Journal of
Cardio - Thoracic Medicine

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Outcome of Fresh Frozen Plasma Versus Albumin in Priming Solution of Extracorporeal Circuit in Neonatal Cardiac Surgery: A Prospective Comparative Observational Study

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ARTICLEINFO

Article type:
Original Article

Article history:
Received: 31 October 2025
Accepted: 6 January 2026

Keywords:
Congenital Heart Disease
Extracorporeal Circulation
Fresh Frozen Plasma
Heart-Lung Machine

ABSTRACT

Introduction: In neonatal cardiac surgery, the choice of cardiopulmonary bypass (CPB) priming fluid is crucial. Fresh frozen plasma (FFP) provides essential coagulation factors that can help reduce bleeding, while albumin helps maintain oncotic pressure and may protect renal function. This study aimed to compare the outcomes of FFP- based priming versus albumin-based priming.

Methods: This prospective observational study was conducted from June 2022 to October 2024 and involved 100 neonates (weighing ≤5 kg) undergoing CPB. Patients were alternately assigned to receive 10 mL/kg of FFP (n = 50) or 5% albumin (n = 50) in the priming fluid. Outcomes included bleeding, transfusion requirements, hemodynamic stability, renal function, mechanical ventilation duration, intensive care unit (ICU) stay, hospital stay, and mortality. Data were analyzed using t tests and chi-square tests.

Results: Baseline characteristics were similar between the two groups. Chest drain output and total blood product use were comparable ($p > 0.05$), except the FFP group required more albumin transfusion at 24 hours ($p = 0.031$). Hemodynamics were mostly similar, although mean arterial pressure was slightly higher in the albumin group at 48 hours ($p = 0.040$). Serum creatinine was significantly higher in the FFP group preoperatively and at 24–48 hours postoperatively ($p \approx 0.02–0.03$), while urine output was similar. Duration of ventilation, ICU stay, hospital stay, and mortality showed no difference.

Conclusion: Albumin priming may offer modest renal protection and reduce donor exposure. FFP remains an acceptable alternative. Larger randomized trials are required.

► *Singh, S., Prajapati, M., Patel, K., Thakut, G., Murugesan, P., Modi, R. Outcome of Fresh Frozen Plasma versus albumin in priming solution of extracorporeal circuit in neonatal cardiac surgery: A Prospective Comparative Observational study. J Cardiothorac Med. 2026; 14(1): 1638-1645.* ***Doi : 10.22038/jctm.2026.92371.1517***

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Introduction

Congenital heart disease (CHD) is the most common birth defect, with an incidence of approximately 8–10 per 1,000 live births, and a significant proportion of affected neonates require surgical correction with cardiopulmonary bypass (CPB) early in life (1,2). While CPB has dramatically improved survival, its use in neonates is associated with unique challenges due to their small circulating blood volume and immature organ systems (3).

One major issue during neonatal CPB is hemodilution, which leads to reduced hematocrit, dilution of coagulation factors, and decreased plasma oncotic pressure (4). These changes contribute to bleeding, increased transfusion requirements, tissue edema, and impaired renal function (5). The choice of priming solution is therefore critical in mitigating these complications.

Fresh frozen plasma (FFP) has been widely used as a priming fluid because it provides coagulation factors and proteins that may reduce coagulopathy and improve early hemostasis (6). On the other hand, albumin solutions offer colloid oncotic support, attenuate hemodilution, and may protect renal function without exposing patients to donor-derived blood products (7). Several studies in pediatric populations have compared these two strategies. Rauf et al. (8) reported that albumin supplementation in the cardiopulmonary bypass prime did not result in a significant reduction in transfusion requirements compared with standard priming strategies. Lee et al (9). Observed improvements in coagulation parameters without a reduction in overall blood loss. Dieu et al (10). similarly found no major clinical differences between FFP and crystalloid priming.

Despite these investigations, evidence specific to neonates remains limited. Most available studies are heterogeneous, including a wide pediatric age range, and their findings cannot be directly extrapolated to neonates, who are at higher risk of hemodilution-related complications (11). Moreover, data on renal outcomes and postoperative hemodynamics in this population are scarce.

Given these gaps, we aimed to compare the effects of FFP and albumin as priming solutions in neonates undergoing cardiac surgery with CPB, focusing on postoperative bleeding, transfusion requirements, renal function, and early clinical outcomes.

Materials and Methods

This single-center, prospective observational study was conducted on neonates with congenital heart disease at our institute from June 2022 to October 2024. The protocol of this study was approved by the institute ethics committee with the code of EC/Approval/05/C.Anae/13/06/2022.

Based on the studied parameters ($\alpha = 0.05$, $\beta = 0.2$, $d = 50$), the required sample size for the study was estimated to be 50 patients in each group. The alternate allocation method was used to assign patients to either the FFP or albumin groups. Signed informed consent was obtained from the parents of the neonates befor surgery.

The inclusion criteria were neonates weighing below 5 kg requiring cardiac surgery with cardiopulmonary bypass, needing a hematic priming solution and having signed informed consent. The exclusion criteria were neonates with renal disorders, preoperatively intubated patients and prior infections.

The induction and maintenance of anesthesia were consistent in both groups. In the operationing room, routine monitoring in pediatric cardiac surgery included a 5-lead Electrocardiogram, invasive blood pressure, pulse oximetry, temperature, central venous pressure and urine output monitoring.

For priming of the cardiopulmonary bypass circuit, 10 ml/kg FFP and 10ml/kg of 5% albumin were used in each group, respectively. During bypass, hematocrit was maintained at 25-30% and mean arterial pressure within 35-50 mmHg, considering age and temperature. The volume of CPB prime and the type of oxygenator used were consistent for all included patients.

The perfusionist was not blinded to the study group allocation. However, the intraoperative transfusion of any allogeneic blood products was solely the responsibility of the handling anesthesiologists. The perfusionist in charge of the CPB was not involved in any intraoperative transfusion decision-making. The intensivist in the post

operative intensive care unit (ICU) was blinded to the study groups.

Baseline parameters such as hemoglobin, total leukocyte count, platelet count, serum urea and creatinine, serum sodium, potassium and chloride, total bilirubin, alkaline phosphatase, Serum Glutamic Oxaloacetic Transaminase (SGOT), Serum Glutamic Pyruvic Transaminase (SGPT), Erythrocyte Sedimentation Rate (ESR) and International Normalized Ratio (INR) of the patients were recorded. In the post-operative period, serum creatinine values were recorded at 24 and 48 hours.

Baseline vitals including heart rate, mean blood pressure, SPO2, Central Venous Pressure (CVP), and lactate were recorded and repeated at the end of surgery and at 6, 24, and 48 hours post operatively. The bypass time, cross-clamp time, and total surgical time were recorded in minutes.

The mean drain output in units of ml/kg was recorded at 24 and 48 hours post operatively. The amount of transfusion of any blood products was also recorded within 48 hours post operatively. The vaso-inotropic score was calculated at the end of surgery and 24 and 48 hours postoperatively. Echocardiography was repeated after 24 hours in the post-operative period and compared with the pre-operative echocardiogram. The total duration of mechanical ventilation, ICU and hospital stay was noted in days. The outcome of the surgery was noted as expired or discharged.

Statistical analysis was performed using SPSS, Version 26.0 (Chicago, IL, USA). The independent sample t-test was used to compare continuous variables. The chi-square test was used to compare categorical variables. In a single group, the means of two variables were compared through a paired sample t-test. Data from more than two groups were compared using a one-way ANOVA test. Data were presented as mean ± SD or proportion as appropriate. A “p” value less than 0.05 was considered significant.

Results

Fifty patients were included in the albumin group, and 50 were in the FFP group. Four patients in the FFP group and one patient in the albumin group expired before completing 48 hours in the post-operative period. All patients were neonates weighing less than 5 kg. The demographic profiles of the patients in both groups were similar. The difference in the mean age of the patients between the two groups was not statistically significant (p=0.096).

Male patients outnumbered female patients in both groups; however, the difference between the groups was not statistically significant (p=0.640). There was no statistically significant difference in the mean weight of the patients between the two groups (p=0.482). Additionally, there was no statistically significant difference in the residential state of the patients between the two groups (p=0.247).

Sixty-nine patients underwent arterial switch operation (ASO), 12 had arch repair, 12 had total anomalous pulmonary venous connection (TAPVC), 5 had arterial switch + arch repair, 1 had aortic repair, and 1 had truncus repair. There was no statistically significant difference in the type of surgery performed between the two groups (p=0.517) (Table 1).

There were no differences in the baseline parameters between the two groups except for serum creatinine values (p=0.011), which were significantly higher in the FFP group. These parameters included baseline hemoglobin, total leukocyte count, platelet count, serum urea and creatinine, serum sodium, potassium, chloride, total bilirubin, alkaline phosphatase, SGOT, SGPT, serum protein, ESR, and INR (Table1).

Comparison of baseline parameters between the two groups in terms of heart rate, central venous pressure, saturation, lactate values and any inotropic requirement showed no statistically significant difference. Comparison of parameters like heart rate, CVP, SPO2, lactate, urine output, and inotropic requirement between the two groups at the end of surgery did not show a statistically significant difference except for the SPO2 values, which were significantly higher in the FFP group (p=0.042).

However, comparisons of similar parameters after 6 hours of ICU admission did not show a statistically significant difference in any of the parameters, such as heart rate, mean blood pressure, CVP, SPO2, lactate, urine output, drain output or inotropic requirement.

Table 1. Baseline data and Laboratory data between the groups.

Variables	Group FFP (n = 50) (Mean(SD))	Group Albumin (n = 50) (Mean(SD))	p-value
Age (Year)	17.52 (9.86)	20.72(9.13)	0.096
Sex: Male **Female**	37 (74%) 13 (26%)	39 (78%) 11 (22%)	0.640
Weight (kg)	2.82 (0.52)	2.75 (0.46)	0.482
Surgery performed (n %)			
ASO (n %)	37 (74%)	32 (64%)	0.517
Arch repair (n %)	5 (10%)	7 (14%)	
TAPVC repair (n %)	4 (8%)	8 (16%)	
ASO + Arch repair (n %)	3 (6%)	2 (4%)	
Aortic repair (n %)	0	1 (2%)	
Truncus repair (n %)	1 (2%)	0	
Haemoglobin (g/dL)	14.04 (2.59)	13.99 (2.09)	0.926
Total leucocyte Count (cells/µL)	11729.4 (4006.89)	10921.6 (3460.3)	0.283
Platelet count (cells/µL)	437.32 (143.7)	437.84 (152.72)	0.986
Serum Urea (mg/dL)	16.21 (7.32)	16.06 (7.2)	0.918
Serum Creatinine (mg/dL)	0.5 (0.17)	0.43 (0.12)	0.011
Serum Na+ (mmol/L)	137.08 (3.29)	136.94 (3.51)	0.838
Serum K+ (mmol/L)	4.78 (0.95)	4.97 (0.82)	0.290
Serum Cl- (mmol/L)	105.7 (5.65)	104.5 (6.21)	0.315
Serum Bilirubin (mg/dL)	7.21 (4.89)	6.74 (4.25)	0.610
ALP (U/L)	218.98 (20.46)	243.44 (145.62)	0.362
SGOT (U/L)	75.78 (64.84)	66.38 (77.17)	0.511
SGPT (U/L)	25.88 (25.79)	33.94 (91.87)	0.552
Serum Protein (g/dL)	5.64 (0.82)	5.52 (0.75)	0.472
ESR (mm/hr)	8.9 (9.13)	5.94 (5.59)	0.054
INR	1.42 (0.44)	1.32 (0.32)	0.206

Abbreviations: ASO: Arterial Switch Operation, **TAPVC:** Total Anomalous Pulmonary Venous Connection, **ALP:** Alkaline phosphatase, **SGOT:** Serum Glutamic-Oxaloacetic Transaminase, **SGPT:** Serum Glutamic Pyruvic Transaminase, **ESR:** Erythrocyte Sedimentation Rate, **INR:** International Normalized Ratio

Similarly, comparisons of similar parameters after 24 hours of ICU admission did not show a statistically significant difference between the two groups except for the serum creatinine values which were significantly raised in the FFP group (p=0.021).

After 48 hours of ICU admission, comparison of parameters did not show a statistically significant difference, except for the mean blood pressure which was significantly higher in the albumin group (p=0.040), and the serum creatinine level , which was again significantly raised in the FFP group (p=0.030). All parameters are shown in Figure 1 and Figure 2, as well as Table 2.

The comparison of the requirement for blood product transfusion between the two groups did not show any statistically significant difference, except for the need for albumin transfusion in the FFP group after 24 hours of ICU admission which was significantly higher (p=0.031) (Table 3).

The differences in bypass time, cross-clamp time, and total surgical time between the two groups were not statistically significant. The total duration of mechanical ventilation, measured in days, as well as the duration of ICU and hospital stay were also similar between the two groups. The comparison of echocardiography reports between the two groups showed no statistically significant difference after 24 hours of surgery (p=0.640). The number of patients who expired in both groups also showed no statistical difference (p=0.171) (Table 4).

Table 2. Post-operative outcomes: Drain output, transfusion, and vaso-inotropic score.

Post-operative time point	Group FFP (n =50) (Mean(SD))	Group Albumin (n =50) (Mean(SD))	p-value
Drain output in 24 hrs (ml/kg)	18.48 (19.33)	20.85 (20.18)	0.5539
Drain output in 48 hrs (ml/kg)	20.32 (28.26)	23.75 (21.17)	0.5033
Blood product transfused in 48 hrs (ml/kg)	29.87 (53.18)	25.07 (39.22)	0.6124
Vaso inotropic score at the end of surgery	20.37 (8.39)	20.4 (8.76)	0.9879
Vaso inotropic score after 24 hrs of icu admission	18.96 (16.55)	15.84 (8.48)	0.2448
Vaso inotropic score after 48 hrs of icu admission	15.48 (14.77)	12.74 (7.83)	0.2579

Table 3. Comparison of blood products transfused between the two groups (N=100).

Transfusion products (ml)		Mean (SD)		p- value
		Group FFP (n = 50) (Mean(SD))	Group Albumin (n = 50) (Mean(SD))	
Packed cell	After 6 hrs	52.5 (24.34)	73.5 (26.87)	0.105
	After 12hrs	45 (32.4)	63 (40.71)	0.461
	After 24hrs	77.14 (68.66)	61.6 (26.13)	0.644
FFP	After 6 hrs	93.33 (30.55)	80 (56.56)	0.746
	After 12hrs	140 (20.33)	80 (10.22)	-
	After 24hrs	45 (12)	0	-
PRP	After 6 hrs	41.25 (8.53)	48 (8.36)	0.272
	After 12hrs	0	0	-
	After 24hrs	0	60 ± 16.22	-
Cryoprecipitate	After 6 hrs	20 (6.03)	20 (6.03)	-
	After 12hrs	20 (6.03)	20 (6.03)	-
	After 24hrs	0	20 (6.03)	-
Albumin	After 6 hrs	29.5 (9)	31.25 (10.3)	0.807
	After 12hrs	33.14 (14.96)	32.72 (17.51)	0.950
	After 24hrs	46.56 (17.09)	34.28 (11.57)	0.031

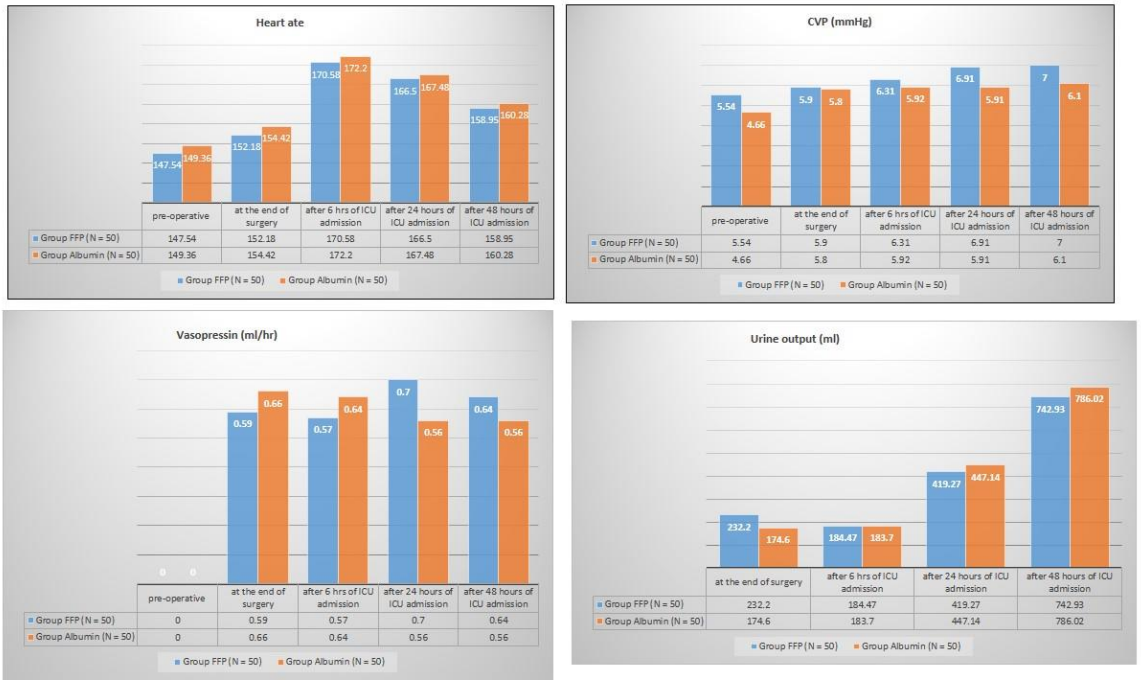

Figure 1. Pre-Post-operative outcomes (Heart Rate, CVP, Vasopressin, and Urine Output).

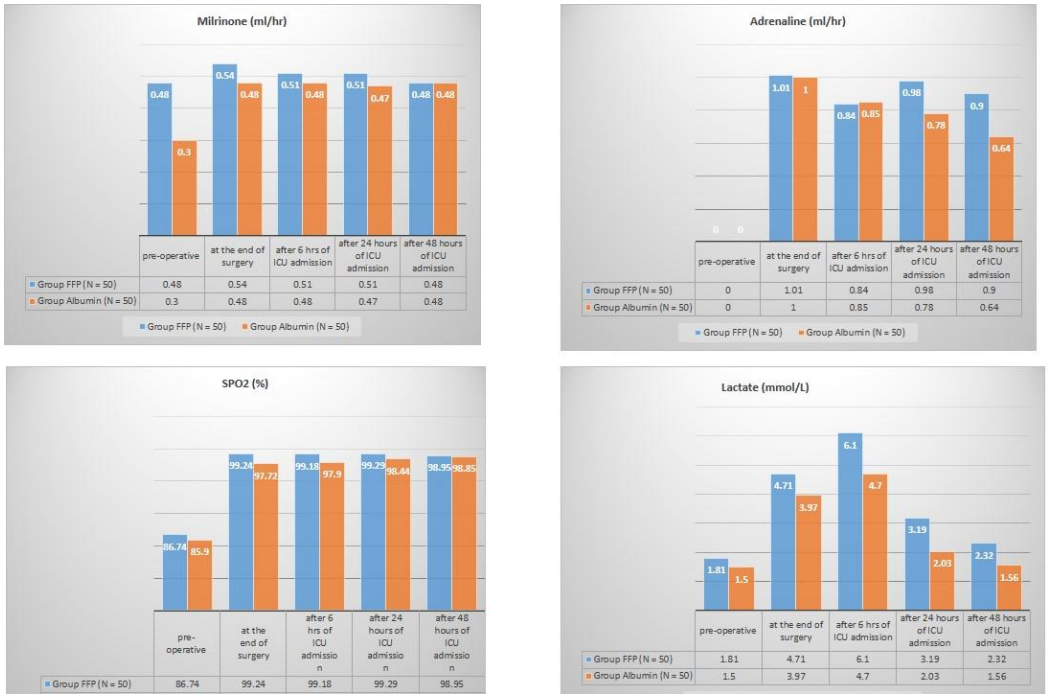

Figure 2. Pre-Post-operative outcomes (Milrione, Adrenaline, SpO2, and Lactate).

Table 4. surgical details, post-operative course, and outcome.

	(Mean(SD))		p-value
	Group FFP (n = 50)	**Group Albumin (n = 50)**	
Surgical details			
Bypass time (mins)	138.06 (73.27)	122.42 (59.59)	0.244
Cross clamp time (mins)	94.36 (49.47)	80.12 (38.39)	0.111
Total surgical time (mins)	235.7 (81.56)	232.4 (95.32)	0.853
Duration of hospital stay			
Duration of mechanical ventilation (days)	10.06 (14.66)	8.56 (10.44)	0.557
Duration of ICU stay (days)	14.66 (16.26)	12.98 (11.52)	0.552
Duration of hospital stay (days)	20.76 (17.53)	20.24 (11.99)	0.863
ECHO after 24 hours (n)			
Normal LV function	37 (76)	39 (78)	0.640
Reduced LV function	13 (26)	11 (22)	
Clinical outcome (n)			
Expired	16 (32)	10 (20)	0.171

Abbreviations: ECHO: echocardiography, **LV:** left ventricle

Discussion

Congenital heart disease frequently necessitates CPB in neonates, where priming solution selection plays a central role in influencing postoperative outcomes. Both albumin and FFP offer theoretical advantages: albumin counteracts hemodilution-induced hypo-oncotic states and supports renal function, while FFP provides essential coagulation factors that may reduce bleeding risks. In our study, no significant differences were observed between the albumin- and FFP-primed groups regarding postoperative bleeding, transfusion requirements, hemodynamic stability, or the duration of mechanical ventilation, ICU stay, and overall hospitalization. These findings suggest that, in neonates, the choice between albumin and FFP does not yield major clinical superiority in most perioperative outcomes (9).

Our results are consistent with those of Dieu et al. (10), who reported comparable postoperative bleeding and transfusion

needs between crystalloid- and FFP-primed circuits in pediatric surgery. Similarly, Lee et al. (9) and McCall et al. (9) demonstrated that although FFP supplementation improves immediate hemostatic parameters, this does not consistently translate into reduced transfusion requirements. Oliver et al.(6,8) reported reduced transfusion in albumin-primed patients; however, subgroup analysis showed higher blood loss in complex cyanotic procedures, contrasting with our observation of no significant difference. These variations likely reflect differences in patient selection, surgical complexity, and baseline coagulation status across studies.

Renal outcomes merit attention. In our cohort, serum creatinine was consistently higher in the FFP group postoperatively (p=0.021 at 24 h; p=0.030 at 48 h), though baseline values were also elevated in this group (p=0.011). While urine output remained similar, this trend raises the possibility of better renal protection with albumin priming, consistent with previous evidence that albumin preserves renal function compared to synthetic colloids. Nonetheless, due to baseline imbalances and limited sample size, this finding should be interpreted cautiously. Hemodynamic parameters remained largely comparable, although mean arterial pressure was marginally higher in the albumin group at 24–48 hours postoperatively (p = 0.040). The more frequent use of milrinone in the FFP group during early ICU admission may suggest subtle differences in ventricular performance, but these did not translate into meaningful clinical outcomes. Taken together, our findings reinforce the notion that neither FFP nor albumin provides clear overall superiority as a priming solution in neonatal CPB. Albumin may offer modest renal advantages and reduced exposure to donor blood products, while FFP remains a practical alternative in resource-limited settings where albumin is unavailable. From a clinical perspective, either solution can therefore be selected based on availability and cost without compromising early postoperative outcomes (12).

This study was conducted at a single center with a relatively small sample size and non-randomized patient allocation. Baseline creatinine imbalances between groups may have confounded the interpretation of renal outcomes. Furthermore, the follow-up period was limited to early postoperative outcomes; longer-term data on renal function and neurodevelopment were not assessed. Large-scale, multicenter randomized controlled trials focusing exclusively on neonates are required to clarify whether albumin confers clinically relevant renal or hemodynamic advantages over FFP. Future cost-effectiveness analyses would also help guide optimal priming strategies in diverse healthcare settings.

Limitation

This single-center, non-randomized study with alternate allocation may be subject to selection bias and have limited generalizability. Baseline imbalances in serum creatinine and the lack of long-term follow-up restrict the definitive interpretation of renal outcomes.

Strength

This prospective study focuses exclusively on neonates undergoing cardiopulmonary bypass and follows standardized anesthetic, perfusion, and postoperative protocols. A comprehensive evaluation of bleeding, transfusion requirements, hemodynamics, renal function, and early clinical outcomes enhances the clinical relevance of the findings.

Conclusion

Based on our study findings, we conclude that using FFP for CPB circuit priming in neonates does not offer any significant clinical or biochemical advantage over albumin-based priming. In fact, FFP may increase the risk of allogeneic transfusion and the theoretical risk of thromboembolic complications. Nevertheless, in situations where albumin is unavailable, FFP can be considered a viable alternative without raising the likelihood of postoperative complications such as prolonged mechanical ventilation, extended ICU or hospital stays, acute kidney injury, increased bleeding or the need for additional blood product transfusions. Moreover, albumin has the added benefit of reducing both the cost burden and the strain on blood bank resources associated with FFP use. Therefore, no definitive recommendation can be made regarding the superiority of one priming agent over the other. Continued research, especially through large –scale multicenter

studies, is essential to identify the optimal CPB priming strategy for neonates.

Funding

The study did not receive any funding.

Conflict of Interest Statement

All authors declare that they have no conflict of interest.

Data Availability Statement

The data presented in this study are available upon request from the corresponding author. The data are not publicly available due to restrictions that could compromise the privacy of research participants.

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