ASSOCIATION BETWEEN PERIOPERATIVE SURGICAL HOME IMPLEMENTATION AND TRANSFUSION PATTERNS IN ADOLESCENTS WITH IDIOPATHIC SCOLIOSIS UNDERGOING SPINAL FUSION

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Summary
Background: Blood transfusions in patients with adolescent idiopathic scoliosis after fusion have been associated with increased morbidity, mortality, and cost.
Objective: The aim of this study was to evaluate the association between implementation of blood-conservation strategies within the perioperative surgical home on transfusion rates for patients with adolescent idiopathic scoliosis undergoing spinal fusion.
Methods: Two hundred and thirteen patients (44 preperioperative surgical home, 169 postperioperative surgical home) who underwent posterior spine fusion for adolescent idiopathic scoliosis between 23 June 2014, and 30 July 2017, were enrolled in this case control study. The perioperative surgical home implemented in March 2015 involved evidence-based perioperative interventions to create a standardized clinical pathway including judicious use of crystalloid management, restrictive transfusion strategy, routine use of cell saver, and standardized administration of anti-fibrinolytics. The primary outcome was odds of perioperative transfusion. Secondary outcomes included volumes of crystalloid, albumin, cell saver, packed red blood cells as well as calculated blood loss. Other variables that were documented included anti-fibrinolytic total dose, mean arterial pressure, temperature, laboratory values, intrathecal morphine dosing, and surgical time. Statistical methods included t test and logistic regression.
Results: For the postperioperative surgical home, the odds of perioperative transfusion were 0.30 (95% CI 0.13-0.70), as compared to preperioperative surgical home. In terms of secondary outcomes, calculated blood loss was significantly lower in the postperioperative surgical home patients (27.0 mL/kg preperioperative surgical home vs 22.8 mL/kg postperioperative surgical home; mean difference = -0.24 [-0.44, -0.04]). Although no difference was noted in the amount of intraoperative cell saver or albumin administered, a reduction was noted in mean intraoperative crystalloid given postperioperative surgical home (41.4 mL/kg ± 20.4 mL/kg preperioperative surgical home vs 28.0 mL/kg ± 13.7 mL/kg postperioperative surgical home; log mean difference = 0.37 [95% CI 0.21-0.53], P < 0.001). Postperioperative surgical home patients also had a significantly higher temperature nadir (mean...
1 | INTRODUCTION

Posterior spine fusion is a complex surgery with the potential for significant blood loss and perioperative transfusion. Perioperative bleeding risk is high because this procedure involves extensive surgical exposure and potentially lengthy operative time. Blood loss in patients with adolescent idiopathic scoliosis who undergo this procedure has been associated with increased morbidity, mortality, and cost. Complications include acute lung injury, immunologic dysfunction, and transmitted infection exposure. Further, studies have shown that transfusion has been associated with longer hospital stays and higher mortality.\(^1\,^2\)

Various approaches have been used to reduce transfusions in the pediatric population, including autologous blood predonation, anti-fibrinolytics, controlled hypotension, intraoperative blood salvage (cell saver), normovolemic hemodilution, restrictive transfusion strategies, and preoperative hemoglobin optimization, and each approach yielded varying levels of success.\(^3\,^4\) Significant work has been undertaken in the adult population to develop comprehensive blood-management programs, which have reduced transfusions effectively across one hospital system.\(^5\) Preliminary data have shown that implementation of a perioperative blood-management program within the supporting structure of a perioperative surgical home model is linked to a reduction in perioperative transfusion in patients with adolescent idiopathic scoliosis.\(^5\) However, studies have not thoroughly described the association of a perioperative surgical home on blood management in this patient population. The intent of this report is to further define the factors associated with a decrease in blood transfusion after the implementation of a perioperative surgical home for patients with adolescent idiopathic scoliosis.

2 | MATERIALS AND METHODS

2.1 | Data acquisition

The authors performed a single-center case-control study. After approval by the institution’s Institutional Review Board, we identified patients who underwent posterior spinal fusion for adolescent idiopathic scoliosis at our institution between 23 June 2014 and 30 July 2017. Preoperative surgical home patients underwent the procedure between 23 June 2014 and 28 February 2015. Postperioperative surgical home patients underwent the procedure between 1 March 2015 and 31 July 2017. No cases were excluded during initial implementation of the perioperative surgical home. Demographics collected for each patient included gender, weight, height, age, ASA class, degree of scoliosis, and spinal levels fused. In addition, preoperative laboratory values were recorded. Intraoperative variables regarding surgical time and volume of fluid and red blood cell administration were obtained. Other intraoperative values recorded included use of vasopressors, use of intrathecal morphine, and mean arterial pressure values. Use of vasopressors was defined affirmative if any dose of ephedrine or phenylephrine was given intraoperatively. No dopamine was given in any of the cases in this study. Certain intraoperative laboratory values were collected, including hematocrit, base deficit, and lactate.

Calculated blood loss was estimated based on a formula previously published\(^6\):

\[
\text{Calculated blood loss} = \text{Estimated blood loss} = \text{Surgical field blood loss} + \text{Blood salvaged} + \text{Blood transfused} + \text{Other sources of blood loss}
\]

Conclusions: Implementation of blood-conservation strategies as part of a perioperative surgical home for patients with adolescent idiopathic scoliosis undergoing posterior spine fusion resulted in significant decrease in perioperative blood transfusions.

**KEYWORDS**

blood loss, patient-centered care/methods, pediatrics/methods, perioperative care/methods, scoliosis/surgery, spinal fusion/methods, surgical/prevention & control

**What is already known**

- Blood transfusions in patients with adolescent idiopathic scoliosis after posterior spine fusion have been associated with increased morbidity, mortality, and cost.

**What this article adds**

- Implementation of the perioperative surgical home model in this patient population was associated with a significant decrease in perioperative blood transfusion.
- Adopting the perioperative surgical home model at our institution contributed to an effective approach toward minimizing unnecessary transfusion.
1. Total RBC loss (mL) = uncompensated blood loss (mL) + compensated blood loss (mL)
2. Uncompensated blood loss (mL) = initial RBC (mL) − final RBC (mL)
3. RBC volume (mL) = estimated blood volume (mL) × hematocrit level (%). Estimated blood volume was calculated using weight (kg) and 70 mL/kg.
4. Compensated blood loss = sum of various sources of transfusion including autologous, allogeneic, and cell saver volumes. Hematocrit levels of autologous and allogeneic volumes were assumed to be 60% based on the average hematocrit as per our institution’s blood bank. Cell saver hematocrit levels were assumed to be 50% based on the average determined by our institution’s transfusion program.
5. Sum of various sources of transfusion = [allogeneic unit volume (mL) × 0.6] + [autologous unit volume (mL) × 0.6] + [cell saver volume (mL) × 0.5]

Postoperative data recorded included blood volumes transfused, laboratory values, and ICU and hospital lengths of stay. All data were collected using manual chart review by research interns working closely with the authors of this study. Data were considered missing if it was not explicitly documented in the patient’s medical chart during the perioperative period.

2.2 | Perioperative surgical home program description

The ASA defines perioperative surgical home as "a patient–centric, team–based model of care created by leaders within the

**TABLE 1** PSH clinical pathway for patients with AIS who undergo PSF

| Preoperative | Preoperative care clinic visit for all patients Efficient scheduling of laboratory tests and MRI Consistent prescribed iron supplementation regimen: 325 mg (65 mg elemental iron) by mouth twice per day for 4 weeks preoperatively Standardized autologous blood donation and blood request Improved patient education Standardized polyethylene glycol use Prewarming using Bear Paws (3M) technology |
|-------------|----------------------------------------------------------------------------------|
| Intraoperative | Standardized patient warming with intraoperative use of Bear Paw (3M) technology, operating room warming, and fluid warmer Reduced patient prep/positioning time in OR Multimodal analgesia including: acetaminophen, remifentanil, and intrathecal morphine (5-10 µg/kg) Standardized aminocaproic acid dosing: mg/kg (max 5 g) over 30 min kg → 40 mg/kg/h; 25-50 kg → 35 mg/kg/h; >50 kg → 30 g/kg/h Crystalloid goal-directed therapy, restrictive transfusion strategy, use of cell saver Safety protocol for change of neuromonitoring Standardized workflow for OR nurses and scrub technicians |
| Postoperative | Creation of fast-track PACU recovery, where patients remain in PACU overnight on POD 0 Standardized start of oral intake on POD 0 and early mobilization Multimodal analgesia including: ketorolac/ibuprofen, acetaminophen, and PCA until POD2. Scheduled timely removal of Foley, drains, and arterial line Patient and family education and progress to discharge Facilitation of weekend progress (physical therapy) and discharge |

AIS, adolescent idiopathic scoliosis; PACU, postanesthesia care unit; POD 0, postoperative day 0; POD2, postoperative day 2; PSF, posterior spine fusion; PSH, perioperative surgical home.
pathway, use of cell saver was instituted for every patient. The bowl sizes were protocolized. Cell saver was available if a minimum of approximately 250 mL of blood was collected. If any cell saver was available (i.e., if ≥250 mL of blood was collected in the bowl), the whole volume was infused. Prior to implementation of the perioperative surgical home on 1 March 2015, these elements were not standardized and there was no clinical guidance regarding preoperative, intraoperative, or postoperative management. During this study period, no changes occurred in the surgical approach or in the staffing of surgeons who completed the procedure.

2.3 | Statistical analysis

Normality was assessed for continuous outcomes using the Shapiro-Wilk normality test and visual inspection of histograms. Where a data transformation was applied, normality was reassessed and verified after transformation. Log transformations were applied to height, weight, scoliosis degree, crystalloid given, intraoperative mean arterial pressure, and the first and last lactate assessments. Square root transformations were applied to cell saver given, urine output per kilogram, and the first and last base deficit assessments. Continuous outcomes between patients

| TABLE 2 Descriptive characteristics |
|------------------------------------|
| **Characteristic** | **Pre PSH** | **Post PSH** |
| | N (%) | Mean ± SD or median (min, max) | N (%) | Mean ± SD or median (min, max) | Mean/median difference (95% CI) | Test statistic | P value |
| Age at surgery (y) | 43 | 14.9 ± 2.1 | 168 | 15.0 ± 2.2 | −0.072 (−0.810, 0.667) | t = −0.19 |
| Height (cm) | 43 | 160 ± 10 | 168 | 161 ± 13 | −0.003 (−0.037, 0.032) | t = −0.17 |
| Weight (kg) | 43 | 59.0 ± 16.2 | 168 | 54.5 ± 16.2 | 0.025 (−0.061, 0.112) | t = 0.57 |
| BMI percentile | 43 | 67 (1, 99) | 167 | 60 (1, 99) | −0.069 (−0.277, 0.137) | z = −0.66 |
| Gender | | | | | | | |
| Male | 10 (23%) | 43 (26%) |
| Female | 33 (77%) | 125 (74%) |
| Race | | | | | | | |
| White | 14 (33%) | 55 (33%) |
| Black/African-American | 15 (35%) | 76 (45%) |
| Amer. Indian/Alaskan | 1 (2%) | 1 (1%) |
| Asian | 2 (5%) | 11 (6%) |
| Other | 11 (25%) | 25 (14%) |
| Ethnicity | | | | | | | |
| Hispanic | 8 (19%) | 5 (3%) |
| NonHispanic | 35 (81%) | 152 (97%) |
| Scoliosis degree | 43 | 62 ± 13 | 168 | 57 ± 8 | 0.079 (0.026, 0.131) | t = 2.94 | 0.004 |
| Levels of fusion | 43 | 11.3 ± 2.0 | 168 | 10.8 ± 2.0 | 0.6 (−0.1, 1.2) | t = 1.70 | 0.09 |
| ASA classification | | | | | | | |
| 1 | 5 (12%) | 34 (20%) |
| 2 | 36 (84%) | 126 (75%) |
| 3 | 2 (5%) | 8 (5%) |
| PT (s) | 41 | 13.8 (12.8, 18.3) | 168 | 13.7 (10.5, 30.2) | −0.17 (−0.36, 0.03) | z = 1.67 | 0.09 |
| PTT (s) | 41 | 31.5 (22.5, 40.5) | 167 | 31.6 (13.6, 52.6) | 0.02 (−0.16, 0.20) | z = −0.20 | 0.84 |
| INR | 41 | 1.04 (0.92, 1.49) | 168 | 1.06 (0.91, 2.99) | 0.21 (0.003, 0.41) | z = −2.07 | 0.039 |
| Platelets (K cells/µL) | 43 | 266 ± 61 | 168 | 266 ± 63 | −0.8 (−21.8, 20.3) | t = −0.07 | 0.94 |
| Fibrinogen (mg/dL) | 3 | 302 (150, 345) | 165 | 269 (83, 511) | −0.08 (−0.95, 0.80) | z = 0.23 | 0.82 |

*Analysis performed on log–transformed data; mean difference expressed on log scale.

*Analysis performed using nonparametric tests; difference expressed as Somers’ D values.

P value < 0.05 (in bold).
prePSh and postperioperative surgical home were compared using t tests for normally distributed outcomes and Wilcoxon rank sum tests for nonnormally distributed outcomes. The outcomes tested using the Wilcoxon rank sum test are indicated in the result tables. Tests for association between perioperative surgical home status and categorical outcomes were performed using Fisher’s exact tests. The comparison of transfusions between preperioperative surgical home and postperioperative surgical home patients was performed using logistic regression, where transfusion was the dependent outcome and perioperative surgical home status and the dependent outcome and perioperative surgical home status was the predictor and the scoliosis degree and the number of levels fused were covariates. Descriptive statistics per perioperative surgical home group are presented in the tables as untransformed values. Outcomes compared with t tests report the mean and standard deviation for each group along with the mean difference and the 95% CI; those compared with a nonparametric test report the median and the minimum and maximum along with Somers’ D and the 95% CI to estimate effect size. A P value of ≤0.05 was considered statistically significant, and owing to the relatedness of the outcomes, no corrections for the number of outcomes tested were made. All analyses were performed using STATA V15 (College Station, TX).

3 | RESULTS

A total of 213 patients (44 preperioperative surgical home, 169 postperioperative surgical home) who underwent posterior spinal fusion for adolescent idiopathic scoliosis between 23 June 2014, and 30 July 2017, were enrolled in the study. Two participants were excluded. One preperioperative surgical home patient had an unusually prolonged length of hospital stay because of a new diagnosis of sleep apnea that required admission to the ICU and extensive workup. The second patient (postperioperative surgical home) was excluded because accurate blood loss data were not available. For the remainder of the patients, no differences were seen in demographics, including age, gender, and weight (Table 2). Likewise, no significant difference was noted in preoperative lab values, except for INR and preoperative hematocrit. INR was slightly higher in postperioperative surgical home patients, but a difference of no clinical significance. The preoperative hematocrit was 31.7 ± 4.7% preperioperative surgical home vs 33.1% ± 3.8 postperioperative surgical home; log mean difference = −1.42 (95% CI [−2.81 to −0.03], P = 0.045). Postperioperative surgical home patients had a significantly smaller degree of scoliosis compared to preperioperative surgical home patients (57° vs 62°; log mean difference = 0.079 [95% CI 0.026–0.131]; P = 0.004). Although the levels of fusion were not statistically different between the 2 groups, the study revealed a trend toward fewer levels of fusion being completed postperioperative surgical home.

In terms of the primary outcome, after introduction of the preperioperative surgical home program, the odds of red blood cell transfusion during the intraoperative period were 0.29 (95% CI 0.10–0.80; P = 0.017), as compared to preperioperative surgical home (Table 4). The odds of an overall transfusion during either period were less after implementation of the perioperative surgical home (OR = 0.30; 95% CI 0.13–0.70; P = 0.005). As for secondary outcomes, when patients were transfused red blood cells, the volume of transfusion when adjusted for weight was decreased postperioperative surgical home. Analysis of perioperative fluid management shows no difference between the two groups in volumes of cell saver or albumin given (Table 3). Crystalloid volumes administered were significantly lower in postperioperative surgical home patients than in preperioperative surgical home patients (41.1 mL/kg ± 20.4 mL/kg preperioperative surgical home vs 28.0 mL/kg ± 13.7 mL/kg postperioperative surgical home; log mean difference = 0.37 [95% CI 0.21–0.53]; P < 0.001). In addition, the mean calculated blood loss was significantly decreased in postperioperative surgical home from that in preperioperative surgical home patients (27.0 mL/kg vs 22.8 mL/kg; mean difference = −0.24 [−0.44, −0.04]).

Regarding other intraoperative outcomes, postperioperative surgical home patients exhibited a higher average temperature nadir (mean difference = −0.59, P < 0.001), and were more frequently given a higher average cumulative dose of anti-fibrinolytic (mean difference = −3.06, P < 0.001), and had reduced surgical time (mean difference = 0.72 [95% CI 0.36–1.09]; P < 0.001) (Table 3). Further, intrathecal morphine was more frequently given to postperioperative surgical home than to preperioperative surgical home patients (80% vs 20%), and the median morphine dose was lower in postperioperative surgical home patients than it was in preperioperative surgical home patients (8 µg/kg vs 0 µg/kg; Somers’ D = 0.51 [95% CI 0.33–0.69]; P < 0.001). Lastly, looking at resuscitation metrics, no difference was noted between the two groups in the first and last intraoperative base deficit and lactate, intraoperative vasopressor use, intraoperative mean arterial pressures, or urine output on the day of surgery. However, the mean hematocrit levels were significantly greater in the postperioperative surgical home patients at the first and last intraoperative assessments (mean difference = −1.42; 95% CI −2.81 to 0.03; P = 0.045 and mean difference = −2.60; 95% CI −4.05 to −1.14; P < 0.001, respectively) (Table 5).

4 | DISCUSSION

The implementation of a standardized clinical care pathway that included blood-conservation strategies as part of the perioperative surgical home model is associated with a significantly reduced need for perioperative red blood cell transfusion in comparison to the standard approach preperioperative surgical home. The postperioperative surgical home patients did have a higher preoperative hematocrit as compared to preperioperative surgical home. This may be secondary to the change in preoperative guidelines. Postperioperative surgical home, all patients were advised to take ferrous nitrate 325 mg (65 mg elemental iron) by mouth twice per day for 4 weeks preoperatively. In contrast, some, but not all, orthopedic
surgeons recommended that the patients take iron with varying dosing preperioperative surgical home. A second potential factor impacting preoperative hematocrit is autologous donation. However, this option was available to patients in both groups with no change in policy with implementation of the perioperative surgical home, so autologous donation was less likely to cause this difference. Thirty percent donated autologous blood pre perioperative surgical home and 45% donated autologous post perioperative surgical home with no significant difference between these groups. Thirteen patients received autologous transfusions perioperatively preperioperative surgical home as compared to 11 patients postsurgical home.

Factors that could have contributed to a reduction perioperative red blood cell transfusion include the decrease in surgical time.\textsuperscript{11} Operative time has previously been identified as one of the most

\begin{table}
\centering
\caption{Perioperative variables}
\begin{tabular}{|l|l|l|l|l|l|l|}
\hline
Characteristic & PrePSH & & & PostPSH & & \\
 & N & Mean ± SD or median (min, max) & & N & Mean ± SD or median (min, max) & \\
\hline
Cell saver (mL/kg)\textsuperscript{a} & 43 & 4.0 ± 4.2 & & 168 & 3.3 ± 3.3 & 1.53 (1.39, 1.67) & \textit{t} = 1.03 & 0.30 \\
Crystalloid (mL/kg)\textsuperscript{a} & 43 & 41.4 ± 20.4 & & 168 & 27.97 ± 13.7 & 0.37 (0.21, 0.53) & \textit{t} = 4.61 & <0.001 \\
Albumin (mL/kg)\textsuperscript{c} & 43 & 6 (0, 25) & & 168 & 6 (0, 31) & 0.07 (−0.12, 0.26) & \textit{z} = 0.69 & 0.49 \\
Total anti-fibrinolytic dose (mg) & 41 & 7538 ± 3088 & & 168 & 11467 ± 4399 & −3939 (−5364, −2495) & \textit{t} = −5.40 & <0.001 \\
CBL (mL/kg)\textsuperscript{c} (OSTHEO method) & 42 & 27.0 (2.8, 76.3) & & 166 & 22.8 (3.4, 74.7) & −0.24 (−0.44, −0.04) & \textit{z} = −2.32 & 0.017 \\
CBL (mL/kg) (cell saver method)\textsuperscript{b} & 43 & 12.0 ± 12.7 & & 168 & 9.8 ± 9.9 & 0.32 (−0.28, 0.93) & \textit{t} = 1.04 & 0.30 \\
Estimated blood loss (mL/kg)\textsuperscript{b} & 43 & 11.9 ± 7.3 & & 168 & 9.1 ± 5.7 & 0.28 (0.09, 0.47) & \textit{t} = 2.89 & 0.004 \\
Mean MAP (mm Hg)\textsuperscript{b} & 40 & 69.1 ± 6.6 & & 161 & 68.7 ± 5.1 & 0.01 (−0.02, 0.03) & \textit{t} = 0.33 & 0.74 \\
IT morphine dose (µg/kg)\textsuperscript{c} & 43 & 0 (0, 21.54) & & 168 & 7.88 (0, 83.33) & 0.51 (0.33, 0.69) & \textit{z} = −5.23 & <0.001 \\
Urine output (POD 0) (mL/kg)\textsuperscript{a} & 43 & 9.21 ± 5.90 & & 168 & 9.47 ± 5.63 & −0.09 (−0.37, 0.19) & \textit{t} = −0.62 & 0.54 \\
Vasopressor use & & & & & & & \textit{\chi}^2 = 1.69 & 0.22 \\
No & 30 & 69.8% & & 99 & 58.9% & & \\
Yes & 13 & 30.2% & & 69 & 41.7% & & \\
Total RBC transfused (mL/kg)\textsuperscript{b} & 43 & 0 (0, 13) & & 168 & 0 (0, 20) & −0.2 (−0.3, −0.07) & \textit{z} = −3.06 & <0.001 \\
Total surgical time (h) & 43 & 5.18 ± 1.28 & & 166 & 4.46 ± 1.01 & 0.72 (0.36, 1.09) & \textit{t} = 3.94 & <0.001 \\
Nonsurgical time (h)\textsuperscript{d} & 43 & 1.68 ± 0.42 & & 166 & 1.52 ± 0.29 & 0.17 (0.06, 0.27) & \textit{t} = 3.02 & 0.003 \\
Lowest temperature (Celsius) & 42 & 34.7 ± 0.8 & & 168 & 35.1 ± 0.7 & −0.47 (−0.70, −0.23) & \textit{t} = −3.95 & <0.001 \\
Length of stay (d) & 43 & 5.14 (3.28, 10.43) & & 168 & 3.38 (1.65, 9.18) & −0.67 (−0.80, −0.55) & \textit{z} = 6.82 & <0.001 \\
\hline
\end{tabular}
\textsuperscript{a}Analysis performed on square root transformed data; mean difference expressed on square root scale.
\textsuperscript{b}Analysis performed on log-transformed data; mean difference expressed on log scale.
\textsuperscript{c}Analysis performed using nonparametric tests; difference expressed as Somers’ D values.
\textsuperscript{d}Nonsurgical time calculated as (total OR time) – (total surgical time).
\textit{P} value < 0.05 (in bold).
The use of aminocaproic acid has been shown to significantly reduce perioperative blood loss and the need for transfusion in this patient population. In this study, the recommended aminocaproic acid dosing in postoperative surgical home patients was based on pharmacokinetic studies that showed that weight-based dosing in this population is appropriate and that recommended infusion rates are 3 times those previously recommended to maintain target plasma concentrations in adolescents who undergo posterior spinal fusion. The increased mean cumulative dose of aminocaproic acid in the postoperative surgical home patients may have played a role in decreasing blood loss and the need for transfusion.

Interestingly, we noted no differences in demographics that could have explained the reduction in transfusion, which is contrary to other reports in which age, height, weight, and male gender were identified as significant patient factors affecting operative blood loss. More postoperative surgical home patients received intrathecal morphine; morphine has been associated with decreased blood loss, although it is notable that mean arterial pressure and use of vasopressors did not change significantly throughout the study period.

Another consideration is the change in perioperative fluid management. Goal-directed therapy may have caused less important predictors of increased blood loss for patients with adolescent idiopathic scoliosis who undergo posterior spinal fusion.

Although no change occurred in the surgical team during the preoperative surgical home and postoperative surgical home periods, the implementation of a clinical care pathway, which included a dedicated team of anesthesiologists and support staff, may have positively affected OR time and may have played a role in decreasing surgical time and nonsurgical time. Further, part of the implementation of the perioperative surgical home included standardizing workflow to increase efficiency both during nonsurgical and surgical time in the operating room. Finally, the Hawthorne effect could have also played a role as all providers were aware that they were being evaluated.

A higher average temperature nadir is associated with a reduction in intraoperative blood loss and may decrease the need for blood transfusion. Hypothermia is known to impair both platelet function and coagulation cascade enzyme function. Rajagopalan et al showed that mild hypothermia (34-36°C) significantly increases blood loss (by 16%) and increases the relative risk for transfusion (by 22%). Although we only recorded the lowest intraoperative temperature, one can speculate that the higher temperature nadir in the postoperative surgical home patients may have led to reduction in blood loss and transfusion because normothermia was reached more quickly.

### TABLE 4 Risks of perioperative transfusion

| Outcome               | PrePSH | PostPSH | Adjusted OR | Adjusted OR 95% CI | P value |
|-----------------------|--------|---------|-------------|-------------------|---------|
| Intraoperative transfusion | No     | 33      | 158         | 1.00              |         |
|                       | Yes    | 10      | 10          | 0.29              | 0.10-0.80 | 0.017 |
| Postoperative transfusion | No     | 35      | 157         | 1.00              |         |
|                       | Yes    | 8       | 11          | 0.54              | 0.18-1.68 | 0.29  |
| Any transfusion       | No     | 27      | 148         | 1.00              |         |
|                       | Yes    | 16      | 20          | 0.30              | 0.13-0.70 | 0.005 |

*Models adjusted for scoliosis degree and levels of fusion. P value < 0.05 (in bold).

### TABLE 5 Perioperative lab values

| Characteristic                | PrePSH | PostPSH | Mean difference (95% CI) | Test statistic | P value |
|------------------------------|--------|---------|--------------------------|---------------|---------|
| First intraoperative hematocrit |        |         |                          |               |         |
| N                            | 42     | 152     | −1.42 (−2.81, −0.03)     | t = −2.02     | 0.045   |
| Mean ± SD                    | 31.7 ± 4.7 | 33.1 ± 3.8 |                       |               |         |
| Last intraoperative hematocrit |        |         |                          |               | <0.001  |
| N                            | 35     | 114     | −2.60 (−4.05, −1.14)     | t = −3.54     |         |
| Mean ± SD                    | 27.7 ± 0.35 | 30.3 ± 3.9 |                       |               |         |
| First lactate<sup>a</sup>    |        |         |                          |               |         |
| N                            | 42     | 152     | 0.00 (−0.13, 0.13)       | t = −0.02     | 0.98    |
| Mean ± SD                    | 1.41 ± 0.55 | 1.42 ± 0.61 |                       |               |         |
| Last lactate<sup>b</sup>     |        |         |                          |               |         |
| N                            | 34     | 113     | 0.00 (−0.18, 0.17)       | t = −0.04     | 0.97    |
| Mean ± SD                    | 1.32 ± 0.49 | 1.39 ± 0.77 |                       |               |         |
| First base deficit<sup>b</sup> |      |         |                          |               |         |
| N                            | 34     | 94      | 0.13 (−0.11, 0.40)       | t = 1.07      | 0.29    |
| Mean ± SD                    | 2.03 ± 1.68 | 1.74 ± 1.28 |                       |               |         |
| Last base deficit<sup>b</sup> |      |         |                          |               |         |
| N                            | 30     | 87      | 0.14 (−0.10, 0.39)       | t = 1.16      | 0.25    |
| Mean ± SD                    | 2.67 ± 1.49 | 2.34 ± 1.61 |                       |               |         |

<sup>a</sup>Analysis performed on log-transformed data; mean difference expressed on log scale.
<sup>b</sup>Analysis performed on square root transformed data; mean difference expressed as square root values.

P value < 0.05 (in bold).
In the setting of using goal-directed crystalloid therapy and a more restrictive red blood cell transfusion strategy as part of the perioperative surgical home, we showed a reduction in both the volume of crystalloid given to patients and in red blood cell transfusion. This approach was not associated with changes in variables linked to underresuscitation, indicating that the change in perioperative fluid management achieved sufficient intraoperative fluid replacement.

Postoperative surgical home patients had decreased lengths of stay compared to preoperative surgical home patients (5.1 days vs 3.4 days; mean difference = −0.67 [95% CI −0.80, −0.55]; \( P < 0.001 \)). Multiple aspects of the perioperative surgical home likely contributed to this reduction in length of stay, and this change is similar to outcomes published regarding the implementation of specific care pathways for patients with adolescent idiopathic scoliosis who underwent posterior spinal fusion at other institutions.\(^1\)\(^8\)\(^9\) Nonetheless, literature suggests that decreased crystalloid use and packed red blood cell transfusion is associated with decrease in length of stay in surgical patients.\(^2\)\(^1\)\(^1\)\(^2\) This finding may have contributed to the improvement in length of stay for postoperative surgical home patients.

We acknowledge several weaknesses in this study. First, inherent limitations exist in the estimation of blood loss. Visual estimates of blood loss by the anesthesiologist and the proceduralist have been proven to be inaccurate.\(^2\)\(^5\) The gravimetric approach to blood loss can also be imprecise.\(^2\)\(^6\) We believe that calculated blood loss is a reasonable method by which to estimate perioperative blood loss.\(^8\) However, although other innovative approaches using image-processing algorithms to estimate blood loss in suction canisters could provide more accurate estimations, they were not used in this study.\(^2\)\(^7\) The second weakness in this study is our reliance on a retrospective preoperative surgical home control group that is quite small and may limit the conclusions made from the comparison to the larger prospective postoperative surgical home group. A third weakness of this study is that the analysis does not determine to what extent the effects seen can be attributed to specific anesthesiologists or surgeons. It has been shown that increased anesthesiologist experience is associated to improved perioperative outcomes in multiple complex surgeries.\(^2\)\(^8\)\(^9\) Another important consideration of this analysis is that while the changes in outcomes we identify are associated with implementation of the perioperative surgical home, we cannot confirm the cause of these changes. These results could be caused by change in practice over time or another cause. One other limitation in this analysis is the lack of data regarding any change in use of preoperative iron supplementation with implementation of the perioperative surgical home, as this may have influenced the starting hemoglobin levels of the patients and impacted transfusion rates. Finally, the data set is incomplete. Missing data may have biased the results; however, it is worth noting that the most important data points, including calculated blood loss and volume of crystalloid, had datasets that were largely intact.

5 | CONCLUSION

Implementation of blood-conservation strategies as part of a perioperative surgical home for patients with adolescent idiopathic scoliosis who undergo posterior spinal fusion is associated with a significant decrease in perioperative blood transfusion. Reasons for this change appear to be multifactorial. Data indicate that the most likely cause is the reduction in hemodilution associated with a more restrictive approach to fluid management in conjunction with a more restrictive red blood cell transfusion strategy. Improved temperature control, standardized administration of anti-fibrinolytics, and shorter surgical time may have also contributed to decreased need for perioperative transfusion in this patient population. Adopting the perioperative surgical home model at our institution contributed to an effective approach to minimizing unnecessary transfusions.

ETHICAL APPROVAL

The protocol for this study was approved by the Children's National Institutional Review Board.

CONFLICT OF INTEREST

The authors have no conflicts of interest to report.

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