Operative Time as the Predominant Risk Factor for Transfusion Requirements in Nonsyndromic Craniosynostosis Repair

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Background: Despite recent advances in surgical, anesthetic, and safety protocols in the management of nonsyndromic craniosynostosis (NSC), significant rates of intraoperative blood loss continue to be reported by multiple centers. The purpose of the current study was to examine our center’s experience with the surgical correction of NSC in an effort to determine independent risk factors of transfusion requirements.

Methods: A retrospective cohort study of patients with NSC undergoing surgical correction at the Montreal Children’s Hospital was carried out. Baseline characteristics and perioperative complications were compared between patients receiving and not receiving transfusions and between those receiving a transfusion in excess or <25 cc/kg. Logistic regression analysis was carried out to determine independent predictors of transfusion requirements.

Results: A total of 100 patients met our inclusion criteria with a mean transfusion requirement of 29.6 cc/kg. Eighty-seven patients (87%) required a transfusion, and 45 patients (45%) required a significant (>25 cc/kg) intraoperative transfusion. Regression analysis revealed that increasing length of surgery was the main determinant for intraoperative ($P = 0.008$; odds ratio, 18.48; 95% CI, 2.14–159.36) and significant (>25 cc/kg) intraoperative ($P = 0.004$; odds ratio, 1.95; 95% CI, 1.23–3.07) transfusions.

Conclusions: Our findings suggest increasing operative time as the predominant risk factor for intraoperative transfusion requirements. We encourage craniofacial surgeons to consider techniques to streamline the delivery of their selected procedure, in an effort to reduce operative time while minimizing the need for transfusion. (Plast Reconstr Surg Glob Open 2020;8:e2592; doi: 10.1097/GOX.0000000000002592; Published online 17 January 2020.)

INTRODUCTION

There are multiple surgical interventions for craniosynostosis including fronto-orbital advancement (FOA), distraction osteogenesis, total cranial vault expansion, and endoscopic/open strip craniectomies. The majority of these techniques rely on wide tissue dissection with significant exposure and calvarial remodeling and have, therefore, been historically associated with significant perioperative complications, including blood loss.¹⁻³ The surgical management of craniosynostosis has evolved greatly in recent years with clear improvements in complication rates, anesthesia protocols, and long-term results.¹⁻⁶ This is likely due to improved perioperative screening, anesthesia delivery and monitoring, developing surgical technique, and close postoperative care by multidisciplinary teams. However, intraoperative blood loss remains a significant concern during craniofacial procedures with studies reporting values between 28.5% and 500% of circulating blood volume.⁷⁻¹¹ In anticipation of expected blood loss during these procedures, it is of great value to determine independent predictors of blood loss and transfusion requirements in an effort to allow craniofacial teams to preemptively assess and control these variables. To that end, the current study has examined our pediatric center’s experience with patients undergoing correction

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of nonsyndromic craniosynostosis (NSC) with a focus on risk factors for intraoperative transfusion.

METHODS

Study Design
After obtaining institutional review board approval, a retrospective cohort study of patients with NSC operated at the Montreal Children’s Hospital between February 2009 and May 2017 was carried out. Inclusion criteria consisted of all NSC patients in the defined study period undergoing any form of surgical correction including open procedures such as FOA and endoscopic-assisted approaches. Patients with a diagnosis of genetically confirmed syndromic craniosynostosis, secondary craniosynostosis, or those with incomplete medical records were excluded.

Postoperative Care Protocol
Postoperatively, patients were transferred to the post-anesthesia care unit for standard monitoring until the following morning. The nurse-to-patient ratio in the recovery area was 1:2. Vital signs were collected hourly as per the standard recovery room protocol for the first 6 hours and then every 4 hours until transfer to the ward. Arterial lines were removed, and blood pressure was measured using an external cuff. Patients were hydrated as needed by peripheral intravenous lines but were encouraged to take fluids (water, juice, formula, or breast milk) orally if tolerated. Blood work was collected at 6 hours postoperatively to assess hemoglobin (Hgb) levels and coagulation parameters (INR/PTT), and patients were transfused as needed based on hemodynamic parameters and blood work values. Patients were not transfused solely based on an absolute Hgb/hematocrit level. Transfusion was considered in the event of tachycardia despite adequate intravenous hydration, urine output, and pain management. For standard open procedures, patients were transferred in the morning to a general surgical ward (1:3 nurse-to-patient ratio), whereas those who had an endoscopic-assisted procedure were discharged home from the recovery room in the morning.

Surgical Technique
The majority of patients enrolled in the present study underwent intracranial vault remodeling by a combined plastic surgery/neurosurgical craniofacial team. Open/strip craniectomies were performed by neurosurgery alone. Anterior vault reconstruction was performed using standard FOA techniques modified as needed for metopic, coronal, and sagittal synostoses as described previously.12 Posterior vault remodeling was performed by transposition of occipital and parietal segments for lambdoid and sagittal synostoses.12 Posterior vault distraction was performed in select NSC patients with multisutural involvement and/or documented elevated intracranial pressures and involved a posterior vault craniotomy and placement of 2 internal cranial distractors. Endoscopic-assisted strip craniectomy was performed for isolated sagittal, metopic, and bicornal craniosynostoses in patients under 6 months of age, with the majority of these procedures being performed before 3.5 months of age. The endoscopic-assisted procedure for sagittal synostosis involved 4-corner barrel staves. Open remodeling for sagittal synostosis was achieved through a vertex craniotomy with barrel staving or biparietal morcellations. The distribution of surgical procedures is summarized in Table 1. Fixation in open procedures was performed with resorbable plates and screws in all cases. Jackson–Pratt drains were routinely placed for open procedures (excluding open strip craniectomies) and were not placed for endoscopic-assisted procedures.

Statistical Analysis
Baseline patient characteristics recorded included sex, age, weight, affected suture(s), and comorbid medical conditions. Intraoperative factors recorded were surgical technique, transfusion volumes, adverse events, and procedure length (from skin incision to closure). Postoperative data including transfusion requirements, length of hospital stay, and postoperative complications within 30 days were recorded. Baseline characteristics were compared between patients receiving and those not receiving transfusions in the perioperative period (from anesthesia start time until transfer to the general surgical ward the following morning). As defined by the American College of Surgeons National Surgical Quality Improvement Program-Pediatric database (ACS-NSQIP), transfusion in excess of 25 cc/kg in the perioperative period was found to be predictive of several adverse perioperative events (bleeding, sepsis, pulmonary complications, etc).13 For this reason, baseline characteristics between patients receiving transfusion in excess and <25 cc/kg were also compared to determine predictors of significant transfusion requirements. Surgical and medical complications were also compared (<25 versus >25 cc/kg and transfusion versus no transfusion). Statistical analysis for direct comparison between groups was achieved through a t test for quantitative variables and the Fisher exact or Pearson χ² tests were used for categorical variables. A P value cutoff of 0.05 was used for statistical significance. Binary logistic regression analysis was used to assess independent predictors of intraoperative transfusion and transfusion in excess of 25 cc/kg. Variables were selected for inclusion in the regression based on a P value cutoff of 0.2 in the direct comparison. All statistical tests were carried out on SPSS v.22 (IBM Corp, Armonk, NY).

RESULTS
Our retrospective analysis yielded 100 NSC patients with clear documentation of transfusion requirements. The specific surgical procedures can be found in Table 1. The average age at surgery was 7.41 months (range, 1.45–62.45; SD, 8.80). Of the 100 patients, 42% had sagittal

### Table 1. Breakdown of Surgical Procedures

| Procedure Type                                      | N (%) |                  |
|----------------------------------------------------|-------|------------------|
| Open procedure                                     | 89 (89)|                  |
| Anterior cranial vault reconstruction (FOA)         | 50 (50)|                  |
| Strip craniectomy                                  | 25 (25)|                  |
| Poster cranial vault reconstruction                 | 12 (12)|                  |
| Poster cranial vault distraction                    | 2 (2.0)|                  |
| Endoscopic procedure                               | 11 (11)|                  |
| Total                                              | 100   |                  |
craniosynostosis, 31% metopic, 14% unicoronal, 8% multisutural, 3.0% bicoronal, and 2.0% lambdoid.

Of the final cohort, 87 patients (87%) required an intraoperative transfusion and 45 patients (45%) required an intraoperative transfusion in excess of 25 cc/kg. The mean intraoperative transfusion requirement for our cohort was 29.6 cc/kg.

Baseline Characteristics

Transfusion Versus No Transfusion

Eighty-seven patients (87%) required an intraoperative transfusion. Patients 0–5 months of age were less likely to require an intraoperative transfusion ($P = 0.021$). Patients undergoing FOA were more likely to require an intraoperative transfusion ($P < 0.001$). In the transfusion group, 57% of patients ($n = 50$) underwent FOA. In contrast, in the no-transfusion group, there were no patients (0%) who underwent FOA. Patients undergoing an open strip craniectomy were less likely to require an intraoperative transfusion ($P = 0.017$). Increasing length of surgery was also associated with the need for an intraoperative transfusion. The mean length of surgery in the transfusion group was 3.62 (range, 1.2-6.33; SD, 1.16) versus 2.12 hours (range, 1.47-3.27; SD, 0.65) in the no-transfusion group with a $P$ value <0.001. The direct comparisons between patients receiving and not receiving an intraoperative transfusion can be found in Table 2.

<25 Versus >25 cc/kg

Forty-five patients (45%) required a significant (>25 cc/kg) intraoperative transfusion. Risk factors associated with the need of a significant intraoperative transfusion included FOA ($P = 0.015$) and increasing length of surgery ($P = 0.001$). The mean length of surgery was 3.88 hours (range, 1.55-6.33; SD, 1.09) in the >25 cc/kg group and 3.05 hours (range, 1.2-5.2; SD, 0.51) in the <25 cc/kg group. The baseline characteristics and direct comparisons between patients receiving and not receiving a significant intraoperative transfusion (>25 versus <25 cc/kg, respectively) can be found in Table 3.

Complications

There were 6 patients (6.0%) who had postoperative complications within 30 days of surgery. One patient was diagnosed with a surgical site infection, and 5 patients (5.0%) had postoperative anemia requiring transfusion on the ward. There were no significant complications such as stroke, venous/pulmonary thromboembolism, seizure, cardiac arrest, or sepsis in our cohort. There were no statistically significant increases in postoperative complication rates related to intraoperative transfusion (Table 4). Moreover, there was no significant increase in complication rates related to a significant (>25 cc/kg) intraoperative transfusion (Table 5).

Binary Logistic Regression for Independent Risk Factors

In the logistic regression evaluating independent risk factors for transfusion requirements (transfusion versus no transfusion), increasing length of surgery remained significant ($P = 0.004$; odds ratio [OR], 18.48; 95% CI, 2.14–159.36). In contrast, FOA was no longer a significant predictor for an intraoperative transfusion. Similarly, strip craniectomy no longer had a significant impact on transfusion. There were no age ranges that remained significant. In the regression evaluating independent risk factors for significant intraoperative transfusion (>25 versus <25 cc/kg), increasing length of surgery was the only variable that remained significant ($P = 0.004$; OR, 1.95; 95% CI, 1.29–3.07).

DISCUSSION

Transfusion risk in craniosynostosis correction has been postulated by previous research to be associated with

| Table 2. Differences in Baseline and Operative Characteristics Based on the Need for Intraoperative Transfusion (Transfusion Versus No Transfusion) |
|---|---|---|
| **Transfusion** (n = 87) | **No Transfusion** (n = 13) | **P** |
| **Sex, n (%)** | | |
| Male | 57 (65.5) | 11 (84.6) | 0.215 |
| Female | 30 (34.5) | 2 (15.4) | |
| **Average age at surgery (mo), n (%)** | | |
| 0–5* | 23 (26.4) | 8 (61.5) | 0.021 |
| 5–7 | 12 (13.8) | 3 (23.1) | 0.407 |
| 7–9* | 30 (34.5) | 1 (7.7) | 0.059 |
| 9–12 | 14 (16.1) | 1 (7.7) | 0.685 |
| 12–24 | 5 (5.7) | 0 (0.0) | 0.999 |
| >24 | 3 (3.4) | 0 (0.0) | 0.999 |
| **Weight (kg),* (n)** | | |
| 8.23 | 7.33 | 0.137 |
| **Type of procedure, n (%)** | | |
| Open procedure* | 79 (90.8) | 10 (76.9) | 0.153 |
| FOA (n)* | 50 (57.4) | 0 (0.0) | <0.001 |
| Strip craniectomy (n)* | 18 (20.7) | 7 (53.8) | 0.017 |
| PCVR (n) | 9 (10.3) | 3 (23.1) | 0.601 |
| PCVD (n) | 2 (2.3) | 0 (0.0) | 0.999 |
| Endoscopic strip craniectomy (n) | 8 (9.2) | 3 (23.1) | 0.847 |
| **Length of surgery (h)*** | | |
| 3.62 | 2.12 | <0.001 |

Values in boldface indicate variables with a significant $P$ value (<0.05). Categorical variables were compared using the Pearson $\chi^2$ or Fisher exact test. Continuous variables were compared using a $t$ test for independent means. $P$ value cutoff of 0.05 used for significance.

*Variables included in the regression based on a $P$ value cutoff <0.2.

PCVD, posterior cranial vault distraction; PCVR, posterior cranial vault reconstruction.
### Table 3. Differences in Baseline and Operative Characteristics Based on the Need for Significant Intraoperative Transfusion (>25 versus <25 cc/kg)

|                         | Transfusion >25 cc/kg (n = 45) | Transfusion <25 cc/kg (n = 55) | P  |
|-------------------------|---------------------------------|---------------------------------|----|
| Sex, female (%)         | 34 (75.6)                       | 34 (61.8)                       | 0.196 |
| Male                    | 11 (24.4)                       | 21 (38.2)                       |     |
| Average age at surgery (mo), female (%) | 8.31                           | 7.95                            | 0.379 |
| Type of procedure, n (%) |                                |                                 |     |
| Open procedure          | 42 (93.3)                       | 47 (85.5)                       | 0.356 |
| Strain craniectomy*     | 29 (64.4)                       | 21 (38.2)                       | 0.015 |
| PCVR                   | 8 (17.8)                        | 17 (30.9)                       | 0.166 |
| PCVD                   | 4 (8.9)                         | 8 (14.5)                        | 0.599 |
| Endoscopic strip craniectomy | 5 (6.7)                      | 8 (14.5)                        | 0.604 |
| Length of surgery (h), n | 3.88                           | 3.05                            | 0.001 |
| Values in boldface indicate variables with a significant P-value (<0.05). Categorical variables were compared using the Pearson χ² or Fisher exact test. Continuous variables were compared using a t-test for independent means. P-value cutoff of 0.05 used for significance.

*Variables included in the regression based on a P-value cutoff of <0.2.

PCVD, posterior cranial vault distraction; PCVR, posterior cranial vault reconstruction.

### Table 4. Perioperative Complications Based on the Need for Intraoperative Transfusion (Transfusion Versus No Transfusion)

|                         | Transfusion (n = 87) | No Transfusion (n = 13) | P  |
|-------------------------|----------------------|-------------------------|----|
| Overall complications, n (%) | 5 (5.7)              | 1 (7.7)                 | 0.999 |
| Wound infection         | 1 (1.1)              | 0 (0.0)                 | 0.999 |
| Dehiscence              | 0 (0.0)              | 0 (0.0)                 |     |
| Hematoma                | 0 (0.0)              | 0 (0.0)                 |     |
| Anemia requiring transfusion | 4 (4.6)            | 1 (7.7)                 | 0.560 |
| Medical complications   | 0 (0.0)              | 0 (0.0)                 |     |
| Pneumonia               | 0 (0.0)              | 0 (0.0)                 |     |
| Pulmonary embolism      | 0 (0.0)              | 0 (0.0)                 |     |
| Venous thromboembolism  | 0 (0.0)              | 0 (0.0)                 |     |
| Acute renal failure     | 0 (0.0)              | 0 (0.0)                 |     |
| Urinary tract infection | 0 (0.0)              | 0 (0.0)                 |     |
| Coma                    | 0 (0.0)              | 0 (0.0)                 |     |
| Stroke                  | 0 (0.0)              | 0 (0.0)                 |     |
| Seizure                 | 0 (0.0)              | 0 (0.0)                 |     |
| Cardiac arrest          | 0 (0.0)              | 0 (0.0)                 |     |
| Sepsis                  | 0 (0.0)              | 0 (0.0)                 |     |

### Table 5. Perioperative Complications Based on the Need for Significant Intraoperative Transfusion (>25 Versus <25 cc/kg)

|                         | Transfusion >25 cc/kg (n = 45) | Transfusion <25 cc/kg (n = 55) | P  |
|-------------------------|---------------------------------|---------------------------------|----|
| Overall complications   | 2 (4.4)                         | 4 (7.3)                         | 0.690 |
| Wound infection         | 0 (0.0)                         | 1 (1.8)                         | 0.999 |
| Dehiscence              | 0 (0.0)                         | 0 (0.0)                         |     |
| Hematoma                | 0 (0.0)                         | 0 (0.0)                         |     |
| Anemia requiring transfusion | 2 (4.4)            | 3 (5.5)                         | 0.999 |
| Medical complications   | 0 (0.0)                         | 0 (0.0)                         |     |
| Pneumonia               | 0 (0.0)                         | 0 (0.0)                         |     |
| Pulmonary embolism      | 0 (0.0)                         | 0 (0.0)                         |     |
| Venous thromboembolism  | 0 (0.0)                         | 0 (0.0)                         |     |
| Acute renal failure     | 0 (0.0)                         | 0 (0.0)                         |     |
| Urinary tract infection | 0 (0.0)                         | 0 (0.0)                         |     |
| Coma                    | 0 (0.0)                         | 0 (0.0)                         |     |
| Stroke                  | 0 (0.0)                         | 0 (0.0)                         |     |
| Seizure                 | 0 (0.0)                         | 0 (0.0)                         |     |
| Cardiac arrest          | 0 (0.0)                         | 0 (0.0)                         |     |
| Sepsis                  | 0 (0.0)                         | 0 (0.0)                         |     |
procedure type, namely more invasive open techniques (ie, FOA), syndromic status, and multisutural involvement.\textsuperscript{11,12} Yan et al\textsuperscript{13} carried out a meta-analysis comparing endoscopic and open approaches and found that open techniques were indeed associated with higher rates of blood loss. In the present study, procedure length in NSC patients was the only independent determinant of transfusion. Although FOAs indeed had a higher percentage of transfusion compared with strip craniectomy in the head-to-head statistical comparison, procedure type was no longer significant in the logistic regression. Rather, our regression revealed that operative time was the sole significant independent risk factor for transfusion. Similarly, the regression assessing the need for a significant transfusion (>25 versus ≤25 cc/kg) revealed that procedure length was also the sole significant independent covariate, whereas procedure type did not contribute significantly.

Conceptually, more complex reshaping procedures involve the removal, reshaping, and fixation of bony segments, compared with “less-invasive” procedures (ie, endoscopic/open strip craniectomy) that involve osteotomies or craniectomies without any large surface area exposure of the dura. The latter have a tendency to bleed steadily, such as under the frontal bone flap in a FOA, for the length of the case and presumably in the acute postoperative period. Thus, in addition to being longer in length, open remodeling procedures are thought to be associated with a “larger” affected surface area of the skull and dura. Indeed, the decreased likelihood of requiring an intraoperative transfusion in the present study in patients under 5 months of age (related to the use of less-invasive approaches, namely strip craniectomy) might also be related to the shorter nature of these procedures in addition to the actual surgical technique employed. Thus, it appears that surgical “complexity,” namely procedures involving significant elevation and rearrangement of skull bones, is potentially confounded by increasing operative time. Similarly, procedures such as strip craniectomies are confounded by decreasing operative time. Given that complex procedures with significant exposure (eg, FOA) and operative time may be viewed as collinear variables, we sought to assess whether length of surgery would remain significant in our regression models after removing FOA as a covariate. In our regression model comparing the transfusion and no-transfusion cohort, length of surgery remained the sole significant variable despite removing FOA from the regression ($P = 0.014$; OR, 5.0; 95% CI, 1.38–18.15). Similarly, after removing FOA as a covariate from our regression model assessing significant intraoperative transfusion (<25 vs >25 cc/kg), length of surgery remained significant ($P = 0.002$; OR, 1.91; 95% CI, 1.28–2.84). Our findings, therefore, suggest that surgical time is the most contributory covariate to the extent of intraoperative blood loss.

The latter finding supports the conclusion of White et al\textsuperscript{14} who found that operative time was the single most important risk factor for blood loss during FOA reconstruction. This finding was also corroborated by Seruya et al\textsuperscript{15} who found that calculated blood loss during FOA reconstruction trended positively with increasing operative time. The present study adds to this finding demonstrating that transfusion risk is predominantly affected by length of surgery in a variety of craniosynostosis procedures (in addition to FOA).

There are several approaches that have been reported in the literature to reduce operative time, including the use of dedicated interdisciplinary teams (surgeons, anesthesiologists, etc.) and standardized anesthesia protocols.\textsuperscript{16} Predictors impacting operative time include surgical team turnover, surgeon experience, and comorbid medical and surgical illness.\textsuperscript{17,18} Wes et al\textsuperscript{19} carried out a retrospective study of 13,100 patients undergoing craniosynostosis repair to assess whether perioperative outcomes differed based on hospital caseload volume. The authors found that centers performing a high volume of craniosynostosis repair had lower perioperative complication rates and decreased hospital stay compared to lower volume centers. They also concluded that more complex reconstructive procedures (ie, mid vault reconstruction) were associated with increased safety profiles in higher volume centers.\textsuperscript{20}

Although rarely associated with adverse events, blood transfusions in the pediatric population can be associated with significant complications such as infection, pneumonia, transfusion-related acute lung injury, and transfusion-related circulatory overload. Potentially life-threatening complications such as transfusion-related acute lung injury and transfusion-related circulatory overload have been reported in as high as 3.6% of pediatric surgical patients receiving a blood transfusion.\textsuperscript{21} Several successful methods for reduction of intraoperative blood loss have been reported in the literature including the use of tranexamic acid, intraoperative cell saver, amino-caproic acid, and recombinant human erythropoietin.\textsuperscript{22–25} Others have explored methods such as hypotensive anesthesia which have been less successful.\textsuperscript{26} In the current cohort, 87% of patients required an intraoperative transfusion, with an overall mean requirement of 29.6 cc/kg. Specifically, our mean transfusion requirement for patients undergoing any form (open or endoscopic) of strip craniectomy (n = 26) was 26.14 cc/kg. In contrast, our mean transfusion requirement for patients undergoing open remodeling (FOA, posterior cranial vault reconstruction, and posterior cranial vault distraction) procedures (n = 61) was 31.07 cc/kg. With respect to the transfusion rates, 89% of our open cohort (n = 79/89) required a transfusion. In our endoscopic cohort, 73% of patients (n = 8/11) required a transfusion. Recent studies on transfusion requirements for patients undergoing open remodeling (eg, FOA) reported transfusion rates between 84% and 100%, which is similar to our reported rate (89%) for patients undergoing open repair.\textsuperscript{27–30} Recent literature assessing transfusion requirements for patients undergoing endoscopic repair reported rates between 0% and 32%.\textsuperscript{28–32} In the current study, the transfusion rate for endoscopic-assisted repair was 73% (n = 8/11), which represents a significant increase compared with the literature on endoscopic suturectomy. However, the endoscopic-assisted cases included in our study were taken directly from the period when this surgery was introduced at our center with its associated surgical learning curve. For the
anesthetists involved in these cases, there was also a learning curve and likely a heightened vigilance in managing these very young children with low body weight (<5 kg) and low circulating blood volume, especially when there can be a physiologic anemia of immaturity before the cases even starts (ie, Hgb starting in 90s). Of note, given that only 11 endoscopic procedures were included in the study period, it is difficult to ascertain the exact nature of this disparity, and future large studies focusing on patients undergoing endoscopic repair are necessary.

According to the American College of Surgeons National Surgical Quality Improvement Program-Pediatric (ACS-NSQIP) database, an intraoperative transfusion in excess of 25 cc/kg has been reported to be a significant threshold for predicting adverse perioperative complications.12 For this reason, we sought to determine factors associated with the need for significant (>25 cc/kg) intraoperative transfusion. Recently, Chow et al10 reported that a transfusion threshold of 25 cc/kg is not significantly predictive of an increased risk for perioperative complications for patients undergoing cranial vault remodeling for craniosynostosis. The authors concluded that 60 cc/kg is a more appropriate safety threshold for this population. However, given that our cohort only had 5 patients with a transfusion requirement above 60 cc/kg, and that our median transfusion requirement was 25.67 cc/kg, we opted to use the previously reported threshold (25 cc/kg) by the ACS-NSQIP. In addition, Gadgil et al13 recently validated the ACS-NSQIP in craniosynostosis surgery and showed that it could reasonably predict adverse perioperative events.

The retrospective nature of the current study is the most significant limitation to our conclusions. Rates of intraoperative crystalloid, colloid, or other transfusion products were not recorded and may have contributed to reduced rates of red cell transfusion. Other studies reporting on transfusion requirements without recording administration of other products also found similar rates.14 The authors were also interested in gleaning from the data set a time threshold above which transfusion became significantly more likely, which would require the use of recursive partitioning. Unfortunately, this was not possible due to the number of patients available for analysis. Thus, despite the study volume being appropriate for the analytics performed, the authors acknowledge that any conclusions should be made with caution given that causality cannot be proven with the retrospective nature of the study. Furthermore, in our head-to-head comparison, there were 15 patients in the “no-transfusion” group, which we recognize to be suboptimal in terms of statistical power. We also recognize that it would be valuable to stratify surgical time above which transfusion became significantly more likely, which would require the use of recursive partitioning.

Our findings suggest that surgical time is the predominant independent risk factor for requiring transfusion in the correction of NSC. We, therefore, encourage craniofacial surgeons to consider techniques to streamline the delivery of their selected procedure, in an effort to reduce operative time while minimizing the need for transfusion.

CONCLUSIONS

Our findings suggest that surgical time is the predominant independent risk factor for requiring transfusion in the correction of NSC. We, therefore, encourage craniofacial surgeons to consider techniques to streamline the delivery of their selected procedure, in an effort to reduce operative time while minimizing the need for transfusion.

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