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Interhospital Variability in Perioperative Red Blood Cell Ordering Patterns in United States Pediatric Surgical Patients

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Objective To evaluate perioperative red blood cell (RBC) ordering and interhospital variability patterns in pediatric patients undergoing surgical interventions at US children's hospitals.

Study design This is a multicenter cross-sectional study of children aged <19 years admitted to 38 pediatric tertiary care hospitals participating in the Pediatric Health Information System in 2009-2014. Only cases performed at all represented hospitals were included in the study, to limit case mix variability. Orders for blood type and crossmatch were included when done on the day before or the day of the surgical procedure. The RBC transfusions included were those given on the day of or the day after surgery. The type and crossmatch-to-transfusion ratio (TCTR) was calculated for each surgical procedure. An adjusted model for interhospital variability was created to account for variation in patient population by age, sex, race/ethnicity, payer type, and presence/number of complex chronic conditions (CCCs) per patient.

Results A total of 357 007 surgical interventions were identified across all participating hospitals. Blood type and crossmatch was performed 55 632 times, and 13 736 transfusions were provided, for a TCTR of 4:1. There was an association between increasing age and TCTR ($R^2 = 0.43$). Patients with multiple CCCs had lower TCTRs, with a stronger relationship ($R^2 = 0.77$). There was broad variability in adjusted TCTRs among hospitals (range, 2.5-25).

Conclusions The average TCTR in US children's hospitals was double that of adult surgical data, and was associated with wide interhospital variability. Age and the presence of CCCs markedly influenced this ratio. Studies to evaluate optimal preoperative RBC ordering and standardization of practices could potentially decrease unnecessary costs and wasted blood. *(J Pediatr 2016;177:244-9).*

Preoperative red blood cell (RBC) ordering for pediatric surgical patients remains largely uninformed by scientific evidence. Although adult surgical literature and practices espouse guidelines for preoperative RBC ordering based on predicted blood losses associated with scheduled procedures and individual medical needs,[1-5] pediatric RBC ordering remains largely disorganized and defensive.[6-9] Without scientific principles guiding RBC ordering, blood products may be ordered by the emergency department physician, the responsible anesthesiologist, the attending surgeon, or a physician in training at any point in the preoperative period, for myriad reasons. Unguided practice may lead to overordering of blood preparatory services, with resultant wasteful spending, an increased burden on laboratory personnel, and wasted blood.[8,10,11]

Overordering of RBC products has been well documented in various settings in the adult literature,[1,5,12-14] and audits of adult hospitals have demonstrated the economic and medical benefits associated with the implementation of preoperative RBC ordering guidelines.[1,15-19] Similar data on RBC ordering practices in the pediatric population are limited, however. In this light, we aimed to characterize preoperative RBC ordering (blood type determination and crossmatch) and postoperative transfusion patterns in surgical patients at freestanding children's hospitals to test 2 hypotheses: (1) that RBC ordering patterns in pediatric surgery differ from those in adult surgery, and (2) that interhospital variability exists in pediatric surgical RBC ordering patterns.

Methods

This study used data from the Children's Hospital Association's Pediatric Health Information System (PHIS), an administrative database containing inpatient data from more than 40 freestanding children's hospitals in the US. The PHIS contains detailed hospital administrative and resource utilization (billing) data, including demographic, diagnostic, procedural, and outcome information, allowing for robust analyses to identify national trends in various surgical fields. Data quality

CCC	Complex chronic condition
MSBOS	Maximum surgical blood order schedule
PHIS	Pediatric Health Information System
RBC	Red blood cell
TCTR	Type and crossmatch-to-transfusion ratio

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and reliability are ensured through a joint effort between the Children's Hospital Association and participating hospitals. Bimonthly coding consensus meetings, coding consistency reviews, and quarterly data quality reports ensure high-quality reporting.[20] This study was approved by the University at Buffalo's Institutional Review Board (775891-1).

Patients aged <19 years who underwent any surgical procedure at any of the participating hospitals between 2009 and 2014 were identified. To limit case mix variability, only case types performed at all represented hospitals were included in this study, resulting in inclusion of 121 procedures performed at all 38 participating hospitals for analysis (**Tables I** and **II**; available at www.jpeds.com). All other procedures identified besides these 121 were removed from the dataset.

Statistical Analyses

RBC ordering was measured by the presence of a billing code for RBC type and crossmatch obtained on the day before or the day of the surgical procedure and RBC transfusion performed on the day of or the day after surgery. The type and crossmatch-to-transfusion ratio (TCTR) was calculated by dividing the total number of type and crossmatch orders by the total number of transfusions ordered for any given surgical procedure. A single-center validation of data was performed by manual chart review of 442 patients (10% of that center's total patient contribution). The center was chosen to match 1 of the authors' access to electronic medical records for manual chart review.

Subjects were stratified by age, sex, race/ethnicity, payer type, and number of complex chronic conditions (CCCs), and overall TCTR was calculated for each subgroup. CCCs were defined based on *International Classification of Diseases, Ninth Revision, Clinical Modification* codes, dividing comorbidities into 9 categories: neuromuscular, cardiovascular, respiratory, renal, gastrointestinal, hematologic or immunologic, metabolic, malignancy, and genetic or other congenital defects. Then an adjusted model for interhospital variability was created to account for variance in patient population by modeling TCTR with Poisson regression using a log-transfusion offset and accounting for clustering of patients within a hospital using a random intercept for each hospital. In addition, to mitigate bias introduced by variable representation of high- and low-TCTR cases by hospital, we divided procedures into TCTR quartiles by frequency. The TCTR quartile was then incorporated into the adjusted model for interhospital variability. We also adjusted the model for age, sex, race/ethnicity, payer type, and number of CCCs per patient. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, North Carolina).

Results

After excluding procedures not performed at all 38 participating hospitals, a total of 357 007 procedures were included in our analysis. In all, RBC type and crossmatch was performed 55 632 times, and 13 736 transfusions were provided, for an overall TCTR of 4.1. The cohort spanned all age categories (<1 year, 1-4 years, 5-9 years, 10-14 years, and 15-18 years) evenly, and comprised 43.6% females and 52.2% non-Hispanic white patients. A slight majority of patients (53.9%) received government assistance. Approximately one-half of the subjects (47.6%) had 1 or more CCCs (**Table III**).

Table III. Patient demographic data

Variables	Surgical cases (n = 357 007), n (%)	RBC type and crossmatch orders (n = 55 632), n (%)	Transfusion orders (n = 13 736), n (%)
Age, y			
15-18	66 322 (18.6)	14 431 (25.9)	2754 (20)
10-14	80 807 (22.6)	13 198 (23.7)	2831 (20.6)
5-9	60 005 (16.8)	6855 (12.3)	1131 (8.2)
1-4	75 264 (21.1)	10 221 (18.4)	2255 (16.4)
<1	74 609 (20.9)	10 927 (19.6)	4765 (34.7)
CCCs			
0	187 030 (52.4)	9271 (16.7)	1223 (8.9)
1	20 778 (5.8)	17 170 (30.9)	4344 (31.6)
2	27 557 (7.7)	16 181 (29.1)	3850 (28)
3	60 390 (16.9)	7160 (12.9)	2171 (15.8)
>3	61 252 (17.2)	5850 (10.5)	2148 (15.6)
Race/ethnicity			
Non-Hispanic white	186 237 (52.2)	30 662 (55.1)	7178 (52.3)
Hispanic	47 561 (13.3)	9231 (16.6)	2216 (16.1)
Non-Hispanic black	79 058 (22.1)	8356 (15)	2393 (17.4)
Asian	8486 (2.4)	1272 (2.3)	328 (2.4)
Other	65 665 (10)	6111 (11)	1621 (11.8)
Payer status			
Government	141 560 (39.7)	28 215 (50.7)	7553 (55)
Other	192 357 (53.9)	3585 (6.4)	1143 (8.3)
Private	23 090 (6.5)	23 832 (42.8)	5040 (36.7)
Sex			
Female	155 597 (43.6)	27 622 (49.7)	6953 (50.6)
Male	201 410 (56.4)	28 010 (50.3)	6783 (49.4)

All P values < .001 for comparisons by category.

The single-center manual chart review performed in 442 (10%) of the center's patients yielded a sensitivity of 96% and specificity of 94% for RBC type and crossmatch performed, and a sensitivity of 98% and a specificity of 97% for transfusion orders.

Across all hospitals, age (P = .002), sex (P = .013), payer type (P = .001), and number of CCCs (P < .001) were independently associated with TCTR value after adjustment (**Table IV**). For example, female patients had a lower adjusted TCTR compared with their male counterparts (4.33 [95% CI, 4.28-4.37] vs 4.58 [95% CI, 4.54-4.62]; P < .001), and patients with private insurance had a higher TCTR compared with those with public insurance (5.28 [95% CI, 5.24-5.32] vs 4.34 [95% CI, 4.3–4.39]; P < .001). In the adjusted model, there was a weak association between increasing age and higher TCTR (R^2 = 0.43 for linear regression), and a stronger association between decreasing number of CCCs and higher TCTR (R^2 = 0.77) (**Figure 1**). In unadjusted analysis, there was great variability in TCTR values among hospitals; in fact, the TCTR values ranged from 1.5-25 when all procedures were included (**Figure 2**; available at www.jpeds.com). After adjusting for age, sex, race, payer type, TCTR quartile, and number of CCCs, there remained broad variability in TCTRs among hospitals, ranging from 2.5 to 26 (**Figure 3**). Removing the 2 high-TCTR