Cardiovascular Topics

Audit of transfusion of blood products in paediatric congenital heart surgery on cardiopulmonary bypass

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Abstract

Background: Cardiac surgery is associated with peri-operative bleeding, which may result in the need for blood transfusion, particularly in paediatric congenital cardiac surgery on cardiopulmonary bypass (CPB). There is a necessity for regular auditing in order to improve practices.

Methods: Retrospective, contextual, descriptive data of 105 patients were collected for the period January to December 2014.

Results: The median age of patients was four (1–6) years, weight was 13 (8.4–20) kg, and mean lowest CPB haemoglobin level was 8.3 (1.5) g/dl. There was a statistically significant difference in median red packed cell (RPC), platelet and cryoprecipitate units per patient transfused across four RACHS (risk-adjusted classification for congenital heart surgery) categories ($p = 0.03$, $p = 0.0013$, $p = 0.0001$, respectively). There was a statistically significant correlation between transfused fresh frozen plasma units with CPB time ($r = 0.2634$, $p = 0.0199$) and RPC units ($r = –0.4654$, $p < 0.001$).

Conclusion: Although no standardised transfusion guidelines were available, overall transfusion of blood products was comparable to reported practices.

Keywords: blood transfusion strategies, paediatric congenital cardiac surgery, cardiopulmonary bypass

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Blood products are a scarce commodity in South Africa, as reported by the South African National Blood Service.[1] Cancellation of surgical cases has been reported due to depletion of blood products from the blood blank.[2] Blood products are transfused commonly in paediatric cardiac surgery on cardiopulmonary bypass (CPB).[3] Transfusion of blood products is intended to treat anaemia, improve oxygen-carrying capacity of the blood and oxygen delivery to the tissues, and to maintain haemostasis.[4]

Transfusion of blood products is not without complications, and can result in adverse haemolytic and non-haemolytic reactions.[5] In paediatric cardiac surgery on CPB, transfusion of blood products has been associated with cardiovascular instability, acute kidney injury,[6] delayed extubation time,[7] prolonged mechanical ventilation, infection,[6,8,9] and increased risk of postoperative bleeding.[10]

The World Health Organisation (WHO) recommends the provision of disease-free blood products, and promotion of appropriate usage of blood products by healthcare providers.[11] The implementation of blood-conservation strategies to reduce rates of transfusion of blood products in paediatric cardiac surgery is recognised by the WHO.[12] These strategies have made it possible to perform bloodless paediatric cardiac surgery on CPB,[13] and have also been used successfully in Jehovah's Witness patients.[14,15]

Blood-transfusion guidelines are available for adult cardiac surgery patients,[16] but could not be found for paediatric patients. The lack of standardised guidelines in paediatric cardiac surgery could be because of multiple factors that influence the transfusion of blood products in this patient population.[6]

There are controversies regarding the safest haemoglobin level on CPB in paediatric cardiac surgery.[13,17-19] A randomised, controlled trial from the Boston Children's Hospital revealed a poor psychomotor developmental index after a year in young patients with a range of congenital cardiac conditions with haematocrits below 21.5% on CPB.[17] By contrast, no neurodevelopmental impairment was observed with a haematocrit below 20% in older patients[13] and infants[18] presenting for low-risk cardiac conditions. There were no outcome differences reported between liberal (9.5 g/dl) and restrictive (7 g/dl) haemoglobin strategies during the postoperative period in paediatric patients post acyanotic cardiac surgery in one study.[19]

The WHO requires appropriate use of blood products by healthcare providers, which can be assessed by regular audits. Although the appropriateness of transfusion of blood products during cardiac surgery is undefined, it is essential to audit institutional practices. Audits are intended to evaluate practices and identify the need to change or modify these practices to improve the use of blood products.

This study aimed at evaluating transfusion practices in paediatric patients at a tertiary hospital, as our practice had not previously been audited. The objectives of the study were

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primarily to describe the demographic and clinical characteristics of the study participants, and secondarily to assess differences in the number of units of transfused blood products between four RACHS (risk-adjusted classification for congenital heart surgery) and body weight categories of the patients.

Methods

A retrospective, contextual, descriptive study was conducted at Charlotte Maxeke Johannesburg Academic Hospital. Approval to conduct the study was obtained from the Human Research Ethics Committee (medical) and other relevant authorities. Informed consent was not required as this was a retrospective study. Data were collected by one author (CTB). Patient confidentiality was maintained by assigning numbers to patient data, and raw data were accessed by the author and supervisor.

Data were collected for patients younger than 18 years of age who underwent cardiac surgery on CPB for congenital heart disease during the period 1 January to 31 December 2014. The charts of the anaesthetists, perfusionists and intensive care unit were reviewed for relevant data. Data collected included patient demographics, cardiac lesion and operation, pre-operative platelet count, peri-operative anticoagulation therapy, peri-operative haemoglobin level, CPB time, aortic cross-clamp (AOX) time and intra-operative blood products used.

Blood products transfused to patients are represented in units, as the practice in the department is not to document products in millilitres. The practice also involves transfusion of products over a period of time, commencing intra-operatively and into the postoperative period [no longer than four hours for red packed cells (RPC) and 30 minutes after thawing for fresh frozen plasma (FFP)]. A unit of RPC has a volume of approximately 300 ml, FFP approximately 225 ml, platelets approximately 160 ml, and cryoprecipitate approximately 15 ml.

Patients who were Jehovah's Witness, and patients with missing or illegible data were excluded.

Statistical analysis

Data collection, management and processing were performed using Microsoft® Excel for Windows, and the analysis was conducted using Stata® 14 (StataCorp.2015, Stata Statistical Software: Release 14. College Station, TX: StataCorp LP). Descriptive analysis was done using tables of frequencies and percentages, mean (standard deviation: SD) and median (interquartile range: IQR) where appropriate, and data are presented according to RACHS categories, as this denotes the complexity of the cardiac surgery.[20]

The Kruskal–Wallis and one-way Anova analysis of variance were conducted to determine the median or mean differences of clinical variables across the RACHS and weight categories. Dunn's comparison with the Holm–Sidak stepwise adjustment was performed as a *post hoc* test to the Kruskal–Wallis to find where the statistically significant difference was between the groups. A pairwise correlation test was performed to assess the linear relationship between RPC, FFP and CPB time. A p-value < 0.05 was considered statistically significant.

Results

A total number of 121 patients were eligible to be included in the study. Of these, 16 patients were excluded due to missing data pertaining to pre-operative results (four), anaesthetic charts (two), perfusionist charts (five) and intensive care unit charts (five). There were six (5.7%) redo surgery patients who were included in the study as their primary surgery had been undertaken outside of the study period. No patients were included more than once in the study.

The patient demographics are presented in Table 1, according to their respective RACHS categories. There were no patients in RACHS category 5; therefore, the category is excluded from the tables.

Pre-operative haemoglobin and platelet counts are presented in Table 2. There was no significant difference in pre-operative platelet count and haemoglobin level across the RACHS categories.

Records showed that aspirin was administered pre-operatively in only three (2.9%) patients but with no doses documented, and these patients where in RACHS category 2. A bolus dose of 300–500 IU/kg heparin was given by the anaesthetist before initiation of CPB. The perfusionists administered additional heparin during CPB with a mean (SD) dose of 1.8 (1.4) mg/kg.

Table 1. Demographics according to RACHS category

Parameters	*RACHS 1*	*RACHS 2*	*RACHS 3*	*RACHS 4*
Demographics				
Patients, *n* (%)	13 (12.4)	62 (59)	27 (25.7)	3 (2.9)
Male, *n* (%)	5 (9.4)	34 (64.2)	12 (22.6)	2 (3.8)
Female, *n* (%)	8 (15.4)	28 (53.8)	15 (28.8)	1 (1.9)
Age (years), median (IQR)	5.5 (3.5–6.25)	4 (1–6)	4 (1–7)	0.08 (0.08–1.04)
Weight (kg), median (IQR)	18 (13–20)	12 (9–19)	13 (8–22)	3.4 (3.3–3.45)
Congenital heart lesions, *n* (%)				
ECD	11 (25.6)	21 (48.8)	11 (25.6)	0 (0)
GVA	2 (28.6)	0 (0)	2 (28.6)	3 (42.9)
TOF	0 (0)	28 (100)	0 (0)	0 (0)
Valve abnormal	0 (0)	13 (56.5)	10 (43.5)	0 (0)
CC abnormal	0 (0)	0 (0)	4 (100)	0 (0)

ECD, endocardial cushion defects; GVA, great vessel anomalies; TOF, tetralogy of Fallot; CC, cardiac chamber; RACHS, risk-adjusted classification for congenital heart surgery.

Table 2. Pre-operative platelet count and haemoglobin level

Parameters, mean (SD)	*RACHS 1*	*RACHS 2*	*RACHS 3*	*RACHS 4*	p-*value*
Platelets ($\times 10^9$cells/l)	317.3 (89.8)	294.8 (128.7)	327 (144.6)	277.7 (96.4)	0.855
Hb (g/dl)	12.7 (1.3)	14.7 (3.7)	14.3 (3.6)	11.1 (2.6)	0.16

RACHS, risk-adjusted classification for congenital heart surgery; Hb, haemoglobin.

Table 3. CPB and AOX time in minutes according to RACHS category

Parameter, median (IQR)	*RACHS 1*	*RACHS 2*	*RACHS 3*	*RACHS 4*	p-*value*
AOX time (min)	18.5 (11–40.5)	76 (50–123.5)	89 (57–120)	157 (112–193)	0.0002*
CPB time (min)	55 (50–97.5)	123 (94.5–89.5)	143 (100–198)	294 (257–447)	0.0001*

*$p < 0.05$; AOX, aortic cross-clamp; CPB, cardiopulmonary bypass; RACHS, risk-adjusted classification for congenital heart surgery.

Table 4. Units of blood products transfused according to RACHS category

Products, n *(%)*	*RACHS 1*	*RACHS 2*	*RACHS 3*	*RACHS 4*	*Total*
RPC					
Total	11 (9.9)	66 (59.5)	28 (25.2)	6 (5.4)	111 (100)
Anaesthetists	0 (0)	8 (7.2)	2 (1.8)	1 (0.9)	11 (9.9)
Perfusionists	11 (9.9)	58 (52.3)	26 (23.4)	5 (4.5)	100 (90.1)
FFP					
Total	2 (3.4)	41 (70.7)	15 (25.7)	0 (0)	58 (100)
Anaesthetists	2 (3.4)	21 (36.2)	12 (20.7)	0 (0)	35 (60.3)
Perfusionists	0 (0)	20 (34.5)	3 (5.2)	0 (0)	23 (39.7)
Platelets (anaesthetists)	0 (0)	16 (51.6)	11 (35.5)	4 (12.9)	31 (100)
Cryoprecipitate (anaesthetists)	0 (0)	17 (60.7)	6 (21.4)	5 (17.9)	28 (100)

RPC, red packed cells; FFP, fresh frozen plasma; RACHS, risk-adjusted classification for congenital heart surgery.

The type of CPB clear prime fluid for the 105 patients was not clearly stated on the charts. Ten out of 105 (9.5%) patients did not receive clear prime fluid on CPB. The median (IQR) fluid volume used was 800 (500–1 000) ml. Albumin was added to the CPB in 32 (30.5%) patients at a mean (SD) dose of 9.7 (4.1) ml/kg.

The median values for AOX and CPB time in minutes between the RACHS categories are shown in Table 3. AOX and CPB times were statistically significantly different between the RACHS scores. There was a statistically significant relationship between transfused FFP units with CPB time ($r = 0.2634$, $p = 0.0199$) and RPC units ($r = –0.4654$, $p < 0.001$) transfused.

Table 4 shows units of blood products transfused, according to the RACHS categories. Platelets and cryoprecipitate were given solely by anaesthetists. Only two (1.9%) patients had a transfusion-free operation and they were in RACHS category 1.

The Kruskal–Wallis test showed a statistically significant difference between median RPC, cryoprecipitate and platelet units transfused between the RACHS categories (Table 5). A *post hoc* Dunn's test for the median RPC, cryoprecipitate and platelet units transfused showed a statistically significant difference between RACHS category 4 and the other three RACHS categories (1, 2 and 3) (Table 6). Additionally, a statistically significant difference was found between RACHS categories 3 and 1 for transfusion of platelet units (Table 6).

Taking into consideration the small sample size in RACHS 4, a further analysis of the RACHS categories into two groups consisting of RACHS 1 and 2, and RACHS 3 and 4 was undertaken, and we found similar results for platelets and cryoprecipitate units (Table 7). The significant difference was lost for RPCs.

The mean peri-operative haemoglobin levels according to RACHS categories are shown in Fig. 1 and Table 8. There was no significant difference in mean peri-operative haemoglobin levels across the RACHS categories.

The median units of blood products by weight categories are presented in Table 9. RPC, platelet and cryoprecipitate units transfused were statistically significantly different across the weight categories. A *post hoc* Dunn's test was done to show where the difference lay between weight categories with regard to transfusion of cryoprecipitate and RPC units. It shows differences predominantly between weight category > 15 kg and other categories, while differences in transfusion of platelet units were between weight categories < 6 kg and 6–15 kg (Table 10).

The blood-conservation strategies used were tranexamic acid, cell salvage and ultrafiltration. A single blood-conservation

Table 5. Median units of blood products per patient transfused, by RACHS category

Products, median (IQR)	*RACHS 1*	*RACHS 2*	*RACHS 3*	*RACHS 4*	*Total*	p-*value*
RPC	1 (1–1)	1 (1–2)	1 (1–1)	2 (2–2)	1 (1–1)	0.03*
FFP	0 (0–0)	0.5 (0–1)	0 (0–1)	0 (0–0)	0 (0–1)	0.053
Platelets	0 (0–0)	0 (0–1)	0 (0–1)	1 (1–2)	0 (0–1)	0.0013*
Cryoprecipitate	0 (0–0)	0 (0–0)	0 (0–0)	1 (1–3)	0 (0–0)	0.0001*

*$p < 0.05$; RPC, red packed cells; FFP, fresh frozen plasma; RACHS, risk-adjusted classification for congenital heart surgery.

Table 6. *Post hoc* Dunn's test of blood product use between RACHS categories

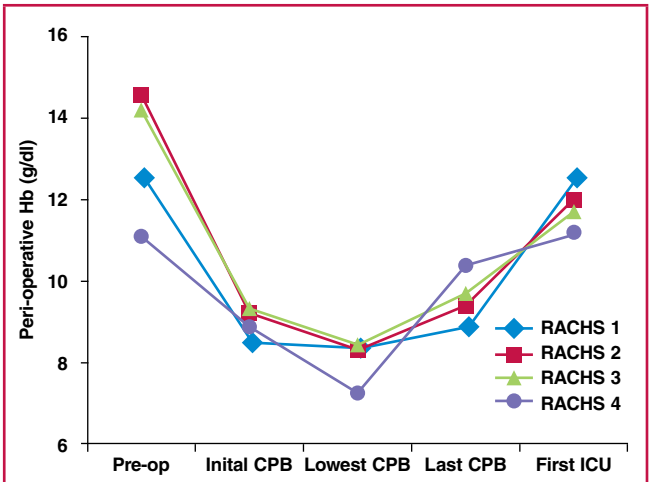
Product	*Categories*	*RACHS 4*	*RACHS 3*	*RACHS 2*
RPC	RACHS 1	0.009*	0.321	0.302
Kruskal–Wallis	RACHS 2	0.018*	0.405	
$p = 0.030$*	RACHS 3	0.022*		
Platelets	RACHS 1	0.001*	0.021*	0.065
Kruskal–Wallis	RACHS 2	0.005*	0.123	
$p = 0.001$*	RACHS 3	0.021*		
Cryoprecipitate	RACHS 1	< 0.001*	0.256	0.349
Kruskal–Wallis	RACHS 2	< 0.001*	0.217	
$p = 0.0001$*	RACHS 3	< 0.001*		

*$p < 0.05$; RPC, red packed cells; RACHS, risk-adjusted classification for congenital heart surgery.

Table 7. Median blood product units per patient transfused between two RACHS category

Products	*RACHS 1+2*	*RACHS 3+4*	*Total*	*p-value*
RPC	1 (1–1)	1 (1–1)	1 (1–1)	0.4359
FFP	0 (0–1)	0 (0–1)	0 (0–1)	0.5218
Platelets	0 (0– 0)	0 (0–1)	0 (0–1)	0.0162*
Cryoprecipitate	0 (0– 0)	0 (0–0)	0 (0–0)	0.0254*

*$p < 0.05$; RPC, red packed cells; FFP, fresh frozen plasma; RACHS, risk-adjusted classification for congenital heart surgery.



CPB, cardiopulmonary bypass; ICU, intensive care unit; RACHS, risk-adjusted classification for congenital heart surgery; pre-op, pre-operative; Hb, haemoglobin

Fig. 1. Peri-operative haemoglobins categorised by RACHS categories.

Table 8. Peri-operative haemoglobins across the RACHS categories

Haemoglobin (g/dl)	*RACHS 1*	*RACHS 2*	*RACHS 3*	*RACHS 4*	p-*value*
Pre-operative	12.6 (1.3)	14.7 (3.6)	14.3 (3.6)	11.1 (2.6)	0.16
Initial CPB	8.5 (1.4)	9.1 (1.8)	9.3 (1.5)	8.9 (2.6)	0.61
Lowest CPB	8.3 (1.4)	8.3 (1.6)	8.5 (1.2)	7.2 (1.2)	0.42
Last CPB	8.9 (1.3)	9.4 (1.3)	9.7 (1.2)	10.3 (1.4)	0.33
Initial ICU	12.5 (1.3)	12.1 (2.1)	11.8 (1.9)	11.2 (1.8)	0.72

CPB, cardiopulmonary bypass; ICU, intensive care unit; RACHS, risk-adjusted classification for congenital heart surgery.

Table 9. Median units of blood products transfused, by body weight

Products	*Weight < 6 kg (n = 11)*	*Weight 6–15 kg (n = 52)*	*Weight > 15 kg (n = 42)*	*Kruskal–Wallis* p-*value*
RPC	1 (1–2)	1 (1–1)	1 (0–1)	0.001*
FFP	0 (0–0)	0 (0–1)	1 (0–1)	0.087
Platelets	1 (0–1)	0 (0–0)	0 (0–1)	0.038*
Cryoprecipitate	0 (0–1)	0 (0–0)	0 (0–0)	0.009*

*$p < 0.05$; RPC, red packed cells; FFP, fresh frozen plasma.

Table 10. *Post hoc* Dunn's test of use of blood products between weight categories

	Products					
	RPC		*Cryoprecipitate*		*Platelets*	
Weight categories	*< 6 kg*	*6–15 kg*	*< 6 kg*	*6–15 kg*	*< 6 kg*	*6–15 kg*
6–15 kg	0.096		0.049*		0.019*	
> 15 kg	0.002*	0.002*	0.004*	0.043*	0.099	0.097

*$p < 0.05$; RPC, red packed cells.

strategy was used in 36 (34.3%) patients and two strategies in 45 (42.9%). All three strategies were used in 16 (15.2%) patients, while eight (7.6%) had no blood-conservation strategy used.

Discussion

This study was difficult to analyse because of multiple variables influencing the use of peri-operative blood products, some of which were not assessed. Guidelines to audit whether blood products were appropriately transfused in paediatric cardiac surgery were not identified. It was also difficult to compare results with the literature because of vast differences within the patient population.

Similar to data in a study by Jobes *et al.*,[21] our documentation of amount of blood products transfused by both the anaesthetists and perfusionists were in units and not in millilitres.

In our study, patients were categorised according to the RACHS category, as it signifies complexity of the congenital cardiac lesion and surgery.[20] There was an increasing progression of transfused blood products across the RACHS categories. Patients in RACHS category 4 had a higher transfusion rate for RPC, platelets and cryoprecipitate than the other groups. These patients were younger and had prolonged CPB and AOX times. Studies by Kipps *et al.*[9] and Szekely *et al.*[6] also demonstrated this association with increased rates of transfusion of blood products.

No FFP was transfused in RACH category 4 patients, with a preference being shown for cryoprecipitate, which contains concentrated clotting factors in a small volume.[5] This allowed for haemostasis to be achieved without the complication of fluid overload in these patients.

Bloodless paediatric cardiac surgery has been performed successfully with the use of miniature circuits.[13,14,18,22] At our institution, miniature CPB circuits were not utilised at the time of the audit. Perhaps this was the reason for only 1.9% of cardiac surgical cases having bloodless surgery in our study. Miniature circuits have also resulted in a decrease in volume of RPC transfusion without an increase in morbidity or mortality rates.[23]

Studies by Redlin *et al.*[24] and Miyaji *et al.*[18] showed higher rates of bloodless cardiac surgery (48%) on patients below 16 kg in weight, and 64% on patients less than 7 kg. A one-year retrospective study by Durandy *et al.*[25] reported 61% of patients between 6 and 15 kg having undergone bloodless cardiac surgery.

The blood products mostly transfused were RPC and FFP, with perfusionists mainly transfusing RPC and anaesthetists transfusing RPC, FFP, cryoprecipitate and platelets. The reason for this might be that the perfusionists primed the CPB circuit with RPC to prevent haemodilution associated with large-volume CPB circuits.[22] As a result, the haemoglobin levels were not significantly different across the RACHS categories throughout the peri-operative period.

There was an overall decrease in haemoglobin from pre-operative levels on initiation of CPB, and an increase to > 10 g/dl on arrival in ICU. A similar peri-operative haemoglobin pattern was seen in the blood transfusion group of the cohort study by Redlin *et al.*[24] This demonstrates the appropriate use of RPC in the maintenance of haemoglobin levels.

The anaesthetists empirically transfused FFP, cryoprecipitate and platelets at the end of CPB to manage bleeding. Only activated clotting time was used as a point-of-care test, which did not give information about the state of the other components of the coagulation system. A recent cohort by Machovec *et al.*[26] in infant cardiac surgery showed decreased transfusion exposure with the use of a haemostasis-management system compared to using activated clotting time.

It has become common practice to use intra-operative point-of-care tests to assess the coagulation status of patients before transfusion of blood products, as well as blood-management programmes in paediatric cardiac surgery.[23,27] This practice has resulted in decreased units of blood products transfused when used in conjunction with algorithms.[26-29] Testing of fibrinogen and platelet function during rewarming resulted in decreased cryoprecipitate transfusion post CPB in a cohort by Machovec *et al.*[29]

Although there were no blood-usage protocols at our institution, the mean haemoglobin level on CPB of 8.3 (1.5) g/dl was attained, which is comparable with haemoglobin trigger levels of 7–8 g/dl observed in other studies.[24,25] Even though transfusion triggers are set, transfusion of blood products should be individualised to the clinical condition of the patient.[4,30]

In this study, an expected statistically significant difference was shown in CPB and AOX times across RACHS categories. There was a statistically significant correlation between FFP units transfused with CPB time, and RPC units transfused. Jenkins *et al.*[20] had concluded that a high RACHS category, signifying the complexity of the surgery, was associated with long CPB time, which increased the risk for transfusion of blood products. A study by Redlin *et al.*[24] revealed a significant association between transfusion amount and CPB time (OR = 1.02, 95% CI = 1.01–1.03, $p \leq 0.0001$). Another study by Salvin *et al.*[31] showed that patients with increased CPB and AOX times were transfused more blood products postoperatively.

In the current study, when secondary analysis was conducted

by categorising data according to body weight, there was no significant difference with median FFP transfusion between the weight categories. There was a statistically significant difference in transfusion of RPC, cryoprecipitate and platelets between the weight groups. Studies have shown that low body weight is associated with an increased transfusion amount of blood products.[9,32]

There are no protocols on conservation strategies at our institution, but the majority of patients utilised some form of blood-conservation strategy, singly or in combination. The impact of the different strategies on blood product use was not assessed as it was beyond the scope of this study.

Only 2.9% of patients received aspirin in the current study, and the bleeding risk was not assessed because there was no point-of-care testing. Aspirin has been associated with increased units of RPC transfused in adult cardiac surgery,[30] but it had no effect on bleeding and transfusion in paediatric cardiac surgery.[31]

The current study was retrospective and depended on the availability of records and record-keeping by colleagues. The study did not look at temperature, metabolic state of the patient, or intra-operative bleeding, which may have contributed to transfusion rates. The study also did not differentiate between cyanotic and acyanotic cardiac lesions as data were not clear on this. Further studies should be conducted to demonstrate whether there is a relationship between our practice and morbidity and mortality rates. Transfusion protocols together with the utilisation of point-of-care testing should be considered.

Conclusion

The use of RPC units was different between RACHS categories, while maintaining similar haemoglobin levels, despite the absence of set transfusion triggers and miniature circuits. The pattern of haemoglobin maintenance was similar to another study. The transfusion of other blood products was empirical as no point-of-care tests were utilised. The use of triggers, algorithms and point-of-care testing in paediatric cardiac patients may result in a decreased level of transfusion of blood products.

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