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ORIGINAL ARTICLE

Complications in pediatric scoliosis surgery

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Summary

Background: Scoliosis surgery in childhood is associated with a range of postoperative complications that may require admission to the pediatric intensive care unit (PICU) or high-dependency unit (HDU).
Aim: The aim of this study was to identify preoperative factors associated with PICU and HDU admissions after corrective surgery and devise a scoring system that could be used by clinicians to predict the level of dependency required postoperatively.
Methods: A retrospective case note review was carried out in 90 patients who underwent corrective scoliosis surgery at Sheffield Children's Hospital (SCH) between January 2008 and October 2010. Predictors of PICU and HDU requirement postoperatively were identified and a simple scoring system created using multiple logistic regression and receiver operator characteristic (ROC).
Results: There was a statistically significant difference in the preoperative parameters (pulmonary function, Cobb angle, and number of vertebrae fused) of those patients who required PICU or HDU care compared with those who did not. The area under the receiver operator characteristic curve for the final scoring system was 0.95 for PICU admission and 0.87 for HDU admission at the optimal cut-off point, demonstrating good diagnostic accuracy.
Conclusions: The authors have identified a significant relationship between preoperative variables and the levels of dependency required postoperatively and have proposed a scoring system which can be used to aid decision-making involving bed planning for patients after corrective scoliosis surgery. However, this work is based on the clinical course of a single set of patients who had surgery in a single tertiary center and has not been tested on patients from other centers.

Introduction

Scoliosis has a peak incidence of 1.2% in the 12–14 years age group (1). Scoliosis is classified according to its etiology into idiopathic and secondary forms. Scoliosis may be secondary to a wide range of underlying pathologies including neuromuscular conditions, such as cerebral palsy and Duchenne muscular dystrophy, and syndromes. Idiopathic scoliosis, which is a genetically modulated growth anomaly, tends to occur more commonly in girls (2).

Corrective scoliosis surgery is a major undertaking. Postoperative complication rates can be high, for example they are reported to occur in 24–75% of neuromuscular patients undergoing spinal surgery (3). Postoperative recovery may be complicated by respiratory failure necessitating ventilatory support. Respiratory failure is most commonly due to intraoperative

atelectasis, or pleural effusions resulting from the large volumes of fluid required to maintain these patients' circulating volumes during surgery, or cardiac failure.

Sheffield Children's Hospital practice is to admit all patients postoperatively to the high-dependency unit (HDU) following corrective scoliosis surgery. Where patients are felt to be at a higher risk of developing complications, they are admitted directly to the pediatric intensive care unit (PICU). This judgment has been based on clinical impression only. Experience has shown that while some patients experience multiple postoperative complications, many are much more stable and do not require HDU level interventions postoperatively. Owing to the surge in admissions experienced during the winter months, many elective surgeries across the country are cancelled owing to a shortage of available HDU beds (4).

Earlier work has already shown that children with scoliosis secondary to cerebral palsy had worse preoperative lung function, larger Cobb angles, fusion of a greater number of vertebrae, and a significantly higher rate of postoperative complications when compared with patients with idiopathic scoliosis (5). However, no work has concentrated on developing a scoring system to predict the level of dependency (PICU, HDU, or orthopedic ward) needed to manage these patients postoperatively based on preoperative parameters.

The aim of this work was to determine whether it was possible to use preoperative variables (pulmonary function testing, Cobb angle, and number of vertebrae fused) to predict the level of dependency (PICU, HDU, or orthopedic ward) necessary to manage scoliosis patients in the immediate postoperative period.

Methods

A retrospective case note review was carried out of 90 patients at Sheffield Children's Hospital (SCH) undergoing corrective scoliosis surgery between January 14, 2008 and October 5, 2010. The target population was identified by a search of hospital clinical coding records. Data collected included classification of the scoliosis, demographic details, any underlying comorbidities, results of any preoperative pulmonary function studies, Cobb angle, number of vertebrae fused, intraoperative blood loss, and any complications that occurred in the first 24 h postoperatively. Case notes were reviewed by one author (DJS), and the extracted data were transcribed into a Microsoft Office Excel 2007™ spreadsheet.

Following this, three authors (DJS, CB, and NH) reviewed the immediate postoperative course of all the patients to ascertain the level of dependency deemed necessary to manage the patients in the first 24 h (see Table 1). Routine HDU and PICU admission criteria were used. The level of dependency assigned to each patient was based on the postoperative complication requiring the highest level of intervention. Patients were then stratified into three subgroups as follows:

1 Those requiring PICU interventions,
2 Those requiring HDU interventions,
3 Those requiring neither PICU nor HDU interventions.

Statistical analysis was then carried out using StatsDirect 2.7.8™ software (Altrincham, Cheshire, UK). Analysis was performed comparing the preoperative variables (pulmonary function testing, Cobb angle, number of vertebrae fused, age, gender, classification) between the following:

1 Those requiring PICU level care postoperatively and those who required a lower level of care,
2 Those requiring HDU level care postoperatively and those who did not.

Univariate analysis was performed using the Mann–Whitney *U*-test. *P*-values <0.05 were considered to be statistically significant.

A scoring system was then designed by first using receiver operator characteristic (ROC) curves, with

Table 1 Postoperative complications and level of dependency deemed necessary to manage them

Complication	Level of dependency needed
Ventilated	PICU
Inotropes	PICU
Pleural effusion	HDU
Postoperative pneumonia needing noninvasive ventilation (NIV)	HDU
Haematemesis	HDU
Postoperative bleeding	HDU
Spinal shock	HDU
Seizures	HDU
Metabolic acidosis	HDU
>40 $ml \cdot kg^{-1}$ fluid postoperatively	HDU
Pneumothorax	HDU
Electrolyte abnormalities (requiring replacement via central line)	HDU
NIV requirement	HDU
Coagulopathy (not requiring fresh frozen plasma)	Ward
Urinary tract infection	Ward
Postoperative pneumonia not requiring NIV	Ward
Transaminitis	Ward
Urinary retention	Ward
Hyperglycemia not requiring insulin infusion	Ward

HDC, high-dependency unit; PICU, pediatric intensive care unit.

equal weighting being given to sensitivity and specificity, to determine the ideal cut-off value for the preoperative variables which were statistically significant, with the outcome measures being either PICU admission or HDU admission. The weighting to be applied to each clinical predictor was determined by multivariate logistic regression and also by calculating the area under the receiver operator characteristic curve (AUROC) for each predictor. Using the scoring system, ROC curves were drawn, with equal weight given to sensitivity and specificity, to calculate the optimum cut-off scores for HDU and PICU admission.

Results

There were 90 patients identified for inclusion in the study. Of these, 43 were female and 47 were male. The median age for female patients was 13 years (range 9–17 years), and the median age for male patients was 14 years (range 2–18 years).

There were 45 patients classified as having idiopathic scoliosis, and the remaining patients had secondary scoliosis – 18 secondary to neuromuscular conditions (13 had cerebral palsy and five had Duchenne muscular dystrophy), and in the remaining 27 patients, it was secondary to a variety of syndromes.

Table 1 shows the range of postoperative complications experienced by the patients in our population, as well as the level of dependency deemed necessary to manage them. Based on these data, 23 (26%) patients required PICU care and 16 (18%) HDU care, and the remaining 51 (64%) could have been managed on an orthopedic ward.

Table 2 shows that there was a statistically significant difference in the preoperative variables (pulmonary function, Cobb angle, and number of vertebrae fused) between the subgroups that required higher levels of dependency and those who did not. There was also a statistically significant difference in the intraoperative blood loss ($ml \cdot l^{-1}$) experienced by those who required PICU or HDU level care and those who did not. Classification of the scoliosis was only statistically significant for those who needed PICU level care.

Receiver operator characteristic curves were used to establish the optimum cut-off points of each statistically significant variable for PICU and HDU admission. Multivariate logistic regression was used to determine the weighting given to each variable in the

Table 2 Median values of predictors according to postoperative dependency needed

	PICU interventions needed (medians, ranges in brackets)	Non-PICU interventions needed (medians, ranges in brackets)	*P*-value
Number	23	67	
FVC, % (percent predicted)	51 (27–113)	83 (43–127)	**<0.0001**
FEV1, % (percent predicted)	51 (26–106)	81 (54–123)	**<0.0001**
Cobb angle	69 (55–100)	58 (24–90)	**<0.0001**
Number of vertebrae fused	15 (9–19)	11 (3–17)	**<0.0001**
Age (years)	14 (9–17)	15 (2–17)	0.1667
Idiopathic to secondary ratio	1 : 4.75	1.58 : 1	**0.0005**
Blood loss intraoperatively ($ml \cdot l^{-1}$)	53.4 (16.3–114.9)	17.4 (2.9–74.2)	**<0.0001**
Male-to-female ratio	1.55 : 1	0.97 : 1	0.4724
	HDU interventions needed (medians, ranges in brackets)	Non-HDU interventions needed (medians, ranges in brackets)	*P*-value
Number	16	51	
FVC, % (percent predicted)	69 (43–107)	88 (52–127)	**0.0042**
FEV1, % (percent predicted)	63 (55–102)	85 (56–123)	**0.0038**
Cobb angle	66 (48–79)	53 (24–90)	**0.0017**
Number of vertebrae fused	13 (9–16)	11 (3–17)	**0.0073**
Age (years)	14.5 (11–18)	13 (2–17)	0.1098
Idiopathic to secondary ratio	1 : 0.60	1 : 0.65	0.8556
Blood loss intraoperatively ($ml \cdot l^{-1}$)	36.9 (14.6–70.0)	14.1 (1.7–74.2)	**0.0005**
Male-to-female ratio	1 : 0.45	1 : 1.32	0.1321

FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; HDC, high-dependency unit; PICU, pediatric intensive care unit.
Significant *P*-values are in bold.

Table 3 AUROC for the predictors of level of dependency in the scoring system

	AUROC PICU interventions (95% confidence intervals)	AUROC HDU interventions (95% confidence intervals)
FVC (percent predicted)	0.89 (0.50–1.00)	0.73 (0.43–1.00)
FEV1 (percent predicted)	0.90 (0.50–1.00)	0.74 (0.43–1.00)
Cobb angle	0.77 (0.67–0.87)	0.75 (0.63–0.88)
Number of vertebrae fused	0.89 (0.81–0.97)	0.72 (0.59–0.85)
Intraoperative blood loss	0.85 (0.77–0.94)	0.78 (0.65–0.92)

AUROC, area under receiver operator curve; FVC, forced vital capacity; HDC, high-dependency unit; PICU, pediatric intensive care unit.

final scoring system. For HDU admissions, the strongest performing equation gave weightings between 0.93 and 1 to each variable (FVC, FEV1, Cobb angle, and number of vertebrae fused). For PICU level interventions, the strongest performing equation involved causation, forced vital capacity (FVC), Cobb angle, and number of vertebrae fused. Equal weightings were given to FVC and number of vertebrae fused, with Cobb angle being weighted four times less heavily and causation ten times less heavily. This had an AUROC of 0.96. In view of the low weighting given to causation, this was excluded and a subsequent equation with an AUROC of 0.95 was produced. This gave weightings between 0.71 and 1 to FVC, forced expiratory volume in 1 s (FEV1), Cobb angle, and number of vertebrae fused.

The AUROC for each predictor was then used to confirm this. These data can be seen in Table 3. It ranges from 0.77 to 0.90 for PICU level interventions and from 0.72 to 0.85 for HDU level interventions. As there is an overlap in the 95% confidence intervals between the strongest performing predictor and the weakest performing predictor, it was decided to give each predictor equal weighting in the final scoring system to allow it to remain simple and applicable in a busy preoperative assessment clinic.

The final scoring system can be seen in Table 4. The best cut-off score for PICU admission, calculated by drawing ROC curves, was ≥7, with those scoring between 4 and 6 requiring HDU admission and those ≤3 requiring ward admission postoperatively. The area under the ROC (AUROC) for the final scoring system was 0.95 (95% confidence interval: 0.89–1.00) for prediction of PICU level dependency postoperatively and 0.87 (95% confidence interval: 0.78–0.96) for HDU level dependency. Table 5 demonstrates sensitivity, specificity, positive predictive value, and negative predictive value of the final scoring system. Table 6 shows the distribution of scores and the level of dependency actually required by patients in each subgroup.

Table 4 Scoliosis postoperative level of dependency scoring system

Clinical predictor	Score
FVC	
≤62%	2
63–72%	1
≥73%	0
FEV1	
≤54%	2
55–69%	1
≥70%	0
Cobb angle	
≥55	2
46–55	1
≤45	0
Number of vertebrae	
≥14	2
11–13	1
≤10	0

FVC, forced vital capacity.

Table 5 Diagnostic accuracy of the scoring system

	PICU level dependency	HDU level dependency
Sensitivity, % (95% CI)	87 (66–97)	89 (75–97)
Specificity, % (95% CI)	97 (89–100)	88 (76–96)
Positive predictive value, % (95% CI)	91 (71–99)	85 (70–94)
Negative predictive value, % (95% CI)	96 (88–99)	92 (80–98)

HDC, high-dependency unit; PICU, pediatric intensive care unit.

Discussion

This study showed a statistically significant difference between preoperative variables (pulmonary function, Cobb angle, and number of vertebrae fused) and the level of dependency needed following corrective scoliosis surgery. As this work involved a retrospective review of notes, this has allowed any potential observer bias to be eliminated. A scoring system has been developed to aid clinical decision-making. The scoring system makes use of objective parameters to limit any variability between different clinicians and increase the reproducibility of results. Previous scoring systems developed for use by clinicians have been criticized for their complexity and lack of applicability to everyday practice (6). Many are viewed as purely research orientated or as use as a service management tool (7). Consequently, this scoring system has been developed with this in mind to ensure ease of use rather than maximum statistical accuracy.

Table 6 Level of dependency actually required and predicted score according to subgroup

	Number	PICU required	HDU required	Ward required	Median score – FVC	Median score – FEV1	Median score – Cobb angle	Median score – number of vertebrae fused	Total median score
Idiopathic	45	4	10	31	0	0	2	1	2
Secondary	45	19	6	20	2	1	2	2	6
Secondary – syndromic	27	6	4	17	1	1	2	1	4
Secondary – neuromuscular	18	13	2	3	2	2	2	2	8

FVC, forced vital capacity; HDC, high-dependency unit; PICU, pediatric intensive care unit.

Measuring pulmonary function reliably in certain subgroups, particularly those with an underlying neuromuscular condition, may be difficult. This has been a problem in earlier work which found that single risk factor for FVC < 39.5% predicted was strongly suggestive of the need for postoperative ventilatory support (8,9). Our scoring system is obviously invalid if two values assessing pulmonary function are unavailable. In this situation, we would recommend the concept of 'diagnostic risk'. As can be seen from Table 6, our data showed that those with an underlying neuromuscular condition had the greatest likelihood of postoperative complications requiring PICU level care (72%). The remainder of the secondary scoliosis population had just a 22% risk of needing PICU. This compares with a 9% chance of PICU requirement in the idiopathic group. The median scores for FVC and FEV1 were 4 in the neuromuscular group, 2 in the syndromic group, and 0 in the idiopathic group. We recommend that if pulmonary function is unavailable, a 'diagnostic risk' of 4 be added to the score for Cobb angle and number of vertebrae fused in the neuromuscular group, 2 in the syndromic group, and 0 in the idiopathic group, to guide the clinician in determining the postoperative level of dependency required for an individual patient.

With the majority of PICU admissions being from the neuromuscular subgroup, it is likely that the statistically significant *P* value obtained when analyzing the causation of those who required PICU level dependency postoperatively vs those who did not is directly related to this population and their underlying comorbidities. Although a score for causation was excluded from the final scoring system in view of its low weighting, it is important to bear in mind the high likelihood of complications in this subgroup.

It is also important to highlight that the decision to send a child to an orthopedic ward postoperatively should not be made purely on the basis of this scoring system. Comorbidity, the time of day, and staffing levels on the orthopedic ward should also be taken into account.

The negative predictive value is the crucial predictive statistic to allow year-round corrective scoliosis surgery and efficient use of operating theater slots when a PICU or HDU bed may not be available. While an unnecessary PICU admission when beds are available should not be particularly problematic, frequent escalation of the level of care when all HDU bed spaces are fully occupied during busy periods would reduce the reliability of the scoring system. With a negative predictive value of 95% for PICU level dependency and 92% for HDU dependency, and concentration of high-risk patients in the summer months, year-round surgery can be carried out reliably.

In practical terms, the negative predictive of 92% would suggest that only 1 in every 12.5 patients sent to the ward (based on the suggested cutoffs) would require unplanned HDU admission within 24 h of surgery. Conversely (based on the positive predictive value), 85% of patients admitted to the HDU would require monitoring or interventions which could not be provided on the ward.

In any scoring system, there will inevitably be individual patients in whom it is necessary to escalate care, to either the PICU or HDU setting. Previous work has shown that there is a relationship between intraoperative blood loss and postoperative complications (10). We have shown that the level of postoperative dependency is significantly related to the intraoperative blood loss (Table 2). ROC curve analysis suggests an optimum cut-off for PICU admission of 39 $ml \cdot l^{-1}$ intraoperative blood loss (AUROC 0.85) and a cut-off of 24.8 $ml \cdot l^{-1}$ (AUROC 0.78) for HDU admission. While it is acknowledged that this information is not available prospectively to aid preoperative bed planning, it may aid clinical judgment when making the final decision about the level of dependency needed in the immediate postoperative period.

A patient who is not admitted to a critical care area postoperatively will still require careful and regular monitoring of their neurological status, adequacy of analgesia, and possible intravascular volume

depletion. Scoring systems such as the PEWS will aid the clinician in identifying deteriorating patients who may require their level of care to be escalated. Our scoring system is quick and easy to use, and we feel that it is useful addition to the judgment of the clinical team in anticipating the level of dependency required by a patient postoperatively. The use of such an objective scoring system can help confirm a clinician's original clinical judgment or even make them question or reconsider it. Successful implementation should also allow for improved bed management and result in fewer operations being cancelled owing to lack of PICU or HDU bed availability during the winter months. We have not yet tested the system on a second population to validate it further; as different units have differing practices, we feel that further validation would best be carried out across a different range of patients from different institutions.

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Conflict of interest

The authors have no conflict of interests to declare.

References

1 Stirling AJ, Howel D, Millner PA *et al.* Late-onset idiopathic scoliosis in children six to fourteen years old. A cross-sectional prevalence study. *J Bone Joint Surg Am* 1996; **78**: 1330–1336.

2 Questions and answers about scoliosis in children and adolescents. Available at: http://www.niams.nih.gov/Health_Info/Scoliosis/. Accessed 21 October, 2013.

3 Benson ER, Thomson JD, Smith BG *et al.* Results and morbidity in a consecutive series of patients undergoing spinal fusion for neuromuscular scoliosis. *Spine* 1998; **23**: 2308–2317.

4 Durani P, Seagrave M, Neumann L. The use of theatre time in elective orthopaedic surgery. *Bull R Coll Surg Engl* 2005; **87**: 170–172.

5 Hod-Feins F, Anekstein Y, Mirovsky Y *et al.* Pediatric Scoliosis Surgery – the association between preoperative risk factors and postoperative complications with emphasis on cerebral palsy children. *Neuropediatrics* 2007; **38**: 239–243.

6 Gorelick MH. Severity of illness measures for pediatric emergency care: are we there yet? *Ann Emerg Med* 2003; **41**: 639–643.

7 Marlias M, Evans J, Abrahamson E. Clinical predictors of admissions in infants with acute bronchiolitis. *Arch Dis Child* 2011; **96**: 648–652.

8 Liang J, Qiu G, Shen J *et al.* Predictive factors of postoperative pulmonary complications in scoliotic patients with moderate or severe pulmonary dysfunction. *J Spinal Disord Tech* 2010; **23**: 388–392.

9 Rawlins BA, Winter RB, Lonstein JE *et al.* Reconstructive spine surgery in pediatric patients with major loss in vital capacity. *J Pediatr Orthop* 1996; **16**: 284–292.

10 Carreon LY, Puno RM, Lenke LG *et al.* Non-neurological complications following surgery for adolescent idiopathic scoliosis surgery. *J Bone Joint Surg Am* 2007; **89**: 2427–2432.