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RESEARCH ARTICLE

Red Blood Cell Transfusion and Cardiopulmonary Bypass Duration as Predictors of In-Hospital Mortality in Emergency Aortic Dissection Surgery

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ABSTRACT

Objectives: Aortic dissection (AD) is a life-threatening condition requiring urgent intervention. Despite advances in anesthetic and perioperative management, surgical outcomes remain poor. Anesthesiologists play a critical role in managing hemodynamics, blood loss, and transfusions. This study aimed to share our experience in emergency AD surgery and identify factors associated with in-hospital mortality.

Methods: This retrospective study included 51 patients who underwent surgery for acute DeBakey type I or II AD. Clinical and perioperative data were obtained from hospital records.

Results: The mean age was 59.7±12.6 years, and 60.8% of the patients were male. Type I dissection was present in 82.4% of patients. The median anesthesia duration was 255 minutes. Packed red blood cell (PRBC) transfusions were administered to 70.6% of patients. In-hospital mortality occurred in 33.3% of cases. Non-survivors had longer cardiopulmonary bypass (CPB) times (p=0.014) and received more PRBC units (p=0.018). A significant correlation was observed between PRBC transfusion and total circulatory arrest duration (r=0.335, p=0.034). In multivariate analysis, both PRBC transfusion (OR: 2.10, 95% CI: 1.03–4.29, p=0.042) and CPB duration (OR: 1.03, 95% CI: 1.01–1.05, p=0.007) were identified as independent predictors of in-hospital mortality.

Conclusion: The number of PRBC units transfused and CPB duration were independent predictors of mortality in emergency AD surgery. PRBC transfusions were also correlated with circulatory arrest duration. These findings highlight the importance of careful transfusion management in this high-risk population.

Keywords: Aortic dissection, cardiopulmonary bypass, erythrocyte transfusion, hospital mortality, hypothermia, induced, risk factors

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Introduction

Aortic dissection is a condition encountered in anesthetic practice more often than anticipated. It typically necessitates emergency intervention and is associated with considerable morbidity and mortality.[1] In aortic dissection, an intimal tear permits blood to enter the media layer of the aortic wall, forming a new channel for blood flow known as a false lumen.[2] This process can obstruct the origins of aortic branch vessels, extend into the aortic root and cause aortic valve insufficiency, rupture into the pericardium or pleural cavity resulting in cardiac tamponade or hemothorax, and ultimately lead to end-organ damage through malperfusion syndrome.[2,3]

Most anesthetic agents cause cardiac depression, vasodilation, or both.[4] The resulting decrease in sympathetic activity during anesthesia administration can lead to catastrophic outcomes, including acute circulatory collapse.[5] Adrenergic responses to anesthetic agents

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and surgical stimuli—such as endotracheal intubation, positive pressure ventilation, blood loss, fluid shifts among body compartments, and temperature fluctuations—exert additional stress on an already compromised cardiovascular system.

The management of acute aortic dissection depends on the patient's clinical condition, the type of dissection, and its anatomical extent. Regardless of the segment of the aorta involved, factors such as application of an aortic cross-clamp, prolonged perfusion and anesthesia times, significant blood loss, extensive transfusion requirements, coagulopathy, and the presence of cardiac, pulmonary, or renal comorbidities—as well as uncontrolled hypertension and diabetes—further complicate perioperative management. Consequently, anesthesiologists play a pivotal role in optimizing perioperative care by managing critical parameters such as hemodynamic stability, fluid balance, correction of coagulopathies, and, most importantly, the judicious use of blood products based on strict clinical indications.

This study aimed to present our institutional experience in the anesthetic management of patients undergoing emergency surgery for acute aortic dissection and to identify perioperative factors associated with in-hospital mortality.

Methods

After obtaining approval from the Clinical Research Ethics Committee of Harran University (Date: 26.08.2024; Approval No: HRÜ/24.12.07), and in accordance with the principles of the Declaration of Helsinki, 51 consecutive patients who underwent surgery for DeBakey type I or II acute aortic dissection at the Cardiovascular Surgery Department of Şanlıurfa Mehmet Akif İnan Training and Research Hospital between January 2023 and July 2024 were included in this study. Since this study was conducted retrospectively and included all eligible patients who underwent emergency surgery for acute aortic dissection at our institution over a defined period, no a priori sample size calculation was performed. Patient data were retrospectively collected from the hospital information system and electronic medical records. The following variables were analyzed: baseline demographic characteristics (sex, age, body mass index), comorbidities, American Society of Anesthesiologists (ASA) physical status scores, baseline laboratory parameters, surgical procedures performed, total anesthesia duration, perfusion time, cross-clamp time, circulatory arrest time, requirement for blood transfusion, intraoperative and postoperative hemofiltration, postoperative complications, hospital length of stay, and in-hospital mortality.

During distal anastomosis, moderate hypothermic circulatory arrest (HCA) was induced by reducing the core body temperature to approximately 26°C. To provide cerebral protection during HCA, selective antegrade cerebral perfusion (SACP) was employed, either unilaterally or bilaterally depending on the patient's vascular anatomy. The duration of circulatory arrest was recorded as HCA time. All patients who underwent surgery during the study period and had complete data available were included. Patients under the age of 18 and those with missing data were excluded.

Classification of aortic dissection is based on the anatomical location of the initial intimal tear, and the DeBakey classification system was used in this study. Accordingly, dissections originating in the ascending aorta and involving the entire aortic segments are classified as type I; those confined to the ascending aorta are classified as type II; and dissections limited to the descending aorta are designated as type III.[6]

After obtaining informed consent from the patients, they were transferred to the operating room, where venous access was established using an 18G peripheral intravenous catheter. Routine cardiac surgery monitoring was performed, including electrocardiography (ECG), invasive arterial blood pressure monitoring via the nondominant radial artery, central venous catheterization, pulse oximetry, and core temperature monitoring, and baseline values were recorded. ASA physical status scores, ejection fractions, dissection types, preoperative arterial blood gas analyses, blood urea nitrogen, creatinine, hemoglobin, hematocrit, CK-MB, and troponin levels were documented.

Anesthesia induction was performed using 0.02 mg/kg midazolam, 2 µg/kg fentanyl, 1–2 mg/kg propofol, and 0.6–0.8 mg/kg rocuronium bromide. Following endotracheal intubation, normocapnic ventilation was achieved with a tidal volume of 6–8 mL/kg using a 50% air–oxygen mixture. Anesthesia was maintained with sevoflurane infusion and intermittent intravenous boluses of 0.3 mg/kg rocuronium bromide. Patients who developed hypotension during induction received a 5–10 mg bolus of ephedrine, and vasopressor support was initiated when needed. Surgery was initiated once hemodynamic stability was achieved. After intubation, central venous pressure (via internal jugular vein catheterization), end-tidal CO_2, urine output, anesthetic agent concentrations, arterial blood gas values, and activated clotting time (ACT) were continuously monitored.

Blood products were reserved in advance from the blood bank for all patients prior to surgery. The transfused products included packed red blood cells (PRBCs), platelets,

Table 1. Baseline clinical and laboratory characteristics of the patients

Variables	n=51
Age (years)	59.7±12.6
Sex, male, n (%)	31 (60.8)
Height (cm)	169.9±10.0
Weight (kg)	83.2±15.9
Body mass index (kg/m^2)	28.9±5.1
Hypertension, n (%)	36 (70.6)
Diabetes mellitus, n (%)	11 (21.6)
Hemoglobin (g/L)	13.1±2.0
Hematocrit (%)	39.3±5.5
Urea (mg/dL)	39.0±11.5
Creatinine (mg/dL)	1.0 (0.8–1.2)
Potassium (mEq/L)	4.4±0.6
pH	7.3±0.1
Lactate (mmol/L)	3.0 (1.9–5.7)
SpO_2 (%)	95.3±3.5
Heart rate (beats/min)	95.0±12.4
Mean arterial pressure (mmHg)	86.7±16.8
CK-MB (ng/mL)	2.4 (1.4–4.4)
Troponin (ng/L)	13.6 (7.5–39.7)
Ejection fraction (%)	55.9±8.1
Type of dissection, n (%)	
Type 1	42 (82.4)
Type 2	9 (17.6)

Values are presented as mean±SD or median (1Q, 3Q) for continuous variables, and n (%) for categorical variables. BMI: Body mass index; SpO_2: Peripheral oxygen saturation; CK-MB: Creatine kinase-MB. Type 1/Type 2: DeBakey classification.

Table 2. Intraoperative and postoperative characteristics of the patients

Variables	n=51	
	n	%
Anesthesia duration, min	255 (210–300)	
Cardiopulmonary bypass (CPB) (time, min)	149 (114–182)	
Cross-clamp time (min)	100 (80–132)	
HCA duration (min)	34 (22–48)	
Perfusion urine output (mL)	650 (300–1263)	
Transfusion requirement	36	70.6
Packed red blood cells (PRBCs)	36	70.6
Fresh frozen plasma (FFP)	51	100)
Apheresis	3	5.9)
Number of PRBC transfusions, units (median, IQR)	3 (0–4)	
Intraoperative hemofiltration	8	15.7
Postoperative hemofiltration	3	5.9
Postoperative complications	6	11.8
Cerebrovascular event	5	9.8
Peripheral embolization	1	2
Hospital length of stay, days	8 (2–10)	
In-hospital mortality	17	33.3

Values are presented as mean±SD or median (1Q, 3Q) for continuous variables, and n (%) for categorical variables. CPB: Cardiopulmonary bypass; HCA: Hypothermic circulatory arrest; PRBC: Packed red blood cells; FFP: Fresh frozen plasma.

fresh frozen plasma (FFP), and cryoprecipitate. The majority of transfusions were administered intraoperatively, and bleeding was monitored using activated clotting time (ACT). In cases where ACT exceeded 140 seconds and arterial blood gas analysis revealed a hematocrit level below 21% or a hemoglobin level below 7 g/dL, PRBC transfusion was initiated. At the conclusion of cardiopulmonary bypass, FFP was administered to all patients. Platelet transfusion was performed postoperatively in patients who developed thrombocytopenia.

Statistical Analysis

Statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). The normality of distribution for continuous variables was assessed using the Kolmogorov–Smirnov test. Normally distributed variables were expressed as mean±standard deviation (SD) and compared using the Student's t-test. Non-normally distributed variables were presented as median and interquartile range (IQR) and compared using the Mann–Whitney U test. Categorical variables were presented as frequencies and percentages, and comparisons were performed using the chi-square test or Fisher's exact test, as appropriate.

Correlations between variables were assessed using Spearman's rank correlation coefficient. To determine independent predictors of in-hospital mortality, both univariate and multivariate logistic regression analyses were conducted. Variables with a p-value<0.10 in univariate analysis were included in the multivariate model. A two-tailed p-value<0.05 was considered statistically significant.

Results

A total of 51 patients who underwent surgery for acute aortic dissection and were admitted to the intensive care unit between January 2023 and July 2024 were retrospectively included in the study. Baseline clinical and laboratory characteristics are summarized in Table 1. The mean age was 59.7±12.6 years, and 31 patients (60.8%) were male. Hypertension was present in 36 patients (70.6%). The mean ejection fraction at admission was 55.9±8.1%. Among the cohort, 42 patients (82.4%) had type I dissection, and 9 patients (17.6%) had type II dissection.

Intraoperative and postoperative characteristics of the patients are summarized in Table 2. The median duration of anesthesia was 255 minutes (IQR: 210–300). Red blood cell (RBC) transfusions were administered in 36 patients

Table 3. Comparison of baseline clinical and laboratory characteristics between deceased and surviving patients

Variables	In-hospital death (+) (n=17)	In-hospital death (–) (n=34)	p
Age (years)	63.9±11.1	57.7±12.9	0.097
Male sex, n (%)	9 (52.9)	22 (64.7)	0.417
Height (cm)	169.3±9.2	170.3±10.5	0.748
Weight (kg)	84.2±13.5	82.8±17.1	0.768
Body mass index (kg/m^2)	29.5±4.9	28.5±5.3	0.522
Hypertension, n (%)	14 (82.4)	22 (64.7)	0.192
Diabetes mellitus, n (%)	3 (17.6)	8 (23.5)	0.630
Hemoglobin (g/L)	13.2±2.0	13.1±1.9	0.850
Hematocrit (%)	39.6±5.8	39.1±5.4	0.757
Urea (mg/dL)	36.8±9.8	40.1±12.3	0.335
Creatinine (mg/dL) (median, IQR)	1.0 (0.9–1.2)	1.0 (0.7–1.2)	0.484
Potassium (mEq/L)	4.4±0.4	4.5±0.7	0.510
pH	7.3±0.1	7.3±0.1	0.604
Lactate, mmol/L (median, IQR)	4.3 (2.5–6.3)	2.5 (1.8–5.1)	0.153
SpO_2 (%)	94.9±4.3	95.5±3.1	0.542
Heart rate (bpm)	91.2±14.8	96.9±10.8	0.126
CK-MB, ng/mL (median, IQR)	2.6 (1.4–4.0)	2.4 (1.4–4.5)	0.968
Troponin, ng/L (median, IQR)	21.7 (6.7–50.2)	13.0 (7.6–38.9	0.772
Ejection fraction (%)	56.5±8.4	55.5±8.0	0.681
Type of dissection, n (%)			
Type 1	15 (88.2)	27 (79.4)	0.699
Type 2	2 (11.8)	7 (20.6)	

Values are presented as mean±SD or median (1Q, 3Q) for continuous variables, and n (%) for categorical variables. Groups: In-hospital Death (+) = non-survivors; In-hospital Death (–) = survivors. Statistics: Student's t-test or Mann–Whitney U test for continuous variables; chi-square test or Fisher's exact test for categorical variables. SpO_2: Peripheral oxygen saturation; CK-MB: Creatine kinase-MB; IQR: Interquartile range.

Table 4. Comparison of intraoperative and postoperative characteristics between survivors and non-survivors

Variables	In-hospital death (+) (n=17)	In-hospital death (–) (n=34)	p
Anesthesia duration (min)	270 (245–337.5)	255 (187.5–300)	0.141
Cardiopulmonary bypass (CPB) duration (min)	185.0 (132.0–225.5)	127.0 (113.8–164.5)	**0.014**
Cross-clamp duration (min)	119.0 (79.0–144.5)	96.5 (81.0–130.3)	0.358
HCA duration (min)	42.0 (28.0–83.5)	29.5 (21.8–41.8)	**0.062**
Perfusion urine output (L)	500 (200–1125)	700 (300–1300)	0.400
Red blood cell transfusion, n (%)	16 (94.5)	20 (58.8)	**0.010**
Number of RBC units transfused	2 (1–4)	1 (0–2)	**0.003**
Total number of transfused blood products (units)	4 (3–8)	3 (2–4),	**0.005**
Postoperative complications, n (%)	2 (11.8)	4 (11.8)	1.000

Values are presented as mean±SD or median (1Q, 3Q). Groups: In-hospital Death (+) = non-survivors; In-hospital Death (–) = survivors. Statistics: Student's t-test or Mann–Whitney U test for continuous variables; chi-square test or Fisher's exact test for categorical variables. CPB: Cardiopulmonary bypass; HCA: Hypothermic circulatory arrest; PRBC: Packed red blood cells.

(70.6%). The median number of RBC units transfused per patient was 3 (IQR: 0–4). In-hospital mortality was observed in 17 patients (33.3%).

A comparison between patients who died in hospital and those who survived is presented in Table 3 and Table 4. No significant differences were observed in baseline clinical or laboratory characteristics between the two groups (Table 3). Regarding intraoperative parameters, there were no statistically significant differences in anesthesia duration (p=0.141) or cross-clamp time (p=0.358). However, cardiopulmonary bypass (CPB) time (p=0.014), hypothermic circulatory arrest (HCA) duration (p=0.062), and the frequency of red blood cell transfusion (p=0.005) were all higher in patients who died.

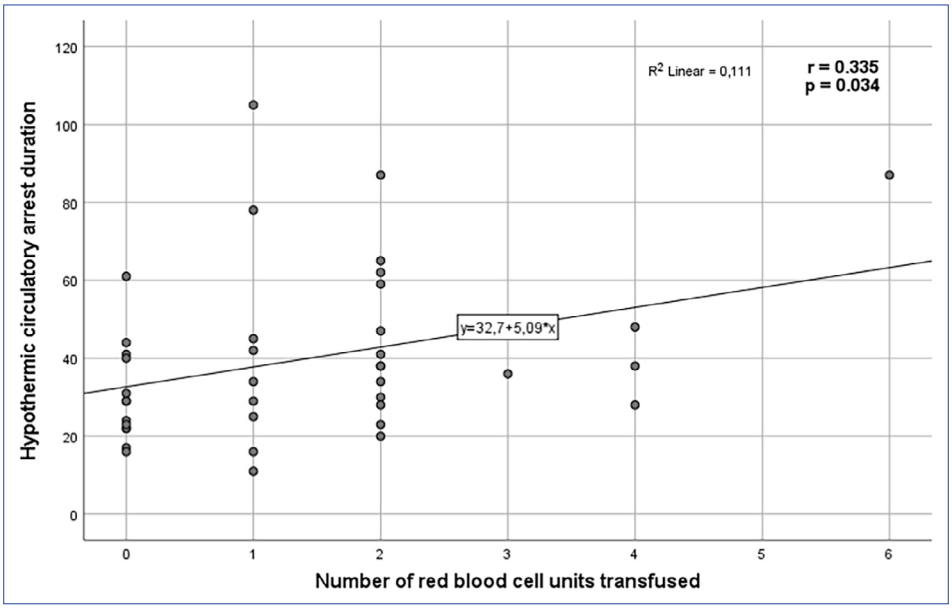

Figure 1. Correlation between the number of blood product transfusions and circulatory arrest duration.

Moreover, the number of RBC units transfused per patient was significantly higher among non-survivors (p=0.003). The total number of transfused blood products was also significantly greater in the deceased group, with a median of 4 units (IQR: 3–8), compared to 3 units (IQR: 2–4) in survivors (p=0.005).

Spearman correlation analysis demonstrated a statistically significant positive association between the number of red blood cell (RBC) units transfused and the duration of hypothermic circulatory arrest (r=0.335, p=0.034) (Fig. 1).

Univariate and multivariate logistic regression analyses were conducted to identify independent predictors of in-hospital mortality. In univariate analysis, the number of red blood cell (RBC) transfusions (p=0.021), cardiopulmonary bypass (CPB) duration (p=0.012), and hypothermic circulatory arrest (HCA) duration (p=0.010) were significantly associated with in-hospital mortality. When included in the multivariate logistic regression model, both the number of RBC transfusions (odds ratio [OR]: 2.101; 95% confidence interval [CI]: 1.029–4.293; p=0.042) and CPB duration (OR: 1.029; 95% CI: 1.007–1.050; p=0.007) remained independent predictors of in-hospital mortality (Table 5).

In our study, 15 patients did not receive red blood cell (RBC) transfusions. To assess the effect of transfusion on in-hospital mortality, patients were categorized into two groups: those who received RBC transfusions (n=36) and those who did not (n=15). The in-hospital mortality rate was significantly higher in the transfused group compared to the non-transfused group (p=0.009) (Fig. 2).

Table 5. Independent predictors of in-hospital mortality

	Univariate analysis			Multivariate analysis		
	OR	**95% CI**	**p**	**OR**	**95% CI**	**p**
Age (years)	1.043	0.992–1.097	0.101			
Gender (male)	0.614	0.188–2.005	0.419			
Body mass index (kg/m^2)	1.039	0.927–1.164	0.514			
Number of RBC units	1.624	1.048–2.516	0.021	2.101	1.029–4.293	**0.042**
Anesthesia duration (min)	1.005	0.998–1.013	0.173			
CPB duration (min)	1.018	1.004–1.032	0.012	1.029	1.007–1.050	**0.007**
Cross-clamp duration (min)	1.009	0.993–1.026	0.273			
HCA duration (min)	1.038	1.009–1.069	0.010	0.991	0.952–1.050	0.643

Values are presented as odds ratio (OR) with 95% confidence interval (CI). Statistics: Univariate and multivariate logistic regression. OR: Odds ratio; CI: Confidence interval; RBC: Red blood cell; CPB: Cardiopulmonary bypass; HCA: Hypothermic circulatory arrest.

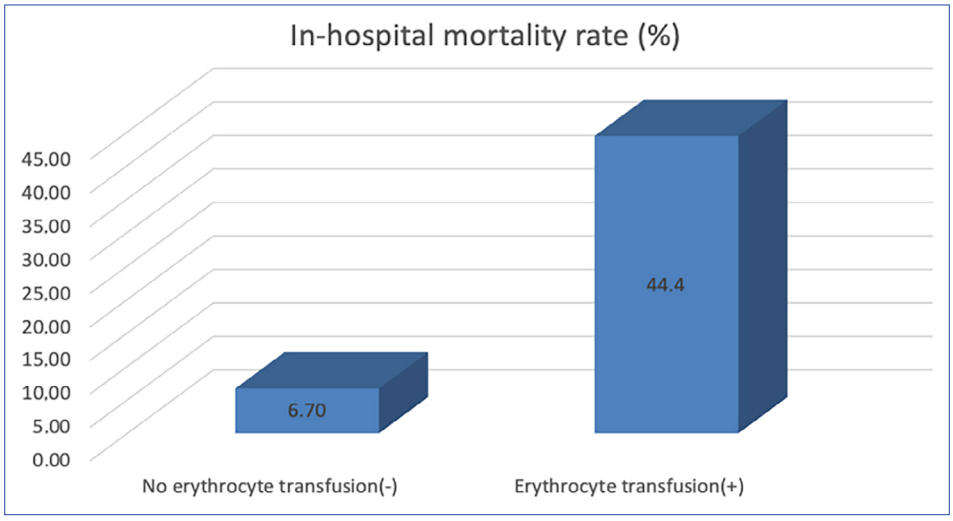

Figure 2. In-hospital mortality rates in patients with and without red blood cell transfusion requirement.

Discussion

In this retrospective study, we analyzed patients who underwent emergency surgery for acute aortic dissection (AD). The key findings can be summarized as follows: (I) the incidence of male sex was higher among patients with AD (male/female ratio: 1.55), and hypertension was present in the majority (70.6%); (II) in-hospital mortality occurred in 33.3% of patients. Multivariate analysis identified both the number of red blood cell (RBC) transfusions and prolonged cardiopulmonary bypass (CPB) duration as independent predictors of in-hospital mortality; (III) a statistically significant positive correlation was observed between the number of RBC transfusions and hypothermic circulatory arrest (HCA) duration; (IV) in-hospital mortality was significantly higher among patients who received RBC transfusions compared to those who did not.

In our study, which included 51 patients, 31 (60.8%) were male, and the mean age was 59.7±12.6 years. According to the International Registry of Acute Aortic Dissection (IRAD), the average age of AD onset is 63 years, with approximately 65% of patients being male.[7] Similarly, a study from the Mayo Clinic involving 375 patients reported that 65.1% were aged 60 years or older and 65.4% were male.[8]

In addition to older age and male sex, hypertension is considered a major risk factor for AD, as it compromises the elastic integrity of the aortic wall. Chronic exposure to elevated blood pressure leads to structural and functional deterioration of the vessel wall, thereby predisposing individuals to dissection. Prior studies have reported a high prevalence of hypertension in patients with AD: 81% in a study by Lio et al.,[9] 79% in the Mayo Clinic cohort.[8] and 76.6% in the study by Evangelista et al.[10] Consistent with these findings, hypertension was present in 70.6% of our patients. These baseline characteristics are in line with the existing literature.

Acute aortic dissection is a catastrophic and life-threatening condition.[11] Despite advances in imaging modalities, the growing use of endovascular techniques, improved anesthetic and surgical approaches, and enhanced postoperative care, mortality rates following surgical repair of aortic dissection remain high.[11,12] Contributing factors include delayed hospital admission, interfacility transfers, and logistical delays in patient referral and transport.[13] Moreover, insufficient preoperative optimization due to the emergent nature of the condition, coexisting comorbidities such as uncontrolled hypertension or hyperglycemia, transfusion requirements, and malperfusion-related organ dysfunction further complicate anesthetic management. Decreased organ perfusion caused by the dissection itself may lead to ischemia, while anesthetic-induced myocardial depression and vasodilation may exacerbate hemodynamic instability. Therefore, anesthesiologists must manage multiple critical variables, including the prevention of hypotension, correction of electrolyte imbalances, maintenance of fluid balance, judicious transfusion of blood products, and temperature regulation.

Blood loss is a common complication in cardiac surgery and places patients at high risk for perioperative blood product transfusion.[14,15] Previous studies have reported that 27% to 92% of cardiac surgery patients may require transfusion, depending on factors such as the surgical center, type of procedure, and disease severity.[14,16] Variables associated with increased transfusion requirements include surgical urgency, preoperative hemoglobin levels, duration of cardiopulmonary bypass (CPB), and the extent of deep hypothermia.[14,17,18] In our study, the median anesthesia

duration was 255 minutes (IQR: 210–300), the median CPB time was 149 minutes (IQR: 114–182), and the median hypothermic circulatory arrest (HCA) duration was 34 minutes (IQR: 22–48). Consistent with prior reports, RBC transfusions were required in 70.6% of patients, with a median of 3 units per patient (IQR: 0–4). Furthermore, a statistically significant positive correlation was identified between the number of RBC units transfused and HCA duration (r=0.335, p=0.034). These findings suggest that longer or more complex surgical procedures may be associated with greater transfusion needs. A plausible mechanism linking HCA and transfusion requirement may involve the bleeding tendency and coagulopathy that can occur during circulatory arrest. Although generally considered safe, HCA is associated with vasoconstriction, platelet dysfunction, and coagulation abnormalities, which may increase intraoperative blood loss and subsequently raise transfusion requirements.[19–21]

In our study, in-hospital mortality occurred in approximately one-third of the patients. This finding is consistent with prior studies reporting similar mortality rates in patients undergoing surgery for acute aortic dissection.[7,22] For instance, a recent multicenter study by Hagan et al.[23] involving 464 patients with aortic dissection reported an in-hospital mortality rate of 27.4%. In our cohort, comparison between survivors and non-survivors revealed that the number of red blood cell (RBC) transfusions and the duration of cardiopulmonary bypass (CPB) were independent predictors of in-hospital mortality. Moreover, in-hospital mortality was significantly higher in patients who received RBC transfusions compared to those who did not (p=0.009). These findings are supported by previous studies indicating that the use of blood products is associated with increased morbidity and mortality following cardiovascular surgery.[14,15,24,25] The underlying mechanism may involve a higher incidence of acute kidney injury among patients who receive more transfusions.[26] However, renal outcomes were not evaluated in our study. Further large-scale studies are needed to confirm this association and to better understand the potential role of transfusion-related complications in postoperative mortality.

Our study has several limitations. The most significant limitations are the small sample size and the single-center design. Additionally, long-term follow-up of the patients was not performed, which could have strengthened the impact and reliability of our findings. Lastly, the development of postoperative acute kidney injury was not evaluated. Investigating the incidence of postoperative kidney injury and its potential association with blood product transfusion could have provided further valuable insights to our study.

Conclusion

In conclusion, despite technological advancements and improvements in postoperative care, the mortality rate among patients undergoing emergency surgery for aortic dissection (AD) remains high. In our study, in-hospital mortality occurred in 33.3% of patients, and both an increased number of erythrocyte transfusions and prolonged cardiopulmonary bypass (CPB) duration were identified as independent predictors of mortality. In addition, a significant association was found between the number of erythrocyte transfusions and the duration of hypothermic circulatory arrest.

These findings highlight the critical role of anesthesiologists in the perioperative management of AD patients. Transfusion decisions should be made with caution, ensuring that blood products are administered only when clinically indicated and in the most judicious manner possible.

Disclosures

Ethics Committee Approval: The study was approved by the Harran University Clinical Research Ethics Committee (no: HRÜ/24.12.07, date:26/08/2024).

Informed Consent: Informed consent has been obtained from the patients.

Conflict of Interest Statement: The authors declare that there is no conflict of interest.

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