (days), median (IQR)	10 (8–11)
Hospital readmission incidence, *n* (%)	3 (3.9)

Yrs years, *SD* standard deviation, *IQR* interquartile range, *hrs* hours, *RBC* red blood cell, *SMA* superior mesenteric artery, *kg* kilogram

[a] One case with a preoperative curve degree of 35° was included in the 40°–70° category

[b] Includes three cases with a preoperative curve >90°

[c] Includes pneumonia ($n = 5$) ± pleural effusion ($n = 11$) ± atelectasis ($n = 4$) ± lower respiratory tract infection ($n = 1$)

[d] Transfusion of allogeneic red blood cells ($n = 33$) ± platelets ($n = 3$) ± fresh-frozen plasma ($n = 10$)

factors. After controlling for age at surgery, gender and surgeon in the multivariate analysis, 'any perioperative blood product transfusion' remained the strongest independent factor associated with preoperative curves >70° (RR 2.1, CI 1.4–2.7, $p = 0.004$).

As regards the differences between the two institutions involved in this study (i.e. OLCHC vs. BRC, respectively)—patients who attended OLCHC were significantly more likely to have been younger at the time of surgery [mean 14.3 years (SD 1.5) vs. 15.7 years (SD 1.9), $p = 0.001$]—have a significantly larger preoperative curve magnitude [mean 67° (SD 13.2) vs. 57° (SD 11.2), $p = 0.001$] and remain in hospital for a shorter duration [median 8 days (IQR 7–10) vs. 10 days (IQR 9–11), $p < 0.0001$].

Secondary outcomes: return to postoperative function

A significantly delayed return to school/college full-time, by approximately 1 month, was observed in patients with preoperative curves >70° (3.5 vs. 2.5 months, $p = 0.045$) (Table 3). The timing of return to both part-time and unrestricted physical activity was similar between the curve severity groups—subjects in both groups returned to unrestricted physical activity by a median of 6 months ($p = 0.418$).

Table 2 Univariate analysis of the effect of preoperative curves >70° vs. ≤70° in relation to radiographic, anthropometric and perioperative factors

Factor	Primary Curves >70° ($n = 21$)	Primary Curves ≤70° ($n = 56$)	p value
Age at surgery (yrs), mean (SD)	14.5 (1.5)	15.2 (2)	0.149
Weight on admission (kg), mean (SD)	49.7 (8.8)	52.8 (11.5)	0.256
BMI (corrected) on admission[a] (kg), mean (SD)	18.9 (2.4)	20 (3.7)	0.209
Preoperative primary curve (°), mean (SD)	80 (7.3)	56 (8.4)	<0.0001
Correction of thoracic curve (°), median (IQR)	52 (45–63)	39 (31–46)	<0.0001
Postoperative thoracic curve (°), median (IQR)	25 (17.5–30)	14 (10–21)	<0.0001
Percent thoracic curve correction, median (IQR)	66.7 (61–78)	73.3 (63–82)	0.225
Correction of lumbar curve, median (IQR)	38 (25–56)	34 (26–40)	0.406
Postoperative lumbar curve (°), median (IQR)	14.5 (9.5–26)	13 (7–18)	0.428
Percent lumbar curve correction, median (IQR)	74 (52–83.6)	70 (59–85)	0.926
No. of fused vertebrae, median (IQR)	13 (12–14)	11 (10–13)	<0.0001
Surgical duration (hrs), median (IQR)	6.5 (5.6–7.3)	5 (4–6)	0.001
Estimated intraoperative blood loss (ml), median (IQR)	1250 (991–2000)	1000 (699–1303)	0.005
Allogeneic RBC transfusion, n (%)	14 (66.7)	19 (33.9)	0.02
Minor perioperative complication rate, n (%)	19 (90.5)	38 (67.9)	0.044
Minor complications, n (%)			
Gastrointestinal (ileus)	0	7 (12.5)	0.18
Respiratory-related[b]	2 (9.5)	14 (25)	0.209
Electrolyte imbalance requiring	5 (23.8)	9 (16.1)	0.433
Supplementation			
Perioperative blood product transfusion[c]	16 (76.2)	20 (35.7)	0.002
Superficial wound infection	2 (9.5)	3 (5.4)	0.61
Major perioperative complication rate, n (%)	0	4 (7.1)	0.57
Length of hospital stay (days), median (IQR)	10 (8–11.5)	9.5 (8–11)	0.498
Hospital readmission incidence, n (%)	1 (4.8)	2 (3.6)	0.423
Surgical waiting time (wks), median (IQR)	50 (26–72)	30 (17–49)	0.029

Yrs years, *SD* standard deviation, *kg* kilogram, *BMI* body mass index, *IQR* interquartile range, *hrs* hours, *RBC* red blood cell, *wks* weeks

[a] Corrected height was calculated using the height loss equation described by Ylikokli [17]; corrected BMI was then computed (i.e. weight in kg/corrected height in m^2)

[b] Includes pneumonia ($n = 5$) ± pleural effusion ($n = 11$) ± atelectasis ($n = 4$) ± lower respiratory tract infection ($n = 1$)

[c] Transfusion of allogeneic red blood cells ($n = 33$) ± platelets ($n = 3$) ± fresh-frozen plasma ($n = 10$)

Cost analysis and surgical waiting time

A strong positive correlation between preoperative primary curve degree and total cost of surgical treatment per patient was demonstrated ($r_s = 0.578$, $p < 0.0001$) (Fig. 1). The overall median cost of surgical treatment per patient for preoperative curves >70° (€33,730) was significantly higher than for curves ≤70° (€28,620) ($p < 0.0001$). Increased implant costs with greater numbers of pedicle screws, rods and specialist rods used ($p < 0.0001$), were identified as major financial contributors to such increased costs (Table 4).

The median surgical waiting time for all patients in this study was 33 weeks (median 50 weeks for OLCHC patients; median 22 weeks for BRC patients; $p < 0.0001$). Severe preoperative curves greater than 70° were associated with a significantly longer surgical waiting time (median 50 vs. 30 weeks; $p = 0.029$) (Table 2). In a separate correlation analyses, longer surgical waiting times were positively correlated with higher intraoperative blood loss ($r_s = 0.27$, $p = 0.044$), a greater number of fusions ($r_s = 0.402$, $p = 0.002$), longer surgical duration ($r_s = 0.565$, $p < 0.0001$) and increased cost of surgical treatment ($r_s = 0.547$, $p < 0.0001$).

Table 3 Association between preoperative curves >70° vs. ≤70°, and reported timing of postoperative return to function after posterior spinal fusion (months)

Factor	Primary Curves >70° ($n = 21$)	Primary Curves ≤70° ($n = 56$)	p value
Follow-up time after surgery, mean (SD)	12.9 (6.4)	12.7 (5.6)	0.891
Return to school/college part-time[a]	1.5 (1–1.7)	1.5 (1–1.6)	0.935
Return to school/college full-time[b]	3.5 (1.5–4.8)	2.5 (1.5–3)	0.045
Return to part-time physical activity[c]	3 (1.7–3.2)	2.7 (1.5–4)	0.957
Return to unrestricted physical activity[d]	6 (5–12)	6 (4–8)	0.418
Return to a normal sleeping pattern uninterrupted by pain, as per the preoperative pattern[e]	0.5 (0.2–0.75)	0.5 (0.1–1)	0.977

Continuous data are presented as medians with interquartile ranges unless otherwise indicated

SD standard deviation

[a] $n = 57$ (two cases excluded who did not attend school/college; $n = 18$ cases only returned full-time due to the timing of their surgery being just prior to, or during the summer holiday)

[b] $n = 75$ (two cases excluded who did not attend school/college preoperatively)

[c] $n = 74$ (three cases excluded who never participated in part-time physical activity preoperatively)

[d] $n = 70$ (seven cases excluded who never participated in unrestricted or 'any' physical activity greater than walking preoperatively; of the 70 eligible cases there were three missing values of those who did not return to unrestricted physical activity during the study)

[e] $n = 76$; includes one missing value of a case (in the >70° category) who did not return to a normal sleeping pattern during study (follow-up to 21 months)—chronic pain was the reported barrier to sleep

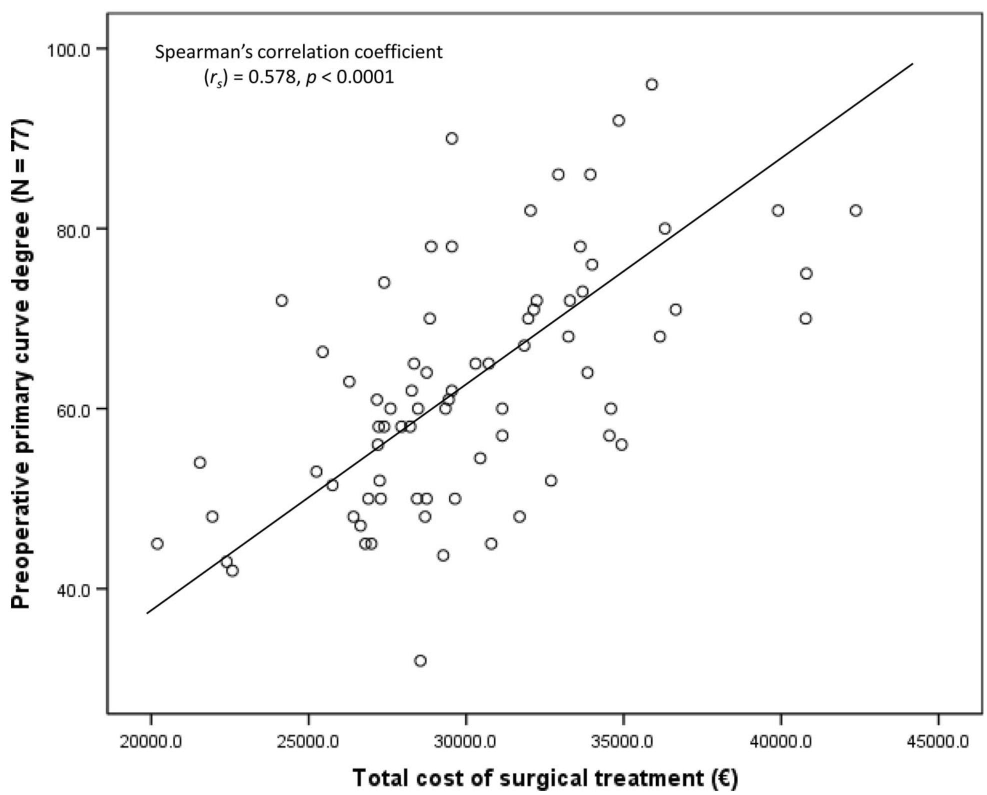

Fig. 1 Correlation between preoperative primary curve degree and total cost of surgical treatment per patient in Euros, from admission to hospital discharge. This *figure* demonstrates that the greater the preoperative Cobb curve angle, the higher the total cost of surgical treatment per patient

Discussion

The current study was undertaken to investigate the impact of severe preoperative curves >70° vs. those ≤70° on perioperative, functional and financial outcomes in a relatively homogenous cohort of AIS patients following PSF. The investigators demonstrated that surgical correction of more severe preoperative deformity >70° in patients with AIS is associated with significantly greater intraoperative blood loss and number of fused vertebrae, longer

Table 4 Estimated cost of surgical treatment per patient in Euro based on key health-care resource outcomes by curve severity group

Resource	Primary Curves >70° ($n = 21$) (€)	Primary Curves ≤70° ($n = 56$) (€)	p value
In-patient room cost/intensive care	9000 (8000–11,150)	8950 (7400–10,500)	0.396
Theatre time[a]	9750 (8438–10,875)	7500 (6206–9282)	0.001
Pedicle screws, rods	13,500 (12,500–14,500)	11,500 (10,500–13,500)	<0.0001
Blood product transfusions (RBC ± platelets ± fresh-frozen plasma)	500 (376–731)	249 (249–498)	<0.0001
Other: radiographs, total parenteral nutrition use, daily blood profiles analysed	550 (445–645)	520 (445–595)	0.559
Total cost of surgical treatment[b]	33,730 (30,794–36,102)	28,620 (27,033–31,144)	<0.0001

Data are presented as medians with interquartile ranges

With the exception of theatre time, costs incurred during the study are based on reported figures provided by the respective Finance Departments of Our Lady's Children's Hospital and the Blackrock Clinic

RBC red blood cell

[a] Estimated theatre time costs based on data from: model of Care for Elective Surgery, Including Implementation Guide. The National Clinical Programme in Surgery (2011). Health Service Executive, Royal College of Surgeons in Ireland and the College of Anaesthetists of Ireland [18]

[b] From the point of hospital admission to hospital discharge inclusive

surgical duration, an increased minor perioperative complication rate, as well as greater (≈18 %) total cost of surgical treatment. Patients with severe curves >70° were 2.1 times more likely to receive a blood product transfusion. A significantly delayed postoperative return to school/college full-time in patients with preoperative curves >70° than ≤70° after PSF was also observed.

No serious major complications occurred in either curve severity group in this study. Preoperative curve magnitude did not negatively influence overall major perioperative complication rates, or length of hospital stay—which is highly reassuring for both patients and surgeons. Miyanji et al. [15]. ($n = 325$ AIS patients) similarly found no association between duration of hospitalisation and curve magnitude. It is clinically relevant, however, that patients with curves >70° were over twice as likely to receive a blood product transfusion. In agreement with this observation, it has been shown that the odds of AIS patients receiving a perioperative blood transfusion increase 1.5-fold for every 10° increase in curve magnitude [15]. Based on the current analysis, in addition to other reports [15], surgeons can expect an increased blood product transfusion risk when performing PSF on AIS patients with larger curve magnitudes.

Significantly increased intraoperative blood loss was identified in patients with preoperative curves >70° vs. ≤70° in this study—a finding at variance with some existing reports [7]. In an idiopathic scoliosis cohort examined by Guay et al. [19], no correlation between intraoperative bleeding and Cobb curve angle was found. It is notable that the mean preoperative Cobb angle in the aforementioned study (55.4°) was lower than that in the current study (62.3°). Other investigators report that preoperative kyphosis rather than Cobb curve angle predicts increased blood loss [20]. To further elucidate these findings, more research is needed.

Previous studies have examined cost of surgical treatment for AIS in relation to hospital charges, surgical approach and spinal instrumentation [21, 22]; published European data on such cost analyses are lacking. To the current investigators' knowledge, this is the first study to provide data concerning estimated cost of surgical treatment with respect to preoperative curve magnitude. A significantly increased median cost of surgical treatment per patient for curves >70° (€33,730) than for those ≤70° (€28,620) was observed in this study (≈18 % cost difference). Similar to existing reports [21, 23], spinal implants including pedicle screws/rods, accounted for 40 % of the total cost of surgery per patient in the >70° curve group—a resource identified as the largest financial contributor to total cost of treatment. More severe curves require longer fusions, hence the need for more spinal instrumentation with its associated cost. These data suggest a significant financial benefit of timely surgical intervention in cases where rapid curve progression is evident.

This study highlights that larger preoperative curve magnitudes greater than 70° are associated with significantly longer surgical waiting times (median 50 vs. 30 weeks) with some of these patients waiting over 72 weeks (≈17 months) for surgery. We also found that longer surgical waiting times correlated with increased blood loss, longer surgical duration, longer fusions required, and an increased cost of surgical treatment. These data add to the literature, and support existing international studies [24]. According to Miyanji et al. [25] in the United States, from a surgeon's perspective, lengthy waitlists have a significantly negative impact on the peri and postoperative care of scoliosis patients by increasing the complexity of surgery. In a Canadian AIS cohort, Ahn et al. [7] found that patients who waited longer than 6 months for surgery had greater progression of curvature, longer surgeries, an increased number of levels fused, as well as an increased risk of additional surgical procedures and other adverse events. Considered together, efforts to support waiting list initiatives in the AIS population are likely to give rise to reduced surgical cost, better outcomes and more manageable curvatures being dealt within a timely fashion.

An interesting and novel finding from this study was the significantly delayed postoperative return to school/college full-time, by approximately 1 month, in patients with preoperative curves >70° vs. ≤70°. Factors such as fear, pain, motivation and self-image levels may have impacted upon the return to school/college rates in our cohort; however, such factors were not collected in this study which limits further comment. Of note, curve severity did not appear to influence the timing of return to physical activity after PSF. Fabricant et al. [26]. examined 42 athletically active adolescents who underwent PSF for AIS, and similarly found no association between major preoperative curve magnitude and postoperative return to physical activity levels. The current study further extends this research—indicating that larger curve magnitudes >70° do not negatively impact on the timing of when AIS patients return to physical activity after PSF; however, these patients can expect a delay in returning to school/college full-time.

Limitations of this study include its moderate sample size, and the fact that the severe preoperative curve group is mainly representative of patients with curves from >70° to 90°. The possibility of increased perioperative complications and cost of treatment associated with curves >90°, possibly needs to be addressed in future studies. The impact of public (i.e. OLCHC) vs. private (i.e. BRC) healthcare on outcomes such as length of hospital stay and surgical waiting times in this study, also needs to be acknowledged. Patients who attended OLCHC compared with the BRC had significantly larger curve magnitudes and remained on the surgical waiting list for a significantly longer duration. This is not surprising as there remains a significant difference in access to resources such has operating facilities between public and private healthcare systems in Irish healthcare. Nonetheless, the current study's findings are relevant and valuable to surgeons who manage AIS populations. Although an 'estimated' cost of surgical treatment per patient from an Irish perspective is presented, such figures are accurate, and represent hospital-specific expenses incurred during the study period. Strong features of this study include the homogeneity of the AIS population who underwent a similar procedure, its prospective design and successful follow-up of all cases. Furthermore, this is the first study of which the current investigators are aware, to assess the perioperative, functional and cost outcomes associated with severe curves >70° vs. ≤70° in otherwise healthy AIS patients who underwent one-stage PSF.

In conclusion, this study showed that surgical correction of preoperative deformity greater than 70° in patients with AIS is associated with significantly greater intraoperative blood loss and number of fused vertebrae, a longer surgical duration and an increased minor perioperative complication rate. Surgeons can expect double the blood-product transfusion risk when performing one-stage PSF procedures on patients with curves >70°. Surgically treating curves >70° was also associated with a significantly delayed return to school/college full-time, as well as an 18 % increase in cost of treatment. Against a backdrop of health budget curtailment, lengthy surgical wait times, resource limitation and prioritisation in Ireland, and many hospitals globally, we demonstrate that surgical correction for curves greater than 70°, often as a result of lengthy surgical waiting lists, significantly increases minor perioperative morbidity, incurs added expense and results in a partial delay in early functional recovery.

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