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ORIGINAL RESEARCH

Predictors of mortality in the surgical intensive care unit among non-cardiac surgery patients receiving transfusion

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Abstract

Background: Postoperative complications are a major contributor to increased mortality rates, which can be reduced by monitoring and managing high-risk patients in the intensive care unit (ICU) following surgery. **Methods**: This retrospective analysis reviewed the records of patients who underwent non-cardiac surgery and received postoperative follow-up care in the ICU between January 2021 and March 2022 using collected demographic data, hematologic parameters, and the number of transfusions performed in the ICU to assess their impact on postoperative mortality. **Results**: The mean ICU length of stay was longer in patients who received red blood cell (RBC) transfusions (4.03 $\pm$ 6.09 days) compared to those who did not. Patients without RBC transfusions were more likely to have preoperative hemoglobin (Hb) levels >10 g/dL (n = 290, 80.8%). Several factors, including ICU length of stay, need for and duration of mechanical ventilation, preoperative Hb levels, platelet (PLT) counts, and American Society of Anesthesiologists (ASA) scores, were significantly associated with mortality ($p < 0.05$). Mortality was higher in patients with preoperative Hb levels <7.5 g/dL (n = 4, 25%) and in those with Hb levels <10 g/dL on ICU day one and at discharge ($p < 0.05$). Low Hb levels were strongly associated with increased mortality. Similarly, low PLT counts demonstrated a significant association with mortality ($p < 0.001$), and patients with an ASA score above 2 had significantly higher mortality rates ($p < 0.001$). **Conclusions**: Anemia was identified as an independent risk factor for adverse outcomes after non-cardiac surgery. While RBC transfusions were associated with poor prognosis, this association was not observed in patients with moderate-to-severe anemia. PLT transfusion was found to be a significant risk factor for mortality. These findings suggest the importance of careful preoperative planning and multidisciplinary management to minimize postoperative transfusion requirements.

Keywords

Transfusion; Mortality; Intensive care unit; Postoperative

1. Introduction

Postoperative complications are a leading contributor to increased mortality rates, and the follow-up of high-risk patients in the intensive care unit (ICU) after surgery has been shown to reduce mortality [1]. Previous studies indicate that fewer than 15% of high-risk surgical patients require intensive care [2]. However, the demand for ICU care continues to rise due to an aging population with multiple comorbidities, despite advancements in medical science. Therefore, greater efforts are needed to prevent, promptly identify and effectively manage potentially life-threatening postoperative complications.

Several perioperative risk scores and prediction models have been developed to estimate postoperative risks. Among these, the American Society of Anesthesiologists Physical Status (ASA-PS) score remains the most widely used. However, its ability to predict individualized risks of adverse outcomes is limited [3]. Anemia is a common condition among surgical ICU patients [4, 5], and it has been significantly linked to increased mortality [6]. For instance, a study involving 821 patients demonstrated that the 30-day survival rate was higher in patients who received transfusions compared to those who did not [4], which highlights the importance of evaluating the impact of blood transfusions and refining approaches to transfusion preparation and administration.

The present study retrospectively analyzed data from the ICU of our hospital to identify predictors of blood transfusion-related outcomes and mortality in the surgical ICU (SICU). The primary outcome measure was the need for perioperative packed red blood cell (RBC) transfusions. Secondary outcome measures included the length of ICU stay, in-hospital mortality

from all causes, and an approximate calculation of transfusion costs based on the quantity of blood products transfused and their unit cost.

2. Methods

This study was approved by the Ethics Committee of Medipol University Hospital (Ethics approval no: E-10840098-772.02-2981). The retrospective nature of the study and its use of anonymized data eliminated the need for informed consent.

All adult patients (>18 years) admitted to the inpatient ICU between January 2021 and March 2022 were retrospectively analyzed. Data were extracted from bedside monitors, ventilators, and the clinical information system. The recorded parameters included patients' age, sex, type of surgical procedure, comorbidities, medications and laboratory data. For patients with multiple ICU admissions, only data from the first admission were included. ASA scores were determined by the intensive care physician on the first day of ICU admission. Hospital records were reviewed to document discharge dates and in-hospital mortality.

In our hospital, all RBC and platelet (PLT) transfusions are electronically recorded, enabling precise documentation of the number of transfusions received by each patient during their ICU stay. Blood transfusion decisions were made by the primary intensive care physician, with the targeted hemoglobin (Hb) range set at 7–9 g/dL during hospitalization. In patients with comorbidities such as ischemic heart disease or hypoperfusion, the targeted Hb level was >9 g/dL. Physicians also conducted routine quality assessments of blood transfusions, and staff underwent regular training to maintain transfusion standards. The records of patients who underwent non-cardiac surgery and received postoperative follow-up care in the SICU between January 2021 and March 2022 were reviewed. Data collected included patients' demographic characteristics, hematologic parameters and the number of transfusions received in the ICU, which were analyzed for their association with postoperative mortality. Subgroup analyses were performed based on Hb levels (<7 g/dL, 7–10 g/dL and >10 g/dL) and PLT counts (<80,000/mcL and >80,000/mcL) to evaluate the relationship between these parameters and mortality outcomes.

The decision to administer transfusions was made by the attending physicians, with the target Hb range set between 7 and 9 g/dL during the ICU stay. Data on intraoperative transfusions were not included in this analysis; only transfusions administered during the ICU period were recorded and evaluated.

3. Statistical analysis

The data were analyzed using IBM SPSS version 25 (IBM Corporation, Armonk, NY, USA). Categorical variables are presented as percentages, while continuous variables are reported as medians or mean ± standard deviation (SD). The Chi-square or Fisher's exact tests were used to analyze categorical variables. Normally distributed continuous variables were compared using the Student's *t*-test, whereas non-normally distributed variables were analyzed using the Mann-Whitney U test. Age, sex, clinical characteristics and laboratory results were initially assessed using univariate logistic regression (LR). Variables identified as significant in the univariate analysis were further analyzed using stepwise multivariate LR (Enter method). The assumption of homogeneity was tested using Levene's Test of Equality of Error Variances. For parameters with repeated measurements, intragroup comparisons were performed using repeated measures Analysis of variance (ANOVA) Test. $p < 0.05$ was considered statistically significant.

4. Results

The sociodemographic and clinical characteristics of the patients are summarized in Table 1. Among the study cohort, 367 patients (56.2%) were male and 286 (43.8%) were female. The mean age was 60.59 ± 14.41 years, ranging from 19 to 93 years. 71.9% of the patients were operated on due to diagnosis of cancer and 28.1% were transferred to intensive care in the postoperative period due to other reasons. Regarding comorbidities, there were 38.5% diabetes mellitus, 48.7% ischemic heart disease, 10.4% chronic obstructive pulmonary disease and 2.4% hematological malignancy. Of the patients, 292 (44.7%) received RBC transfusions, 25 (3.8%) received PLT transfusions and 131 (20.1%) required mechanical ventilation. The mean duration of mechanical ventilation was 8.33 ± 5.05 days. An ASA score above 2 was documented in 219 patients (33.6%) and 282 patients (43.2%) had at least one comorbidity. Mean Hb levels were 11.27 ± 4.10 g/dL preoperatively, 10.25 ± 1.73 g/dL on ICU day one, and 10.12 ± 1.69 g/dL at discharge. Mean PLT counts were 239.43 ± 129.15 × 10^9/L preoperatively, 221.17 ± 189.59 × 10^9/L on ICU day one and 211.84 ± 117.66 × 10^9/L at discharge.

Patients who received RBC transfusions were compared to those who did not in terms of sociodemographic and clinical characteristics (Table 2). Statistically significant differences were observed between the two groups in age, ICU length of stay, Hb levels and the frequency of PLT transfusions ($p < 0.05$). The mean age of patients who received RBC transfusions was 61.82 ± 13.77 years, which was significantly higher than the mean age of those who did not receive transfusions. Similarly, the mean ICU length of stay was longer in the RBC transfusion group, at 4.03 ± 6.09 days, compared to the non-transfusion group. Patients who did not receive RBC transfusions were more likely to have preoperative Hb levels >10 g/dL (n = 290, 80.8%). These patients also maintained Hb levels >10 g/dL on the first day in the ICU and at discharge, with significant differences observed ($p < 0.05$). Notably, all patients who received PLT transfusions also received RBC transfusions, indicating a close relationship between the need for PLT transfusion and RBC administration.

The association between sociodemographic and clinical characteristics and mortality was analyzed (Table 3), and the results demonstrated statistically significant relationships between mortality and length of ICU stay, the need for and duration of mechanical ventilation, Hb levels, PLT count and ASA scores ($p < 0.05$). The mean length of ICU stay was significantly higher among patients who died (15.18 ± 20.82 days) compared to those who were discharged. Similarly,

TABLE 1. Baseline demographic and clinical characteristics of the study cohort.

Variables	n (%)
Sex	
Female	286 (43.8)
Male	367 (56.2)
Age (mean ± SD)	60.59 ± 14.41
RBC (mean ± SD)	4.70 ± 4.41
Received RBC transfusion	292 (44.7)
Not received RBC transfusion	361 (55.3)
PLT (mean ± SD)	0.12 ± 0.09
Received PLT transfusion	25 (3.8)
Not received PLT transfusion	628 (96.2)
Length of stay in the ICU (d) (mean ± SD)	3.81 ± 3.55
Length of mechanical ventilation (d) (mean ± SD)	8.33 ± 5.05
Received mechanical ventilation	131 (20.1)
Not received mechanical ventilation	522 (79.9)
ASA score (mean ± SD)	2.32 ± 0.84
ASA Score ≤2	433 (66.4)
ASA Score >2	219 (33.6)
Medication	
Aspirin	1 (0.2)
Warfarin	3 (0.5)
DOAC	2 (0.3)
LMWH	585 (99.0)
Comorbidities	
Absent	371 (56.8)
Present	282 (43.2)
Preoperative Hb (g/dL)	
<7.5	16 (2.5)
7.5–10	183 (28.1)
>10	452 (69.4)
Preoperative Hb (mean ± SD)	11.27 ± 4.10
Hb (g/dL) on day one of the ICU	
<7.5	18 (2.8)
7.5–10	315 (48.4)
>10	318 (48.8)
Hb on day one of the ICU (mean ± SD)	10.25 ± 1.73
Hb (g/dL) at discharge from the ICU	
<7.5	15 (2.3)
7.5–10	352 (54.2)
>10	283 (43.5)
Hb at discharge from the ICU: (mean ± SD)	10.12 ± 1.69
PLT preoperative ($\times 10^6$)	
<80	30 (4.6)
>80	621 (95.4)
Preoperative PLT (mean ± SD)	239.43 ± 129.15

TABLE 1. Continued.

Variables	n (%)
PLT on day one of the ICU	
<80	29 (4.5)
>80	622 (95.5)
PLT on day one of the ICU (mean ± SD)	221.17 ± 189.59
PLT at discharge from the ICU	
<80	36 (5.5)
>80	614 (94.5)
PLT at discharge from the ICU (mean ± SD)	211.84 ± 117.66
Overall mortality	
Discharge	621 (95.1)
Died	32 (4.9)
30-day mortality	
Discharge	628 (96.2)
Died	25 (3.8)

SD: Standard Deviation; RBC: red blood cell; PLT: platelet; ICU: intensive care unit; ASA: American Society of Anesthesiologists; Hb: hemoglobin; DOAC: Direct Oral Anticoagulant; LMWH: Low molecular weight heparin.

the mean duration of mechanical ventilation was longer in patients who died (14.52 ± 20.17 days), and mortality was more frequently observed in patients with preoperative Hb levels <7.5 g/dL (n = 4, 25%) and in those with Hb levels <10 g/dL on ICU day one and at discharge ($p < 0.05$). Low Hb levels were significantly associated with increased mortality risk. In addition, a strong association was observed between low PLT counts and mortality ($p < 0.001$). Patients with an ASA score above 2 also exhibited significantly higher mortality rates ($p < 0.001$).

Univariate LR analysis identified mechanical ventilation, ASA score, Hb levels and PLT counts as significant predictors of mortality ($p < 0.05$) (Table 4). Patients requiring mechanical ventilation demonstrated a 161.20-fold increased risk of mortality (95% CI (confidence interval): 21.76–1194.45; $p < 0.001$). Similarly, an ASA score above 2 was associated with a 34.13-fold higher risk of mortality (95% CI: 8.07–144.26; $p < 0.001$). Preoperative Hb levels also showed a strong association with mortality. Patients with preoperative Hb levels between 7.5 and 10 g/dL had a 9.69-fold increased mortality risk compared to those with Hb levels >10 g/dL (95% CI: 2.80–33.59). For patients with preoperative Hb levels <7.5 g/dL, the mortality risk was 2.22 times higher than in those with Hb levels >10 g/dL (95% CI: 1.04–4.77; $p < 0.05$). Hb levels on ICU day one and at discharge were similarly predictive of mortality. Patients with Hb levels <7.5 g/dL on ICU day one had a 6.39-fold increased risk of mortality compared to those with Hb levels >10 g/dL on day one (95% CI: 2.05–19.89; $p = 0.001$). Additionally, patients with Hb levels <7.5 g/dL at discharge had an 11.25-fold increased mortality risk compared to those with Hb levels >10 g/dL at discharge (95% CI: 3.32–38.08; $p = 0.001$). PLT counts also showed a significant relationship with mortality. Patients with preoperative PLT counts $<80 \times 10^9$/L had a 7.24-fold higher mortality risk compared to those with PLT counts $>80 \times 10^9$/L (95% CI: 2.84–18.47; $p < 0.001$). For PLT counts measured on ICU day one, a value $<80 \times 10^9$/L was associated with a 9.48-fold increased risk of mortality compared to counts $>80 \times 10^9$/L (95% CI: 3.81–23.56; $p < 0.001$). At discharge, a PLT count $<80 \times 10^9$/L was found to be associated with a 25.04-fold increased risk of mortality compared to counts $>80 \times 10^9$/L (95% CI: 11.04–56.83; $p < 0.001$).

Univariate LR analysis identified mechanical ventilation, ASA score, Hb level and PLT count as statistically significant predictors of 30-day mortality ($p < 0.05$) (Table 5). Patients who required mechanical ventilation had a significantly higher 30-day mortality risk, with an odds ratio (OR) of 116.86 (95% CI: 15.64–873.18; $p < 0.001$), compared to those who did not require mechanical ventilation. Similarly, patients with an ASA score >2 exhibited a 53.17 times greater 30-day mortality risk (95% CI: 7.14–395.83; $p < 0.001$). Hb levels also demonstrated a strong association with 30-day mortality. Patients with preoperative Hb levels <7.5 g/dL had a 13.36-fold increased risk (95% CI: 3.72–48.07; $p < 0.001$) compared to those with preoperative Hb levels >10 g/dL. On ICU day one, a Hb level <7.5 g/dL was associated with a 7.76-fold higher 30-day mortality risk (95% CI: 2.45–24.64; $p < 0.001$) compared to Hb levels >10 g/dL. Similarly, patients with a Hb level <7.5 g/dL at discharge had an 11.29-fold increased risk (95% CI: 3.34–38.22; $p < 0.001$) compared to those with Hb levels >10 g/dL at discharge. Low PLT counts were also significant predictors of 30-day mortality. Patients with preoperative PLT counts $<80 \times 10^9$/L had a 10.20-fold higher risk (95% CI: 3.87–26.82; $p < 0.001$) compared to those with counts $>80 \times 10^9$/L. On ICU day one, a PLT count $<80 \times 10^9$/L was associated with a 10.68-fold increased 30-day mortality risk (95% CI: 4.04–28.20; $p < 0.001$) compared to counts $>80 \times 10^9$/L. At discharge, patients with PLT counts $<80 \times 10^9$/L exhibited a 15.36-fold higher mortality risk (95% CI: 6.30–37.45; $p < 0.001$) compared to those with counts >80

TABLE 2. Comparison of clinical characteristics between patients with and without RBC transfusion.

Variables	Did not receive RBC (n = 361)	Received RBC (n = 292)	*p*
	n (%)	n (%)	
Sex			
Female	145 (40.2)	141 (48.3)	0.038*
Male	216 (59.8)	151 (51.7)	
Age (mean ± SD)	59.60 ± 14.85	61.82 ± 13.77	0.048†
Comorbidity			
Absent	208 (57.6)	163 (55.8)	0.645*
Present	153 (42.4)	129 (44.2)	
Length of ICU stay (mean ± SD)	3.63 ± 8.55	4.03 ± 6.09	<0.001‡
Hb_preoperative			
<7.5	5 (1.4)	11 (3.8)	<0.001*
7.5–10	64 (17.8)	119 (40.8)	
>10	290 (80.8)	162 (55.5)	
Hb_day one			
<7.5	9 (2.5)	9 (3.1)	<0.001*
7.5–10	147 (40.9)	168 (57.5)	
>10	203 (56.5)	115 (39.4)	
Hb at discharge			
<7.5	7 (2.0)	8 (2.7)	<0.001*
7.5–10	163 (45.5)	189 (64.7)	
>10	188 (52.5)	95 (32.5)	
PLT preoperative			
<80	15 (4.2)	15 (5.1)	0.562*
>80	344 (95.8)	277 (94.9)	
PLT on day one			
<80	15 (4.2)	14 (4.8)	0.705*
>80	344 (95.8)	278 (95.2)	
PLT at discharge			
<80	15 (4.2)	21 (7.2)	0.096*
>80	343 (95.8)	271 (92.8)	
ASA_Score			
<2	247 (68.6)	186 (63.7)	0.187*
>2	113 (31.4)	106 (36.3)	
PLT			
Received	0 (0)	25 (8.6)	<0.001*
Not Received	361 (100)	267 (91.4)	
Mechanical ventilation			
Received	68 (18.8)	63 (21.6)	0.385*
Not Received	293 (81.2)	229 (78.4)	
Outcome in the ICU			
Discharged	343 (95)	278 (95.2)	0.918*
Died	18 (5)	14 (4.8)	
30-day mortality			
Discharged	346 (95.8)	282 (96.6)	0.629*
Died	15 (4.2)	10 (3.4)	

**p value was obtained from Fisher Exact or Chi-square test.*

†p value was obtained from Student's t-test.

‡p value was obtained from Mann-Whitney U test.

SD: Standard Deviation; RBC: red blood cell; PLT: platelet; ICU: intensive care unit; ASA: American Society of Anesthesiologists; Hb: hemoglobin.

TABLE 3. Association between demographic and clinical characteristics and mortality.

Variables	Survivor (n = 621)	Died (n = 32)	*p*
	n (%)	n (%)	
Sex			
Female	270 (43.3)	16 (50.0)	0.462*
Male	351 (56.7)	16 (50.0)	
Age (mean ± SD)	60.55 ± 14.30	61.41 ± 16.75	0.744†
Length of stay in the ICU (mean ± SD)	3.22 ± 5.59	15.18 ± 20.82	<0.001‡
Mechanical ventilation			
Received	100 (16.1)	31 (96.9)	<0.001*
Not Received	521 (83.9)	1 (3.1)	
Length of ventilation (d) (mean ± SD)	6.41 ± 12.58	14.52 ± 20.17	0.024‡
PLT			
Received	22 (3.5)	3 (9.4)	0.094*
Not Received	599 (96.5)	29 (90.6)	
RBC			
Received	277 (44.8)	14 (4.8)	0.918*
Not Received	343 (55.2)	18 (5.0)	
Comorbidity			
Absent	352 (56.8)	18 (4.9)	0.953*
Present	268 (43.2)	14 (5.0)	
Hb_preoperative			
<7.5	12 (2.0)	4 (12.5)	<0.001*
7.5–10	170 (27.5)	13 (40.6)	
>10	436 (70.5)	15 (46.9)	
Hb_day one			
<7.5	13 (2.1)	5 (15.6)	<0.001*
7.5–10	306 (49.4)	9 (28.1)	
>10	299 (48.5)	18 (56.3)	
Hb at discharge			
<7.5	10 (1.6)	5 (15.6)	<0.001*
7.5–10	337 (54.5)	15 (46.9)	
>10	270 (43.9)	12 (37.5)	
PLT_preoperative			
<80	23 (3.7)	7 (21.9)	<0.001*
>80	597 (96.3)	25 (78.1)	
PLT_day one			
<80	21 (3.4)	8 (25.0)	<0.001*
>80	596 (96.6)	24 (75.0)	
PLT_discharge			
<80	21 (3.4)	15 (46.9)	<0.001*
>80	597 (96.6)	17 (53.1)	
ASA_Score			
<2	430 (69.5)	2 (6.3)	<0.001*
>2	189 (30.5)	30 (93.8)	

**p value was obtained from Fisher Exact or Chi-Square test.*
†p value was obtained from the Student's t-test.
‡p value was obtained from the Mann-Whitney U test.
SD: standard deviation; RBC: red blood cell; PLT: platelet; ICU: intensive care unit; ASA: American Society of Anesthesiologists; Hb: hemoglobin.

TABLE 4. Univariate and multivariate logistic regression analysis for the prediction of overall mortality.

Variables	Univariate LR		Multivariate LR	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Sex (Male)	0.77 (0.38–1.57)	0.469		
Age >65 yr	0.58 (0.28–1.18)	0.130		
RBC transfusion	0.96 (0.47–1.97)	0.910		
PLT transfusion	2.81 (0.80–9.94)	0.108		
Mechanical ventilation	161.20 (21.76–1194.45)	<0.001	95.21 (12.55–721.92)	<0.001
Comorbidity	1.02 (0.50–2.09)	0.953		
ASA Score >2	34.13 (8.07–144.26)	<0.001	20.79 (4.36–99.06)	<0.001
Hb_preop (ref >10)		0.001		
7.5–10	9.69 (2.80–33.59)	<0.001		
<7.5	2.22 (1.04–4.77)	0.040		
Hb_day one (ref >10)		<0.001		
7.5–10	0.49 (0.21–1.11)	0.085		
<7.5	6.39 (2.05–19.89)	0.001		
Hb_discharge (ref >10)		<0.001		
7.5–10	1.01 (0.46–2.18)	0.997		
<7.5	11.25 (3.32–38.08)	0.001		
PLT_preop (ref >80)	7.24 (2.84–18.47)	<0.001		
PLT_First day in ICU (ref >80)	9.48 (3.81–23.56)	<0.001		
PLT_discharge (ref >80)	25.04 (11.04–56.83)	<0.001		

RBC: red blood cell; PLT: platelet; ICU: intensive care unit; ASA: American Society of Anesthesiologists; Hb: hemoglobin; LR: logistic regression; OR: odds ratio; CI: confidence interval; ref: reference.

$\times 10^9$/L at discharge.

Repeated measurements of Hb and PLT levels were analyzed using intra-group comparisons for patients who survived and were discharged and for those who died (Table 6). The results showed that in patients who were discharged, their Hb levels showed significant variation over time ($p = 0.001$). The mean preoperative Hb level in this group was 11.33 $\pm$ 4.16 g/dL, which decreased significantly to 10.24 $\pm$ 1.66 g/dL on ICU day one and remained significantly lower at 10.13 $\pm$ 1.6 g/dL at discharge. In patients who died, PLT levels exhibited significant variation over time ($p = 0.001$). The mean preoperative PLT count was 251.28 $\pm$ 217.82 $\times 10^9$/L, which decreased significantly to 174.16 $\pm$ 112.26 $\times 10^9$/L on ICU day one and further declined significantly to 140.88 $\pm$ 159 $\times 10^9$/L at discharge ($p = 0.016$).

5. Discussion

This study revealed significant findings. First, adult patients undergoing elective non-cardiac surgery at our center exhibited a remarkably high prevalence of preoperative anemia. Most patients in our cohort met the World Health Organization (WHO) criteria for anemia, with Hb levels indicative of anemia observed in over 50% of the sample. This prevalence significantly exceeds values reported in prior literature and was an unexpected finding. Although the underlying causes and duration of preoperative anemia were not determined, our results suggest a close relationship between anemia, aging, the severity of comorbidities and the complexity of the presenting surgical condition. Second, preoperative anemia was a significant and independent predictor of perioperative RBC transfusion. Among anemic patients, 94.5% demonstrated a three-and-a-half-fold increased likelihood of receiving perioperative transfusions, even when the anemia was mild (Hb $\geq$10 g/dL). This increased transfusion incidence in the anemic group also contributed to substantially higher financial costs associated with their care. Third, preoperative anemia was strongly associated with higher in-hospital mortality and adverse postoperative outcomes, including prolonged ICU stays.

The present study investigated the administration of RBC and PLT transfusions during ICU follow-up and their association with 30-day mortality. Patients who received RBC transfusions had a longer ICU stay compared to those who did not. However, this extended length of stay was likely attributable to the underlying anemia rather than the transfusions themselves.

In addition, there were three key findings reported in our present study. First, adult patients presenting for elective heart surgery at our center were highly likely to have preoperative anemia. The majority of patients in our sample met the WHO criteria for anemia, meaning their Hb level was greater than 50%. This high prevalence of preoperative anemia, which is far greater than previously documented in the literature, was an unexpected finding. The reason and duration of the preoperative anemia were not found, but our findings suggest

TABLE 5. Univariate and multivariate logistic regression analysis for the prediction of 30-day mortality.

Variables	Univariate LR		Multivariate LR	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Sex (Male)	1.19 (0.54–2.66)	0.666		
Age >65 yr	1.71 (0.76–3.83)	0.192		
RBC transfusion	0.82 (0.36–1.85)	0.629		
PLT transfusion	1.05 (0.14–8.08)	0.964		
Mechanical ventilation	116.86 (15.64–873.18)	<0.001	171.81 (11.63–2537.75)	<0.001
Comorbidity	1.22 (0.55–2.73)	0.621		
ASA Score >2	53.17 (7.14–395.83)	<0.001	35.19 (3.53–350.62)	0.002
Hb_preop (ref >10)		<0.001		0.296
7.5–10	2.32 (0.97–5.55)	0.060	0.19 (0.01–3.72)	0.272
<7.5	13.36 (3.72–48.07)	<0.001	0.11 (0.01–2.08)	0.142
Hb_day one (ref >10)		<0.001		0.177
7.5–10	0.33 (0.12–0.91)	0.032	12.39 (0.44–352.16)	0.141
<7.5	7.76 (2.45–24.64)	<0.001	22.28 (0.79–626.96)	0.068
Hb_discharge (ref >10)		<0.001		0.003
7.5–10	0.53 (0.21–1.30)	0.165	0.01 (0.01–0.14)	0.002
<7.5	11.29 (3.34–38.22)	<0.001	0.03 (0.01–0.66)	0.027
PLT_Preop (ref >80)	10.20 (3.87–26.82)	<0.001	0.53 (0.05–5.12)	0.581
PLT_day one of ICU (ref >80)	10.68 (4.04–28.20)	<0.001	1.89 (0.21–17.01)	0.570
PLT_discharge (ref >80)	15.36 (6.30–37.45)	<0.001	0.14 (0.02–0.84)	0.032

RBC: red blood cell; PLT: platelet; ICU: intensive care unit; ASA: American Society of Anesthesiologists; Hb: hemoglobin; LR: logistic regression; OR: odds ratio; CI: confident interval; ref: reference.

TABLE 6. Association of repeated measurements of Hb and PLT with mortality.

Variables	Discharge	Died
	Mean ± SD	Mean ± SD
Preop Hb	^{a}11.33 ± 4.16	10.05 ± 2.67
Hb on day one of the ICU	^{b}10.24 ± 1.66	10.34 ± 2.87
Hb at discharge from the ICU	^{c}10.13 ± 1.60	9.97 ± 2.91
*p**	0.001	0.540
Preop PLT	238.78 ± 123.21	^{a}251.28 ± 217.82
PLT on day one of the ICU	223.54 ± 295.96	^{b}174.16 ± 112.26
PLT at discharge from the ICU	215.44 ± 114.16	^{b}140.88 ± 159.00
*p**	0.083	0.016

**p value was obtained from Repeated ANOVA test, ^{a,b,c}: Different lower-case superscript letters indicate significant differences among the repeated measures.*
SD: standard deviation; Hb: hemoglobin; ICU: intensive care unit; PLT: platelet.

that anemia and aging, the severity of comorbidities at the same time, and the complexity of the presenting non-cardiac surgical situation are closely related. Second, preoperative anemia was a significant and independent predictor of perioperative RBC transfusion. Among anemic patients, 94.5% demonstrated a three and a half-fold increase in the likelihood of requiring perioperative transfusion, even when the anemia was mild (Hb concentration ≥10 g/dL), which also resulted in higher financial costs. Third, preoperative anemia was strongly associated with increased in-hospital mortality and a higher incidence of postoperative adverse outcomes, including prolonged stays in the ICU.

Preoperative anemia in non-cardiac surgery represents a potentially treatable condition with important therapeutic implications. If postoperative adverse outcomes are indeed attributable to preoperative anemia, addressing low Hb levels prior to elective non-cardiac surgery could reduce mortality rates and decrease the duration of prolonged ICU stays.

The present study demonstrated that perioperative and postoperative mortality are influenced by multiple factors by assessing several key elements, including length of ICU stay, the requirement for and duration of mechanical ventilation, Hb levels, PLT counts and ASA scores, all of which showed significant associations with mortality. The observed associations may be related to anemia or to various mechanisms by which stored allogeneic erythrocytes disrupt homeostasis. Some of these mechanisms, such as impaired rheological properties, reduced oxygen delivery and the procoagulant effects of RBC-derived microparticles [7–11], manifest immediately. In contrast, other adverse effects, particularly those related to transfusion-associated immunomodulation (TRIM), develop over time [12]. Although the precise mechanisms underlying TRIM remain unclear, the modulation of cellular immunity is thought to play a key role [13].

The widened mortality gap between the transfusion and non-transfusion groups observed in this study supports the hypothesis that immunological factors likely contributed to the poorer outcomes in the transfusion group. Significant differences were also observed between these groups in terms of age distribution, ICU length of stay, Hb levels and PLT transfusion rates.

The results of the current research align with previous research investigating preoperative anemia as defined by the WHO [14, 15]. Several studies have associated anemia with an increased risk of postoperative complications [16, 17]. In the present analysis, the mortality risk was found to be 9.69 times higher in patients with preoperative Hb levels of 7.5 to 10 g/dL (95% CI: 2.80–33.59) and 2.22 times higher in those with preoperative Hb levels <7.5 g/dL (95% CI: 1.04–4.77) compared to patients with preoperative Hb levels >10 g/dL.

Blaudszun *et al.* [17] reported an inverse correlation between preoperative hematocrit levels and the risk of cardiac complications or death in patients undergoing non-cardiac surgery. Similarly, Mazer *et al.* [18] demonstrated an association between preoperative anemia and increased 30-day mortality (OR = 612, 95% CI: 573–654) as well as perioperative complications (OR = 330, 95% CI: 320–340) in non-cardiac surgical patients. Additionally, an analysis of cancer patients identified a relationship between anemia and an elevated risk of postoperative complications [16]. In the present study, univariate logistic regression analysis revealed that mechanical ventilation, ASA score, Hb level and PLT count were statistically significant predictors of 30-day mortality.

Several randomized controlled trials have evaluated the safety and potential benefits of a restrictive transfusion strategy in both cardiac and non-cardiac surgeries [19–21]. One study reported no superiority of a higher Hb threshold (Hb 10 g/dL) over a lower threshold (Hb 8 g/dL) in terms of survival and mobility at day 60 after hip surgery (OR = 1.01, 95% CI: 0.84–1.22) [18]. In the present study, univariate logistic regression analysis identified mechanical ventilation, ASA score, Hb level and PLT count as statistically significant predictors of mortality.

Three large randomized trials did not confirm the safety of a restrictive transfusion strategy (Hb threshold of 7.5–8 g/dL) compared to a liberal transfusion strategy (Hb threshold of 9–10 g/dL) in patients following cardiac surgery [19, 20, 22]. Conversely, evidence from vascular surgery suggests that transfusion at a higher Hb threshold (Hb 9 g/dL) improved cerebral oxygenation parameters and resulted in fewer complications compared to a lower threshold (Hb 8 g/dL) [23]. In the present study, 30-day mortality risk was found to be 13.36 times higher in patients with a preoperative Hb level of <7.5 g/dL compared to those with levels >10 g/dL (95% CI: 3.72–48.07, $p < 0.001$). Similarly, the 30-day mortality risk was 7.76 times higher in patients with a Hb level of <7.5 g/dL on the first day of the SICU compared to those with levels >10 g/dL (95% CI: 2.45–24.64, $p < 0.001$).

Reducing exposure to the identified mortality risk factors can potentially improve patient outcomes. Patients with elevated ASA scores should receive perioperative care specifically tailored to their physiological status and the surgical procedure. In the present study, the ASA score was identified as an independent risk factor for mortality, with the 30-day mortality risk being 53.17 times higher in patients with an ASA score above 2.

PLT transfusion has been identified as an independent risk factor for poor postoperative outcomes following cardiac surgery and liver transplantation [24, 25]. In the present study, a preoperative PLT value of $<80 \times 10^9$/L was associated with a 30-day mortality risk 10.20 times higher than in patients with a PLT value $>80 \times 10^9$/L (95% CI: 3.87–26.82). Similarly, on the first day of the surgical SICU, patients with a PLT value $<80 \times 10^9$/L had a 10.68-fold higher risk of 30-day mortality compared to those with a PLT value $>80 \times 10^9$/L (95% CI: 4.04–28.20). At discharge, patients with a PLT value $<80 \times 10^9$/L showed a 15.36-fold increased mortality risk compared to those with a PLT value $>80 \times 10^9$/L (95% CI: 6.30–37.45), with all these above findings showing statistical significance ($p < 0.001$).

In critically ill adult patients admitted to the ICU, the prevalence of hospital-acquired thrombocytopenia (HAT) ranges from 8.3% to 67.6%, with a prevalence of 14%–44% during ICU treatment [26, 27]. Recent data indicate that HAT is associated with an increased risk of bleeding, transfusion, ICU mortality, prolonged ICU stay and the need for organ support [28]. HAT frequently occurs following major surgeries, including hip replacement, abdominal surgery and cardiac procedures. Typically, PLT counts reach their lowest levels postoperatively between the first and fourth day, return to preoperative levels by the fifth to seventh day and peak around Day 14 due to tissue injury and blood loss [29]. While this clinical pattern appears brief, temporary and reversible, and often unrelated to the patient's postoperative recovery, emerging evidence suggests it is not a benign process. For instance, a PLT count of $<75 \times 10^9$/L after cardiac surgery has been associated with complications such as acute kidney injury (AKI), infection and stroke [25]. In the present study, a preoperative PLT count of $<80 \times 10^9$/L was associated with a 30-day mortality risk 10.20 times higher than patients with a count $>80 \times 10^9$/L (95% CI: 3.87–26.82). Similarly, on the first day in the surgical ICU (SICU), patients with a PLT count $<80 \times 10^9$/L exhibited a 10.68-fold higher 30-day mortality risk compared to those with counts $>80 \times 10^9$/L (95% CI: 4.04–28.20, $p < 0.001$).

6. Limitations

This study has several limitations that should be acknowledged. The primary limitation is the lack of detailed information on underlying medical conditions and surgical variables, such as whether surgery was performed and if transfusions were administered during surgery. These factors likely have a significant impact on transfusion decisions, especially in the ICU, where such considerations are pivotal. In addition, comorbidities were not comprehensively recorded, and their inclusion, along with more detailed factors and analyses, could have provided a deeper understanding of the findings. Moreover, the study is subject to biases inherent due to its retrospective, single-center design, which may limit the generalizability of the results. The study's external validity is restricted, as it included only critically ill patients, which may not represent the broader surgical population. Furthermore, the observational design of the study prevents the establishment of definitive causal relationships between anemia, RBC transfusion and postoperative complications. The absence of detailed comorbidity data and surgical variables highlights the need for future studies to include these parameters to better understand their impact on transfusion practices and patient outcomes, and prospective, multicenter studies are necessary to validate these findings and explore the causal pathways underlying the observed associations.

7. Conclusions

This study demonstrates that the incidence of preoperative anemia reported here is among the highest documented in existing literature. The findings establish a clear relationship between anemia and transfusion, with transfusion-related anemia being associated with poorer postoperative outcomes in non-cardiac surgery. Anemia was identified as an independent predictor of adverse outcomes, with older patients (aged over 65 years) exhibiting reduced tolerance to anemia. While RBC transfusion appeared to worsen prognosis, this effect was not observed in cases of moderate-to-severe anemia. PLT transfusion was shown to significantly increase mortality risk, underscoring its role as an independent risk factor. The study highlights the need for further research to identify which patients benefit from PLT transfusions, the surgical procedures that demand higher PLT usage, and the associated risk factors. These insights are critical for developing targeted transfusion strategies to improve surgical outcomes. Future studies could aim to refine transfusion protocols to minimize risks and improve survival rates, and further evidence-based guidelines could enable clinicians to personalize transfusion practices based on patient-specific factors and surgical requirements, thereby enhancing perioperative care and reducing mortality risks.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

SS—designed the research study; wrote the manuscript.. BT—performed the research. BS—analyzed the data. All authors read and approved the final manuscript. All authors critically revised the manuscript, agreed to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Ethics Committee of Medipol University Hospital (Ethics approval no: E-10840098-772.02-2981). Informed consent was waived by the Ethics Committee of Medipol University Hospital.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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