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ORIGINAL ARTICLE

Red Blood Cell Transfusion in the Postoperative Care of Pediatric Cardiac Surgery: Survey on Stated Practice

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Abstract The optimal red blood cell transfusion threshold for postoperative pediatric cardiac surgery patients is unknown. This study describes the stated red blood cell transfusion practice of physicians who treat postoperative pediatric cardiac surgery patients in intensive care units. A scenario-based survey was sent to physicians involved in postoperative intensive care of pediatric cardiac surgery patients in all Canadian centers that perform such surgery. Respondents reported their red blood cell transfusion practice in four postoperative scenarios: acyanotic or cyanotic cardiac lesion, in a neonate or an infant. In part A of each scenario, the patient was critically ill, but stabilized; in part B, the patient became unstable. Response rate was 58 % (71 of 123), with 45 respondents indicating direct involvement in postoperative intensive care. There was a wide variability in stated transfusion threshold, ranging from <7.0–14.0 g/dL for stabilized cases. There was no significant difference between neonates and infants in stated transfusion threshold. The mean hemoglobin level below which respondents would transfuse a stabilized patient was 9 g/dL for acyanotic and 11.2 g/dL for cyanotic patients, a statistically significant difference (2.2 $\pm$ 0.9 g/dL, $p < 0.001$). All clinical determinants of instability significantly increased transfusion threshold. Hemodynamic instability increased transfusion threshold by 2.3 $\pm$ 1.3 g/dL in acyanotic patients and by 1.3 $\pm$ 1.1 g/dL in cyanotic patients. Cyanotic lesion and clinical instability, but not patient age, increased stated red blood cell transfusion threshold. Significant variation in reported red blood cell transfusion practice exists among physicians treating pediatric patients in intensive care following cardiac surgery.

Keywords Pediatric · Cardiac surgery · Transfusion threshold · Intensive care · Blood

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Introduction

Red blood cell (RBC) transfusion is common in the care of pediatric cardiac surgery patients, with reported transfusion rates up to 79 and 55 % for surgery with and without bypass, respectively [1]. However, RBC transfusions are not without risk. Though transfusion-related infectious complications of RBC transfusions have decreased in recent years [2], significant non-infectious serious hazards of transfusion remain, including storage lesions and transfusion-related immunomodulation [2–4]. RBC transfusion in pediatric cardiac surgery patients has been associated with longer ventilation time, prolonged hospital stay and increased infections [5–7]. Furthermore, RBC transfusion is associated with increased morbidity and mortality in adults with cardiac disease [8–10]. Indeed, a restrictive RBC transfusion strategy was not inferior to a liberal strategy in clinical trials of critically ill adults [11], critically ill children [12], and critically ill children after cardiac surgery [13, 14]. Whether these studies have changed clinical practice is unknown.

Three scenario-based surveys have been published on stated transfusion practice in pediatric intensive care units (PICU); none specifically addressed cardiac patients [15–17]. We therefore surveyed physicians caring for postoperative cardiac surgery patients in PICU in order to describe stated RBC transfusion practice and the determinants that influence transfusion decision making.

Materials and Methods

Study Design

We developed a cross-sectional self-administered scenario-based survey. The questionnaire was designed to determine which patient, respondent, and center-related characteristics modulate the hemoglobin (Hb) concentration below which physicians prescribe a RBC transfusion.

Study Population

We aimed to contact physicians directly involved in the postoperative care of pediatric cardiac surgery patients in all seven pediatric cardiac surgery programs in Canada. Names and contact details of pediatric intensivists, cardiologists, and cardiac surgeons were obtained from websites of Stollery Children's Hospital, Montreal Children's Hospital, Centre Hospitalier Universitaire de Québec, Children's Hospital of Eastern Ontario, British Columbia Children's Hospital, Hospital for Sick Children and CHU Sainte-Justine. Each center was telephoned to confirm the information. Respondents were asked to indicate if they were directly involved in postoperative ICU care of pediatric cardiac surgery patients and if not, to return the survey blank.

Questionnaire Development

We asked 26 physicians at our center (cardiac surgeons, cardiologists, intensivists, and PICU fellows) to list all clinical and laboratory data that would prompt them to prescribe RBC transfusion in a postoperative cardiac surgery patient. Fourteen clinical and nine laboratory items were identified. Three authors (KH, JL, and NP) selected final items using the Delphi method. After two iterations, 11 possible determinants were retained: age, cyanotic cardiopathy, desaturation, pulmonary hypertension, hypotension, hypovolemia, increased inotropes, hyperlactatemia, decreased mixed venous saturation (SvO_2), active bleeding, and extracorporeal membrane oxygenation (ECMO) support. A self-administered survey was constructed with four scenarios (Table 1 and see electronic supplementary material for all four scenarios) describing the postoperative condition of a neonate or infant with a cyanotic (palliated) or acyanotic (corrected) cardiac malformation. Mean Hb level and lower limit of normal by age group were provided as a reference. Part A of each scenario described a hemodynamically stable patient, who became unstable in part B. In each scenario, clinical determinants of stability were changed one at a time and respondents asked to indicate their Hb transfusion threshold. The survey also requested information on physician and PICU characteristics (Table 2).

Questionnaire Pretesting

Three PICU attending physicians, four PICU fellows, and one pediatric cardiac surgeon rated the final version of the questionnaire for discriminality, clarity, utility, face validity, content validity, construct validity, and absence of redundancy [18] using a 7-point Likert scale ranging from one (complete disagreement) to seven (complete agreement). Responses between five and seven were considered satisfactory. The respondents considered 84 % of questions satisfactory, with a mean Likert score of 5.6 for all quality criteria.

Questionnaire Administration

The survey was distributed according to the principles of Dillman et al. [19]. It was mailed in June 2009; reminders with survey attached were sent 3 and 4 months after the first mailing.

Statistics

Three variable categories were considered possible determinants of RBC transfusion in critically ill children: disease (scenarios), clinical patient characteristics, and characteristics of respondents and ICUs.

First, baseline mean and standard deviation (SD) of stated transfusion threshold were calculated for each scenario. Second, the effect of each respondent's characteristic on baseline Hb was analyzed separately, using two-way ANOVA with scenarios and respondent characteristics as independent variables. Third, changes from baseline transfusion threshold were calculated for each determinant by scenario and compared to uncover statistically significant changes between determinants. The effect of scenarios 1–4 on baseline transfusion threshold was assessed by one-way ANOVA. The effect of determinants on differences between baseline Hb transfusion threshold in each scenario and determinant-defined transfusion threshold was evaluated by two-way ANOVA. Significant interactions between scenarios and determinants were explored: Thus, one-way ANOVAs (factor = scenario) were performed for each determinant to estimate the effect of scenarios and

Table 1 Example of a scenario proposed in the self-administered questionnaire

Scenario 1A: A 6-day-old child is in the intensive care unit 6 h after an arterial switch operation for transposition of the great arteries. The postoperative echocardiogram showed good contractility and no significant residual lesion. Ventilator settings include a rate of 30 bpm, peak inspiratory pressure of 20 cmH_2O, PEEP 4 cmH_2O, and FiO_2 0.40. Arterial oxygen saturation is 99 %. The child is receiving milrinone 0.5 mcg/kg/min and dopamine 5 mcg/kg/min. Heart rate is 150/min, sinus rhythm. Arterial blood pressure is 70/35 mmHg. CVP is 8 mmHg. Pulmonary systolic pressure is one-third systemic. The child is warm, with good peripheral perfusion. Urine output is 1 ml/kg/h. There is no active bleeding. Ventilator and inotropic support have not been changed in the last 2 h	
Recent laboratory results include:	
Arterial blood gas: pH 7.41, PaO_2 120 mmHg, PCO_2 40 mmHg, bicarbonate 22 mmol/L	
Mixed venous saturation (SvO_2): 70 %	Lactate: 1.5 mmol/L
Platelet count: 100 × 10^9/L (=× 10^3/μL)	aPTT:40 s INR 1.2
Scenario 1B: Over the following hours, the patient's condition deteriorates. Heart rate is now 200/min, sinus rhythm. Arterial blood pressure is 48/28. Serum lactate is 6.8, and mixed venous saturation is 45 %. The patient has cool extremities, and there has been no urine output in the last hour. There is no active bleeding. A cardiac echo has been requested, and adjustments of inotropic support are being made. You are informed of the patient's current hemoglobin level	

See electronic supplementary material for the complete four scenarios

APTT activated partial thromboplastin time, *CVP* central venous pressure, FiO_2 fraction of inspired oxygen, *INR* international normalized ratio, PaO_2 partial pressure of oxygen in arterial blood, PCO_2 partial pressure of carbon dioxide in arterial blood, *PEEP* positive end-expiratory pressure

likewise, one-way ANOVAs (factor = determinants) were carried out for each scenario to estimate the effect of determinants. The latter analysis compared the mean change associated with each determinant for each scenario separately. Pairwise comparisons between determinants were carried out, and a Tukey's HSD post hoc test was used to account for multiplicity. Analyses were done by a statistician (Thierry Ducruet) with SAS program (v. 9.3, SAS Institute Inc., Cary, NC).

Results

The survey was sent to 123 physicians; 71 responded (58 %), of whom 45 (63 %) indicated direct involvement in postoperative cardiac surgery ICU care. Only 17 responses were missing (17/2520 = 0.7 %) in the surveys that we received; most unanswered questions were about physician age (6 of 17 unanswered questions) and number of PICU beds (5 of 17).

Physician and PICU characteristics are described in Table 2. Average age of respondents was 43 ± 9 years. Pediatrics was the primary specialty for 32 of 45 (71 %). Most (62 %) had ten or more years of practice as attending physician. Average number of PICU beds was 16 ± 5.9. 73 % of respondents stated their institution performed 0–200 operations per year using cardiopulmonary bypass (CPB). 18 of 45 physicians answered that 26–50 % of cardiac surgeries were performed on patients aged under 30 days.

Figure 1 reports the number of times each Hb transfusion threshold was chosen in the four hemodynamically stable scenarios. For neonates, the average Hb transfusion threshold for an acyanotic patient (arterial switch) was 9.2 ± 1.3 g/dL and was 11.3 ± 1.6 g/dL for a cyanotic patient (systemic-pulmonary shunt for tetralogy of Fallot with pulmonary atresia). For infant cases, the mean Hb transfusion threshold was 8.8 ± 1.3 g/dL for an acyanotic patient (corrective surgery for complete atrioventricular canal) and 11.1 ± 1.4 g/dL for a cyanotic patient (stage 2 cavopulmonary shunt palliation for hypoplastic left heart syndrome).

Mean transfusion threshold was higher in cyanotic than in acyanotic patients, by 2.2 g/dL (95 % confidence interval 2.0–2.4, $p < 0.001$) in stabilized patients and by 1.3 g/dL (95 % CI, 1.1–1.6, $p < 0.001$) in unstable patients (part B of the scenarios). Age was not a significant factor: The difference between mean transfusion threshold for neonates and infants was 0.3 g/dL (95 % CI −0.1 to 0.8, $p = 0.17$) in stabilized patients and 0.2 g/dL (95 % CI −0.1 to 0.6, $p = 0.14$) in unstable patients.

Physician and PICU characteristics did not significantly affect stated threshold Hb in all scenarios (Table 2). Transfusion threshold was lower in higher-volume centers (>200 cardiopulmonary bypass cases/year), but this was not statistically significant ($p = 0.08$).

Table 3 shows the average increase in Hb transfusion threshold for each possible clinical determinant within each scenario; all clinical determinants significantly increased transfusion threshold. Hemodynamic instability (part B vs. part A of the scenarios) was also associated with important increases in transfusion threshold over baseline for all scenarios. In acyanotic cases, the most important increase over baseline Hb transfusion threshold was observed with ECMO (+2.2 ± 1.4 g/dL), active bleeding (+2.0 ± 1.2 g/dL), and decreased SvO_2 (+2.0 ± 1.3 g/dL). In cyanotic cases, decreased SvO_2 (+1.2 ± 1.1 g/dL), oxygenation

Table 2 Characteristics of 45 respondents who answered to the four scenarios

Characteristic	Response	Respondents	p Value[a]
Age of the respondents (years)[b]		43 ± 9	0.53
		Number (%)	
Year of completion of MD degree			
Prior to 1970		1 (2)	0.93
1970–1979		6 (13)	
1980–1989		19 (42)	
1990–1999		11 (24)	
≥2000		8 (18)	
Primary specialty other than intensive care			
Cardiac surgery		2 (4)	0.20
Cardiology		10 (22)	
Pediatrics		32 (71)	
Anesthesia		1 (2)	
Academic rank			
Professor		7 (16)	0.84
Associate professor		16 (36)	
Assistant professor		18 (40)	
Lecturer		3 (7)	
No academic affiliation		1 (2)	
Number of years in practice as an attending			
0–4		9 (20)	0.54
5–9		8 (18)	
10–14		9 (20)	
≥15		19 (42)	
Type of Intensive Care Unit in which postoperative cardiac surgery patients are treated			
Pediatric ICU		43 (96)	0.69
Pediatric cardiac ICU		2 (4)	
Number of beds in the intensive care unit[c]			
≤10		11 (28)	0.29
11–20		16 (40)	
>20		13 (33)	
Number of pediatric cardiac operations using cardiopulmonary bypass performed in institution per year			
0–100		9 (20)	0.08
101–200		24 (53)	
>200		11 (24)	
Don't know		1 (3)	
Percentage of cardiac operations using cardiopulmonary bypass in institution performed on neonatal patients (age less than 30 days)			
0–10 %		2 (4)	0.70
11–25 %		10 (22)	
26–50 %		18 (40)	
51–75 %		5 (11)	
76–100 %		1 (2)	
Don't know		9 (20)	
Type of red blood cell transfusion			
Packed red blood cells		43 (96)	0.80
Whole blood		2 (4)	
Stated average storage time of red blood cells prior to transfusion[d]			
Less than 7 days		5 (12)	0.47

Table 2 continued

Characteristic	Response	Respondents	*p* Value[a]
7 –14 days		3 (7)	
More than 14 days		2 (5)	
Don't know		34 (77)	
Stated presence of a local policy to use "fresh" red blood cells in cardiac patients			
Yes		22 (49)	0.07
No		16 (36)	
Don't know		7 (16)	

Mean ± standard deviation or proportions and percentage (in parentheses)

ICU intensive care unit

[a] Two-way repeated-measures analysis of variance: one characteristic (×1) and the four scenarios (×2) versus baseline threshold hemoglobin level (*y*). The *p* values describe the characteristic's effect

[b] 6 missing values

[c] 5 missing values

[d] 1 missing value

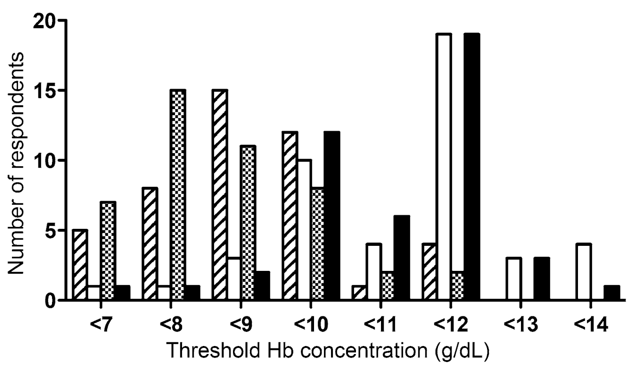

Fig. 1 Distribution of hemoglobin (Hb) threshold for hemodynamically stable patients (Part A in all scenarios). The mean Hb threshold below which respondents would prescribe packed red blood cells transfusion was statistically different between acyanotic scenarios and cyanotic scenarios ($p < 0.0001$). *Diagonal lines* 6 days of age, arterial switch. *White bar* 6 days, systemic-pulmonary shunt. *Dots* 5 months atrioventricular canal. *Black bar* 5 months Glenn for hypoplastic left heart syndrome

difficulties (+1.0 ± 1.0 g/dL), and active bleeding (+1.0 ± 1.0 g/dL) were also important clinical determinants. The increase in Hb transfusion threshold for acyanotic cases was significantly higher than in cyanotic cases for the actively bleeding child and for ECMO.

Discussion

This study describes the stated RBC transfusion practice pattern of physicians in the postoperative ICU care of pediatric cardiac surgery patients. We also characterized clinical, practitioner, and center-dependent determinants of RBC transfusion. Significant variability of Hb transfusion threshold was noted among physicians when presented four different clinical scenarios, ranging from <7.0 to 14.0 g/dL for cyanotic patients and<7.0 to 12.0 g/dL for acyanotic stabilized patients. This wide variation reflects the lack of consensus in the medical community regarding Hb transfusion threshold for pediatric postoperative cardiac surgery patients.

Few trials have attempted to define the ideal Hb transfusion threshold in pediatric cardiac surgery. They studied different transfusion thresholds, populations and outcomes, making comparisons difficult. In acyanotic patients, two randomized controlled trials sought to determine the lowest acceptable hematocrit level during CPB. The first study showed in 113 children younger than 9 months that hemodilution during CPB to hematocrit of 21.5 % (Hb ≈ 7.5 g/dL) compared to 27.8 % (Hb ≈ 9.3 g/dL) was associated with lower Bayley Psychomotor Development index at 1 year of age (81.9 ± 15.7 vs. 89.7 ± 14.7, $p = 0.008$) [20]. However, in a different study of 124 patients, the same psychomotor development index was similar at 1 year of age in subjects with hematocrits of 24.8 % (Hb ≈ 8.3 g/dL) and 32.6 % (Hb ≈ 10.9 g/dL) during CPB [21]. A subgroup analysis of 125 infants enrolled in the TRIPICU study after cardiac surgery [12] showed no significant difference in incidence of multiple organ dysfunction syndrome and death (12.7 vs. 6.3 %; $p = 0.36$) when comparing restrictive and liberal transfusion groups (Hb: 7.0 vs. 9.5 g/dL); however, neonates and patients with cyanotic heart disease were excluded from this trial [14]. Finally, a single-center randomized controlled trial in children with acyanotic congenital heart defects requiring elective cardiac surgery [22] demonstrated that a restrictive transfusion strategy (Hb < 8.0 g/dL) in the operating room and ICU, compared to a liberal one (Hb < 10.8 g/dL), was associated with shorter length of hospital stay. These studies

Table 3 Association between possible determinants and increase in threshold hemoglobin concentration

Scenario					
Scenario characteristics	1	2	3	4	*p*-Value†
Patient's age in the scenario	6 days	6 days	5 months	5 months	
Acyanotic (Acy) versus cyanotic (Cy)	Acy	Cy	Acy	Cy	
Baseline threshold Hb chosen by respondents (g/dL)	9.2 ± 1.3	11.3 ± 1.6	8.8 ± 1.3	11.1 ± 1.4	2, 4 > 1, 3
Determinants	Increase of threshold Hb over baseline (g/dL)				*p* value†
(1) Oxygenation					
(1a) $SaO_2 = 89$ % with $FiO_2 = 100$ % despite increased ventilator settings	1.5 ± 1.0		1.6 ± 1.0		0.75
(1b) $SaO_2 = 60$ % with $FiO_2 = 100$ %despite increased ventilator settings		0.8 ± 0.9		1.2 ± 1.1	0.14
(2) Pulmonary pressure is systemic	1.2 ± 1.1	0.4 ± 0.7	1.2 ± 1.2	NA	1, 3 > 2
(3) Blood pressure					
(3a) 48/28 rather than 70/35 mmHg	1.7 ± 1.2	0.7 ± 1.0			<0.001
(3b) 58/30 rather than 85/40 mmHg			1.5 ± 1.3	0.7 ± 0.9	0.001
(4) CVP = 2 mmHg, urine output = 0 in past hr	1.1 ± 1.2	0.4 ± 0.8	1.2 ± 1.3	0.6 ± 0.9	1, 3 > 2; 3 > 4
(5) Adrenaline increased to 0.2 mcg/kg/min	1.3 ± 1.2	0.5 ± 0.8	1.2 ± 1.2	0.6 ± 1.0	1 > 2, 4; 3 > 2
(6) Blood lactate: 6.8 rather than 1.5 mmol/L	1.7 ± 1.1	1.0 ± 1.0	1.9 ± 1.3	1.0 ± 1.1	1, 3 > 2, 4
(7) Mixed venous O_2 saturation (SvO_2)					
(7a) SvO_2: 45 % rather than 70 %	1.9 ± 1.2		2.0 ± 1.3		0.50
(7b) SvO_2: 25 % rather than 55 %		1.2 ± 1.0		1.3 ± 1.1	0.62
(8) The child is actively bleeding	2.1 ± 1.2	0.9 ± 1.0	2.1 ± 1.2	1.0 ± 1.0	1, 3 > 2, 4
(9) The child is on ECMO	2.1 ± 1.5	0.6 ± 1.4	2.3 ± 1.4	0.8 ± 1.4	1, 3 > 2, 4
(10) Hemodynamically unstable patient (part B of each scenario)	2.2 ± 1.3	1.2 ± 1.0	2.3 ± 1.3	1.4 ± 1.1	1, 3 > 2, 4

CVP central venous pressure, *ECMO* extracorporeal membrane oxygenation, *FiO_2* fraction of inspired oxygen, *Hb* hemoglobin, *Hr* hour *SaO_2* arterial oxygen saturation. All clinical determinants increase significantly the threshold Hb

† *p* values report comparison(s) between two scenarios for each determinant of instability; when the same determinant was compared between more than two scenarios, post hoc pairwise comparisons were performed using Tukey's HSD test to account for multiplicity. Statistically significant contrasts are shown. For example, for lactate, 1, 3 > 2, 4 means that the Hb level in scenario #1 was higher than in #2 and #4, that the Hb level in scenario 3 was higher than in #2 and #4, and that the difference was statistically significant ($p < 0.05$)

suggest that Hb concentrations over 8.3 g/dL during CPB and over 7.0 g/dL in the PICU are likely safe in acyanotic pediatric cardiac surgery patients.

Less is known about the appropriate transfusion threshold for cyanotic postoperative patients. Physicians target higher Hb values for critically ill children with cyanotic heart disease [23]. A study of adults with cyanotic heart disease showed direct correlation between oxygen saturation and ideal Hb [24]. Yet, whether maintaining higher Hb levels in cyanotic postoperative cardiac surgery patients improves morbidity or mortality is unknown. To date, only one small randomized controlled trial addressed the question by allocating 60 children with cyanotic cardiac lesions to either a restrictive or liberal transfusion strategy (Hb < 9.0 vs. < 13.0 g/dL); no difference was observed in the postoperative blood lactate level [13]. Unfortunately, Beekman's [25] statement in 1985 that "the optimal Hb concentration for children with cyanotic heart disease has yet to be determined" remains true three decades later.

Patient age did not significantly influence stated Hb transfusion threshold of respondents, with an increase of only 0.3 g/dL for neonates compared to infants. This differs from two previous surveys on stated transfusion practice in PICU patients, each including one cardiac scenario. In 2002, Laverdière et al. reported a mean increase of 0.9 g/dL Hb transfusion threshold for neonates compared to infants after correction of tetralogy of Fallot [15]. Twelve years later, Du Pont-Thibodeau et al. reported a smaller increase of 0.6 g/dL for the same scenario [17].

All nine determinants of hemodynamic instability increased Hb transfusion threshold in every scenario. Hb transfusion threshold for ECMO and for active bleeding was significantly higher for acyanotic cases compared to cyanotic cases. This may suggest a ceiling effect in transfusion thresholds, as cyanotic cases in our survey began with a higher baseline stated Hb transfusion threshold.

Whether there is a benefit to transfusing whole blood versus packed red cells or an optimal length of blood storage time remains a question of interest in this population. In this survey, 96 % of respondents state that they use packed red cells rather than whole blood. Twenty-two respondents (49 %) reported that there was a policy to use "fresh" RBC units transfused to their cardiac patients (Table 2), though 77 % stated that they did not know the average length of red cell storage prior to transfusion. Spinella [26] asked the same question to American blood bankers and pediatric intensivists: Most children's hospitals (≥40 %) responded that they use RBC units stored less than 8 days in pediatric cardiac patients. It would be interesting to compare the outcomes of pediatric cardiac patients who received or did not receive RBC units stored less than a week.

One strength of this study is that we reached physicians across Canada involved in the postoperative care of pediatric cardiac surgery patients; our results represent national practice. The questionnaire's scenarios were well validated and identified the most important determinants for practitioners. More importantly, this is the first survey of Hb transfusion threshold in pediatric cardiac surgery. There are, however, limitations to this study. Although considerable efforts were made to reach every physician providing postoperative cardiac PICU care in Canada, some may not have been reached. Survey response rate was 58 %. While it is possible that many of the non-respondents were not in fact direct participants in postoperative ICU patient care, we were not able to confirm this through this study. Systematic reviews of postal questionnaires reported a mean response rate of 54 % [27] to 61 % [28] for physicians. Our rate would be considered good, though not optimal, by experts in the field [29]. The results of this survey must be interpreted cautiously because its sample size is small. Furthermore, our results may not represent practice in other countries. Finally, generalizability of stated practice to actual practice is limited by desirability bias and the challenge to create scenarios that fully capture the complexity of real life cases.

In conclusion, there is a wide variation in reported RBC transfusion practice among Canadian physicians treating postoperative pediatric cardiac surgery patients in the ICU. Presence of cyanotic lesion and clinical determinants of instability, but not patient age, increased stated Hb transfusion threshold.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Human and Animal Rights This article does not contain any studies with animals performed by any of the authors.

Informed Consent The return of a completed survey was considered to indicate consent to participate, as per institutional ethics committee guidance.

References

1. Keung CY, Smith KR, Savoia HF, Davidson AJ (2009) An audit of transfusion of red blood cell units in pediatric anesthesia. Pediatr Anesth 19:320–328. doi:10.1111/j.1460-9592.2009.02939.x
2. Hendrickson JE, Hillyer CD (2009) Noninfectious serious hazards of transfusion. Anesth Analg 108:759–769. doi:10.1213/ane.0b013e3181930a6e
3. Zubair AC (2009) Clinical impact of blood storage lesions. Am J Hematol 85:117–122. doi:10.1002/ajh.21599
4. Vamvakas EC, Blajchman MA (2007) Transfusion-related immunomodulation (TRIM): an update. Blood Rev 21:327–348. doi:10.1016/j.blre.2007.07.003
5. Kipps AK, Wypij D, Thiagarajan RR et al (2011) Blood transfusion is associated with prolonged duration of mechanical ventilation in infants undergoing reparative cardiac surgery. Pediatr Crit Care Med 12:52–56. doi:10.1097/PCC.0b013e3181e30d43
6. Salvin JW, Scheurer MA, Laussen PC et al (2011) Blood transfusion after pediatric cardiac surgery is associated with prolonged hospital stay. Ann Thorac Surg 91:204–210. doi:10.1016/j.athoracsur.2010.07.037
7. Székely A, Cserép Z, Sápi E et al (2009) Risks and predictors of blood transfusion in pediatric patients undergoing open heart operations. Ann Thorac Surg 87:187–197. doi:10.1016/j.athoracsur.2008.09.079
8. Shaw RE, Johnson CK, Ferrari G et al (2013) Blood transfusion in cardiac surgery does increase the risk of 5-year mortality: results from a contemporary series of 1714 propensity-matched patients: long-term outcome of blood transfusion. Transfus (Paris) 54:1106–1113. doi:10.1111/trf.12364
9. Murphy GJ, Reeves BC, Rogers CA et al (2007) Increased mortality, postoperative morbidity, and cost after red blood cell transfusion in patients having cardiac surgery. Circ 116:2544–2552. doi:10.1161/CIRCULATIONAHA.107.698977
10. Du Pont-Thibodeau G, Harrington K, Lacroix J (2014) Anemia and red blood cell transfusion in critically ill cardiac patients. Ann Intensive Care 4:16. doi:10.1186/2110-5820-4-16
11. Hébert PC, Wells G, Blajchman MA et al (1999) A multicenter, randomized, controlled clinical trial of transfusion requirements in critical care. N Engl J Med 340:409–417. doi:10.1056/NEJM199902113400601
12. Lacroix J, Hébert PC, Hutchison JS et al (2007) Transfusion strategies for patients in pediatric intensive care units. N Engl J Med 356:1609–1619. doi:10.1056/NEJMoa066240
13. Cholette JM, Rubenstein JS, Alfieris GM et al (2011) Children with single-ventricle physiology do not benefit from higher hemoglobin levels post cavopulmonary connection: results of a prospective, randomized, controlled trial of a restrictive versus

liberal red-cell transfusion strategy*. Pediatr Crit Care Med 12:39–45. doi:10.1097/PCC.0b013e3181e329db
14. Willems A, Harrington K, Lacroix J et al (2010) Comparison of two red-cell transfusion strategies after pediatric cardiac surgery: a subgroup analysis. Crit Care Med 38:649–656. doi:10.1097/CCM.0b013e3181bc816c
15. Laverdière C, Gauvin F, Hébert PC et al (2002) Survey on transfusion practices of pediatric intensivists. Pediatr Crit Care Med 3:335–340. doi:10.1097/01.PCC.0000031371.88694.2B
16. Nahum E, Ben-Ari J, Schonfeld T (2004) Blood transfusion policy among european pediatric intensive care physicians. J Intensive Care Med 19:38–43. doi:10.1177/0885066603257966
17. Du Pont-Thibodeau G, Tucci M, Ducruet T, Lacroix J (2014) Survey on stated transfusion practices in PICUs*. Pediatr Crit Care Med 15:409–416. doi:10.1097/PCC.0000000000000121
18. Cook DJ, Guyatt GH, Jaeschke R et al (1995) Determinants in canadian health care workers of the decision to withdraw life support from the critically ill. Canadian critical care trials group. JAMA 273:703–708
19. Dillman DA (1978) Mail and telephone surveys: the total design method. John Wiley and Sons, New York
20. Jonas RA, Wypij D, Roth SJ et al (2003) The influence of hemodilution on outcome after hypothermic cardiopulmonary bypass: results of a randomized trial in infants. J Thorac Cardiovasc Surg 126:1765–1774. doi:10.1016/j.jtcvs.2003.04.003
21. Newburger JW, Jonas RA, Soul J et al (2008) Randomized trial of hematocrit 25 % versus 35 % during hypothermic cardiopulmonary bypass in infant heart surgery. J Thorac Cardiovasc Surg 135(347–354):e4. doi:10.1016/j.jtcvs.2007.01.051
22. Gast-Bakker DH, Wilde RBP, Hazekamp MG et al (2013) Safety and effects of two red blood cell transfusion strategies in pediatric cardiac surgery patients: a randomized controlled trial. Intensive Care Med 39:2011–2019. doi:10.1007/s00134-013-3085-7
23. Demaret P, Tucci M, Ducruet T et al (2014) Red blood cell transfusion in critically ill children (CME). Transfus (Paris) 54:365–375. doi:10.1111/trf.12261 **(quiz 364)**
24. Broberg CS, Jayaweera AR, Diller GP et al (2011) Seeking optimal relation between oxygen saturation and hemoglobin concentration in adults with cyanosis from congenital heart disease. Am J Cardiol 107:595–599. doi:10.1016/j.amjcard.2010.10.019
25. Beekman RH, Tuuri DT (1985) Acute hemodynamic effects of increasing hemoglobin concentration in children with a right to left ventricular shunt and relative anemia. J Am Coll Cardiol 5:357–362
26. Spinella PC, Dressler A, Tucci M et al (2010) Survey of transfusion policies at us and canadian children's hospitals in 2008 and 2009: transfusion policy survey in children. Transfus (Paris) 50:2328–2335. doi:10.1111/j.1537-2995.2010.02708
27. Asch DA, Jedriewski MK, Christakis NA (1997) Response rates to mail surveys published in medical journals. J Clin Epidemiol 50:1129–1136
28. Cummings SM, Savitz LA, Konrad TR (2001) Reported response rates to mailed physician questionnaires. Health Serv Res 35:1347–1355
29. Burns KEA, Duffett M, Kho ME et al (2008) A guide for the design and conduct of self-administered surveys of clinicians. Can Med Assoc J 179:245–252. doi:10.1503/cmaj.080372