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Original Article

Early Outcomes of Re-Exploration for Bleeding After Elective Cardiac Surgeries in Adult Patients

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Abstract

Background: Re-exploration for bleeding is a serious complication following elective cardiac surgery, consistently associated with increased morbidity, mortality, prolonged hospital stay, and greater use of healthcare resources. We aimed to investigate the causes of re-exploration for bleeding in adult cardiac surgery patients, determine its impact on the outcomes, and analyze the predictors of mortality.

Methods: A prospective observational study was conducted on 200 consecutive adult patients who underwent exploration for bleeding during 1450 elective cardiac surgeries between July 2024 and March 2025.

Results: The mean age was 49.18 ± 12.71 years, and 26.5% were females. Comorbidities included diabetes (22%), hypertension (42.5%), and smoking (58.5%). Mean preoperative EF was 58.18 ± 6.54%. Procedures included CABG (43%), mitral valve replacement (22%), double valve replacement (17.5%), aortic valve replacement (15%), and Bentall (2.5%). Mean cardiopulmonary bypass and cross-clamp times were 120.01 ± 35.32 and 88.31 ± 23.90 minutes, respectively. Early mortality was 7.5%. Major complications included shock (4.5%), massive transfusion (18%), and renal failure (2%). Most re-explorations occurred within 6–12 hours (47%). Bleeding was surgical in 81.5% and medical in 18.5%. Multivariable regression identified prolonged mechanical ventilation as a significant predictor of early mortality (OR = 1.226, p = 0.016).

Conclusion: Surgical causes predominate in postoperative bleeding, though medical causes remain significant. Bleeding is associated with significant morbidity and mortality. Preventive surgical measures and multidisciplinary management are essential to improve outcomes.

KEYWORDS

Re-exploration; Bleeding; Cardiac surgery; Predictors; Mortality

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Introduction

Re-exploration after cardiac surgery is considered a serious complication that has a high rate of mortality and major morbidity [1 - 3]. The rate of re-exploration after adult cardiac surgery varies across studies, ranging from 2 to 16% [4 - 6]. Re-exploration of the chest is mandatory with postoperative significant bleeding, cardiac tamponade, hemodynamic instability, or a forgotten foreign body [7]. The three most common surgical causes of bleeding are the site of graft anastomosis (20.2%), the sternum at the site of wires (17.0%), and surgical vascular sutures (12.5%) [8, 9].

The criteria for diagnosing significant bleeding post cardiac surgery include one or more of the following findings: (1) More than 500 ml bloody drainage during the first hour following cardiac surgery, more than 400 ml blood loss/hour in the first two hours, more than 300 ml/hour in the first three hours, more than one liter in total drainage during the first four hours, and more than 1200ml during the first five postoperative hours; (2) excessive bleeding that restarts (indicating mostly a surgical cause); and/or (3) sudden massive bleeding [10,11].

The clinical pathway for significant postoperative bleeding follows a structured escalation. Initial management focuses on correcting coagulopathy, guided by point-of-care viscoelastic testing (e.g., TEG/ROTEM) or conventional coagulation assays, allowing targeted administration of specific blood products (e.g., fresh frozen plasma, platelets, cryoprecipitate) rather than reflexive massive transfusion [10 - 12]. Simultaneously, pharmacological agents, most notably the anti-fibrinolytic tranexamic acid, are administered to stabilize the clot [3].

The challenge for clinicians is to balance the risks of ongoing bleeding and tamponade against the documented harms of high-volume transfusion. Therefore, identifying reliable predictors of the need for surgical re-exploration is paramount. Such predictors would enable earlier, more definitive intervention, thereby reducing both the exposure to blood products and the associated morbidity and mortality. The postoperative resuscitation predominant strategy is deliberate and excessive transfusion of blood products, which has remarkable ill-effects on morbidity and mortality after cardiac surgery, as we previously reported [12]. The most common complications of blood product administration are hemolytic reactions and transfusion-related acute lung injury [13]. Thus, this study aims to investigate the causes, assess the clinical impact, and identify predictors of mortality after reoperation for bleeding in adult cardiac surgery patients.

Patients and Methods

This is a prospective observational study, which encompassed 200 adult patients who underwent re-exploration for bleeding after elective cardiac surgery between July 2024 and March 2025.

Inclusion and Exclusion Criteria

Eligible patients were adults (≥18 years) who required re-exploration for bleeding following elective cardiac surgery. Emergency procedures, patients with congenital heart disease, or those transferred to the intensive care unit with an open chest were excluded.

Preoperative Assessment

Baseline demographic and clinical data were documented, including a history of antiplatelet or anticoagulant use. Relevant laboratory investigations included hemoglobin level, platelet count, and international normalized ratio (INR). Preoperative echocardiographic parameters were left ventricular ejection fraction (EF) and LV dimensions. Additional routine investigations were performed in accordance with hospital protocol.

Intraoperative Assessment

Operative details were recorded, including the type of surgery, duration of cardiopulmonary bypass (CPB), aortic cross-clamp time, type of cardioplegia, and other intraoperative complications.

Table 1: Demographics, laboratory, and pre-operative echocardiography of the patients. Data are presented as mean (SD) or numbers (%)

Characteristic	Value (n= 200)
Female gender	53 (26.5%)
Age (years)	49.18 ± 12.71
Diabetes mellitus	44 (22.0%)
Hypertension	85 (42.5%)
Smoking	117 (58.5%)
Weight (Kg)	84.82 ± 12.03
Height (cm)	168.79 ± 6.18
BMI (Kg/M²)	29.74 ± 3.77
Last dose of antiplatelet	
No	111 (55.5%)
≥ 5 days	77 (38.5%)
< 5 days	12 (6.0%)
Blood tests	
Hb concentration (g/dL)	13.30 ± 1.41
Platelet count (×10³/µL)	203.92 ± 49.95
INR	1.17 ± 0.14
Pre-operative echocardiogram	
LVEDD (cm)	5.28 ± 0.79
LVESD (cm)	4.06 ± 0.62
EF (%)	58.18 ± 6.54

BMI: Body mass index, Hb: Hemoglobin, INR: International normalized ratio, LVEDD: Left ventricular end diastolic diameter, LVESD: Left ventricular end systolic diameter, EF: Ejection fraction

Postoperative Assessment

Postoperative data included intensive care unit (ICU) course, requirement for inotropic support, amount and timing of bleeding, etiology of bleeding (surgical or medical), complications, early mortality, and total length of hospital stay. Study variables were collected according to the EuroSCORE II definitions.

Statistical analysis

Data were analyzed using SPSS version 20 (IBM Corp., Armonk, NY, USA). Categorical variables are expressed as frequencies and percentages, and continuous variables as mean ± standard deviation. Univariate logistic regression was performed to identify potential predictors of early mortality. Variables with a P-value < 0.1 in the univariate analysis were entered into a multivariate logistic regression model. Multicollinearity was assessed using the variance inflation factor (VIF), and no significant multicollinearity was detected. The analysis was performed on a complete case basis, as there were no missing data for the variables included in the final regression model. Odds ratios (OR) with 95% confidence intervals (CI) were recorded, and a P-value < 0.05 was considered statistically significant.

Results

Patient Characteristics

During the study period, 1,450 patients had elective heart surgery. 200 patients (13.8%) required re-exploration due to postoperative bleeding. The mean age was 49.18 ± 12.71 years, and 53 patients (26.5%) were female. The mean BMI was 29.74 ± 3.77 kg/m². Among the cohort, 44 patients (22%) were diabetic, 85 (42.5%) were hypertensive, and 117 (58.5%) were smokers.

Regarding antiplatelet use, 111 patients (55.5%) had not received any. Among those who did, 77 patients (38.5%) discontinued the drug >5 days before surgery, whereas 12 (6%) received their last dose <5 days prior.

Baseline laboratory results showed a mean hemoglobin of 13.3 ± 1.4 g/dL, platelet count of 203.92 ± 49.95 × 10³/µL, and INR of 1.17 ± 0.14. Preoperative echocardiography revealed a mean LVEDD of 5.28 ± 0.79 cm, a mean LVESD of 4.06 ± 0.62 cm, and a mean ejection fraction (EF) of 58.2 ± 6.5%. (Table 1).

Intraoperative Data

The primary procedures performed were CABG in 86 patients (43%), MVR in 44 (22%), DVR in 35 (17.5%), AVR in 30 (15%), and the Bentall procedure in 5 (2.5%). Sixteen patients (8%) underwent redo surgery. The mean cardiopulmonary bypass time was 120.0 ± 35.3 minutes, and the mean cross-clamp time was 88.3 ± 23.9 minutes. Cold cardioplegia was used in 117 patients (58.5%) and warm cardioplegia in 83 (41.5%).

Intraoperative bleeding due to surgical injury occurred in 11 patients (5.5%). Hemostasis was achieved by residents in 89 patients (44.5%), specialists in 90 (45%), and consultants in 21 (10.5%). Blood products administered intraoperatively included packed RBCs in 34

Table 2: Intra-operative data of the patients. Data are presented as number (%) or mean (SD)

Variable	Value
Main procedure	
MVR	44 (22.0%)
AVR	30 (15.0%)
DVR	35 (17.5%)
CABG	86 (43.0%)
Bentall	5 (2.5%)
Redo cardiac surgery	16 (8.0%)
Cardiopulmonary bypass time (min)	120.01 ± 35.32
Cross clamp time (min)	88.31 ± 23.90
Type of cardioplegia	
Cold	117 (58.5%)
Warm	83 (41.5%)
Intra-operative bleeding due to injury	11 (5.5%)
Level of surgeon who did hemostasis	
Resident	89 (44.5%)
Specialist	90 (45.0%)
Consultant	21 (10.5%)
Intra-operative blood products	
Packed RBCs	
No	166 (83.0%)
1 unit	12 (6.0%)
2 units	19 (9.5%)
3 units	3 (1.5%)
Fresh blood	
No	12 (6.0%)
1 unit	143 (71.5%)
2 units	45 (22.5%)
Fresh frozen plasma	
No	164 (82.0%)
1 unit	5 (2.5%)
2 units	31 (15.5%)
Platelets	
No	178 (89.0%)
12 units	17 (8.5%)
24 units	5 (2.5%)

MVR: Mitral valve replacement, AVR: Aortic valve replacement, DVR: Double valve replacement, CABG: Coronary artery bypass grafting, RBC's: Red blood cells

patients (17%), fresh blood (defined as whole blood stored for <24 hours) in 188 (94%), fresh frozen plasma in 36 (18%), and platelets (pooled concentrates) in 22 (11%). (Table 2)

Table 3: Post-operative data of the patients. Data are presented as mean (SD) or numbers (%)

Variable	Value
Inotropic support	
Adrenaline	97 (48.5%)
Dobutamine	64 (32.0%)
Levosimendan	2 (1.0%)
Duration of mechanical ventilation (h)	31.63 ± 11.76
Post-operative Blood tests	
Hb concentration (g/dL)	10.19 ± 1.14
Platelet count (×10³/µL)	143.61 ± 26.53
INR	1.63 ± 0.23
Complications	
Shock	9 (4.5%)
Massive blood transfusion	36 (18.0%)
Renal failure	4 (2.0%)
TRALI	5 (2.5%)
Hepatic impairment	8 (4.0%)
Mortality	15 (7.5%)
Cause of mortality (n=15)	
Uncontrolled bleeding	3 (20.0%)
DIC	6 (40.0%)
Multi-organ failure	3 (20.0%)
ARDS	2 (13.3%)
Sepsis	1 (6.7%)
Wound infection	
No	184 (92.0%)
SSWI	13 (6.5%)
DSWI	3 (1.5%)
Vacuum assisted device	3 (1.5%)
Total ICU stay (days)	5.77 ± 2.51
Total hospital stay (days)	15.39 ± 5.95
Post-operative Echo	
LVEDD (cm)	5.20 ± 1.16
LVESD (cm)	4.44 ± 0.88
EF (%)	49.05 ± 10.53
Pericardial effusion	20 (10.0%)
Management of PE (n=20)	
Conservative	16 (80.0%)
Sub-xiphoid drainage	4 (20.0%)

Hb: Haemoglobin, INR: International normalized ratio, TRALI: Transfusion-related lung injury, DIC: Disseminated intravascular coagulation, ARDS: Acute respiratory distress syndrome, SSWI: Superficial sternal wound infection, DSWI: Deep sternal wound infection, ICU: Intensive care unit, LVEDD: Left ventricular end diastolic diameter, LVESD: Left ventricular end systolic diameter, EF: Ejection fraction, PE: Pericardial effusion

Postoperative Outcomes

The most commonly used inotropes were adrenaline (97 patients, 48.5%), dobutamine (64 patients, 32%), and levosimendan (2 patients, 1%).

The mean ventilation time was 31.6 ± 11.8 hours. Postoperative labs demonstrated a mean hemoglobin of 10.2 ± 1.1 g/dL, a platelet count of 143.6 ± 26.5 × 10^3/μL, and an INR of 1.63 ± 0.23 (Table 3).

Complications included shock in 9 patients (4.5%), massive transfusion in 36 (18%), renal failure in 4 (2%), transfusion-related lung injury (TRALI) in 5 (2.5%), and hepatic impairment in 8 (4%). The overall early mortality rate was 7.5%, with causes including disseminated intravascular coagulation (DIC) (40%), uncontrolled bleeding (20%), multi-organ failure (20%), acute respiratory distress syndrome (ARDS) (13.3%), and sepsis (6.7%) (Table 3).

The incidence of wound infection was 8%, comprising 13 superficial sternal wound infections (6.5%) treated conservatively and 3 deep sternal wound infections (1.5%) managed with vacuum-assisted closure. The mean ICU stay was 5.8 ± 2.5 days, and the mean hospital stay was 15.4 ± 6.0 days. Postoperative echocardiography revealed a mean LVEDD of 5.20 ± 1.16 cm, an LVESD of 4.44 ± 0.88 cm, and an EF of 49.1 ± 10.5%. Significant pericardial effusion developed in 20 patients (10%), of whom 16 (80%) were managed conservatively, while 4 (20%) required subxiphoid drainage.

Blood Product Transfusion in the first 24 Hours

Within the first 24 hours postoperatively, transfusion requirements were as follows:

- Packed RBCs: 1 unit (1.5%), 2 units (30%), 3 units (48%), 4 units (19.5%), 5 units (1%).
- Fresh blood: 1 unit (68.5%), 2 units (29%).
- Fresh frozen plasma: 3 units (20.5%), 4 units (55%), 5 units (24.5%).
- Platelets: 12 units (24%), 24 units (25.5%), 36 units (2%) (Table 4).

Bleeding Characteristics and Re-exploration

The mean total drainage was 481.2 ± 232.1 ml at 3 hours, 989.4 ± 165.9 ml at 6 hours, 1457.5 ± 181.0 ml at 12 hours, and 1915.5 ± 182.7 ml at 24 hours. The timing of re-exploration was 1–3 hours in 18 patients (9%), 3–6 hours in 37 patients (18.5%), 6–12 hours in 94 patients (47%), and 12–24 hours in 15 patients (7.5%).

Table 4: The amount of bleeding, the blood products, and the causes of bleeding. Data are presented as mean (SD) or numbers (%)

	(n= 200)
Packed RBC's	
1 unit	3 (1.5%)
2 units	60 (30.0%)
3 units	96 (48.0%)
4 units	39 (19.5%)
5 units	2 (1.0%)
Fresh Blood	
None	5 (2.5%)
1 unit	137 (68.5%)
2 units	58 (29.0%)
Fresh frozen plasma	
3 units	41 (20.5%)
4 units	110 (55.0%)
5 units	49 (24.5%)
Platelets	
None	97 (48.5%)
12 units	48 (24.0%)
24 units	51 (25.5%)
Total drains before re-exploration (ml)	
3 hours	481.15 ± 232.09
6 hours	989.38 ± 165.89
12 hours	1457.52 ± 181.04
24 hours	1915.48 ± 182.74
Time to re-exploration	
1 - 3 hours	18 (9.0%)
3 - 6 hours	73 (36.5%)
6 - 12 hours	94 (47.0%)
12 - 24 hours	15 (7.5%)
Cause of bleeding	
Medical	37 (18.5%)
Surgical	163 (81.5%)
Surgical Causes (n=163)	
Atriotomy	15 (9.2%)
Aortotomy	7 (4.3%)
Cannulation site	18 (11.0%)
Distal anastomosis	6 (3.7%)
Proximal anastomosis	12 (7.4%)
Sternal wire	38 (23.3%)
Thymic fat	14 (8.6%)
Graft	17 (10.4%)
Mammary bed	22 (13.5%)
Others	14 (8.6%)

The causes of re-exploration were medical in 37 patients (18.5%) and surgical in 163 (81.5%).

Surgical causes included bleeding from sternal wires (19%), mammary beds (11%), cannulation sites (9%), atriotomy (7.5%), grafts (8.5%), thymic fat (7%), proximal anastomoses (6%), aortotomy (3.5%), distal anastomoses (3%), and others (7%) (Table 4).

Mortality Predictors

Univariate logistic regression identified several predictors of mortality: preoperative LVEDD (OR = 3.276, p = 0.010), LVESD (OR = 4.115, p = 0.017), EF (OR = 0.859, p = 0.021), redo surgery (OR = 7.143, p = 0.039), CPB time (OR = 1.023, p = 0.011), cross-clamp time (OR = 1.057, p = 0.002), intraoperative injury (OR = 105.0, p < 0.001), ventilation time (OR = 1.234, p = 0.006), and massive blood transfusion (OR = 30.667, p = 0.002). On multivariate analysis, ventilation time remained the only independent predictor of mortality (OR = 1.226, p = 0.016) (Table 5).

Discussion

Bleeding after cardiac surgery is a well-known complication. Colson PH et al. reported that the incidence of active bleeding varied across centers (0-16%) but was independent of cardiac surgical experience. They referred to the variable definitions of active bleeding and the amount of bleeding considered significant [14]. While our study focused on a cohort of patients who underwent re-exploration rather than on the overall incidence, our findings on the causes of bleeding align with previously reported patterns. We observed that surgical causes accounted for the vast majority of bleeding events (81.5%), with sternal wire (19%) and mammary bed bleeding (11%) being the most common surgical sites. This data is consistent with findings by Biancari et al., who reported the body of grafts (20.2%), sternum (17.0%), vascular sutures (12.5%), internal mammary artery harvest site (13.0%), and anastomoses (9.9%) as frequently implicated sites [9].

The reported risk factors for re-exploration for bleeding include emergency state, redo, low BSA, high EuroSCORE, dual antiplatelet less than 5 days before operation, on-pump surgery, combined valve and CABG, long bypass and clamping times, and lowest hematocrit. Debate exists about increasing age, preoperative renal dysfunction, and LV grade as risk factors for re-exploration [14–16]. Our study observed an early mortality rate of 7.5% among patients undergoing re-exploration for bleeding. This rate falls within the range reported in large registries and studies, such as Mehta et al. (9.1% vs. 2% for non-re-explored) [17] and Vivacqua et al. (8.5% vs. 1.8%) [16].

A prior meta-analysis including 597,923 patients found that re-exploration for bleeding was strongly and significantly associated with a higher risk of operative mortality [risk ratio (RR) 3.27], stroke (RR 2.18), and sternal wound infection (RR 4.52) at short-term follow-up [18]. The primary causes of mortality in our cohort were disseminated intravascular coagulation (40%), multi-organ failure (20%), uncontrolled bleeding (20%), acute respiratory distress syndrome (13.3%), and sepsis (6.7%), reflecting the systemic impact of severe bleeding and subsequent interventions. These findings are in line with the known sequelae of massive transfusion and prolonged critical illness associated with re-exploration [1, 12, 13]. However, Tambe and colleagues showed that including massive blood transfusion in their propensity score–matched analysis resulted in no statistically significant difference in adverse outcomes between patients who underwent re-exploration and patients with no re-exploration. This finding led these investigators to conclude that it was not re-exploration itself, but factors associated with re-exploration, such as continuing patient instability and the need for excessive blood transfusion, that resulted in adverse outcomes [19].

Beyond mortality, our cohort experienced significant morbidity linked to postoperative bleeding and re-exploration. Our series noted prolonged mechanical ventilation, longer ICU and hospital stays, renal dysfunction, infection, and transfusion-related lung injury. These complications mirror findings from a study, which indicated that re-exploration is associated with higher rates of acute kidney injury, sternal wound infections, stroke, and longer ICU and hospital durations [20]. In addition to surgical site infection, other postoperative complications like prolonged ventilator support, renal impairment,

Table 5: Univariate and multivariate logistic regression analyses for independent factors for mortality

Univariable analysis	Odds ratio (95% Confidence interval)	P value
Pre-operative LVEDD	3.276 (1.324- 8.105)	0.010
Pre-operative LVESD	4.115 (1.290- 13.128)	0.017
Pre-operative EF	0.859 (0.755- 0.978)	0.021
Redo cardiac surgery	7.143 (1.109- 45.991)	0.039
Cardiopulmonary bypass time	1.023 (1.005- 1.041)	0.011
Cross clamp time	1.057 (1.021- 1.094)	0.002
Intra-operative injury	105 (11.640- 947)	<0.001
Ventilation time	1.234 (1.061- 1.436)	0.006
ICU stay	1.203 (1.001- 1.452)	0.054
Massive blood transfusion	30.667 (3.346- 281.035)	0.002
Multivariable analysis		
Ventilation time	1.226 (1.041- 1.862)	0.016

LVESD: Left ventricular end systole diameter, LVEDD: Left ventricular end diastolic diameter, EF: Ejection fraction,

sepsis, and reoperation contribute significantly to morbidity and mortality in patients with DSWI [21, 22]. These complications are strongly associated with prolonged ventilator days, increased renal impairment, and higher sepsis rates, as highlighted by recent studies [22-28]. In a contemporary single-center experience, re-exploration independently correlated with increased ventilator days, renal impairment, and infection compared to non-re-explored patients [29]. Together, these data underscore that bleeding complications impose a “second hit” on patients, not only increasing risk of death but also prolonging recovery and heightening resource use [30,31].

The timing of re-exploration greatly affects the outcome. Delayed re-exploration (> 12 h) is associated with worse outcomes and up to a 37.5% increase in mortality [14, 20]. Karthik and colleagues suggested that surgical causes of bleeding requiring early intervention and reopening were identified in 82% of cases [21]. In our study, only 15 patients (7.5%) reopened after 12 to 24 hours. This low percentage of delayed re-explorations is directly related to our institutional policy of reacting early when significant bleeding is observed. This proactive approach is consistent with recommendations for early intervention in suspected surgical hemorrhage.

Nonsurgical bleeding could be attributed to several factors, such as hemodilution, hypothermia, the cardiopulmonary bypass circuit due to consumption of platelets and coagulation factors, platelet dysfunction, systemic inflammation, fibrinolytic system activation, and the impact of preoperative antiplatelet and anticoagulants [22]. Patients reopened for an identifiable source of bleeding had lower mortality than those with diffuse bleeding [9].

In our study, nearly half of the re-explored patients required inotropic or vasopressor support in the postoperative period. This demonstrates the hemodynamic instability that frequently follows systemic inflammation, cardiac stress, hypovolemia, and significant bleeding. Prior research has demonstrated that, compared with non-re-explored controls, re-explored patients have higher lactate levels, lower cardiac output, and greater vasopressor requirements [29]. Clinically, this means that, to prevent organ damage, centers should anticipate these patients' increasing vasoactive needs, implement early

hemodynamic monitoring, and optimize fluid balance.

The American Society of Anesthesiologists (ASA) recommends using FFP in cases of active bleeding with reduced coagulation factor levels [3]. The National Institutes of Health (NIH) and ASA recommend platelet transfusion for active bleeding associated with thrombocytopenia (platelets < 50,000 μL^{-1}) or abnormal platelet function [3]. Tranexamic acid use has been shown to reduce the rates of allogenic blood transfusion and re-exploration [23]. Recombinant activated factor VIIa may be considered in cases of life-threatening bleeding (e.g., intracranial or > 500–1000 ml/hr) unresponsive to usual hemostatic agents [24].

Our univariate analysis identified several factors that are widely known to increase the risk of adverse outcomes following cardiac surgery, such as significant blood transfusions, prolonged cardiopulmonary bypass and cross-clamp times, worse preoperative cardiac function, and redo cardiac surgery. In univariate analysis, the significant correlations between major blood transfusion (OR = 30.667) and intraoperative injury (OR = 105.000) underscore their immediate and vital impact on patient survival and stability. The sole independent predictor of death in the multivariate logistic regression model, however, was ventilation time (OR = 1.226, P = 0.016). This is an important conclusion. A patient's overall severity and need for re-examination are influenced by various factors, but prolonged mechanical ventilation is likely a reliable indicator of the full burden of critical illness and its consequences. Patients with severe inflammatory reactions, pulmonary problems, chronic hemodynamic instability, and general multi-organ failure frequently require longer breathing periods. Such an outcome implies that the capacity to quickly wean off of ventilator assistance after bleeding may be the primary reason for re-examination, but it is also a crucial sign of survival and recovery.

The mainstay of reducing morbidity and mortality associated with re-exploration remains prevention. Re-exploration rates and intensive care unit stay have been demonstrated to decrease when a hemostasis checklist is used before sternal closure [30]. Furthermore, real-time coagulation monitoring (e.g., thromboelastography) enables more targeted transfusion therapy and may reduce unnecessary blood product use [31], while anti-fibrinolytic therapy, such as tranexamic acid, has been shown to lower the risk of transfusion and bleeding [31]. Patients undergoing cardiac surgery are expected to have better results, shorter hospital stays, and higher survival rates because of such methodical approaches.

Working together as one unit (multidisciplinary teams) and constructing a strong team including cardiac surgeons, perfusionists, anesthetists, clinical pharmacists, and ICU physicians is required to prevent and manage postoperative bleeding. As demonstrated by Loor et al., algorithmic and checklist-based approaches significantly reduce re-exploration rates [26]. Such systematic strategies are likely to contribute to better outcomes, shorter hospital stays, and improved survival in patients undergoing cardiac surgery.

Limitations

Despite its prospective design and comprehensive data collection, our study has several limitations that should be acknowledged. Firstly, it was conducted as a single-center study. Secondly, a small sample size. A larger, multi-center study would provide more statistical power to detect additional, potentially subtle, independent predictors of mortality. Finally, our study focused on early outcomes following re-exploration. Long-term morbidity and mortality, which are also significant aspects of patient recovery, were not assessed. Future studies with longer follow-up periods would be beneficial for a better understanding of the lasting impact of re-exploration for bleeding.

Conclusion

Surgical causes predominate in postoperative bleeding, though medical causes remain significant. Bleeding is associated with significant morbidity and mortality. Preventive surgical

measures and multidisciplinary management are essential to improve outcomes.

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