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Article

Efficacy and Feasibility of Preoperative Autologous Blood Donation in Elective On-pump Cardiac Surgeries: A Propensity-score Matching Study

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Abstract

Objective: The global shortage of blood resources has become a significant concern. This study aimed to assess the effects and feasibility of preoperative autologous blood donation (PABD) in elective on-pump cardiac surgeries. **Methods**: This retrospective single-center study included 219 patients who underwent elective on-pump cardiac surgeries between January 2015 and June 2023. All procedures were performed by a single experienced surgical team. Of these patients, 101 (PABD group) donated autologous blood preoperatively and were compared with the Non-PABD group (n = 118). Using the propensity-score matching (PSM) method, 83 well-matched pairs were yielded based on five variables: gender, age, baseline hemogloin level, left ventricular ejection fraction (LVEF), and EuroscoreII. Transfusion data and perioperative outcomes were retrospectively compared. Multivariate logistic regression analyses were employed to assess the independent impact of PABD on outcome indicators. **Results**: In the propensity-matched cohort, there were significant reductions in allogenic red blood cell (RBC) transfusion in the PABD group, both intraoperatively and postoperatively ($p < 0.05$). Patients in the PABD group experienced a shorter duration of mechanical ventilation ($p < 0.05$). There was no significant difference in early mortality ($p = 0.613$). However, the incidences of hemoglobinuria and acute kidney injury (AKI) were significantly lower in the PABD group ($p = 0.016$ and $p = 0.043$, respectively). Furthermore, the use of PABD was identified as an independent protective factor for postoperative AKI odds ratio (OR = 0.204; 95% CI, 0.051–0.816; $p = 0.025$) and hemoglobinuria (OR = 0.141; 95% CI, 0.027–0.723; $p = 0.019$). **Conclusion**: The use of PABD in cardiac surgeries is beneficial, reducing allogenic RBC transfusions and certain complications without increasing adverse events.

Keywords

preoperative autologous blood donation; cardiopulmonary bypass; allogenic transfusion; propensity score matching

Introduction

Cardiac surgery is associated with a high transfusion requirement [1], primarily due to significant intraoperative bleeding, hemodilution, and coagulation disturbances resulting from cardiopulmonary bypass (CPB) [2]. Although cardiac surgeries represent a small proportion of total surgical procedures, it consumes a significant fraction of banked blood [3]. It is estimated that patients undergoing cardiac surgeries use 20% of banked blood in the United States [1,4] and nearly half require transfusions perioperatively [1].

The aging global population has exacerbated the mismatch between blood demand and supply [5]. Furthermore, allogeneic blood transfusion (ABT) can lead to adverse effects such as hemolytic reactions, immunosuppression, transfusion-related lung injury, and the spread of infectious diseases [6,7]. By contrast, autologous transfusions can effectively mitigate these shortcomings. As a typical representative of autologous transfusion, preoperative autologous blood donation (PABD) has been advocated to conserve blood and reduce dependence on ABT [8–10]. This strategy involves the predonation and storage of autologous blood for use in subsequent surgical procedures [8,9]. PABD's advantages in preventing ABT-related complications and conserving blood resources have led to its adoption in general surgery, orthognathic surgery, and gynaecology [8,11]. However, its routine application in cardiac centers is limited, mainly due to concerns about its safety and efficacy in cardiac procedures [9,12]. Given the limited literature on PABD in cardiac surgeries, this study aims to explore its feasibility and efficacy in elective on-pump cardiac procedures. Moreover, the PSM method was employed to minimize selection bias due to confounding factors. To our knowledge, this is the first study of its kind in the literature.

Methods

Patient Selection

This study adhered to the Helsinki Declaration principles and received approval from our hospital's Institutional

Ethical Review Board. We conducted a retrospective analysis of all patients who underwent elective on-pump cardiac surgeries performed by a single surgeon at our center between January 2015 and June 2023. The inclusion criteria for this study were as follows: (1) preoperative hemoglobin (Hb) concentration $\geq$11 g/dL; (2) weight: males $\geq$45 kg, females $\geq$40 kg; (3) age <80 years; (4) absence of infective endocarditis or other acute infections; (5) absence of advanced heart failure, coagulation disorders, severe hepatic and renal dysfunction, malnutrition, or malignant tumors. A total of 219 patients meeting these criteria were identified. Among them, 101 (PABD group) underwent PABD and were compared to the remaining 118 patients (Non-PABD group).

Preoperative Donation

Based on individual patient conditions, appropriate therapy was administered to improve heart function, alleviate symptoms, and address underlying diseases after admission. Only patients in good general condition were eligible for PABD. PABD was performed 1–3 weeks prior to surgery, with 1 to 3 donations per patient, depending on the patient's hemoglobin level, estimated blood loss, and the time interval before surgery. The target volume for each donation was 400 mL.

Blood was drawn using a needle inserted into the median cubital vein and collected into citrate phosphate dextrose adenine (CPDA) anticoagulant preservative bags for storage. The volume removed was replenished by an intravenous infusion of 500 mL of Voluven (hydroxyethyl starch 130/0.4 and sodium chloride solution) during the donation. Electrocardiographic monitoring and close bedside observation were mandatory during the donation process. Donation was to be immediately halted if patients exhibited tachycardia, syncope, or discomfort. After donation, the CPDA bags were stored at 4 °C in the blood bank's refrigerator. All donors were advised to take an oral supplement of ferrous sulfate (210 mg, twice a day) from the day of donation until the day of surgery. For repeat donors, donations were scheduled at a minimum interval of three days, and recombinant erythropoietin was administered intramuscularly at a dose of 75 IU/kg if the Hb level was below 13.0 g/dL before the next donation. All donations were completed at least three days prior to surgery.

Surgical and CPB Techniques

All surgical procedures were performed under general anesthesia. Cardiopulmonary bypass (CPB) was routinely established through standard aortic and bicaval cannulation after median sternotomy. The ascending aorta was cross-clamped and myocardial protection was achieved by antegrade perfusion of cardioplegia. Once CPB was successfully established, intracardiac manipulations (such as valve replacement/repair, congenital defect repair, cardiac tumor resection *etc.*) were performed in a standardized fashion by a single surgeon group.

Reinfusion and Transfusion Strategy

The intraoperative transfusion triggers were set at Hb $\leq$7 g/dL during CPB and Hb $\leq$8 g/dL after CPB, while the postoperative allogeneic RBC transfusion trigger was set at Hb <9 g/dL during the ICU stay [3]. In the PABD group, both donated autologous blood and allogeneic RBCs were administered intraoperatively to maintain Hb levels above 7 g/dL during CPB and above 8 g/dL after CPB. It is important to note that autologous blood reinfusion was always prioritized over allogeneic transfusion. Although transfusion triggers were identical in both groups, in the Non-PABD group, only allogenic transfusions were administered based on the aforementioned criteria. After surgery, aminomethylbenzoic acid and tranexamic acid were routinely administered to both groups.

Baseline Data Collection

The baseline data of enrolled subjects included gender, age, weight, cardiac function, comorbidities, laboratory test results, echocardiographic data, and the type of cardiac surgery. Based on the baseline data, the European System for Cardiac Operative Risk EvaluationII (EuroSCOREII) was calculated for each patient to assess the potential death risk of the heart surgery [13]. Laboratory test results, collected at admission, included baseline hemoglobin level, platelet count, prothrombin time, serum creatinine. All 219 patients underwent transthoracic echocardiography (TTE) preoperatively, with data such as left ventricular ejection fraction (LVEF), left atrial diameter (LAD), left ventricular end-diastolic diameter (LVEDD), pulmonary artery systolic pressure (PASP) being recorded.

Study Endpoints

The primary endpoint of this study was the use of allogeneic RBCs. Secondary endpoints included postoperative outcomes, early mortality, and the morbidities of various complications. Postoperative outcomes encompassed the duration of mechanical ventilation, ICU stay length, and postoperative drainage volume. Early mortality was defined as death within 30 days following surgery. Postoperative complications included pulmonary infection, wound infection, pleural effusion, reoperation for bleeding, myocardial infarction, hemoglobinuria, AKI, and gastrointestinal hemorrhage. AKI was defined as either a two-fold increase in serum creatinine or a urine output of less than 0.5 mL/kg/hr for 12 hours [14].

Statistical Analysis

Normally distributed quantitative data were expressed as means ± standard deviations (SD) and compared using Student's *t*-test. Non-normally distributed quantitative data were summarized by median (25th, 75th percentile) and compared using the Mann–Whitney U test. Qualitative data were reported as n (%) and compared using the Chi-square test or Fisher's exact test.

PSM analysis was conducted to control for important confounders. The propensity to undergo PABD was calculated using multivariable logistic regression, modeling whether PABD was needed for the 219 patients in the initial cohort. Independent variables were selected based on the results of inter-group comparisons. Only variables significant at the 0.10 alpha level ($p < 0.10$) in the inter-group comparisons could be included into the final PSM model. PSM was executed in a 1:1 nearest neighbour fashion with a caliper distance of 0.10. The balance after PSM was assessed using the standardized mean difference (SMD), and results were presented in a balance diagnostic plot known as a "love plot" [15]. The love plot was generated using the cobalt package in R version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria). To further assess the independent impact of PABD on outcome indicators, we adjusted for confounding factors using multivariate logistic regression analyses in the original cohort. All statistical analyses were performed using R software and SPSS Statistics 25.0 (IBM, Chicago, IL, USA).

Results

During the process of donation and reinfusion, no severe adverse events, such as myocardial infarction, stroke, or deaths, were observed in the PABD group. Among the 101 patients in the PABD group, 90 donated once, approximately 5.51 ± 2.37 days before surgery. Eleven patients donated multiple times (ten cases twice, one case thrice), with the average time intervals from the first and last donations to the surgery date being 9.18 ± 2.27 days and 4.09 ± 1.14 days, respectively. The 101 patients donated a total of 40,060 mL of autologous blood, averaging 396.63 ± 143.21 mL per person.

Table 1 details the baseline characteristics of the two groups. However, the baseline characteristics were not entirely balanced between groups before PSM. The PABD group tended to be younger (49.91 vs. 54.64, $p = 0.008$), had higher baseline hemoglobin level (142.89 vs. 139.31, $p = 0.044$), higher LVEF (60.04% vs. 57.86%, $p = 0.047$) and lower Euro Score (2.09 vs 2.57, $p = 0.040$) compared to the Non-PABD group. Additionally, a trend towards a higher percentage of males (70.3% vs. 58.5%, $p = 0.069$) was observed in PABD group. These five variables, significant at the 0.10 alpha level ($p < 0.10$), were included in the final model. Propensity score matching yielded 83 well-matched pairs. Fig. 1 demonstrated that all these five key confounders were well balanced, with SMDs reduced to the level of 0.10 after PSM. As also shown in Table 1, all baseline variables were balanced between groups after PSM ($p > 0.05$).

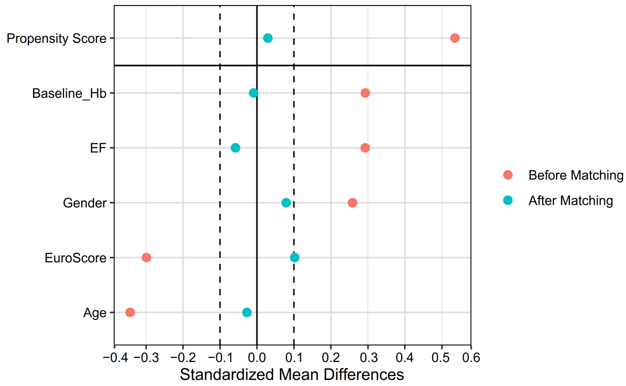

Fig. 1. Balance diagnostic plot (Love plot). Standardized mean difference (SMD) for each confounder variable.

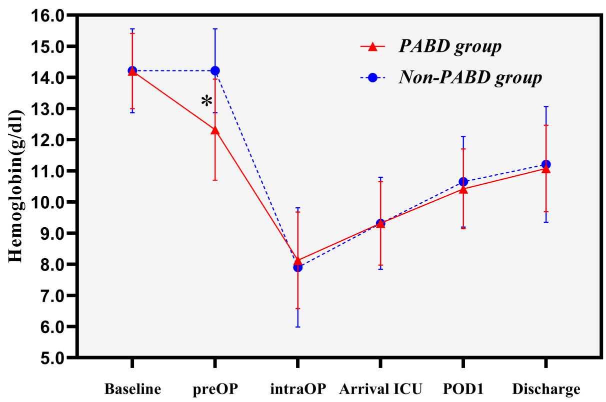

Fig. 2. Hemoglobin trend during perioperative stage. Baseline, hemoglobin level before donation; preOP, preoperative hemoglobin level; intraOP, lowest hemoglobin level during operation; Arrival ICU, hemoglobin level upon intersive care unit arrival; POD1, hemoglobin level of first operative day; PABD, preoperative autologous blood donation; Discharge, hemoglobin level before discharge. *, $p < 0.001$.

Transfusion data for the two matched groups are presented in Table 2. A significant reduction in the transfusion of allogeneic RBCs was observed in the PABD group, both intraoperatively and postoperatively ($p < 0.05$). Accordingly, transfusion costs were significantly lower in the PABD group than in the Non-PABD group ($p < 0.05$). According to the trend of Hb levels shown in Fig. 2, the preoperative Hb level of the PABD group was significantly lower than that of the Non-PABD group (12.3 ± 1.6 vs. 14.2 ±

Table 1. Baseline characteristics.

Characteristics	Before PSM				After PSM			
	PABD (N = 101)	Non-PABD (N = 118)	*p*-value	SMD	PABD (N = 83)	Non-PABD (N = 83)	*p*-value	SMD
Male [n (%)]	71 (70.3)	69 (58.5)	0.069	0.26	56 (67.5)	53 (63.9)	0.624	0.08
Age (years)	49.91 ± 13.80	54.64 ± 12.34	0.008	–0.34	51.36 ± 13.02	51.73 ± 12.67	0.852	–0.03
Weight (kg)	64.80 ± 11.78	62.32 ± 11.46	0.116	0.21	64.63 ± 11.47	62.60 ± 11.56	0.259	0.18
NYHA cardiac function	2.68 ± 0.51	2.68 ± 0.57	0.944	0.01	2.71 ± 0.48	2.61 ± 0.51	0.215	0.20
Baseline hemoglobin (g/L)	142.89 ± 12.23	139.31 ± 13.74	0.044	0.29	142.07 ± 12.08	142.18 ± 13.47	0.957	–0.01
Baseline platelet count ($\times 10^9$/L)	205.58 ± 71.00	197.65 ± 57.45	0.362	0.11	201.80 ± 71.94	200.78 ± 57.16	0.920	0.01
Baseline prothrombin time (s)	13.14 ± 1.22	13.44 ± 1.48	0.110	–0.24	13.10 ± 1.08	13.37 ± 1.57	0.195	–0.25
Baseline serum creatinine (µmol/L)	77.70 ± 23.27	75.42 ± 20.60	0.441	0.10	78.69 ± 24.97	76.62 ± 20.07	0.558	0.08
LVEF (%)	60.04 ± 7.46	57.86 ± 8.73	0.047	0.29	59.52 ± 7.88	59.95 ± 6.97	0.708	–0.06
LAD (mm)	47.17 ± 10.18	47.51 ± 9.81	0.804	–0.03	47.85 ± 9.62	46.22 ± 9.40	0.272	0.17
LVEDD (mm)	53.15 ± 9.19	53.52 ± 8.89	0.761	–0.04	53.49 ± 9.45	52.92 ± 8.69	0.687	0.06
PASP (mmHg)	44.49 ± 16.49	45.31 ± 15.01	0.698	–0.05	44.08 ± 16.62	43.49 ± 13.50	0.802	0.04
Hypertension [n (%)]	23 (22.8)	30 (25.4)	0.648	–0.06	21 (25.3)	19 (22.9)	0.717	0.06
Diabetes [n (%)]	2 (2.0)	7 (5.9)	0.260	–0.28	2 (2.4)	4 (4.8)	0.678	–0.16
Cerebrovascular disease [n (%)]	10 (9.9)	16 (13.6)	0.404	–0.12	10 (12.0)	10 (12.0)	1.000	0.00
EuroSCORE II^a	2.09 (1.42, 3.18)	2.57 (1.71, 3.50)	0.040	–0.30	2.20 (1.50, 3.51)	2.31 (1.59, 3.10)	0.862	0.10
Main procedure								
Mitral valve surgery	43 (42.6)	45 (38.1)	0.504	0.09	37 (44.6)	33 (39.8)	0.530	0.10
Mitral valve surgery+CABG	4 (4.0)	4 (3.4)	1.000	0.03	3 (3.6)	0 (0.0)	0.244	0.19
Aortic valve surgery	21 (20.8)	20 (16.9)	0.467	0.09	18 (21.7)	16 (19.3)	0.701	0.06
Aortic valve surgery+CABG	0 (0.0)	1 (0.8)	1.000*	–0.13	0 (0.0)	1 (1.2)	1.000*	–0.16
CABG	0 (0.0)	1 (0.8)	1.000*	–0.13	0 (0.0)	0 (0.0)	-	0.00
Mitral+aortic valve surgery	14 (13.9)	24 (20.3)	0.207	–0.19	11 (13.3)	15 (18.1)	0.393	–0.14
Congenital defect repair	16 (15.8)	17 (14.4)	0.767	0.04	11 (13.3)	16 (19.3)	0.293	–0.18
Cardiac tumor resection	2 (2.0)	4 (3.4)	0.824	–0.10	2 (2.4)	1 (1.2)	1.000	0.08
Aortic surgery	1 (1.0)	2 (1.7)	1.000	–0.07	1 (1.2)	1 (1.2)	1.000*	0.00

LVEF, left ventricular ejection fraction; LAD, left atrial diameter; LVEDD, left ventricular end-diastolic diameter; PASP, pulmonary artery systolic pressure; NYHA, New York Heart Association functional class; PSM, propensity-score matching; SMD, standardized mean difference; PABD, preoperative autologous blood donation; CABG, coronary artery bypass grafting; ^{a}, European System for Cardiac Operative Risk Evaluation II. *compared by Fisher's exact test.

Table 2. Perioperative blood transfusion data for propensity-matched groups.

Variables	PABD (N = 83)	Non-PABD (N = 83)	p-value
Autologous blood transfusion (mL)	401.33 ± 148.10	-	-
Intraoperative allogenic RBC (U)	0.0 (0.0, 0.0)	2.0 (0.0, 3.0)	0.000
Postoperative allogenic RBC (U)	2.0 (0.0, 3.0)	3.5 (1.0, 4.5)	0.000
Total allogenic RBC (U)	2.0 (0.0, 4.0)	4.0 (3.5, 6.0)	0.000
Transfusion costs (×100$)	1.54 (0.77, 2.07)	1.94 (1.74, 2.67)	0.000
Platelets transfusion [n (%)]	1 (1.2)	1 (1.2)	1.000*
Cryoprecipitate transfusion [n (%)]	1 (1.2)	0 (0.0)	1.000*

RBC, red blood cell. *compared by Fisher's exact test. 1$ =7.33 RMB.

1.3, $p < 0.001$). However, in the early postoperative period, there was no significant difference in Hb levels upon arrival at the ICU (9.3 ± 1.3 vs. 9.3 ± 1.5, p = 0.987), the first postoperative day (10.4 ± 1.3 vs. 10.7 ± 1.5, p = 0.283), and at discharge (11.1 ± 1.4 vs. 11.2 ± 1.9, p = 0.606) between the groups.

The perioperative outcomes for the two matched groups are presented in Table 3. The PABD group and Non-PABD group experienced similar CPB times (150.48 vs. 143.43 min, $p > 0.05$) and aortic clamping times (99.63 vs. 91.42 min, $p > 0.05$). However, a significantly shorter mechanical ventilation time (15.0 vs. 17.0 h, p = 0.036) was observed in the PABD group.

Among the 219 cases of the initial cohort, 30-day mortality occurred in six cases (three in each group). Of the three deaths in the PABD group, two cases died of multiple organ dysfunction syndrome (MODS) and one case of sudden cardiac arrest. In the Non-PABD group, one case died of refractory bleeding and two of MODS. Moreover, after PSM, there was no significant difference in early mortality between the two groups (Table 3). There was no significant difference between the two groups in the incidence of complications such as pulmonary infection, wound infection, pleural effusion, reoperation for bleeding, myocardial infarction, and gastrointestinal hemorrhage (Table 3). However, the incidence of hemoglobinuria and postoperative AKI was significantly lower in the PABD group ($p <$ 0.05).

Among the 101 patients in the PABD group, 90 donated once and 11 underwent multiple donations. However, there was no significant difference in the incidence of postoperative complications between the single and multiple donation groups ($p > 0.05$) (Table 4).

The independent impact of PABD on the postoperative AKI and hemoglobinuria was further investigated by using logistic regression analyses in the initial cohort of 219 cases. In the univariate logistic regression analysis for postoperative AKI, four variables were statistically significant ($p < 0.05$), including baseline serum creatinine, LVEF, PABD, and CPB duration. The results of the univariate analysis for AKI are presented in the forest plot (Fig. 3). These four variables were then included in a multivariate logistic regression model, and the results indicated that only PABD and baseline serum creatinine were independently associated with AKI. More specifically, utilization of PABD is likely an independent protective factor (odds ratio (OR) = 0.204; 95% CI, 0.051–0.816; p = 0.025) for AKI, while baseline serum creatinine appears to be an independent risk factor (OR = 1.027; 95% CI, 1.007–1.048; p = 0.006) (Table 5).

Furthermore, univariate logistic regression analysis found that seven variables were significantly associated with postoperative hemoglobinuria (Fig. 4), including baseline prothrombin time, left atrial diameter (LAD), LVEF, PABD, main procedure type, CPB duration, and aortic clamping duration ($p < 0.05$). However, after multivariate logistic regression analysis, only PABD was demonstrated to be independently associated with hemoglobinuria (OR = 0.141; 95% CI, 0.027–0.723; p = 0.019) (Table 6).

Discussion

The main findings of this study are summarized as follows: (1) PABD was associated with significant reductions in allogenic RBC transfusion for patients undergoing elective on-pump cardiac surgeries; (2) Significantly shorter mechanical ventilation time, and lower incidences of postoperative AKI and hemoglobinuria were observed in PABD group; (3) the use of PABD was an independent protective factor for postoperative AKI and hemoglobinuria, as demonstrated by multivariate logistic regression analyses.

According to the result of our study, no symptom deterioration or other serious adverse event was observed during the donation and reinfusion process. We suggest that PABD can be safely performed for patients undergoing cardiac surgeries as long as standardized PABD procedures are utilized. Previously, there has always been controversy about the effectiveness of PABD, and the effects of PABD remain inconsistent across different studies [9,12,16]. Admittedly, it is difficult to ascertain the efficacy of PABD without careful adjustment for potential confounders related to patient and surgical factors. We used PSM to reduce bias related to confounding. For example, the non-PABD group had a

Table 3. Perioperative outcomes and complications for propensity-matched groups.

Variables	PABD (N = 83)	Non-PABD (N = 83)	p-value
Perioperative outcomes			
CPB duration (min)	150.48 ± 54.96	143.43 ± 46.97	0.376
Aortic clamping duration (min)	99.63 ± 44.84	91.42 ± 44.55	0.239
Drainage volume^a (mL)	260.0 (210.0, 345.0)	310.0 (210.0, 430.0)	0.090
Mechanical ventilation time (h)	15.0 (6.00, 18.0)	17.0 (7.00, 19.0)	0.036
ICU length of stay (h)	43.0 (35.0, 65.0)	43.0 (40.0, 71.0)	0.119
In-hospital complications			
30-day Mortality [n (%)]	3 (3.61)	1 (1.20)	0.613
AKI [n (%)]	3 (3.61)	10 (12.0)	0.043
Hemoglobinuria [n (%)]	2 (2.41)	10 (12.0)	0.016
Wound Infection [n (%)]	3 (3.61)	4 (4.82)	1.000
Reoperation for bleeding [n (%)]	0 (0.00)	1 (1.20)	1.000*
Myocardial infarction [n (%)]	0 (0.00)	0 (0.00)	-
Pleural effusion [n (%)]	3 (3.61)	1 (1.20)	0.613
Pulnonary Infection [n (%)]	1 (1.20)	5 (6.02)	0.212
Gastrointestinal hemorrhage [n (%)]	0 (0.00)	1 (1.20)	1.000*

CPB, cardiopulmonary bypass; ICU, intensive care unit; AKI, acute kidney injury. ^{a}, the first 12-hour drainage volume after surgery; *compared by Fisher's exact test.

Table 4. Comparison of postoperative complications between single and multiple donation group.

Variables	Single donation (N = 90)	Multiple donation (N = 11)	p-value
30-day Mortality [n (%)]	3 (3.3)	0 (0.0)	1.000*
AKI [n (%)]	3 (3.3)	0 (0.0)	1.000*
Hemoglobinuria [n (%)]	2 (2.2)	0 (0.0)	1.000*
Wound Infection [n (%)]	3 (3.3)	0 (0.0)	1.000*
Reoperation for bleeding [n (%)]	0 (0.0)	0 (0.0)	-
Myocardial infarction [n (%)]	0 (0.0)	0 (0.0)	-
Pleural effusion [n (%)]	3 (3.3)	0 (0.0)	1.000*
Pulnonary Infection [n (%)]	2 (2.2)	0 (0.0)	1.000*
Gastrointestinal hemorrhage [n (%)]	0 (0.0)	0 (0.0)	-

AKI, acute kidney injury. *compared by Fisher's exact test.

higher EuroScore II-predicted mortality before PSM (2.57 vs. 2.09, p = 0.040), one might also speculate that these patients were sicker and more likely to experience poorer outcomes. However, after PSM, EuroScore II (2.31 vs. 2.20, p = 0.862) and other variables were completely balanced between groups, indicating good comparability. Additionally, all operations in this study were performed by a single surgeon group, which helped minimize the impact of technical differences between surgeons.

Our study found that the PABD group experienced reduced allogeneic RBC transfusion, consistent with previous reports on autologous transfusion for cardiac surgeries [4,10]. This reduction may result from two factors: first, the reinfusion of donated autologous blood decreased the dependence on allogenic RBC transfusions; second, hemodilution caused by preoperative donation may minimize RBC destruction during extracorporeal circulation.

Considering that perioperative allogenic RBC transfusion is strongly associated with increased risks of infection, renal dysfunction, stroke, and prolonged hospital stay [17], autologous blood transfusion has significant implications in reducing the morbidity of such complications [18]. Additionally, ABT has been independently associated with AKI following cardiac surgeries in many studies [19,20]. In our study, after careful propensity matching, a significantly decreased incidence of complications, such as AKI and hemoglobinuria, was observed in the PABD group. Furthermore, to determine whether PABD independently influenced these complications, we employed multivariate logistic regression analysis, confirming PABD as an independent protective factor for both postoperative AKI and hemoglobinuria. These findings suggest that PABD may be beneficial in reducing kidney-related complications after on-pump cardiac surgeries. Although the specific causal

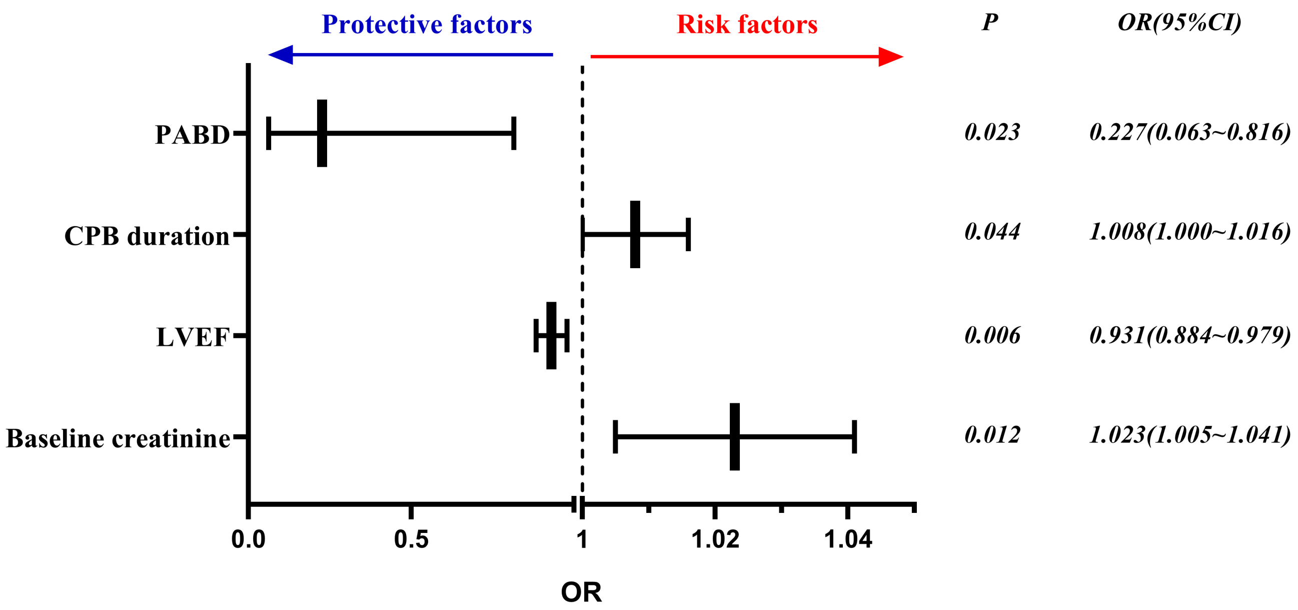

Fig. 3. Odds Ratio (OR) forest plot of univariate logistic regression for AKI.

Table 5. Multivariate logistic regression results of risk factors for AKI.

Variables	Univariate Analysis			Multivariate Analysis		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Male	1.919	0.604–6.100	0.269			
Age	1.038	0.992–1.086	0.106			
Weight	1.009	0.969–1.052	0.663			
Hypertension	1.799	0.632–5.123	0.272			
Diabetes	1.516	0.178–12.886	0.703			
Baseline serum creatinine	1.023	1.005–1.041	0.012	1.027	1.007–1.048	0.006
Baseline hemoglobin	1.003	0.966–1.041	0.882			
Baseline platelet count	1.000	0.992–1.007	0.902			
Baseline prothrombin time	0.860	0.574–1.288	0.463			
LAD	1.035	0.988–1.085	0.151			
LVEDD	1.050	0.994–1.110	0.078			
LVEF	0.931	0.884–0.979	0.006	0.955	0.897–1.017	0.148
PASP	1.012	0.983–1.042	0.411			
EuroSCORE II[α]	1.084	0.931–1.263	0.300			
PABD	0.227	0.063–0.816	0.023	0.204	0.051–0.816	0.025
CPB duration	1.008	1.000–1.016	0.044	1.005	0.996–1.015	0.274
Aortic clamping duration	1.009	0.997–1.021	0.096			
Main procedure type	5.786	0.897–37.313	0.065			

LVEF, left ventricular ejection fraction; LAD, left atrial diameter; LVEDD, left ventricular end-diastolic diameter; PASP, pulmonary artery systolic pressure; [α], European System for Cardiac Operative Risk Evaluation II; PABD, preoperative autologous blood donation; CPB, cardiopulmonary bypass; OR, odds ratio.

mechanism between PABD and renal protection is difficult to establish at this stage, there are several possible explanations. First, preoperative donation can dilute the blood before the initiation of CPB, thus reducing erythrocyte destruction during the CPB process. This may help decrease or avoid hemolysis. Additionally, hemolyzed erythrocytes increase the concentration of free hemoglobin (FHB), iron, and proinflammatory factors, which are assumed to be toxic to the kidneys [20–22]. In our study, the preoperative hemoglobin (Hb) concentration in the PABD group, measured post-donation, was significantly lower than that in the non-PABD group (12.3 ± 1.6 vs. 14.2 ± 1.3, $p < 0.001$, Fig. 2), indicating that preoperative donation can well achieved the goal of hemodilution before surgery, and

Table 6. Multivariate logistic regression results of risk factors for hemoglobinuria.

Variables	Univariate Analysis			Multivariate Analysis		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Male	1.037	0.369–2.920	0.944			
Age	1.024	0.982–1.067	0.276			
Weight	1.016	0.975–1.058	0.446			
Hypertension	0.651	0.180–2.361	0.514			
Diabetes	1.516	0.178–12.886	0.703			
Baseline creatinine	1.000	0.977–1.024	0.991			
Baseline hemoglobin	1.021	0.983–1.059	0.286			
Baseline platelet count	1.002	0.995–1.010	0.523			
Baseline prothrombin time	1.380	1.030–1.847	0.031	1.074	0.767–1.505	0.677
LAD	1.064	1.015–1.115	0.010	1.032	0.968–1.101	0.341
LVEDD	1.023	0.968–1.080	0.422			
LVEF	0.926	0.880–0.974	0.003	0.978	0.913–1.047	0.513
PASP	1.013	0.984–1.044	0.359			
EuroSCORE II[a]	1.129	0.980–1.300	0.094			
PABD	0.139	0.031–0.623	0.010	0.141	0.027–0.723	0.019
CPB duration	1.014	1.006–1.022	0.001	1.005	0.989–1.021	0.544
Aortic clamping duration	1.019	1.007–1.031	0.001	1.010	0.984–1.036	0.448
Main procedure type	3.086	1.030–9.248	0.044	0.908	0.164–5.034	0.912

LVEF, left ventricular ejection fraction; LAD, left atrial diameter; LVEDD, left ventricular end-diastolic diameter; PASP, pulmonary artery systolic pressure; [a], European System for Cardiac Operative Risk Evaluation II; PABD, preoperative autologous blood donation; CPB, cardiopulmonary bypass; OR, odds ratio.

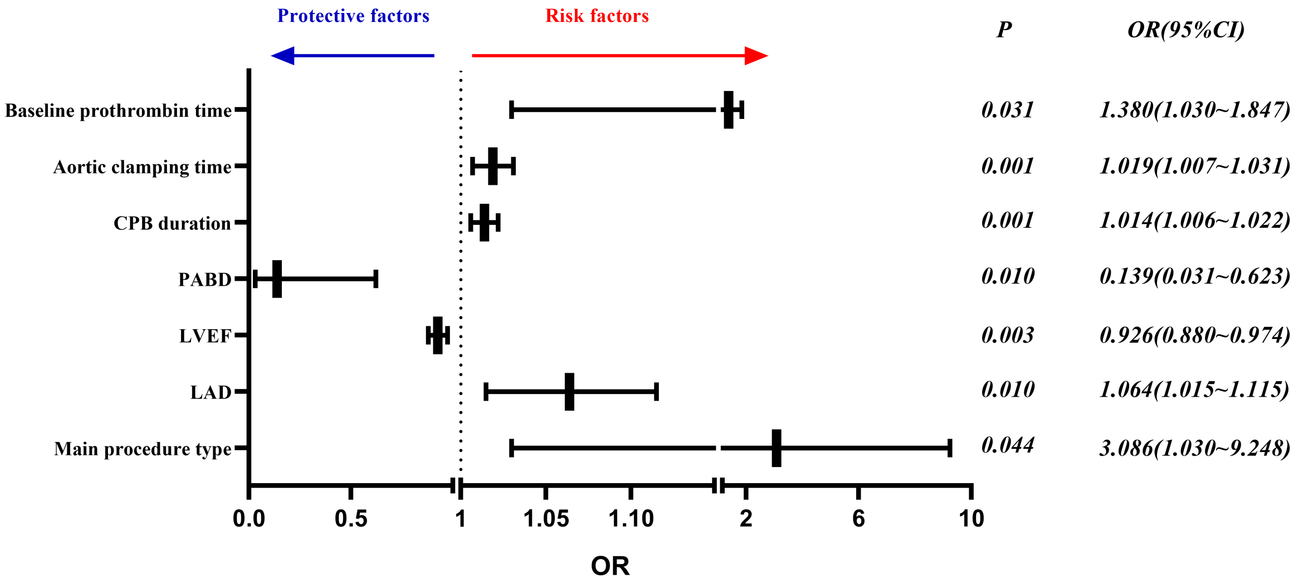

Fig. 4. Odds Ratio forest plot of univariate logistic regression for hemoglobinuria.

this may contribute to lower incidence of postoperative AKI and hemoglobinuria. However, no significant difference was observed in other complications and early mortality between the two matched groups, consistent with previous study [9].

Studies have showed that allogenic RBCs transfusion is independently associated with prolonged mechanical ventilation [23,24]. In our study, the PABD group was associated with significantly shorter postoperative mechanical ventilation time, indicating faster postoperative recovery. We speculated this difference may be attributed to reductions in allogenic RBCs usage and a lower incidence of related complications in the PABD group. However, the lack of difference in ICU stay time could be due to our ICU protocol, where all patients are routinely kept in the ICU for at least one night postoperatively.

Zheng *et al*. [4] reported that postoperative and at-discharge levels of HCT in the autologous blood transfusion group were significantly lower than those in the control group. In contrast, our study demonstrated no significant difference in hemoglobin levels in the early postoperative stage between the two matched groups, similar to previous findings reported by Lim *et al*. [9] and Martin *et al*. [10]. Notably, in Zheng *et al*.'s study [4], autologous donation was performed intraoperatively, just before the initial systematic heparinization of CPB, which is quite different from our PABD strategy. This may be the reason for the opposite results. By removing a certain amount of blood from the patients' bodies preoperatively, PABD can increase the secretion of erythropoietin [25], which promotes hematopoiesis and facilitates rapid recovery of hemoglobin levels in the early postoperative stage.

Priye *et al*. [26] described the application of PABD in a 45-year old male with Bombay blood group undergoing mitral valve replacement in India. Similarly, in this study, we successfully performed PABD for a 50-year-old male with type-O, Rh-negative blood, due to the unavailability of homologous blood of this blood group preoperatively. We suggest that PABD could be a rational solution to the scarcity of rare blood types before elective cardiac surgeries.

Limitations

There are several limitations of this study. Firstly, it was a retrospective observational study. The lack of a prospective and randomized design is an inherent limitation. Secondly, it summarized clinical data from only a single center. A limited sample size may reduce the power to yield statistically significant results. Thus, these findings still require confirmation by prospective, multi-center, randomized controlled clinical trials. Thirdly, transfusion costs in this study may not be generalizable to other centers due to different economic levels and inflation rates.

Conclusion

In conclusion, the utilization of PABD in on-pump cardiac surgeries was associated with reduced allogeneic RBC usage, without increasing adverse events. In response to the shortage of blood resources, PABD is worth further promotion. Future studies are still warranted to confirm its safety and efficacy in a larger population.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

Concept-YYL, FL; Design-FL, YYL; Writing-YYL; Supervision-FL; Data Collection-YYL, SDL, XL, CHL; Analysis-YYL; Literature Review-YYL, SDL; Critical review-FL. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics Approval and Consent to Participate

The study was carried out in accordance with the guidelines of the Declaration of Helsinki. This study was approved by the Institutional Ethical Review Board of the First Affiliated Hospital of Anhui Medical University (Approval No.20221241). Informed consent was obtained from all patients and the ethics committee approved the procedures.

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Conflict of Interest

The authors declare no conflict of interest.

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