**Assessing the Impact of Blood Loss in Cranial Vault Remodeling: A Risk Assessment Model Using the 2012-2013 Pediatric National Surgical Quality Improvement Program Datasets**

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**Introduction:** Most Cranial Vault Remodeling (CVR) for craniosynostosis is associated with substantial intraoperative blood loss necessitating transfusion.[1, 2] The transfusion of over 25 mL/kg of red blood cells has long been considered an important safety threshold, with the National Surgical Quality Improvement Program-Pediatric (NSQIP-P) recently identifying this threshold as a significant marker of health care quality.[3, 4] Thus we sought to ascertain risk factors for transfusion in CVR and to quantify the effect of transfusion volume on post-operative complications.

**Materials and Methods:** Patients who underwent CVR for craniosynostosis were identified from the NSQIP-P database. Multivariate regression models were used to identify independent risk factors for transfusion and to assess the impact of transfusion on subsequent outcomes. Multiple methods were used to determine if a transfusion threshold independently predictive of complications existed.

**Results:** 1,059 patients met inclusion criteria with 777 patients (73.4%) requiring a transfusion and 520 patients (49.1%) requiring a transfusion in excess of 25 mL/kg. Mean transfusion volume was 52.1±373.8 mL/kg. Independent risk factors for transfusion included age between 7-9 months ($p$=0.025), asthma ($p$=0.035), impaired cognitive status ($p$=0.012), increasing total procedure RVU ($p$<0.001), and increasing operative time ($p$=0.008) (Table 1 and 2). Neither transfusion nor transfusion volume in excess of 25 mL/kg were associated with an independently increased risk of any type of complication, reoperation, readmission, or increased length of stay following multivariate analysis.

Given that current transfusion thresholds were not predictive of post-operative complications, we attempted to determine a more meaningful threshold. The top 20% of transfusion volumes were ≥45.28 mL/kg, while recursive partitioning generated a threshold of 62.52 mL/kg. The threshold obtained via recursive partitioning was able to independently predict a greater number of complications and was associated with higher odds ratios than the quintile method. A threshold of 60 mL/kg was chosen for simplicity and was independently predictive of overall complications ($p$=0.009), medical complications ($p$=0.004), and increased length of stay ($p$<0.001).

**Table 1.** Multivariate Logistic Regression Evaluating Risk Factors for Transfusion

| Variable | Odds Ratio | 95% Confidence Interval | *p*-value |
|---|---|---|---|
| Age Ranges | | | |
| 0-5 months (reference) | 1.00 | | |
| 5-7 months | 1.53 | 0.85-2.75 | 0.156 |
| 7-9 months | 2.12 | 1.10-4.07 | 0.025* |
| 9-12 months | 1.23 | 0.66-2.30 | 0.516 |
| 12-24 months | 0.97 | 0.50-1.89 | 0.937 |
| >24 months | 0.86 | 0.38-1.93 | 0.710 |
| Weight, kilograms‡ | 0.99 | 0.96-1.02 | 0.525 |
| Procedure | | | |
| Craniectomy for Multiple Suture Craniosynostosis | 0.75 | 0.22-2.55 | 0.647 |
| Extensive Craniectomy for Multiple Suture Craniosynostosis | 1.12 | 0.65-1.91 | 0.690 |
| Frontoorbital Advancement and Reconstruction | 0.88 | 0.51-1.51 | 0.633 |
| Total RVU‡ | 1.02 | 1.01-1.03 | <0.001* |
| Premature Birth | 1.62 | 0.89-2.94 | 0.116 |
| Asthma | 5.00 | 1.12-22.39 | 0.035* |
| Impaired Cognitive Status | 2.5 | 1.22-5.11 | 0.012* |
| Structural CNS Abnormality | 1.11 | 0.76-1.64 | 0.592 |
| Preoperative Hematocrit | 0.96 | 0.91-1.03 | 0.245 |
| Operative Time, hours‡ | 1.23 | 1.06-1.43 | 0.008* |

*Denotes statistical significance <0.05

‡For continuous variables, reported odds ratio above or below 1 indicate the additional risk associated with a per unit change in the variable

Hosmer-Lemeshow Statistic: 0.454 and C-statistic: 0.750 indicating adequate model discrimination and calibration, respectively

**Table 2.** Multivariate Logistic Regression Evaluating Risk Factors for Transfusion ≥ 25 mL/kg

| Variable | Odds Ratio | 95% Confidence Interval | *p*-value |
|---|---|---|---|
| Age Ranges | | | |
| 0-5 months (reference) | 1.00 | | |
| 5-7 months | 0.97 | 0.56-1.68 | 0.905 |
| 7-9 months | 1.28 | 0.71-2.28 | 0.412 |
| 9-12 months | 0.86 | 0.48-1.55 | 0.62 |
| 12-24 months | 0.52 | 0.27-0.99 | 0.049* |
| >24 months | 0.27 | 0.11-0.67 | 0.005* |
| Weight, kilograms‡ | 0.92 | 0.87-0.97 | 0.002* |
| Procedure | | | |
| Craniectomy for Multiple Suture Craniosynostosis | 1.06 | 0.31-3.60 | 0.929 |
| Extensive Craniectomy for Multiple Suture Craniosynostosis | 1.36 | 0.86-2.13 | 0.186 |
| Frontoorbital Advancement and Reconstruction | 0.88 | 0.56-1.39 | 0.593 |
| Total RVU‡ | 1.02 | 1.01-1.02 | <0.001* |
| Premature Birth | 1.46 | 0.89-2.39 | 0.135 |
| Asthma | 5.39 | 2.16-13.42 | <0.001* |
| Impaired Cognitive Status | 2.52 | 1.43-4.45 | 0.001* |
| Structural CNS Abnormality | 1.04 | 0.73-1.46 | 0.839 |
| Preoperative Hematocrit | 1.01 | 0.96-1.07 | 0.699 |
| Operative Time, hours‡ | 1.63 | 1.41-1.89 | <0.001* |

*Denotes statistical significance <0.05

‡For continuous variables, reported odds ratio above or below 1 indicate the additional risk associated with a per unit change in the variable

Hosmer-Lemeshow Statistic: 0.072 and C-statistic: 0.774 indicating adequate model discrimination and calibration, respectively

**Conclusions:** Transfusion is common in complex CVR. The current described transfusion occurrence threshold of 25 mL/kg does not accurately convey postoperative risk. We demonstrate that transfusion in excess of 60 mL/kg significantly increases risk for complications and length of stay in CVR.

**References:**


1. Meara, J.G., et al., *Blood-conservation techniques in craniofacial surgery.* Ann Plast Surg, 2005. **54**(5): p. 525-9.

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3. Hillyer, C.D., et al., *Handbook of Pediatric Transfusion Medicine*. 2004: Elsevier Science.

4. Polites, S.F., et al., *A comparison of two quality measurement tools in pediatric surgery—The American College of Surgeons National Surgical Quality Improvement Program-Pediatric versus the*

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