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Factors associated with the increased bleeding in the postoperative period of cardiac surgery: A cohort study

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Abstract

Aims and objectives: To identify factors associated with the increased bleeding in patients during the postoperative period after cardiac surgery.

Background: Bleeding is among the most frequent complications that occur in the postoperative period after cardiac surgery, representing one of the major factors in morbidity and mortality. Understanding the factors associated with the increased bleeding may allow nurses to anticipate and prioritise care, thus reducing the mortality associated with this complication.

Design: Prospective cohort study.

Methods: Adult patients in a cardiac hospital who were in the postoperative period following cardiac surgery were included. Factors associated with the increased bleeding were investigated by means of linear regression, considering time intervals of 6 and 12 hr.

Results: The sample comprised 391 participants. The factors associated with the increased bleeding in the first 6 hr were male sex, body mass index, cardiopulmonary bypass duration, anoxia duration, metabolic acidosis, higher heart rate, platelets and the activated partial thromboplastin time in the postoperative period. Predictors in the first 12 hr were body mass index, cardiopulmonary bypass duration, metabolic acidosis, higher heart rate, platelets and the activated partial thromboplastin time in the postoperative.

Conclusions: This study identified factors associated with the increased postoperative bleeding from cardiac surgery that have not been reported in previous studies. The nurse is important in the vigilance, evaluation and registry of chest tube drainage and modifiable factors associated with the increased bleeding, such as metabolic acidosis and postoperative heart rate, and in discussions with the multiprofessional team.

Relevance to clinical practice: Knowledge of the factors associated with the increased bleeding is critical for nurses so they can provide prophylactic interventions and early postoperative treatment when needed.

KEYWORDS

bleeding, cardiovascular nursing, thoracic surgery

1 | INTRODUCTION

The leading cause of mortality worldwide is cardiovascular disease; for more than 20 years, the increase in cardiac-related deaths has grown exponentially (World Health Organization, World Heart Federation, World Stroke Organization, 2011). Death from cardiovascular diseases occurs in approximately 7.3 million people studies per year, and this rate of death is expected to exceed 23.6 million by 2030 (World Health Organization, World Heart Federation, World Stroke Organization, 2011).

As a result of the increase in the incidence of cardiovascular diseases, the number of cardiac surgeries has increased considerably. Each year more than one million patients undergo these types of procedures worldwide (Dixon et al., 2014).

The increase in the number of cardiac surgeries justifies the need for knowledge about the possible complications such as bleeding that represents an important aspect of morbidity and mortality (Atik, Miana, Jatene, Auler Júnior, & Oliveira, 2004; Dixon et al., 2014; Gwozdziewicz, Olsak, & Lonsky, 2008; Miana et al., 2004; Soares et al., 2011). The causes of bleeding during the postoperative period are related to several factors and can be associated with surgical injury to the blood vessels or disorders of the haemostatic mechanisms (Atik et al., 2004; Gwozdziewicz et al., 2008).

Because bleeding is one of the most significant complications and causes of death in the immediate postoperative period of cardiac surgery (Dixon et al., 2014), knowing its predictors is of great importance to clinical practice. Generally, bleeding incidence and associated factors differ between each institution (Lopes, Brunori, Cavalcante, et al., 2015), as well as between countries where data are collected. In Brazil, the last study performed at the largest cardiopneumology centre in Latin America, where we developed this study, was conducted 14 years ago (Miana et al., 2004). Epidemiological aspects related to bleeding may be different today from those 14 years ago.

Excessive bleeding after cardiac surgery causes an increase in the number of complications already described in the literature, as well as the need for an extra surgery, an increase in the duration of mechanical ventilation and the length of stay in an intensive care unit (ICU). The aim of this study was to identify factors associated with the increased bleeding in the postoperative period after cardiac surgery, to motivate studies that identify factors related to bleeding after cardiac surgery so that strategies to avoid or minimise this event can be implemented and to highlight the importance of the nurse in the evaluation of factors related to the risk of bleeding, especially in the surveillance, assessment and documentation of drain debt.

What does this paper contribute to the wider global clinical community?

- This study identifies factors associated with increased bleeding in the postoperative period of cardiac surgery;
- Nurses having knowledge of the factors associated with the increased bleeding in this population help prioritise the evaluation, the establishment of prophylactic interventions and early postoperative treatment, thus reducing the mortality associated with this complication.

1.1 | Background

The incidence of bleeding in the postoperative cardiac surgery period ranges from 6.4% to 52.9%. It is a serious complication that increases length of stay in the ICU, days of endotracheal intubation and the need for additional procedures to maintain haemostasis (Lopes, Brunori, Santos, et al., 2015).

The treatment for bleeding depends on the clinical aspects of the patient, the decision of the physician and the volume of bleeding. Miana et al. (2004) and Pontes (2012) define significant bleeding by thoracic drainage after cardiac surgery as that which exceeds 150 ml/hr. This information is corroborated by Christensen, Dziewior, Kempel, and Heymann (2012), who define excessive bleeding as that which reaches 200 ml in 1 hr, or 2ml/Kg/hr during 2 consecutive hours in the first 6 hr after surgery. According to Christensen et al. (2012), blood loss >495 ml in 24 hr is associated with impairment of the target organ, resulting in longer ventilatory support, a higher incidence of systemic inflammatory response syndrome, need for dialysis and renal replacement, in addition to the need for larger numbers of transfusions of blood components and blood products and higher hospital costs.

Dixon et al. (2014) reported that a blood loss of 1,000 ml in 24 hr is sufficient to increase the risk of death by four times in the postoperative period.

In the immediate postoperative period, the requirement for blood transfusion is high, around 48%, and although it is fundamental and lifesaving for some patients after surgery, in the long term this increases mortality from 5.4% to 13.4% (Lopes, Brunori, Cavalcante, et al., 2015). Because of this increase, the use of a restrictive perioperative transfusion strategy compared with a more liberal strategy resulted in noninferior rates of the combined outcome of 30-day all-cause mortality and severe morbidity (Hajjar et al., 2010). Thus, bleeding prevention strategies must be promoted to avoid reduced allogeneic blood product administration and minimise associated risks related to transfusion (Ghadimi, Levy, & Welsby, 2016).

The literature lists several risk factors for excessive bleeding in the postoperative cardiac surgery period, including age; use of anticoagulant medications, such as heparin, warfarin and enoxaparin; antiplatelet agents, such as acetylsalicylic acid and clopidogrel; comorbidities, such as diabetes mellitus and systemic arterial hypertension; altered laboratory tests, such as elevated urea, creatinine and haemoglobin; type of surgery; surgeon's haemostasis technique; hypothermia; metabolic acidosis; and prior history of bleeding (Christensen et al., 2012; Lopes, Santos, et al., 2015).

Other risk factors for bleeding also reported in the literature are male sex; lower body mass index (BMI); impaired left ventricular function; previous myocardial infarction (Dixon et al., 2014); prolonged time of cardiopulmonary bypass (CPB) and aortic clamping; high doses of heparin (Hernández-González et al., 2008); problems with the surgical technique; and a greater number of anastomoses (Ghavidel, Toutounchi, Shahandashti, & Mirmesdagh, 2015).

Therefore, the occurrence of bleeding is multifactorial and differs among health institutions, depending on the characteristics of the patients being attended to, a fact that prompts the need to provide studies on the subject to help identify factors associated with the increased bleeding that have not yet been explored. According to Lopes, Brunori, Cavalcante, et al. (2015), the knowledge of these factors can support the prioritisation of evaluation, monitoring and assistance in a focused and anticipated way. Besides that, identification of risk factors for bleeding can drive prophylactic interventions, such as discontinuation of preoperative antiplatelet therapy and meticulous surgical haemostasis, and can also allow early postoperative treatment with platelets, plasma, coagulation factors and surgical intervention, if necessary (Greiff et al., 2015). In the postoperative period, nurses can prioritise vigilance of chest tube drainage and actions related to accurate assessment, documentation and reporting, thus improving the quality of care and patient safety (Lopes, Santos, et al., 2015).

2 | METHODS

This was a prospective cohort study conducted at the Surgical Intensive Care Unit (SICU) of the Heart Institute (InCor) of the Hospital das Clinicas HCFMUSP, Faculdade de Medicina, Universidade de São Paulo, São Paulo, SP, Brazil. It is a public, tertiary, university hospital specialising in cardiorespiratory conditions, with 446 active beds. The SICU consists of 40 beds and serves patients in the postoperative period of cardiac, thoracic, and pulmonary surgeries, and pulmonary and cardiac transplants.

All patients over the age of 18 years who underwent coronary artery bypass grafting, valve replacement or repair, aneurysm repair or aortic dissection, or cardiac transplantation were included, if they agreed to participate in the study, from June to October of 2016. Patients with a previous diagnosis of coagulopathy, such as Von Willebrand's disease, haemophilia, and any deficiency in blood clotting factors and those who died during the surgical procedure were excluded from the study.

Sample size was estimated using the population mean model (Kish, 1995), considering a 95% confidence level, a standard error of $\alpha = 0.05$ and bleeding incidence in the postoperative period of cardiac surgery of 50%. The minimum study sample included 385 patients. The project was approved by the Research Ethics Committee of the Hospital das Clinicas HCFMUSP, Faculdade de Medicina, Universidade de São Paulo, São Paulo, SP, Brazil, CAAE:55701616.7.0000.0068, n°1.551.613. The data collection was prospective and started after the signing of the free informed consent form (EHIC) by the patient or family member in the immediate preoperative period, when the bleeding outcome was not yet known.

Data collection was started in the immediate preoperative period. The occurrence of bleeding was investigated 24 hr after admission to the SICU, and there were no losses to follow up. The instrument for data collection included pre-, intra- and postoperative data. The choice of the potential variables associated with excessive bleeding was based on a literature review (Lopes, Santos, et al., 2015) about predictive factors for excessive bleeding in adults after cardiac surgery, including studies published in English, Spanish and Portuguese between 2004 and 2014.

The patient's electronic medical record was used for the collection of data on independent clinical and preoperative characteristics: sex, age, skin colour, body mass index (BMI), left ventricular ejection fraction (LVEF), comorbidities (heart failure, systemic arterial hypertension, diabetes mellitus, peripheral vascular disease, chronic obstructive pulmonary disease and chronic renal failure), smoking, history of cardiac surgery, bleeding and haemodialysis, previous use of anticoagulants and antiplatelet drugs, and examinations.

The independent intraoperative data were collected from electronic medical records and from the anaesthesiologist's records; collection started immediately after the patient's admission to the SICU. Data included the type of surgery performed, cardiopulmonary bypass time (CPBT), anoxia time and anaesthesia, amount of heparin used, number of sternal wires, initial and final activated coagulation times, vital signs, number of thoracic drains, flow rate for blood and the use of blood components, blood products and procoagulants. Intraoperative blood flow measurement was taken by summing the weight of compresses and gauzes (discounting the dry weight), aspirator and thoracic drainage flow.

The independent variables of the first 6 and 12 postoperative hours were collected from the nursing team notes and electronic medical records. Independent variables included vital signs, laboratory tests, such as metabolic acidosis (pH <7.35 and a bicarbonate concentration <22 mEq/L) and the bleeding-dependent variable, measured by drainage blood flow (estimated in millilitres per kilogram of weight per hour [ml/Kg/hr]). Postoperative bleeding was measured in the first 6 and 12 hr after patient admission to the SICU, through the sum of the median and pleural drainage flow. It has not been defined yet what would or would not be excessive bleeding measured by the cut. Literature studies diverge a lot in relation to this definition; therefore, a statistical model has been used to assess the factors related to the increase in bleeding.

Mortality risk scores evaluated on patient admission to SICU were also collected and were estimated using the European System for Cardiac Operative Risk (euroSCORE; ranging from 0 to 39 points). The euroSCORE scores were divided as follows: 0–2 low-risk group, 3–5 medium-risk group and more than 6 high-risk mortality group in the postoperative period of cardiac surgery (Andrade, Neto, & Andrade, 2014).

The data were stored in a database in the 2013 Microsoft Excel program. Data were analysed using Software R. For the treatment of missing data during data collection, the imputation method was used (Azur, Sturt, Frangakis, & Leaf, 2011; Raghunathan, Lepkowksi, Van Hoewyk, & Solenbeger, 2001). A descriptive analysis of the categorical variables was performed according to absolute and relative frequencies. Continuous variables were presented descriptively using means, standard deviations, medians and minimum and maximum values. Bleeding in the postoperative period of cardiac surgery had a normal distribution.

ANOVA and Mann–Whitney tests were used to compare the bleeding volume averages between the groups created by categorical variables and Pearson's correlation to associate with the continuous variables, both divided into groups of 6 and 12 hr of bleeding (Kutner, Nachtsheim, Neter, Li, & Nachtsheim, 2004). The correlation considered weak was one that ranged from low <0.3, moderate from 0.5 to <0.7 and high above 0.7 (Moore, Notz, & Flinger, 2013). The variables were filtered for regression by choosing all those with $p \leq 0.10$. To select the factors associated with the increased bleeding, the Least Absolute Shrinkage and Selection Operator (LASSO) (Tibshirani, 1996) was used and later linear regression was performed (Kutner et al., 2004). The value of $p \leq 0.05$ was considered statistically significant.

3 | RESULTS

The study included 400 patients, seven of whom were excluded due to coagulopathy and two due to their death in the operating room, leaving a total of 391 patients. The socio-demographic and clinical aspects are listed in Table 1. The majority of the patients were male (67.00%), with a mean age of 58 years (*SD* 11.88), 69.30% had systemic arterial hypertension (SAH) and 29.40% had type II diabetes mellitus (DM). The mean body mass index (BMI) was 27.1 (*SD* 5.63), which is considered overweight. In the evaluation of patient severity, the mean obtained by the euroSCORE was 5.27 points (*SD* 2.72).

In the intraoperative period (Table 2), cardiopulmonary bypass (CPB) was used in most procedures (96.20%), with a mean time of use of 96 minutes (*SD* 39.78), and mean bleeding was 387.58 ml (*SD* 282.99). Among the types of cardiac surgery, coronary artery bypass grafting (CABG) was the most frequently performed (45.80%).

In the postoperative period, as demonstrated in Table 3, metabolic acidosis was present in 287 patients (73.40%), and the lowest arterial pH was 7.05, with a mean of 7.28. Postoperative laboratory examinations showed a decrease in platelet count and international normalised ratio (INR) increase, compared with the preoperative average.

Postoperative bleeding was measured in the first 6 and 12 hr of admission to the SICU, with a mean of 197.30 ml in the first 6 hr, which is equivalent to 0.46 ml/Kg/hr of blood loss. In the total of 12 hr, the mean was 292.50 ml, equivalent to 0.34 ml/Kg/hr.

The association of the categorical variables with the bleeding during the first 6 and 12 postoperative hours is described in Table 4. Factors associated with increased bleeding volume at 6 hr were male sex ($p = 0.037$) and metabolic acidosis ($p < 0.001$) and at 12 hr only the metabolic acidosis ($p = 0.001$).

Regarding the continuous variables studied in the first 6 and 12 hr (Table 5), in the first 6 hr, the positive correlations significantly associated with the higher volume of bleeding included preoperative INR ($p = 0.033$), CPB duration ($p = 0.010$), number of thoracic drains ($p = 0.002$), intraoperative bleeding ($p = 0.004$), postoperative INR ($p < 0.001$) and activated partial thromboplastin time (APTT) ($p = 0.006$). The significant negative correlations were BMI ($p = 0.001$) and postoperative platelets ($p = 0.003$). At 12 hr, the positive correlations included the number of thoracic drains ($p = 0.016$), intraoperative blending ($p = 0.041$), postoperative higher heart rate ($p < 0.001$), postoperative INR ($p < 0.001$) and APTT ($p = 0.003$). The significant negative correlations were BMI ($p = 0.026$) and preoperative ($p = 0.045$) and postoperative ($p = 0.003$) platelets.

In linear regression (Table 6), the factors significantly associated with the increased bleeding in the first 6 hr of the postoperative period of cardiac surgery were male sex ($p = 0.039$), which increases bleeding on average 0.1 ml/Kg/hr; BMI ($p = 0.006$), in which each point decreases bleeding on average 0.01 ml/Kg/hr; CPB duration ($p = 0.001$), anoxia duration ($p = 0.001$), metabolic acidosis ($p < 0.001$), which increases bleeding on average 0.2 ml/Kg/hr; postoperative higher heart rate ($p = 0.003$) and postoperative platelets ($p = 0.001$). These factors explain 22% of the bleeding phenomenon in the first 6 postoperative hours after cardiac surgery (multiple *R*-squared = 0.219).

In linear regression, the factors significantly associated with the increased bleeding in the first 12 hr of the postoperative period after cardiac surgery were metabolic acidosis ($p = 0.001$), which increases bleeding on average 0.1 ml/Kg/hr, postoperative higher heart ($p < 0.001$), postoperative platelets ($p = 0.002$) and APTT ($p = 0.025$). These factors explain 16% of the bleeding phenomenon in the first 12 postoperative hours after cardiac surgery (multiple *R*-squared = 0.162).

4 | DISCUSSION

The present report identified the factors associated with increased bleeding within 12 postoperative hours after cardiac surgery. Compared with the results of an integrative review of the literature, which evaluated the predictors of postoperative bleeding in the postoperative period of cardiac surgery in adults (Lopes, Santos, et al., 2015), four of the factors identified in the review were also identified in this study: male sex, lower BMI, increased CPB time and metabolic acidosis. As of now, the study developed at the same institution where data were collected (Miana et al., 2004) 14 years ago identified as risk factors for excessive bleeding: the emergency surgery, postoperative metabolic acidosis, preoperative thrombocytopenia and extended period of extracorporeal circulation, all of which were kept in this study, apart from the emergency surgery.

TABLE 1 Socio-demographic and clinical aspects of patients undergoing cardiac surgery (*n* = 391). São Paulo, 2016

Characteristics	f	%	Mean	Median	*SD*	Vmin	Vmax
Sex							
Male	262	67.00					
Female	129	33.00					
Age			58.58	61	11.88	20	81
Weight (kg)			73.98	73	14.42	43	118
Height (cm)			165.70	165	9.39	143	202
BMI (kg/cm^2)			27.10	26.35	5.63	14.69	89
LVEF (%)			56	60	13	20	85
Creatinine (mg/dl) preoperative			1.33	1.05	1.34	0.49	12.85
Platelet (/mm^3) preoperative			218,370	215,000	68,882	22,000	627,000
Hb (g/dl) preoperative			13.14	13.30	1.97	7.6	18
Ht (%) preoperative			38.95	40	5.49	23	54
INR preoperative			1.11	1.10	0.19	0.9	3.1
Skin colour							
White	348	89.00					
Black	37	9.50					
Yellow	6	1.53					
HF	114	29.15					
Functional class NYHA I	6	1.53					
Functional class NYHA II	47	12					
Functional class NYHA III	45	11.50					
Functional class NYHA IV	16	4.10					
History of cardiac surgery	40	10.2					
History of cardiogenic shock	15	3.8					
History of sepsis	14	3.6					
HS prior	12	3.06					
SAH	271	69.30					
Peripheral vascular disease	11	2.8					
COPD	11	2.8					
Liver disease	15	3.8					
Diabetes mellitus							
Type I	7	1.80					
Type II	115	29.40					
Smoking	57	14.60					
Bleeding history	6	1.53					
CRF history	44	11.25					
History of haemodialysis	22	5.6					
Prior anticoagulants	89	22.75					
Prior antiplatelet	148	37.83					

Note. BMI, body mass index; HF, heart failure; NYHA, New York Heart Association; HS, haemorrhagic stroke; SAH, systemic arterial hypertension; COPD, chronic obstructive pulmonary disease; CRF, chronic renal failure; ASA: acetylsalicylic acid; LVEF, left ventricular ejection fraction; Hb, haemoglobin; Ht, haematocrit; INR, international normalised ratio. Categorical data presented according to absolute frequency (f) and relative frequency (%). Continuous data presented as mean, median, standard deviation (*SD*), minimum value (Vmin) and maximum value (Vmax).

In this study, men with a mean age of 58 years and a history of systolic arterial hypertension (SAH) and type II DM prevailed, similar to other populations of patients in the postoperative period after cardiac surgery (Lopes, Brunori, Cavalcante, et al., 2015). In a study with 2,575 patients conducted at St. Vincent Hospital in Melbourne, the mean age was 66 years, of which 73% were males, and SAH and DM appeared as the most prevalent comorbidities (Dixon et al., 2014). In the study by Lopes et al. (2016), male sex was also

TABLE 2 Intraoperative characterisation of patients undergoing cardiac surgery (*n* = 391). São Paulo, 2016

Variable	f	%	Mean	Median	*SD*	Vmin	Vmax
Classification of surgery							
Urgency	17	4.34					
Elective	373	95.40					
Coronary artery bypass grafting	179	45.80					
Valvar	172	44.00					
Aorta	30	7.70					
Heart transplant	14	3.60					
CPB	376	96.20					
Time of CPB (min)			96	92	39.78	30	372
Time of anoxia (min)			72.11	70	35.26	19	420
Time of anaesthesia (min)			447.70	432.50	95.31	80	840
Thoracic drains			2.28	3	0.88	1	3
Blood product transfusion	101	25.83					
Red blood cells bags	81	20.70	1.88	1	1.53	1	11
Platelets bags	38	9.70	2.76	1	3.80	1	20
Plasma bags	26	6.64	2.73	3	1.51	1	9
Cryoprecipitate bags	10	2.60	9.50	7.50	7.69	1	30
Haemoderivates transfusion	10	2.60					
Procoagulants	306	78.30					
Cell saver (ml)	27	6.90	430	290	350.12	30	1.540
Heparin (UI)			35,916.67	35,000	25,385	2,500	350,000
Sternal wires (*n*)			8.27	8	1.53	4	11
Initial ACT (s)			136.30	117	92.79	59	774
Final ACT (s)			139.62	116	101.86	70	709
Minimum body temperature (°C)			33.55	34.50	2.74	19	36.7
Higher mean blood pressure (mm Hg)			91.53	90	13.75	50	170
Higher heart rate (bpm)			100.92	100	16.93	60	170
Bleeding (ml)			387.58	350	282.99	10	2,500

Note. CPB, cardiopulmonary bypass; ACT, activated coagulation time. Categorical data presented according to absolute frequency (f) and relative frequency (%). Continuous data presented as mean, median, standard deviation (*SD*), minimum value (Vmin) and maximum value (Vmax).

reported as a factor associated with excessive bleeding. Roeloffzen et al. (2010) explained that this occurs because women have a more procoagulant profile compared with men due to the faster formation rate of fibrins.

Thourani et al. (2011) state that patients with body mass index 24 or less are at significantly increased risk of in-hospital and long-term mortality after cardiac valvular surgery, and Wagner et al. (2007) demonstrated that BMI is an independent predictor of mortality and morbidity after CABG. Valentijn et al. (2013) states that overweight and obese patients have a more sufficient nutritional reserve and might be functioning in a more efficient metabolic state; thus, the inflammatory and immune response to surgery might be more adequate. Lopes et al. (2016) explain that more dramatic dilution occurs to coagulation factors during CPB in patients with a lower BMI.

The predominant BMI found in the study population was classified as overweight. Most studies demonstrate a low BMI as a predictor of bleeding, as reported by Ghavidel et al. (2015) and Lopes et al. (2016), stating that low BMI is a factor associated with excessive bleeding in the postoperative period of cardiac surgery. However, in the study by Hernández-González et al. (2008), overweight was cited as a possible bleeding factor. In this study, the lower BMI is a significant protective factor associated with the bleeding 6 and 12 hr postoperative and each point of BMI decreases bleeding on average 0.01 ml/Kg/hr.

Concerning the bleeding average, a study developed by Colson et al. (2016) states that the ideal quantification of active bleeding within 24 postoperative hours after heart surgery happens according to the amount of time-related bleeding and the person's weight, as this study has depicted. Colson et al. (2016) has also identified, among other things, that BMI and the presence of metabolic acidosis in the postoperative period are risk factors for complications.

Colson et al. (2016) defined active bleeding as blood loss >1.5 ml/Kg/hr for 6 consecutive hours within the first 24 hr. In our

TABLE 3 Postoperative characterisation of patients undergoing cardiac surgery (*n* = 391). São Paulo, 2016

Variable	f	%	Mean	Median	*SD*	Vmin	Vmax
Metabolic acidosis	287	73.40					
Minimum body temperature (°C)			35.10	35	1.72	32.40	37.10
Higher mean blood pressure (mm Hg)			107.05	106	12.50	54	183
Higher heart rate (bpm)			113.16	113	16.72	71	200
Platelets (/mm^3)			145,966.75	138,000.50	56,333.81	31,000	424,000
INR			1.28	1.30	0.15	1	2.10
APTT (s)			29.23	29	8.46	0.80	82.80
Hb (g/dl)			11.69	11.60	1.66	7.20	16.40
Ht (%)			35.63	35	5.30	5	50
Bleeding 6 hr (ml/Kg/hr)			0.46	0.36	0.46	0.06	3.44
Bleeding 12 hr (ml/Kg/hr)			0.34	0.28	0.37	0.09	5.03

Note. INR, international normalised ratio; APTT, activated partial thromboplastin time; Hb, haemoglobin; Ht, haematocrit. Categorical data presented according to absolute frequency (f) and relative frequency (%). Continuous data presented as mean, median, standard deviation (*SD*), minimum value (Vmin) and maximum value (Vmax).

study, the mean bleeding was well below this, 0.46 ml/Kg/hr in 6 hr and 0.34 ml/Kg/hr in the first 12 postoperative hours. Compared with data in the literature that also defined excessive bleeding as that which reaches 2 ml/Kg/hr for 2 consecutive hours occurs in the first 6 hr after surgery and is associated with higher 30-day mortality and other postoperative complications (Christensen et al., 2012), the mean bleeding of the population in the current study was considered low. This could perhaps be because the hospital where the study was performed is a cardiac surgery centre, and due to experience, precautions that avoid postoperative complications, among them bleeding, are already established.

Coronary artery bypass grafting was the most prevalent surgical procedure. This was the case in the study by Waldén, Jeppsson, Nasci, Backlund, and Karlsson (2014) and Kindo et al. (2014) in which CABG was also the single most performed surgical procedure, a fact that can be explained by the increase in the development of acute coronary syndrome among the general population, due to known risk factors, such as obesity, sedentary lifestyle, eating habits, among others.

The greater the number of grafts performed in CABG, the greater the risk of bleeding due to the increased cardiopulmonary bypass (CPB) duration, greater complexity of the procedure, and more precisely the increase in the number of potential bleeding sites (Ghavidel et al., 2015; Karthik, Gravson, McCarron, Pullan, & Desmond, 2004). According to Ferraris et al. (2007) and Rivera et al. (2007), grafts performed with the bilateral internal mammary arteries lead to increased postoperative blood loss compared with the saphenous vein graft.

Coagulopathy caused by CPB increases patient morbidity and mortality and is associated with longer length of stay (Thiele & Raphael, 2014). The longer CPB duration is an independent predictor of postoperative morbidity and mortality after cardiac surgery (Karkouti et al., 2010; Salis et al., 2008), because it causes a decrease in platelet counts, fibrinogen concentration, the amount of and potential for thrombin formation and a greater risk of bleeding and need for transfusion of red blood cells, platelets, plasma, or cryoprecipitate, or even re-exploration. The increased CPB time is directly related to the need for increased doses of heparin, also a predictor of excessive postoperative bleeding (Hernández-González et al., 2008; Lopes, Santos, et al., 2015). In this study, every minute of duration of CPB increased bleeding by 0.003 ml/Kg/hr.

Regarding the time of anoxia turning up as a predictor of increase in bleeding after heart surgery, it is believed that this happens due to the increased probability of producing tissue hypoxia, anaerobic metabolism that generates lactate, carbon dioxide and oxygen, which consequently leads to a state of metabolic acidosis, which is another factor that increases bleeding and is reported in many studies as the predictor of this increased bleeding (Lopes, Santos, et al., 2015; Lopes et al., 2016; Miana et al., 2004). An increase in heart rate in the postoperative period may represent arrhythmias and also predisposes to low cardiac output, which causes an increase in the production of lactic acid in the blood and, consequently, metabolic acidosis (Jones, 2010; Lopes, Santos, et al., 2015).

In this study, metabolic acidosis was the most significant aspect associated with the increase in postoperative heart surgery bleeding, increasing the bleeding to almost 0.2 ml/Kg/hr. Metabolic acidosis is associated with greater postoperative bleeding and surgical revision rate in the postoperative period of cardiac surgery (Lopes, Santos, et al., 2015; Lopes et al., 2016; Miana et al., 2004; Ranucci, Baryshnikova, Simeone, Ranucci, & Scolletta, 2015). Acidosis inhibits coagulation enzymes, decreases platelet count and function, retarding the reactions leading to fibrin polymerisation and strengthening of the clot (Achneck et al., 2010; Lopes, Santos, et al., 2015). According to Despotis, Avidan, and Eby (2009), severe acidosis should be corrected in the postoperative cardiac surgery period, because acidosis impairs coagulation by inhibiting thrombin generation and retarding the reactions leading to fibrin polymerisation. Therefore, nurses must ensure timely postoperative arterial blood gas sampling and handling

TABLE 4 Association of categorical variables with bleeding volume at 6 and 12 hr. São Paulo, 2016

Variable	Bleeding 6 hr Mean	SD	p-Value	Bleeding 12 hr Mean	SD	p-Value
Sex						
Male	0.50	0.45	0.037	0.36	0.29	0.161
Female	0.40	0.49		0.31	0.49	
Skin colour						
White	0.47	0.47	0.595	0.35	0.38	0.855
Black	0.44	0.37		0.33	0.26	
Yellow	0.29	0.56		0.27	0.33	
HF						
NYHA I	0.48	0.53	0.957	0.37	0.40	0.958
NYHA II	0.43	0.43		0.32	0.24	
NYHA III	0.47	0.39		0.32	0.24	
NYHA IV	0.53	0.43		0.39	0.36	
Prior HS	0.34	0.27	0.346	0.26	0.13	0.437
SAH	0.45	0.43	0.227	0.33	0.29	0.155
Diabetes type I	0.19	0.26	0.114	0.19	0.13	0.257
Diabetes type II	0.46	0.46	0.820	0.33	0.29	0.702
Peripheral vascular disease	0.43	0.41	0.827	0.33	0.26	0.878
COPD	0.41	0.36	0.660	0.30	0.33	0.677
Smoking	0.50	0.38	0.550	0.36	0.27	0.696
Liver disease	0.49	0.56	0.911	0.34	0.37	0.965
History of bleeding	0.32	0.19	0.440	0.25	0.13	0.532
History of renal failure	0.49	0.44	0.764	0.35	0.31	0.915
History of haemodialysis	0.50	0.42	0.751	0.36	0.25	0.816
Prior anticoagulant	0.50	0.42	0.221	0.35	0.30	0.776
Prior antiplatelet agent	0.69	0.49	0.083	0.47	0.32	0.322
Surgery						
Urgent	0.64	0.46	0.117	0.43	0.30	0.308
Elective	0.46	0.46		0.34	0.37	
History of sepsis	0.52	0.43	0.647	0.35	0.23	0.967
History of cardiogenic shock	0.59	0.35	0.273	0.39	0.21	0.602
Coronary artery bypass grafting	0.50	0.42	0.185	0.36	0.27	0.374
Valve surgery	0.43	0.53	0.243	0.33	0.47	0.462
Aortic surgery	0.35	0.35	0.163	0.28	0.32	0.324
Heart transplant	0.67	0.42	0.091	0.44	0.25	0.303
CPB	0.46	0.47	0.116	0.34	0.37	0.165
Blood product transfusion (intraoperative)	0.50	0.56	0.317	0.38	0.56	0.192

(Continues)

TABLE 4 (Continued)

Variable	Bleeding 6 hr Mean	SD	p-Value	Bleeding 12 hr Mean	SD	p-Value
Haemocyte concentrate	0.54	0.59	0.096	0.41	0.60	0.054
Plasma	0.45	0.44	0.893	0.34	0.36	0.947
Platelets	0.45	0.48	0.854	0.31	0.29	0.530
Cryoprecipitate	0.55	0.42	0.545	0.36	0.29	0.881
Transfusion of haemoderivatives (intraoperative)	0.73	0.98	0.063	0.46	0.55	0.290
Procoagulant agents (intraoperative)	0.47	0.46	0.752	0.35	0.39	0.344
Cell saver (intraoperative)	0.41	0.40	0.537	0.28	0.24	0.366
Metabolic acidosis	0.51	0.50	<0.001	0.38	0.41	0.001

Note. NYHA, New York Heart Association; HS, haemorrhagic stroke; SAH, systemic arterial hypertension; COPD, chronic obstructive pulmonary disease; CPB, cardiopulmonary bypass. The amount of bleeding was estimated per millilitres per kilogram of weight per hour (ml/Kg/hr). Categorical data presented using ANOVA and Mann–Whitney tests.

of the laboratory result and interpretation (Lopes, Santos, et al., 2015).

In this study, the number of platelets in the postoperative heart surgery period was associated with the increase in the risk of bleeding, i.e., the greater the number of platelets, the lower the risk of bleeding. The bleeding caused by coagulopathy in the postoperative period was multifactorial, including the quantitative reduction in the number of platelets.

Ichikawa, Yoshiko Osada, Kodaka, Nishiyama, and Komori (2017) found a reduction of 30%–40% in the number of platelets during surgery with CPB, which remained low even after platelet transfusion at the end of the surgery. This phenomenon may be credited to a combination of factors, the increase in the consumption of platelets caused by the activation of the coagulation system, haemodilution, platelet dysfunction and adherence to the surface of the CPB circuit.

A study developed by Pillai, Fraser, Ziegenfuss, and Bhaskar (2014) observed that the reduction in the number of platelets and low levels of fibrinogen in the postoperative heart surgery period is associated with the increase in bleeding ($p < 0.0001$). On the other hand, Orlov et al. (2014) remarked that after the adjustment for the risk of haemorrhage, each increase of 10×109/L in the counting of functional platelets activated by collagen during the reheating and post protamine, respectively, was associated with a relative risk of 0.89 (95% CI, 0.82–0.97; $p = 0.006$) and 0.87 (95% CI, 0.78–0.98; $p = 0.02$) for bleeding. In other words, the increase in the number of platelets was a protective aspect, just as happened in this study.

The Activated Partial Thromboplastin Time (aPTT) has also been proven to be associated with the increase in bleeding in the initial

TABLE 5 Correlation of continuous variables with bleeding volume at 6 and 12 hr after cardiac surgery. São Paulo, 2016

Variable	Bleeding 6 hr		Bleeding 12 hr	
	Pearson correlation	*p*-Value	Pearson correlation	*p*-Value
Age	0.044	0.382	0.071	0.163
BMI	−0.164	0.001	−0.113	0.026
EuroSCORE	0.061	0.230	0.035	0.485
LVEF	0.008	0.870	0.021	0.686
Creatinine (preoperative)	0.064	0.205	0.051	0.310
Platelets (preoperative)	−0.098	0.056	−0.102	0.045
Hb (preoperative)	0.024	0.645	0.018	0.730
Ht (preoperative)	0.044	0.390	0.039	0.441
INR (preoperative)	0.108	0.033	0.080	0.115
Number of grafts	0.103	0.168	0.102	0.173
CPB duration	0.130	0.010	0.095	0.060
Anoxia duration	−0.030	0.557	−0.026	0.614
Anaesthesia duration	0.014	0.784	0.013	0.791
Heparin	−0.099	0.061	−0.069	0.192
Sternal wires	0.093	0.086	0.049	0.370
Initial ACT	−0.010	0.859	−0.008	0.878
Final ACT	0.098	0.070	0.070	0.192
Number of thoracic drains	0.159	0.002	0.121	0.016
Minimum body temperature (intraoperative)	0.020	0.724	0.020	0.731
Higher mean arterial pressure (intraoperative)	−0.026	0.607	−0.025	0.618
Higher heart rate (intraoperative)	−0.042	0.408	−0.027	0.596
Bleeding (intraoperative)	0.146	0.004	0.104	0.041
Minimum body temperature (postoperative)	−0.055	0.276	−0.069	0.171
Higher mean arterial pressure (postoperative)	−0.009	0.862	0.027	0.590
Higher heart rate (postoperative)	0.182	<0.001	0.199	<0.001
Platelets (postoperative)	−0.151	0.003	−0.151	0.003
INR (postoperative)	0.209	<0.001	0.267	<0.001
APTT (postoperative)	0.144	0.006	0.156	0.003
Hb (postoperative)	−0.057	0.261	−0.034	0.506
Ht (postoperative)	−0.053	0.297	−0.028	0.576

Note. BMI, body mass index; euroSCORE, European System for Cardiac Operative Risk; LVEF, left ventricular ejection fraction; Hb, haemoglobin; Ht, haematocrit; INR, international normalised ratio; APTT, activated partial thromboplastin time; CPB, cardiopulmonary bypass; ACT, activated coagulation time. Correlation of continuous data presented according to Pearson's correlation.

TABLE 6 Linear regressions of factors associated with increased bleeding volume in the first 6 and 12 hr after cardiac surgery. São Paulo, 2016

Bleeding 6 hr	β	CI 95%	*p*-Value
Sex: male	0.096	0.005 to −0.187	0.039
BMI	−0.011	−0.018 to −0.003	0.006
Diabetes type I	−0.268	−0.587 to 0.051	0.100
INR (preoperative)	0.114	−0.113 to 0.341	0.321
CPB duration	0.003	0.001 to 0.004	0.001
Anoxia duration	−0.003	−0.005 to −0.001	0.001
Final ACT (s)	<0.001	−0.0002 to 0.0007	0.220
Bleeding (intraoperative)	<0.001	−0.0001 to 0.0002	0.301
Metabolic acidosis	0.180	0.081 to 0.280	<0.001
Higher heart rate (postoperative)	0.004	0.001 to 0.007	0.003
Postoperative platelets (every 10,000)	−0.013	−0.020 to −0.005	0.001
APTT (postoperative)	0.005	−0.001 to 0.011	0.108
Multiple *R*-squared: 0.210			
Bleeding 12 hr	**β**	**CI 95%**	***p*-Value**
BMI	−0.005	−0.011 to 0.001	0.110
INR (preoperative)	0.086	−0.098 to 0.269	0.357
CPB duration	<0.001	−0.0003 to 0.0014	0.228
Metabolic acidosis	0.139	0.058 to 0.219	0.001
Higher heart rate (postoperative)	0.004	0.002 to 0.006	<0.001
Postoperative platelets (every 10,000)	−0.009	−0.016 to −0.003	0.002
APTT (postoperative)	0.005	0.001 to 0.010	0.025
Multiple *R*-squared: 0.139			

Note. BMI, body mass index; INR, international normalised ratio; CPB, cardiopulmonary bypass; ACT, activated coagulation time; APTT, activated partial thromboplastin time; β, estimative, beta coefficient. The estimate refers to the amount of bleeding in millilitres per kilogram of weight per hour (ml/Kg/hr).

12 hr of postoperative heart surgery in this study ($p = 0.025$). The enlargement of aPTT in the postoperative period, which predisposes to bleeding, may be connected to recirculation of heparin, which is used before the cannulation of CPB in the dose of 4 mg/kg of weight and neutralised after the withdrawal of CPB through the use of protamine. In a retrospective study involving 2,800 patients in the heart surgery postoperative period developed by Ranucci, Pistuddi, Baryshnikova, Colella, and Bianchi (2016), the aTPP and the level of fibrinogen were independent predictors associated with bleeding. In a similar study, Yang, Vuylsteke, Gerrard, Besser, and Baglin (2013) also reported that the aTTP is an independent variable of blood loss in postoperative cardiothoracic surgery.

The importance of nursing in this context is closely related to the qualification of the nurses (Lopes, Santos, et al., 2015). During the immediate postoperative heart surgery period, the nurse will remain at the patient's bedside intensively monitoring him/her, performing a thorough assessment of vital signs, prioritising the surveillance of the drain debt, and changes in the physical examination that may indicate tweaking that may be required.

The nurse will redouble attention to patients who have characteristics associated with increased postoperative bleeding after heart surgery. Cook, Idzior, Benac, and Albert (2017) conducted a study aimed at evaluating what interferes with the time that the nurse dedicates to monitoring the draining of thoracic drains. Knowledge of patients' previous factors, in particular in patients known to be predisposed to postoperative bleeding, anticipates the assessment, as well as the amount of time they take to evaluate drain debt.

As limitations, we emphasise the fact that this study was conducted in a single centre, so the findings cannot be generalised. The number of research variables was elevated, and the centre has many surgical teams; therefore, the data collected might have been inaccurate.

5 | CONCLUSIONS

The factors associated with increased bleeding in the first 6 hr were male sex, body mass index, cardiopulmonary bypass duration, anoxia duration, metabolic acidosis, higher heart rate, platelets and the activated partial thromboplastin time in the postoperative period. Predictors in the first 12 hr were body mass index, cardiopulmonary bypass duration, metabolic acidosis, higher heart rate, platelets and the activated partial thromboplastin time in the postoperative period. Among these factors, some had not been identified in previous studies on the subject, such as the anoxia duration in the intraoperative period, higher heart rate, platelets and the activated partial thromboplastin time in the postoperative period.

It is important for the nurse to be vigilant in the evaluation and registry of chest tube drainage, thromboelastogram monitoring, platelet mapping and modifiable predictive factors of increased bleeding, such as metabolic acidosis and postoperative heart rate, to discussion with the multiprofessional team.

6 | RELEVANCE TO CLINICAL PRACTICE

Postoperative bleeding is one of the main surgical complications that increase morbidity and mortality in the immediate postoperative period of cardiac surgery. Nurses' having knowledge of the factors that contribute to this event is fundamental to provide timely identification and correction, the establishment of prophylactic interventions and early postoperative treatment when needed.

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CONFLICTS OF INTEREST

There are no conflicts of interest to declare for the authors listed.

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