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PERIOPERATIVE TRAJECTORY OF HAEMOGLOBIN, PREDICTORS OF BLOOD TRANSFUSION AND TAILORING TARGETS FOR PATIENT BLOOD MANAGEMENT INTERVENTIONS: A SINGLE-CENTRE, RETROSPECTIVE STUDY OF NON-EMERGENT CARDIAC SURGERY PATIENTS

Mihai Ștefan[1,*,†], Anca Roxana Lupu[2,†], Ștefan Andrei[3,†], Liana Văleanu[1,3,†], Ovidiu Știru[4,5], Cornel Robu[1], Teodora Bute[1], Bianca Moroșanu[1], Anamaria Dumitrescu[1], Alice Stegaru[1], Șerban Bubenek[1,3] and Daniela Filipescu[1,3]

[1]Department of Anaesthesiology and Intensive Care, 'Prof Dr CC Iliescu' Emergency Institute for Cardiovascular Diseases, Bucharest
[2]Discipline of Haematology, 'Carol Davila' University of Medicine and Pharmacy, Bucharest
[3]Discipline of Anaesthesiology and Intensive Care, 'Carol Davila' University of Medicine and Pharmacy, Bucharest
[4]Department of Cardiovascular Surgery, 'Prof Dr CC Iliescu' Emergency Institute for Cardiovascular Diseases, Bucharest
[5]Discipline of Cardiovascular Surgery, 'Carol Davila' University of Medicine and Pharmacy, Bucharest

Abstract

Background: *Anaemia and blood transfusion are two independent contributing factors to perioperative morbidity in cardiac surgery. While preoperative treatment of anaemia has been shown to improve outcomes, in real life, logistical difficulties remain substantial, even in high-income countries. The adequate trigger for transfusion in this population remains controversial, and there is a wide variability in transfusion rates among centres.*
Objectives: *To assess the impact of preoperative anaemia on perioperative transfusion in elective cardiac surgery, to describe the perioperative trajectory of haemoglobin (Hb), to stratify outcomes based on preoperative presence of anaemia and to identify predictors of perioperative blood transfusion.*
Materials and Methods: *We included a retrospective cohort of consecutive patients who underwent cardiac surgery with cardiopulmonary bypass in a tertiary centre of cardiovascular surgery. Recorded outcomes included hospital and intensive care unit (ICU) length of stay (LOS), surgical re-exploration due to bleeding, packed red blood cell (PRBC) transfusion pre-, intra- and postoperatively. Other record perioperative variables were preoperative chronic kidney disease, duration of surgery, use of rotation thromboelastometry (ROTEM) and cell saver, and fresh frozen plasma (FFP) and platelet (PLT) transfusion. Hb values were recorded at four distinct time points: Hb1 – at hospital admission, Hb2 – last Hb recorded preoperatively, Hb3 – first Hb recorded postoperatively and Hb4 – at hospital discharge. We compared the outcomes between anaemic and non-anaemic patients. Transfusion was decided by the attending physician on a case-by-case basis.*
Results: *Of the 856 patients operated during the selected period, 716 underwent non-emergent surgery and 710 were included in the analysis. Also, 40.5% (n = 288) of patients were anaemic preoperatively (Hb <13 g/dl); 369 patients (52%) were transfused PRBCs, with differences found between anaemic and non-anaemic patients regarding the percentage of transfused patients perioperatively (71.5% vs 38.6%, p < 0.001) and in the total median number of units transfused (2 [IQR 0–2] vs 0 [IQR 0–1], p <0.001). We built a multivariate model, and logistic regression analysis showed that preoperative Hb <13 g/dl (odds ratio [OR] 3.462 [95% CI 1.766–6.787]), female sex (OR 3.224 [95% CI 1.648–6.306]), age (1.024 per year [95% CI 1.0008–1.049]), hospital LOS (OR 1.093 per day of hospitalisation [95% CI 1.037–1.151]) and FFP transfusion (OR 5.110 [95% CI 1.997–13.071]) are associated with PRBC transfusion.*
Conclusions: *Untreated preoperative anaemia leads to more transfusion in elective cardiac surgery patients, both as a ratio of transfused patients and as the number of units of PRBCs per patient, and this is associated with an increased use in FFP.*

Keywords

transfusion • anaemia • cardiac surgery • patient blood management

1. Introduction

The strategies involved in improving outcomes in patients undergoing cardiac surgery are continuously evolving. Blood conservation measures, grouped in the modern concept of patient blood management (PBM), are paramount for decreasing perioperative morbidity, both in elective and emergency surgery (1–3).

* Corresponding author e-mail: mihai.steph@gmail.com

† MS, ARL, SA and LV contributed equally to the manuscript and should be considered first authors.

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Anaemia is one of the most frequent preoperative, correctable factors that are associated with postoperative morbidity and mortality in major surgery (4–7). According to the World Health Organization (WHO), anaemia is defined as haemoglobin (Hb) <13 g/dl in men and <12 g/dl in women (8). Its prevalence in the cardiac surgical setting varies in published cohorts between 23% and 45% (7). In cardiac surgery, preoperative and severe intraoperative anaemia were associated with more postoperative blood transfusions, longer intensive care unit (ICU) and total hospital stay and a greater incidence of postoperative cardiovascular events and renal failure (2,9).

Allogeneic blood transfusion is also associated with unfavourable outcomes in cardiac surgery, such as heart failure, respiratory and neurological complications, infections and increased mortality (10–13). Transfused patients who are also anaemic fare worse than those who are either just anaemic or just transfused (14).

In real life, due to logistical problems, implementation of PBM guidelines is difficult, even in high-income countries, as preoperative adequate treatment of anaemia is effective when done 2–4 weeks before surgery (15). Recent data suggests that the correction of anaemia can still be achieved with combined erythropoietic treatments, even the day before surgery (16).

Moreover, the WHO definition of anaemia is based on populational statistics, and not on physiological necessities. Regardless of the mean Hb value in the population, lower Hb equals lower erythroid mass, and a lower reserve of mobilisable oxygen delivery, in both males and females. This was proven in clinical trials, and several expert consensus statements suggest that 13 g/dl should be the new standard for both males and females (17–19).

In Romania, based on the experience of a PBM pilot programme led by a multidisciplinary group of physicians, national recommendations have been elaborated (20) and transformed into guidelines endorsed by the Ministry of Health (21). Data from hospitals participating in the programme have previously been published (22).

Real-life implementation of PBM measures is conditioned by several barriers and challenges such as access to knowledge, personal beliefs of clinicians, culture, the tension for change and availability of resources (23–25). Despite increased financial investments for healthcare in the last years, in a low- to middle-income country, there is a compulsory selectivity of applicable measures, which is also related to costs. This selectivity is further enabled by the lack of direct costs of blood in some healthcare systems.

We hypothesised that in a cohort of elective cardiac surgery patients, Hb lower than 13 g/dl, irrespective of sex, is associated with more perioperative transfusion, higher perioperative morbidity and longer hospital stay.

The primary objective of this study was to assess the impact of preoperative anaemia, defined as Hb <13 g/dl, in both males and females on the number of packed red blood cell (PRBC) transfusions per patient and on the percentage of transfused patients. The secondary objectives were to describe the perioperative trajectory of Hb, to stratify outcomes based on preoperative presence of anaemia and to identify predictors of perioperative blood transfusion.

2. Materials and Methods

Patient population and data collection

As part of the Romanian national pilot programme of PBM, we performed a single-centre, retrospective study in a tertiary centre of cardiovascular surgery.

We analysed consecutive patients who underwent surgery between two periods, 1 January–30 June 2017 and 1 July–31 December 2018, before and after publication of the Romanian PBM Recommendations, which were subsequently published as an Order of the Romanian Ministry of Health (ORMH), number 1251/2018, but before implementation of the said recommendations. Due to this, the study was not designed as a before-and-after comparative study, but rather as a benchmarking study of current clinical practice. Inclusion criteria were: cardiac surgery with cardiopulmonary bypass (CPB) and age over 18. Exclusion criteria were emergency cardiac surgery and inadequate records.

Data was recorded as per the directives of the ORMH 1235/2018 for benchmarking hospital practice at the beginning of implementation of the guideline. The institutional ethical board approval for analysis and publication was obtained (no. 15324/2021).

The primary recorded variable was perioperative PRBC transfusion. The secondary variables were preoperative Hb, hospital length of stay (LOS), ICU LOS, preoperative chronic kidney disease (CKD) with estimated glomerular filtration rate (eGFR) <60 ml/min, duration of surgery, surgical re-exploration due to bleeding, use of rotation thromboelastometry (ROTEM) (as explained below) and cell saver, fresh frozen plasma (FFP) and platelet (PLT) transfusion. Hb values were recorded at four distinct time points: Hb1 – at hospital admission, Hb2 – last Hb recorded preoperatively, Hb3 – first Hb recorded postoperatively and Hb4 – at hospital discharge. Intraoperative (CPB) Hb was available to the anaesthetist via point-of-care devices, with different calibration than general laboratory Hb, so this was not included in the analysis.

For our analysis, we defined anaemia as Hb value <13 g/dl, regardless of sex.

Sample size

Based on previous published data in international cohorts (7), with a statistical power of 90% and confidence interval of 99%, 95 patients were needed in each group to detect a difference of 27.3% in transfusion rate. However, we decided to include all patients in the described time intervals for epidemiological reasons (this is, to our knowledge, the first such study coming from our country) and to aid in the value of the secondary analyses.

Clinical management

Patients included in the study underwent surgery with CPB. The list of surgeries performed and the distribution of patients are available in Table 1.

CPB was performed using crystalloid priming, and cardioplegia strategies included either 4:1 mix blood–crystalloid cardioplegia or Bretschneider solution, depending on the anticipated duration of surgery, at the discretion of the attending surgeon.

Heparin was administered before bypass at a dose of 350 units per kilogram of body weight, aiming for an activated clotting time superior to 480 s, and was antagonised with protamine at a protamine-to-heparin ratio of 0.8 of the initial heparin dose.

Institutional practice did not include routine use of cell saver in non-emergent surgery. Intraoperative haemofiltration was used at the discretion of the attending anaesthesiologist.

Point-of-care viscoelastic haemostasis monitoring was available, and was used primarily in high-risk patients (complex surgeries and patients on double antiplatelet therapy, at the discretion of the attending anaesthesiologist) using ROTEM and integrated into an institutional bleeding management algorithm, which included allogeneic blood products (FFP and PLT) and factor concentrates (fibrinogen and four-factor prothrombin complex concentrate). The full decision algorithm is available in Supplement 1. All patients received hyperfibrinolysis prophylaxis with tranexamic acid.

Generally, PRBC transfusion was administered using a restrictive oriented approach, based on Hb triggers of 7 g/dl during CPB and 8 g/dl during the rest of the perioperative period, but leaving the decision at the discretion of the attending physician to integrate other variables that could justify it, such as patient characteristics, SvO2 and lactate level.

Table 1. Types of surgeries.

Type of surgery	Number of patients
CABG	259 (36.48%)
One valve	251 (35.35%)
Two or more valves	67 (9.44%)
Valve(s) and CABG	60 (8.45%)
Surgery on aorta	46 (6.48%)
Other	27 (3.8%)

CABG, Coronary artery by-pass grafting.

Statistical analysis

Data analysis involved the use of Microsoft Excel® and SPSS® (IBM SPSS Statistics for Windows, version 21.0; IBM Corp., Armonk, NY, USA). A *p*-value of <0.05 was considered statistically significant.

Quantitative data were expressed as medians with (25%–75%) interquartile ranges (IQRs). Normal distribution for continuous variables was evaluated by histograms and the Shapiro–Wilk test. Student's *t*-test or Mann–Whitney U-test was used as appropriate for comparison of continuous variables. Qualitative data were expressed as numbers (percentages). Chi-square or Fisher's exact test was used to compare categorical variables, as appropriate.

To investigate the association between perioperative variables and transfusion risk, we built a multivariable logistic regression model using the perioperative transfusion requirement as the dependent variable and predictors selected by univariate analysis with a *p*-value less than 0.05.

3. Results

There were 856 patients operated in our centre, who were included in the analysis, out of whom 716 suffered non-emergent surgery. Six patients had inadequate records and were excluded from the analysis (Fig. 1).

3.1. Demographic characteristics and outcomes (Table 2)

In the cohort, 40.5% (*n* = 288) of patients were anaemic preoperatively (Hb <13 g/dl). Anaemic patients were older

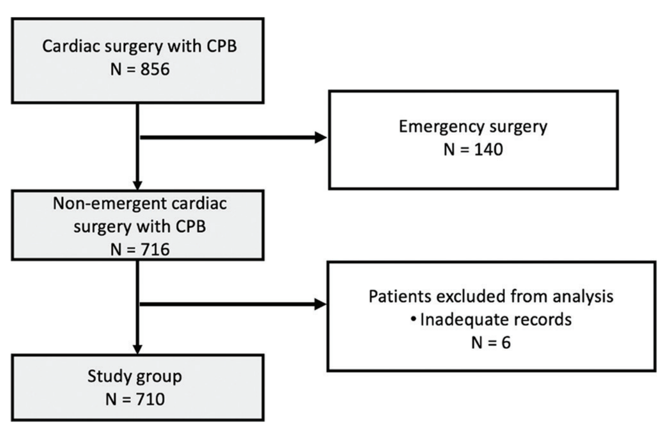

Figure 1. Study flowchart.

CPB, cardiopulmonary bypass

Table 2. Demographic characteristics and outcomes of the whole cohort, anaemic and non-anaemic patients.

Variables	Whole cohort (n = 710)	Hb <13 g/dl (n = 288, 40.5%)	Hb ≥13 g/dl (n = 422, 59.4%)	P-value
Age	64 (58–69)	66 (59–71)	63 (57–68)	<0.001
Male sex, n (%)	469 (66%)	148 (51.4%)	321 (76.0%)	<0.001
Chronic kidney disease (eGFR <60 ml/min)	58 (8.1%)	29 (10%)	29 (6.8%)	0.058
Hb at hospital admission	13.3 (12.3–14.4)	12 (11.2–12.6)	14.3 (13.5–14.9)	<0.001
Hb preoperative	13.3 (12.2–14.4)	12 (11.2–12.5)	14.2 (13.5–14.8)	<0.001
Hb postoperative	9.9 (8.9–10.8)	9.3 (8.5–10.1)	10.4 (9.4–11.3)	<0.001
Hb at discharge	9.7 (9–10.6)	9.4 (8.8–10)	10.1 (9.2–10.8)	<0.001
Duration of surgery (min)	270 (220–333)	275 (220–347)	270 (220–330)	0.798
Hospital LOS (days)	13 (10–17)	14 (10–17)	13 (10–16)	0.826
ICU LOS (days)	2 (2–4)	2 (2–4)	2 (2–4)	0.181
Postoperative bleeding- 24 h (ml)	375 (275–550)	375 (275–550)	375 (275–550)	0.325
Surgical re-exploration, n (%)	45 (6.3%)	23 (8%)	22 (5.2%)	0.136
Hospital death, n (%)	23 (3.2%)	13 (4.5%)	10 (2.4%)	0.113
PRBC transfusion, n (%)	369 (52%)	206 (71.5%)	163 (38.6%)	<0.001
Total PRBC transfusion, (n)	1 (0–2)	2 (0–3)	0 (0–1)	<0.001
Preoperative PRBC transfusion	0	0	0	
Intraoperative transfusion	0 (0–1)	1 (0–2)	0 (0–1)	<0.001
Postoperative transfusion	0 (0–1)	0 (0–1)	0 (0–0)	<0.001
ROTEM use, n (%)	123 (17.3%)	58 (20.1%)	65 (15.4%)	0.102
Cell saver, n (%)	7 (1%)	4 (1.4%)	3 (0.7%)	0.450
Patients receiving FFP transfusion, n (%)	184 (25.9%)	93 (32.3%)	91 (21.6%)	0.001
FFP units per patient, n	0 (0–2)	0 (0–2)	0 (0–0)	0.001
Patients receiving PLT transfusion, n (%)	66 (9.3%)	31 (10.8%)	35 (8.3%)	0.266

Data are reported as medians with interquartile range.
Hb is reported in g/dl.
eGFR, estimated glomerular filtration rate; FFP, fresh frozen plasma; Hb, haemoglobin; ICU, intensive care unit; LOS, length of stay; PLT, platelet; PRBC, packed red blood cell; ROTEM, rotation thromboelastometry

(66 years [IQR 59–71] vs 63 years [IQR 57–68], $p < 0.0001$), and non-anaemic patients were predominantly male (76% males in non-anaemic patients vs 51.4% males in anaemic patients, $p < 0.0001$).

In total, 369 patients (52%) were transfused PRBCs, and there were statistically significant differences between anaemic and non-anaemic patients in the percentage of transfused patients perioperatively (71.5% vs 38.6%, $p < 0.0001$) as well as in the total median number of units transfused (2 [IQR 0–2] vs 0 [IQR 0–1] $p < 0.0001$), primarily due to intraoperative transfusion (1 [IQR 0–2] vs 0 [IQR 0–1], $p < 0.0001$).

There were no significant differences between groups regarding hospital LOS (14 days [IQR 10–17] vs 13 days [IQR 10–16], $p = 0.826$), ICU LOS (2 days [IQR 2–4] in both groups, $p = 0.181$), preoperative CKD (10% vs 6.8%, $p = 0.058$), duration of surgery (275 min [IQR 220–347] vs 270 min [IQR 220–330], $p = 0.798$), hospital death (4.5% vs 2.4%, $p = 0.113$), surgical re-exploration (8% vs 5.2%, $p = 0.136$), cell saver use (1% vs 0.7%, $p = 0.450$) or PLT transfusion (10.8% vs 8.3%, $p = 0.266$).

We found a trend towards more ROTEM use in the anaemic group (20.1% vs 15.4%, $p = 0.102$), as well as a statistical difference in FFP transfusion (median 0 [IQR 0–2] vs 0 [IQR 0–0], $p = 0.001$).

The types of surgeries performed in the cohort are described in Table 1.

3.2. *Perioperative trajectory of Hb and differences in transfusion rates*

As described in Fig. 2, patients had a predictable decrease in Hb levels throughout the hospital stay, which was marginal before surgery, significant during and due to the surgical intervention and then stabilised from the admission to the ICU up to hospital discharge.

There are three quasi-parallel curves describing this trajectory, from the upper curve, in non-anaemic patients, to the lower curve, in anaemic patients, which converge towards hospital discharge, where the difference between anaemic and non-anaemic patients drops from 2.5 g/dl (mean 14.3 vs 11.8 g/dl) to 0.6 g/dl (mean 10.1 vs 9.5 g/dl).

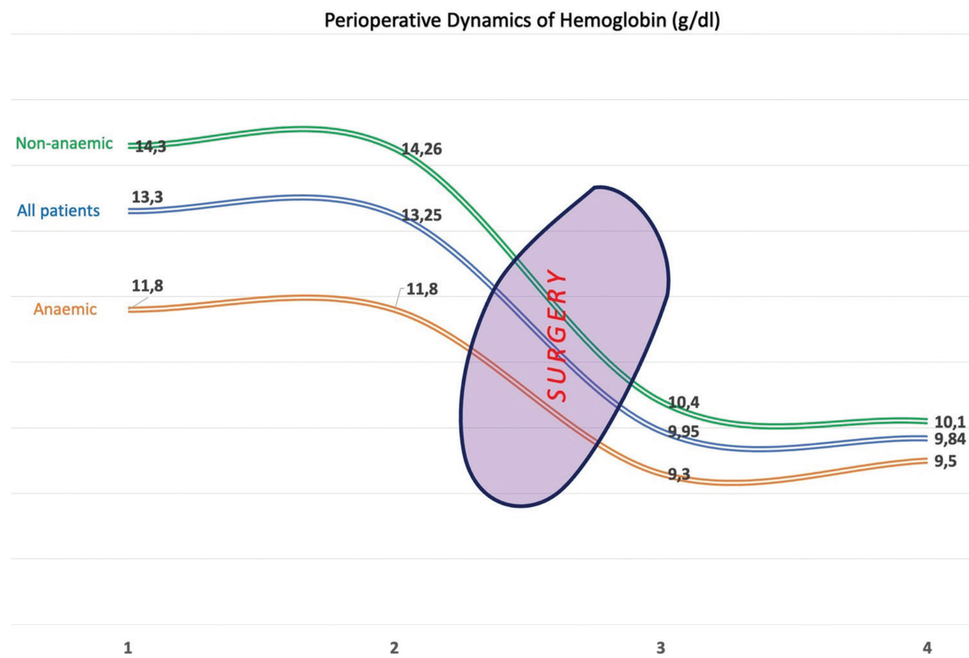

Figure 2. Perioperative trajectory of Hb in the whole cohort, anaemic and non-anaemic patients. Values on chart represent g/dl haemoglobin at four time points – 1 at hospital admission, 2 immediately before surgery, 3 immediately after surgery and 4 at hospital discharge. Numbers on the figure refer to Hb levels expressed as g/dl.

Hb, haemoglobin

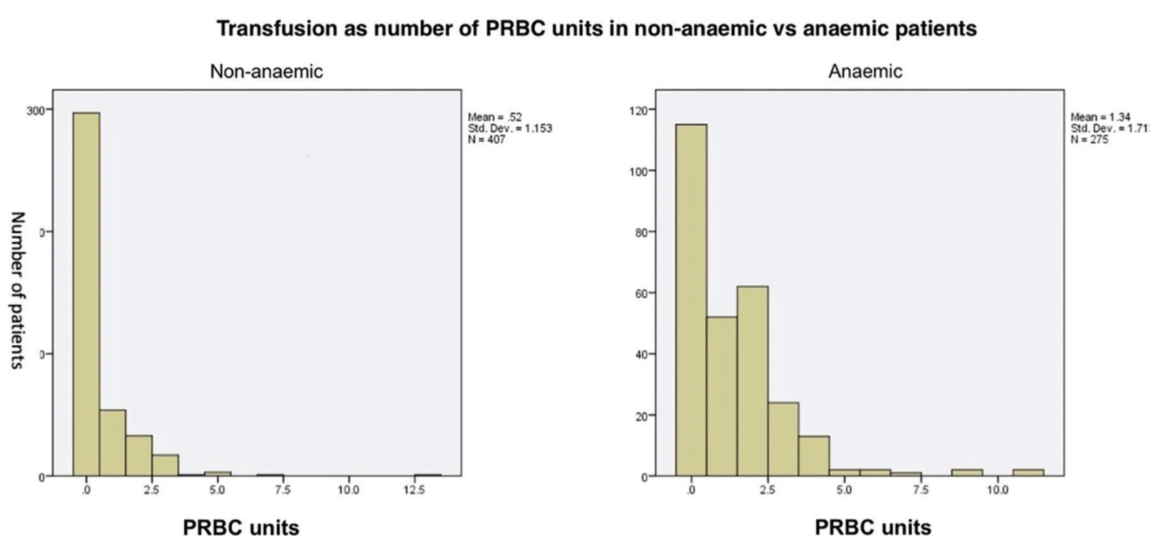

Figure 3. Transfusion of PRBCs in non-anaemic versus anaemic patients during the perioperative period.

Convergence occurs because there is significantly less transfusion of PRBC in the non-anaemic group (Table 2, Fig. 3), both in terms of global rate of transfused patients as well as the mean and median number of transfused units of PRBC.

3.3. Association between perioperative variables and transfusion risk

In univariate analysis (Table 3), we selected age (odds ratio [OR] 1.038 per year, 95% confidence interval [CI] 1.023–1.053), female sex (OR 3.249, 95% CI 2.331–4.528), hospital

Table 3. Univariate and multivariate analyses of the association between perioperative variables and transfusion risk.

Variables	Univariate		Multivariate	
	OR (95% CI)	*p*	*OR (95% CI)*	*p*
Age	1.038 (1.023–1.053)	<0.001	1.024 (1.0008–1.049)	0.043
Female sex	3.249 (2.331–4.528)	<0.001	3.224 (1.648–6.306)	0.014
Hospital LOS	1.039 (1.014–1.064)	0.002	1.093 (1.037–1.151)	<0.001
ICU LOS	1.068 (1.013–1.127)	0.015	1.029 (0.93–1.138)	0.579
CKD (eGFR <60 ml/min)	2.104 (1.013–1.127)	0.011	1.051 (0.365–3.027)	
Surgery time (h)	1.127 (1.012–1.256)	0.003	0.949 (0.827–1.088)	0.440
Hospital death	10.228 (2.38–43.959)	0.002	Not included in the model	
Preoperative Hb <13 g/dl	3.992 (2.892–5.510)	<0.001	3.462 (1.766–6.787)	<0.001
Hb1	0.559 (0.496–0.630)	<0.001	Not included in the model	
Hb2	0.594 (0.530–0.685)	<0.001	Not included in the model	
Hb3	0.567 (0.500–0.642)	<0.001	0.564 (0.434–0.732)	<0.001
Hb4	0.785 (0.691–0.891)	<0.001	Not included in the model	
Postop bleeding ≥500 ml	2.592 (1.754–3.833)	<0.001	2.295 (1.044–5.045)	0.039
Surgical re-exploration	3.469 (1.690–7.119))	0.001	1.132 (0.195–6.580)	0.687
ROTEM use	4.090 (2.590–6.457)	<0.001	1.568 (0.723–3.401)	0.255
FFP use	7.083 (4.639–10.816)	<0.001	5.110 (1.997–13.071)	<0.001
PLT use	0.169 (0.085–0.335)	<0.001	1.690 (0.360–7.928)	0.276

CI, confidence interval; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; FFP, fresh frozen plasma; Hb, haemoglobin; ICU, intensive care unit; LOS, length of stay; OR, odds ratio; PLT, platelet; ROTEM, rotation thromboelastometry

LOS (OR 1.039 per day, 95% CI 1.014–1.064), ICU LOS (OR 1.068 per day, 95% CI 1.013–1.127), preoperative CKD (OR 2.104, 95% CI 1.187–3.731) surgery time (OR 1.127 per hour surgery, 95% CI 1.012–1.256), hospital death (OR 10.228, 95% CI 2.38–43.959), preoperative anaemia (OR 3.992, 95% CI 2.892–5.510), postoperative bleeding ≥500 ml (OR 2.592, 95% CI 1.754–3.833) , surgical re-exploration due to bleeding (OR 3.469, 95% CI 1.690–7.119), ROTEM use (OR 4.090, 95% CI 2.590–6.457) and FFP transfusion (OR 7.083, 95% CI 4.639–10.816) as factors associated with perioperative transfusion, while PLT transfusion inversely correlated with PRBC transfusion (OR 0.169, 95% CI 0.085–0.335).

Using these variables as predictors and perioperative transfusion as the dependent variable, we built a multivariate model, and logistic regression analysis showed that preoperative Hb <13 g/dl (OR 3.462, IQR 1.766–6.787), female sex (OR 3.224, IQR 1.648–6.306), age (1.024 per year, IQR 1.0008–1.049), hospital LOS (OR 1.093 per day of hospitalisation, IQR 1.037–1.151) and FFP transfusion (OR 5.110, IQR 1.997–13.071) are associated with PRBC transfusion.

4. Discussion

The data shows that in our centre, there was a high incidence of preoperative anaemia (40.5%), which was associated with postoperative PRBC transfusion. Other independent predictors of perioperative transfusion were age, female sex, hospital LOS and perioperative FFP transfusion.

There was a significant impact of preoperative untreated anaemia on perioperative transfusion rate, both as a percentage of transfused patients (52% in all patients, 71.5% in anaemic and 36.6% in non-anaemic patients) and as the number of units per patient (Table 2). This is concordant to previously published data from a national audit conducted in the UK, where the authors found a PRBC transfusion incidence of 45.1% in the general cohort, 63.9% in anaemic patients and 36.6% in non-anaemic patients, with significant variability between centres (7). In our multivariate analysis, anaemia is the most important predictor of transfusion, together with female sex.

Perioperative analysis of Hb trajectory showed that cardiac surgery significantly affects the patient's reserve of Hb, as it is presented in Fig. 2. This is most likely pluri-factorial, not only due to intraoperative loss of blood, but also due to the haemodilution, which is inherent to the use of CPB (26).

This leads to a drop in Hb, which, in the absence of preoperative anaemia, does not expose the patient to severe postoperative anaemia, not even at the level at which most liberal protocols advocate transfusion. Consequently, transfusion rate is substantially lower in non-anaemic patients, that is, 38.6% (163 patients) versus 71.5% (206 patients). What stands out in the data is that most patients who were transfused in the non-anaemic cohort received only one or two units of PRBC (Fig. 3).

Furthermore, there are additional factors associated with perioperative transfusion of PRBC. These are age, female sex, the duration of hospital LOS and FFP transfusion.

The duration of hospital stay is an expected result, as it has been shown in previous studies that the longer a patient is hospitalised, the higher his risk of transfusion (27,28).

The correlation of FFP transfusion with PRBC transfusion might have two explanations. Firstly, in bleeding patients, PRBC transfusion is associated with increased requirements for haemostatic products. Secondly, as observed in Table 2, there is an increased rate of FFP transfusion in anaemic patients versus non-anaemic patients: 93 patients (32.3%) received FFP in the anaemic group versus 91 patients (21.6%) in the non-anaemic group ($p < 0.0001$). This was not paralleled by higher rates of postoperative bleeding or surgical re-explorations due to bleeding. This finding is not confirmatory of other previously published studies (29), but FFP transfusion was an independent predictor of PRBC in the multivariate analysis (Table 3).

The high use of FFP is explained by its integration in the perioperative bleeding management algorithm as an alternative to prothrombin complex concentrates (PCCs), at the discretion of the attending physician. This is supported by guidelines, as PCC is associated with fewer re-explorations for bleeding, less blood loss and fewer transfusions compared to FFP, but might be associated with an increased risk of thromboembolic events and acute kidney injury (30).

Female sex was also an independent factor associated with PRBC transfusion in our study. This is probably due to lower body mass and blood volume, which exposes females to a higher risk of perioperative anaemia, both due to blood loss (for the same volume of blood lost, women lose a higher proportion of the erythrocyte reserve) and due to higher effect of haemodilution (lower nadir Hb during CPB), both leading to Hb levels that trigger PRBC transfusion (31).

Also, there was a higher incidence of preoperative anaemia in females versus males (58% of females or 140 patients had a Hb <13 g/dl vs 31.5% of males or 148 patients).

Age was another independent predictor of perioperative PRBC transfusion in our cohort. This is explained by the frailty of older patients, as well as potentially by the perceived worse tolerance to anaemia, a paradigm which has been challenged in recent literature (32). This could be explained by the increased prevalence of anaemia in the elderly, but age remains significant as a predictor in the multivariate model.

Given the significant strain on hospital logistics and perceived increase in short-term costs (33), PBM measures can be difficult to implement in an all-or-nothing approach (23), especially in countries where blood products are not paid for by hospitals. Indirect costs related to excessive blood product use are not easily quantified (34). Based on our data, we propose a stepwise implementation of those measures which seem to fit more to our current practices. While data shows that adequate treatment of preoperative anaemia and iron deficiency translates into better postoperative outcomes (35), this measure is the most difficult to implement due to logistical barriers, partly also due to more difficult access to clinical care in the context of the ongoing pandemic (36), but not restricted to it. Given that the most significant impact on patient Hb and cause of anaemia is the surgery itself (Fig. 2), it seems logical to implement or improve measures aimed at optimising intraoperative blood loss, while using individualised, physiology-based transfusion triggers. In our case, such measures could be routine use of cell salvage, both in cases of complex cardiac surgery and/or in anaemic patients, who are at higher risk of intraoperative transfusion in the presence of minimal blood loss, and improving CPB techniques, thus aiming, in selected cases, for the use of alternate techniques of priming (retrograde autologous priming). Also, using intraoperative haemofiltration to mitigate the effects of haemodilution could prove useful.

Our hospital uses point-of-care viscoelastic monitoring of haemostasis via ROTEM, integrated in a step-based bleeding management algorithm, generally in patients on dual antiplatelet therapy and/or suffering complex cardiac surgery, leading to a global use of this tool in 17.3% of patients. This is available in Supplement 1. It could be advocated that a wider use of ROTEM could help better stratify those patients at risk of perioperative bleeding and further reduce perioperative transfusion. This has been proven in previous studies in cardiac surgery (37).

Another point could be stricter monitoring of restrictive triggers of transfusion by optimising the patient's tolerance to anaemia, by discouraging physicians to transfuse patients without certain indications and by limiting PRBC transfusion to a one-unit policy. There is some controversy as to what the delicate balance of non-harmful permissive anaemia is, and this should not be mistaken for restraining from transfusion at all costs (38). The anaesthesiologist must manage the individual patient's characteristics and comorbidities (coronary disease, the association of shock or low cardiac output states, adequate monitoring of volemia and depth of anaesthesia), while keeping anaemia as a factor in the decision-making process (2, 38-40). Given the complexity of such a decision, we advocate simplistic Hb triggers are inadequate when deciding on PRBC transfusion. However, one solution could be implementing individual forms for each unit of PRBC prescribed, either electronic or on paper, on which the attending physician can justify the indication for transfusion, based on Hb value and on other clinical factors, including the functional triggers for transfusion (20).

There are important limitations to our study. Firstly, this is a single-centre, retrospective study. Data was collected as per the recommendations of the Romanian PBM Programme, so there is specific data related to the cardiac surgery field which is unavailable. Also, while point-of-care monitoring of Hb was available for all patients, both intraoperatively and postoperatively in the ICU, given the difference in machinery and measuring accuracy, these were not recorded in our study, so as to not increase noise in the analysis. Furthermore, as systematic treatment of anaemia was not yet implemented in our centre, data was deemed irrelevant to the present analysis.

Further studies, including a clinical audit aimed at monitoring implementation of the measures described, are to be undertaken in our centre.

5. Conclusions

Untreated preoperative anaemia, defined as Hb <13 g/dl irrespective of sex, leads to more transfusion in non-emergent cardiac surgery patients, both as a ratio of transfused patients and as the number of units of PRBCs per patient, and this is associated with an increased use of non-PRBC allogeneic blood products.

Our clinical audit brings data from an eastern European cohort, not only confirming previously published findings, but also defining some particularities, which are related primarily to two factors: limited resources and no direct cost for blood products.

Therefore, our analysis is also focused on tailoring medium-specific measures, rather than an all-in-one approach. We find this to be relevant for hospitals in a similar environment, which could be facing the same challenges.

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