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ORIGINAL ARTICLE

Evaluation of Factors Affecting Bleeding in Coronary Artery Bypass Surgery

Osman UZUNDERE[1], Berivan BEDIR SERT[1], Selen TOPALEL[1], Sule OZGUN[1], Sahin KANDEMIR[1], Fatma ACIL[1], Ali Ihsan YUREKLI[1]

[1] RT HSU Diyarbakır Gazi Yaşargil TRH, Department of Anesthesiology and Reanimation, Diyarbakır, Türkiye

ABSTRACT

Aim: Postoperative bleeding is one of the most frequently encountered complications following coronary artery bypass grafting (CABG). This study aims to investigate preoperative and intraoperative risk factors affecting postoperative bleeding in CABG surgery. **Methods:** A total of 242 patients who underwent CABG between March 2019 and January 2023 were retrospectively analyzed. Based on postoperative bleeding volume, patients were classified into two groups: normal bleeding (Group N) and excessive bleeding (Group B). The groups were compared in terms of demographic, clinical, and perioperative variables. **Results:** Patients in Group B demonstrated significantly lower preoperative platelet counts (p=0.005), a lower prevalence of COPD (p=0.01), and longer anesthesia durations (p=0.033). Logistic regression analysis identified the absence of COPD (OR: 0.202; 95% CI: 0.054–0.759) and low platelet levels (OR: 0.995; 95% CI: 0.991–0.999) as independent predictors of excessive bleeding after CABG surgery. **Conclusion:** The findings indicate that reduced preoperative platelet count and the absence of COPD are significant risk factors for excessive bleeding following CABG. Moreover, these patients exhibited higher rates of postoperative complications and mortality.

Keywords: Bleeding, Cardiac Surgery, Mortality, Postoperative Complications

ÖZET

Amaç: Koroner arter bypass greftleme (CABG) cerrahisi sonrasında karşılaşılan en önemli komplikasyonlardan biri postoperatif kanamadır. Bu çalışmanın amacı, CABG cerrahisi geçiren hastalarda postoperatif kanamayı etkileyen preoperatif ve intraoperatif risk faktörlerini araştırmaktır. **Yöntem:** Bu çalışmada Mart 2019 ile Ocak 2023 tarihleri arasında CABG cerrahisi uygulanan 242 hasta retrospektif olarak değerlendirildi. Postoperatif dönemde kanama miktarına göre hastalar normal kanama (Grup N) ve aşırı kanama olanlar (Grup B) şeklinde iki gruba ayrıldı. Gruplar demografik, klinik ve perioperatif değişkenler açısından karşılaştırıldı. **Bulgular:** Grup B'deki hastalarda anlamlı bir şekilde daha düşük preoperatif trombosit sayısı (p=0,005), daha düşük KOAH prevalansı (p=0,01) ve daha uzun anestezi süreleri (p=0,033) olduğu saptandı. Lojistik regresyon analizi, KOAH öyküsü olmayışını (OR: 0,202; %95 GA: 0,054–0,759) ve düşük trombosit seviyelerini (OR: 0,995; %95 GA: 0,991–0,999) KABG ameliyatından sonra aşırı kanama için bağımsız risk faktörleri olarak tanımladı. **Sonuç:** Bu sonuçlar, düşük preoperatif trombosit düzeyi ve KOAH öyküsünün olmamasının, CABG cerrahisi sonrası aşırı kanama için bağımsız risk faktörleri olduğunu ortaya koymuştur. Ayrıca, aşırı kanaması olan hastalarda postoperatif komplikasyonların ve mortalitenin daha sık görüldüğü bulunmuştur.

Anahtar Kelimeler: Kanama, Kardiyak Cerrahi, Mortalite, Postoperatif Komplikasyonlar

Corresponding Author: Osman Uzundere **Correspondence Adress:** RT HSU Diyarbakır Gazi Yaşargil TRH, Department of Anesthesiology and Reanimation, Elazığ Yolu 10. Km Üçkuyular Mevkii 21070 Diyarbakır, Türkiye. **Mail:** osmanuzundere@gmail.com **Received:** 24.03.2025; **Accepted:** 30.06.2025.

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INTRODUCTION

Coronary artery bypass grafting (CABG) is a commonly applied surgical approach in patients with advanced coronary artery disease requiring revascularization. It is estimated that nearly 400,000 CABG procedures are carried out each year in the United States, reflecting its ongoing clinical relevance (1). Although CABG surgery is a major operation with low mortality rates globally, it also brings about various complication risks (1, 2).

Among the major postoperative complications following CABG surgery, excessive bleeding remains particularly prevalent and clinically important. Postoperative bleeding is more frequently observed in cardiovascular surgical procedures compared to other surgeries. Approximately 10% of patients undergoing cardiac surgery experience severe or major blood loss (3). Excessive postoperative bleeding can lead to numerous issues such as increased use of blood and blood products, higher morbidity and mortality risk, increased need for reoperation, and prolonged stays in intensive care units (ICU) and hospitals (4-6). Therefore, understanding and managing the factors affecting bleeding after CABG surgery is critical in patient care.

Previous research has indicated that numerous elements, including genetic background, demographic characteristics, perioperative medication use, and procedural factors such as surgical technique and duration, can influence bleeding risk after CABG. Additionally, the patient's overall health status, particularly kidney and liver functions, coagulation disorders, and preoperative blood values are also important factors (7-9). Despite this, the exact nature of the risk factors has not yet been definitively determined.

This study aims to investigate preoperative and intraoperative risk factors affecting postoperative bleeding in CABG surgery patients by analyzing our hospital's data. As a secondary objective, the effects of excessive bleeding on postoperative mortality, morbidity, ICU, and hospital stay durations will be examined.

MATERIAL AND METHODS

Study Design and Patient Selection

This retrospective cross-sectional study included patients who underwent CABG surgery at the Cardiovascular Surgery (CVS) Department of Diyarbakır Gazi Yaşargil TR Hospital between March 2019 and January

2023 and were monitored in the CVS ICU for at least 24 hours postoperatively. Ethical approval was obtained from the Diyarbakır Gazi Yaşargil TR Hospital Ethics Committee (Date/No 27.01.2023/327). All procedures followed the ethical standards set by the 2013 version of the Declaration of Helsinki.

Patients aged 18 and over who underwent CABG surgery within the specified dates were included in the study. Cardiac surgeries performed off-pump, surgeries performed for reasons other than CABG, emergency operations, patients who died intraoperatively or within the first 24 hours postoperatively, and those with incomplete data were excluded. The study flow diagram is shown in Figure 1.

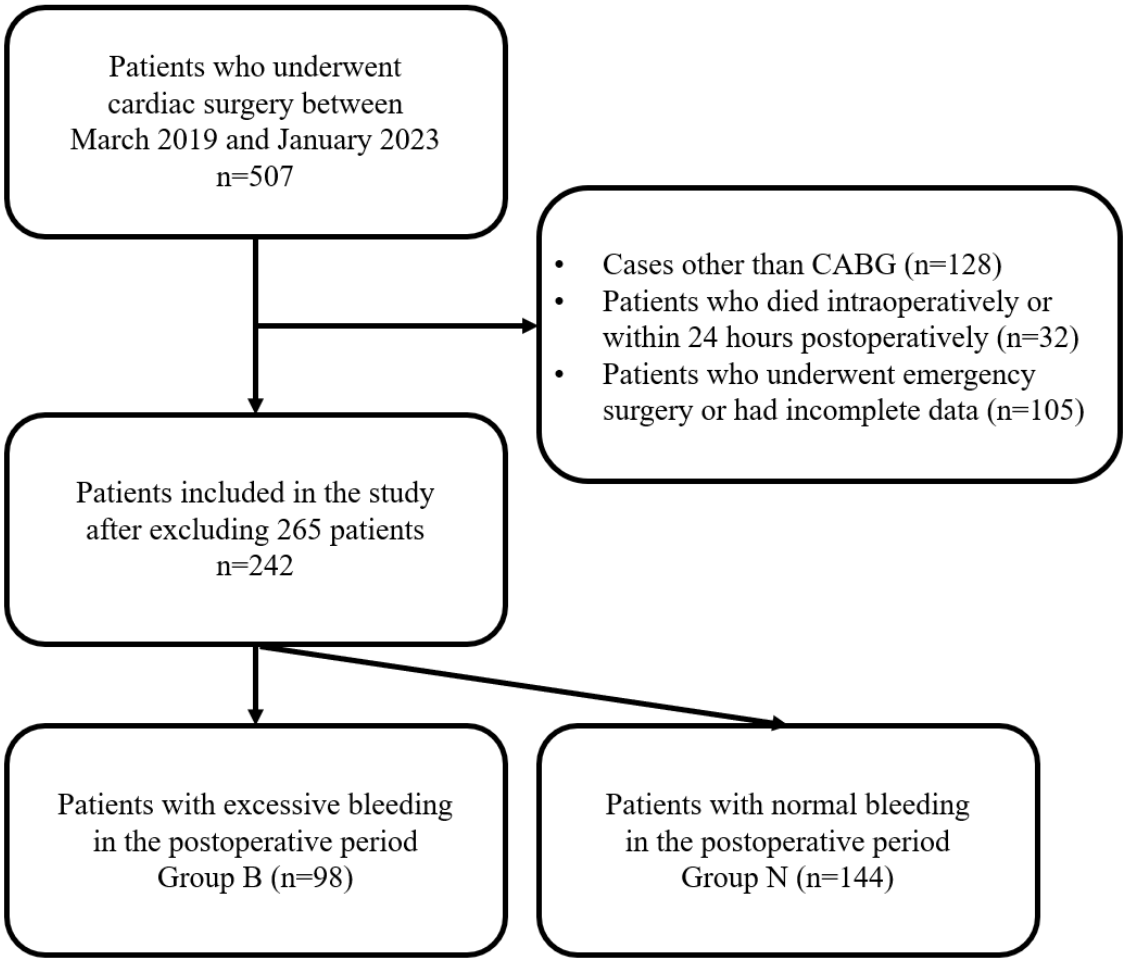

Figure 1. Study flow diagram

Demographic, preoperative, intraoperative, and postoperative data of the included patients were obtained from patient files and the hospital information system. Data such as age, gender, body surface area (BSA), chronic diseases (hypertension, diabetes mellitus, chronic obstructive pulmonary disease (COPD), kidney failure, etc.), type of surgery (number of vessels operated on, and whether valve repair was performed with CABG), ejection fraction (EF), New York Heart Association (NYHA) heart failure classification (10), European System for Cardiac Operative Risk Evaluation (EuroSCORE) II (11), preoperative laboratory values (hemoglobin, hematocrit, platelet, prothrombin time), intraoperative tranexamic acid (TXA) use, mean arterial pressure during surgery, initial, pump start, and operation end activated clotting time (ACT) values, cross-clamp (CC) and cardiopulmonary bypass (CPB) durations, surgery and anesthesia durations, intraoperative urine output, ultrafiltration application, intraoperative inotropic need and type of inotrope used, intraoperative blood and blood product need, hourly bleeding amounts from thoracic and mediastinal tubes in the first 24 hours postoperatively, total blood and blood product need postoperatively, ICU and hospital stay durations, and mortality were recorded.

Patients were categorized into two groups according to the volume of thoracic and mediastinal drainage and the quantity of transfused blood products. A case was classified as having excessive bleeding if it met at least one of the following predefined criteria:

•Bleeding amount from thoracic and mediastinal tubes ≥200 mL/hour at any time

•Continuous bleeding ≥2 mL/kg/hour for 2 consecutive hours within the first 24 hours

•Total bleeding amount ≥1500 mL in 24 hours

•Class 3-4 according to the Universal definition of perioperative bleeding in adult cardiac surgery criteria (7,8,12)

Patients who did not meet any of the specified criteria were assigned to the normal bleeding group (Group N), while those fulfilling at least one criterion were placed in the excessive bleeding group (Group B). These two cohorts were subsequently compared based on their demographic, clinical, and perioperative features to identify potential factors influencing bleeding in patients undergoing CABG.

Preoperative Evaluation and Intraoperative Management

All patients were evaluated preoperatively by an anesthesia specialist in the anesthesia clinic and on the ward the day before surgery. Detailed verbal explanations were given, and written informed consent was secured from both patients and their legal guardians or relatives.

After patients were taken to the operating room, standard monitoring was applied (electrocardiogram (ECG), pulse oximeter (SpO2), and non-invasive blood pressure). Sedoanalgesia was provided with

midazolam (1-2 mg IV) or midazolam (1-2 mg IV) and fentanyl (1-2 μg/kg IV) based on clinical status and vital signs. After sedoanalgesia, radial artery cannulation was performed for invasive blood pressure monitoring. For anesthesia induction, propofol (1-3 mg/kg IV) as a general anesthetic, fentanyl (1-2 μg/kg IV) as an analgesic, and rocuronium (0,6-0,9 mg/kg IV) as a neuromuscular blocker were used. In critical patients with low EF, induction was performed with midazolam (0,1 mg/kg IV) and fentanyl (5 μg/kg IV) instead of propofol. Patients were intubated and connected to a mechanical ventilator, and central venous catheterization was performed via the right jugular vein. Anesthesia maintenance was achieved with 2% sevoflurane, 50% O2, and 50% air mixture.

Coronary artery bypass surgery and cardiopulmonary bypass procedures were performed according to clinical protocol and the surgeon's preference. All interventions during cardiopulmonary bypass were made with the joint decision of the surgeon, anesthesiologist, and perfusionist. After the procedure, all patients were transferred to the CVS ICU intubated and followed up postoperatively.

Statistical Analysis

All statistical analyses were carried out using SPSS software (v24.0, SPSS Inc., Chicago, IL, USA). Categorical data were presented as counts and percentages, while continuous variables were expressed as mean ± standard deviation. The chi-square test or Fisher's exact test was utilized for analyzing categorical variables. To assess the distribution of continuous variables, the Kolmogorov–Smirnov test was performed. Based on the distribution pattern, comparisons were made using either the Student's t-test for normally distributed variables or the Mann–Whitney U test for data not conforming to normality. Variables identified as significant in the univariate analysis, along with those previously recognized in the literature as potential predictors of excessive bleeding, were incorporated into the binary logistic regression model (13). COPD, type of surgery performed, EuroSCORE II, preoperative platelet count, intraoperative use of TXA, cross-clamp and cardiopulmonary bypass durations, and surgery and anesthesia durations were included in the analysis. The association between excessive bleeding and exposure to the risk factors was reported using the odds ratio (OR) with a 95% confidence interval (CI). In all comparisons, a p-value of <0.05 was considered significant.

RESULTS

A total of 242 patients who underwent CABG between March 2019 and January 2023 and were monitored for a minimum of 24 hours in the cardiovascular surgery intensive care unit were enrolled in the study. The mean age of the study population was 61±9.32 years, with a predominance of male patients (192 males vs. 50 females). The incidence of excessive postoperative bleeding was calculated as 40.4%. Among the patients with excessive bleeding, the rate of those who underwent revision surgery was 9.18% (9/98

patients). Table 1 presents the demographic, clinical, and preoperative characteristics of the patient cohort included in the study.

Comparison of demographic, clinical, and preoperative variables revealed that patients in Group B had significantly lower preoperative platelet counts (p=0.005), while a history of COPD was more prevalent in Group N (p=0.01) (Table 1). No other variables showed statistically significant differences between the two groups.

Table 1. Demographic, clinical, and preoperative characteristics of patients

	All patients (n = 242) Mean±Std	**Group N (n = 144) Mean±Std**	**Group B (n = 98) Mean±Std**	**p**
Age (year)	61±9.32	60.5±9.24	61.6±9.47	0.4*
Body space area (m^2)	1.86±0.15	1.85±0.15	1.87±0.16	0.44*
Ejection fraction (%)	52.07±8.5	52.2±8.4	51.7±8.5	0.65
Euroscore II	1.34±0.78	1.27±0.6	1.44±0.98	0.54
NYHA class 2/3/unknown (n)	51/29/162	32/20/92	19/9/70	0.4
Hemoglobin (g/dl)	14.04±1.65	14.03±1.71	14.04±1.56	0.73
Hematocrit (%)	42.7±4.82	42.7±4.9	42.8±4.73	0.97
Platelet (× 10^3/uL)	257.7±72.8	268.7±78.9	241.6±59.6	**0.005**
Prothrombin time (s)	12.1±1.47	12.2±1.28	12.06±1.72	0.12
Mean arterial pressure (mmHg)	101.4±17.8	102.4±18.1	100.01±17.2	0.3*
Sex Female/Male (n)	50/192	33/111	17/81	0.29
Comorbidity (n, %)	213 (88)	129 (51.7)	84 (39.4)	0.36
Diabetes	149 (61.6)	84 (56.4)	65 (43.6)	0.21
Hypertension	132 (54.5)	83 (62.9)	49 (37.1)	0.24
CKD	7 (2.9)	5 (71.4)	2 (28.6)	0.7**
COPD	21 (8.7)	18 (85.7)	3 (14.3)	**0.01****

NYHA: New York Heart Association; CKD: Chronic kidney disease; COPD: Chronic obstructive pulmonary disease

*Student t test p value; **Fisher's Exact p value

Analysis of intraoperative variables indicated that the majority of patients underwent isolated CABG, whereas 13 individuals (5.4%) received concomitant valve surgery. Although cross-clamp time, cardiopulmonary bypass duration, surgical time, and anesthesia time were all longer in Group B, only the difference in anesthesia duration reached statistical significance (p=0.033). Details regarding other intraoperative characteristics are shown in Table 2.

Factors affecting excessive bleeding in patients who underwent CABG were evaluated using binary logistic regression. The results of the binary logistic regression analysis are shown in Table 3. The analysis found that COPD (OR, 0.202; 95% CI, 0.054–0.759) and preoperative platelet values (OR, 0.995; 95% CI, 0.991–0.999) were independent risk factors for excessive bleeding in patients who underwent CABG.

Table 2. Comparison of groups in terms of intraoperative characteristics

Characteristic	All patients (n = 242) Mean±Std	Group N (n = 144) Mean±Std	Group B (n = 98) Mean±Std	p
Type of surgery (n, %)				
CABG	222 (94.6)	139 (57.4)	90 (37.2)	0.11
CABG + valve surgery	13 (5.4)	5 (3.5)	8 (3.3)	
CABG (n, %)				
≤2 vessel	78 (32.2)	47 (19.4)	31 (12.8)	0.86
≥3 vessel	164 (67.8)	97 (40.1)	67 (27.7)	
Tranexamic acid (n, %)	80 (33.1)	52 (21.5)	28 (11.6)	0.22
ACT before CPB (s)	129.8±25.09	130.3±24.8	129.2±25.5	0.71
ACT during CPB (s)	616.8±162.5	621.7±164.7	609.6±159.9	0.6
ACT after protamine (s)	119.4±16.1	119.1±15.7	119.7±16.8	0.3
Cross clemping time (min)	58.3±28.9	56.6±28.2	60.8±30.01	0.25
Cardiopulmonary bypass time (min)	95.8±38.2	92.2±34.3	101.05±43.07	0.17
Duration of surgery (min)	214.3±48.4	209.4±46.3	221.5±50.7	0.06
Duration of anesthesia (min)	242.7±47.05	237.3±45.6	250.7±48.2	**0.033**
Urine output (ml)	658.5±515.08	676.3±542.01	632.3±474.2	0.12
Inotrope (n, %)	170 (70.2)	96 (39.7)	74 (30.6)	0.14
Erythrocyte suspension (unit)	0.5±0.8	0.8±0.06	0.98±0.09	0.31
Fresh frozen plasma (unit)	1.5±0.9	0.91±0.07	0.89±0.09	0.12

CABG: Coronary artery bypass graft; ACT: Activated clootting time; CPB: Cardiopulmonary bypass

Table 3. Binary logistic regression model for excessive bleeding

Characteristic	Exp (B)	95% C.I.for EXP(B)		p
		Lower	Upper	
Chronic obstructive pulmonary disease	0.202	0.054	0.759	**0.018**
Type of surgery	1.366	0.250	7.448	0.719
Euroscore II	1.257	0.825	1.916	0.287
Preoperatif platelet count	0.995	0.991	0.999	**0.009**
Tranexamic acid	0.877	0.451	1.705	0.698
Cross clemping time	0.981	0.956	1.006	0.143
Cardiopulmonary bypass time	1.015	0.996	1.035	0.116
Duration of surgery	0.983	0.953	1.014	0.281
Duration of anesthesia	1.021	0.989	1.054	0.197

Postoperative outcomes revealed that 24-hour bleeding volume in Group B was nearly double that observed in Group N (1057 mL vs. 542 mL, p<0.001). Additionally, patients in Group B received significantly higher amounts of erythrocyte suspension and fresh frozen plasma (p<0.001), and experienced greater rates of ICU complications (p<0.001) and mortality (p=0.003). Despite these differences, no statistically significant variation was noted between the groups regarding ICU or hospital length of stay (Table 4).

Table 4. Comparison of groups in terms of postoperative characteristics

Characteristic	All patients (n = 242) Mean±Std	Group N (n = 144) Mean±Std	Group B (n = 98) Mean±Std	p
Postoperative 24-hour drainage (ml)	751.03±442.3	542.3±249.3	1057.6±484.6	**<0.001**
Erythrocyte suspension (unit)	2.0±1.6	1.4±1.02	2.8±2.02	**<0.001**
Fresh frozen plasma (unit)	2.9±1.7	2.42±1.02	3.79±2.2	**<0.001**
ICU complication (n, %)	72 (29.8)	26 (10.7)	46 (19)	**<0.001**
Mortality (n, %)	9 (3.7)	1 (0.4)	8 (3.3)	**0.003**
Length of stay in the ICU (day)	3.2±2.1	3.03±1.8	3.4±2.4	0.061
Length of stay in the hospital (day)	9.6±5.1	9.8±5.5	9.4±4.4	0.7

ICU: Intensive care unit

DISCUSSION

In this study investigating factors associated with excessive postoperative bleeding in patients undergoing CABG, it was observed that patients with excessive bleeding had lower preoperative platelet counts and a lower incidence of COPD. Both reduced platelet levels and the absence of COPD were identified as independent predictors of excessive bleeding. Furthermore, these patients required more blood and blood product replacement and had higher rates of complications and mortality.

When reviewing studies that have investigated factors affecting bleeding after coronary artery surgery, it has been indicated that various factors can influence bleeding. One such study by Biancari et al. in 2016 aimed to develop a scoring method to classify the risk of severe bleeding in patients undergoing CABG surgery based on initial risk factors and antithrombotic therapy. The study concluded that the use of anticoagulant and antiplatelet agents in the preoperative period, anemia, female gender, acute coronary syndrome, kidney failure, and critical preoperative condition were risk factors for excessive bleeding (9). In another study, Özbayrak et al. analyzed data from their center over two years and found the early postoperative bleeding rate after open cardiac surgery to be 9.7%, identifying COPD, preoperative antiplatelet use, high EuroSCORE, long CC and CPB durations as parameters predicting excessive bleeding (12).

Rodrigues et al. examined 682 patients requiring reoperation due to bleeding after cardiac surgery and emphasized that a history of kidney failure, prior anticoagulant use, high intraoperative heart rate, and intraoperative blood product need were factors associated with reoperation due to bleeding in the postoperative period (14). In their study analyzing preoperative and operative factors related to excessive bleeding in patients undergoing CABG surgery, Bastopçu et al. found that male gender, low body mass index (BMI), low platelet values, and long CPB duration were factors associated with bleeding (4). Lopes et al. noted in their 2015 review that many factors could affect excessive bleeding in cardiac surgery (13). Following this review, they prospectively examined 323 adult open cardiac surgery patients and identified male gender, BMI, preoperative platelet count, and intraoperative heparin dose >312.5 mg without subsequent platelet transfusion as factors associated with bleeding (15).

The findings of this study demonstrated that the absence of COPD and reduced preoperative platelet counts independently predicted the occurrence of postoperative bleeding in patients undergoing CABG. A review of previous literature also confirms that low platelet levels have been frequently associated with increased bleeding risk in similar patient populations (4,6,15). Previous studies have reported conflicting results regarding the impact of COPD on postoperative bleeding (12,16). While some studies have associated COPD with increased

bleeding due to chronic inflammation and vascular fragility (12), our findings suggest a lower prevalence of excessive bleeding in patients with COPD. This may be attributed to COPD-associated changes such as increased platelet aggregation, elevated mean platelet volume, and reactive thrombocytosis, which may provide a protective effect against bleeding (16). These physiopathological mechanisms may help explain the unexpected inverse relationship observed in our cohort.

As summarized in these studies, various factors can influence postoperative bleeding in patients undergoing CABG surgery (4,9,12,13,15,17). Variations in study outcomes are likely influenced by multiple factors, with differences in patient populations being among the most significant contributors. While most studies included all cardiac surgery patients, fewer studies focused solely on patients undergoing isolated CABG surgery. Additionally, the lack of international clear criteria for defining excessive bleeding is another significant reason for different results. Dyke et al.'s 2014 study is noteworthy in this context (8). In this study, the authors categorized and classified postoperative bleeding in cardiac surgery patients based on the amount of drainage from chest tubes, the amount of blood and blood products replaced, and the presence of reexploration/tamponade, aiming to contribute to international standards for defining postoperative bleeding.

Significant increases in complications and mortality risk are observed in patients monitored in the ICU for excessive bleeding following coronary artery bypass graft surgery (18). During this period, various complications can develop in addition to bleeding, including myocardial infarction, cardiac arrhythmia, stroke, wound infection, renal dysfunction, prolonged mechanical ventilator support, and death (17). As supported by the results of our study, these complications are more frequently observed in patients with excessive bleeding, leading to a significant increase in morbidity and mortality risk.

The primary limitation of this study lies in its retrospective design and reliance on data collected from a single institution. A notable shortcoming that may have influenced the study's findings was the limited availability of preoperative information regarding patients' use of antiplatelet and anticoagulant agents. Another limitation of this study is the absence of thromboelastography (TEG) monitoring, which could have provided a more detailed assessment of coagulation status. However, due to the retrospective design of the study and the lack of routine TEG use in our institution during the study period, this data could not be included.

CONCLUSION

In conclusion, postoperative bleeding, a common complication in patients undergoing CABG surgery, can lead to decreased oxygen delivery, increased need for blood product replacement, and increased morbidity and mortality. Identifying risk factors during the preoperative period and taking necessary precautions for high-risk patients, ensuring appropriate conditions before surgery, can

reduce the amount of postoperative bleeding and contribute to a decrease in postoperative morbidity and mortality. Conducting multicenter studies on this subject will contribute to the establishment of clear criteria for postoperative bleeding in CABG.

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Conflict of Interest: The authors declare no conflicts of interest.

Ethics Approval: Ethical approval was obtained from the Diyarbakır Gazi Yaşargil TR Hospital Ethics Committee (Date/No 27.01.2023/327). All procedures followed the ethical standards set by the 2013 version of the Declaration of Helsinki.

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