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# Predicting blood transfusion needs in colorectal surgery at a university hospital in Saudi Arabia: insights into anemia, malnutrition, and surgical factors

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## Abstract

**Background** In Saudi Arabia, nearly a quarter of a hospital's blood supply is consumed in operating rooms. However, blood is a scarce resource, and its unavailability has led to the cancellation of many surgeries. This study aims to identify risk factors for perioperative blood transfusion in colorectal surgery, thus providing valuable insights for better blood management and transfusion planning.

**Methods** We conducted a retrospective cohort study of patients who underwent colorectal surgery at King Abdulaziz University Hospital from 2013 to 2022. Data on patient demographics, comorbidities, surgical details, and transfusion outcomes were collected and analyzed. Statistical analyses included logistic regression to identify predictors of transfusion and over-transfusion.

**Results** We collected data from 434 patients. Women were almost twice as likely (OR = 1.98; 95%CI = 1.35–2.90) as men to receive one or more units of RBCs. Also more likely to be transfused were patients with a higher ASA score; a lower pre-operative serum hemoglobin (Hgb) level; and malignant disease as the reason for surgery (all $p < 0.001$). On multivariable analysis, receiving a transfusion of packed blood cells (RBCs) was statistically linked to volume of intra-operative blood loss and Hgb level (both $p < 0.001$); as well as to pre-operative body mass index (BMI), with patients who were under-weight and of normal weight most at risk, and patients with a BMI between 25 and 35 less likely to be transfused. Patients whose pre-operative serum Hgb level was 12 g/dL or higher were more than twice as likely to not receive a transfusion, while those with pre-operative Hgb levels from 8.0 to 9.9 g/dL were three times more likely than not to receive blood, and those with a pre-operative Hgb under 8.0 g/dL almost five times as likely as not.

**Conclusions** Key risk factors for perioperative blood transfusion in colorectal surgery are preoperative anemia, diabetes, low BMI, and significant blood loss. Addressing these through a multidisciplinary approach and the development of perioperative protocols may reduce transfusion needs. Future prospective studies are needed to validate these findings and refine transfusion risk assessments.

**Keywords** Perioperative transfusion, Colorectal surgery, Anemia, Blood management, Transfusion risk factors, Replacement donors, Saudi Arabia

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## Introduction

In Saudi Arabian hospitals, 23% of the blood banks' supply is utilized in the operating room (Shash et al. 2022). However, blood is a valuable and limited resource, reliant entirely on volunteer donations. A safe and effective synthetic blood alternative has yet to be developed. In 2010, the World Health Organization (WHO 2010) developed a global framework for action to achieve 100% voluntary blood donation and phase out paid donations and replacement donors (WHO 2010). Many developed countries have succeeded in establishing this goal such as the National Transfusion Services in the United Kingdom and Canada as well as the Red Cross in the USA (Abdelgader and Al Ghumlas 2020). Unfortunately, 40–60% of donors in Saudi Arabia remain replacement donors (Abdelgader and Al Ghumlas 2020).

Therefore, at many hospitals in Saudi Arabia, the anesthetist requests assurance that a specific number of packed red blood cell (PRBC) units are available and cross-matched according to the type of surgery (maximal blood order schedule (MBOS)) before elective procedures. For colorectal surgery, the MBOS is often 2 units of PRBC. Unfortunately, it is estimated that the unavailability of blood is the cause of 5% of surgery cancellations (Boker 2008; Dhafar et al. 2015). Many of those cancelations may be preventable. A study by Guinn et al. has shown a decrease in transfusion rates from 26.77 to 12.60% with preoperative optimization (Guinn et al. 2022). Enabling anesthetists to perform a preoperative evaluation to identify patients at high risk of transfusion would allow for better decision-making. It would ensure appropriate optimization, referrals, and blood ordering. This medical optimization may assist in conserving blood banks' supplies and decrease cancellations.

Several published studies have examined the risk factors for perioperative transfusion in colorectal surgery patients (Halabi et al. 2013; Ristescu et al. 2019; Kwon et al. 2019; Nilsson et al. 2002). However, most of these studies were conducted in North America, where patient demographics, surgical techniques, and resources differ significantly from those in Saudi Arabia. Consequently, the findings from these studies may not directly apply to our population and cannot be used to develop recommendations. Preoperative patient management guidelines developed in North America and Europe often assume a readily available blood supply including the universal donor O-negative (Abdelgader and Al Ghumlas 2020). Unfortunately, this is not the case for many hospitals in Saudi Arabia, where limited resources and blood availability must be considered when making surgical decisions (Boker 2008).

The goal of our study was to identify the risk factors for perioperative transfusion of PRBCs in patients undergoing colorectal surgery in Saudi Arabia. Our secondary goal is to identify the risk factors for transfusion of more than 2 units of PRBC and over-transfusion (postoperative hemoglobin > 11).

## Methodology

We obtained ethical approval from the King Abdulaziz University Department of Research Ethics. This retrospective cohort study included all patients who underwent elective colorectal surgery between 2013 and 2022 at King Abdulaziz University Hospital (KAUH). In KAUH, all patients' laboratory investigations and blood products received are entered into an electronic patient record (EMR). Furthermore, surgery-related information is entered into the same EMR by the operating room circulating nurse. This includes all anesthesia and surgical times, names of the operating room personnel, type, and number of blood products consumed, as well as blood loss. We retrieved our data from this online patient record as an XLS sheet and stored it in a password-protected online account. We electronically retrieved all surgeries from the hospital's EMR system that were labeled colorectal surgery. Our initial search retrieved 941 procedures. We eliminated 404 procedures that were done emergently and ended up with 537 procedures. We reviewed the OR documentation for the details of the procedure and eliminated any that did not meet our definition of intraperitoneal colorectal surgery and ended up with 451 procedures. We then excluded any procedures that occurred for the same patient within 6 months of another procedure and ended up with 434 procedures (Fig. 1). Pre-operative transfusions were those transfused during the admission for surgery. Intraoperative transfusions were all transfusions performed in the operating suite. Post-operative transfusions were those performed after leaving the operating room suit and before discharge from the hospital.

### Statistical methods

Data was examined for completeness and clear outliers. Virtually all variables had data for 99–100% of the patients, the vast majority of these having 100%. No clear outliers were identified. Continuous variables have been summarized as means with standard deviations, as well as minimum and maximum values. All nominal and ordinal variables have been summarized as absolute numbers with percentages against totals.

Prior to any inferential analysis, all continuous variables of interest to the current analysis were screened for normal versus nonnormal distribution using the Shapiro–Wilk's test; all variables but intra-operative blood loss were found to be non-normally distributed. For this reason, and because all inter-group comparisons involved just two patient groups, the

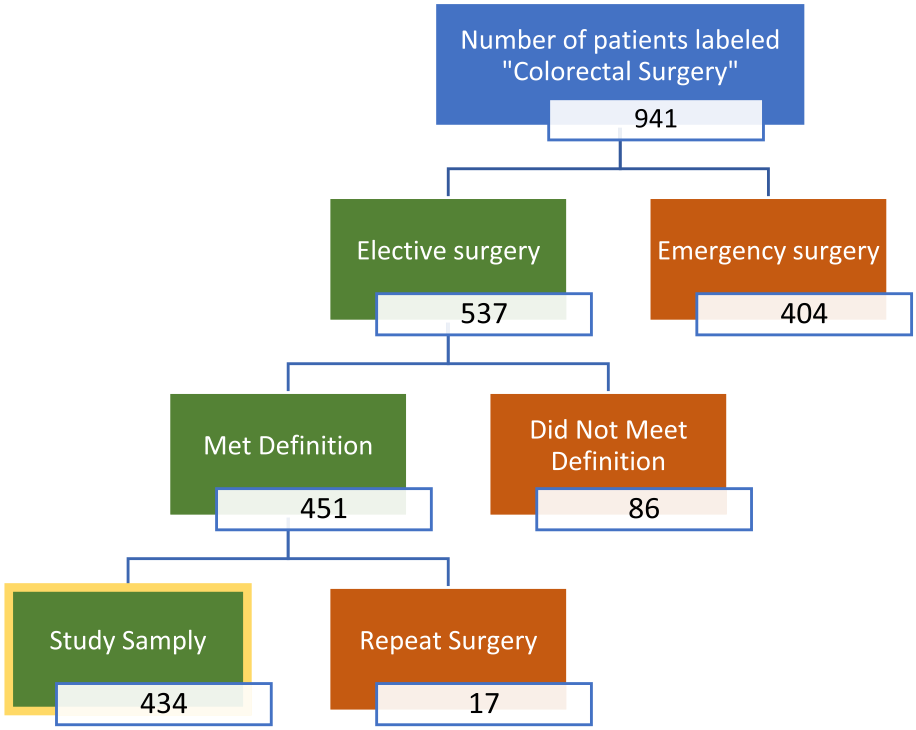


**Fig. 1** Patient selection flowchart

non-parametric Mann–Whitney *U* test was used for all continuous variables except blood loss, for which an unpaired Student's *t*-test was used. All inter-group comparisons of categorical variables were performed using Pearson $\chi 2$ analysis or Fisher's exact test, as indicated based upon the lowest number of cases per cell. Odds ratios with 95% confidence intervals (95% CI) were generated for inter-group comparisons involving $2 \times 2$ tables.

Since data were either non-normally distributed or ordinal, Spearman's correlation coefficients were generated to assess the relationship between the volume of intra-operative blood loss, the number of units of red blood cells (RBCs) transfused intra- plus post-operatively, and the number of postoperative complications identified, including death.

For multivariable analysis, since all the dependent variables of interest were binary (e.g., under-transfused versus over-transfused), hierarchical logistic regression was performed by entering variables in five blocks by forward entry. The criteria for model entry and exclusion were $p \leq 0.10$. For all other analyses, a Bonferroni-adjusted *p* value of $p < 0.001$ was used to identify statistically significant differences. All analyses were two-tailed and performed in SPSS version 28.0 by a PhD-level statistician.

## Results

Table 1 summarizes the demographic and baseline clinical characteristics of the patient sample, and patients' pre-operative characteristics, respectively. Table 2 summarizes the complications experienced by patients. Note that 110 patients (25.3%) presented with a pre-operative serum hemoglobin (Hgb) level of 13 g/dL or greater; while 146 (33.6%) had a level from 10 to 13 (mildly anemic), and 178 (41.0%) a level below 10 g/dL. A pre-operative transfusion of RBCs was given to 3/110 of the patients with a Hgb > 13 (2.7%), to 10/146 with a Hgb from 11 to 13 (6.8%); and to 48/178 with a Hgb under 11 g/dL (27.0%). Among women, 12.4% had a Hgb level > 13, 41.1% from 11 to 13, and 46.4% < 11. Among men, these percentages were 37.3%, 26.7%, and 36.0% ($\chi 2 = 36.11$, df = 2, $p < 0.001$).

Table 3 compares the 231 patients who did not receive any transfusions of RBCs intra- or post-operatively against the 203 patients who did. Women were almost twice as likely (OR = 1.98; 95%CI = 1.35–2.90) as men to receive one or more units of RBCs. Also more likely to be transfused were patients with a higher ASA score; a lower pre-operative serum hemoglobin (Hgb) level; and malignant disease as the reason for surgery (all $p < 0.001$). Patients scheduled for open versus laparoscopic surgery also were much more likely to receive a transfusion

**Table 1** Characteristics of the patient sample

| | Number, *n* | Percentage, % |
|---|---|---|
| Total number of patients | 434 | 100.0% |
| Age Mean (years) | 53.46 | |
| Standard deviation (SD) | 16.42 | |
| Range | 15–99 | |
| Age categories < 20 years | 8 | 1.8% |
| 20–39 years | 82 | 18.9% |
| 40–59 years | 179 | 41.2% |
| 60–79 years | 150 | 34.6% |
| 80–99 years | 15 | 3.5% |
| Gender Female | 209 | 48.2% |
| Male | 225 | 51.8% |
| Body mass index (BMI) Mean | 26.31 | |
| SD | 5.81 | |
| Range | 14.0–59.8 | |
| BMI categories < 18.5 kg/m$^2$ | 30 | 6.9% |
| 18.5–24.9 | 171 | 39.4% |
| 25.0–29.9 | 123 | 28.3% |
| 30–34.9 | 76 | 17.5% |
| 35.0–39.9 | 26 | 6.0% |
| ≥ 40.0 | 7 | 1.6% |
| Data missing | 1 | 0.2% |
| Comorbidities Diabetes mellitus | 121 | 27.9% |
| Hypertension | 135 | 31.1% |
| Ischaemic heart dz | 28 | 6.5% |
| Heart failure | 7 | 1.6% |
| Chronic lung dz | 11 | 2.5% |
| Chronic liver dz | 18 | 4.1% |
| Chronic kidney dz | 10 | 2.3% |
| Cerebrovascular dz | 11 | 2.5% |
| ASA status Class I | 31 | 7.1% |
| Class II | 237 | 54.6% |
| Class III | 157 | 36.2% |
| Class IV | 9 | 2.1% |
| Reason for surgery Benign dz | 105 | 24.2% |
| Malignant dz | 329 | 75.8% |
| Pre-op Hgb (g/dl) Mean | 11.47 | |
| Standard deviation (SD) | 1.99 | |
| Range | 5.6–16.5 | |
| Anaemia No (Hgb > 13 g/dl) | 110 | 25.3% |
| Mild (Hgb = 10–13 g/dl) | 146 | 33.6% |
| Warranting treatment (Hgb < 10 g/dl) | 178 | 41.0% |
| Units of RBCs given pre-op None | 373 | 85.9% |
| 1–2 units | 45 | 10.4% |
| > 2 units (3–9 units) | 16 | 3.7% |
| Surgical approach Laparoscopic | 145 | 33.4% |
| Conversion to open | 38 | 8.8% |
| Open | 251 | 57.8% |
| Duration of surgery Mean (hours) | 5.92 | |
| Standard deviation (SD) | 2.66 | |
| Range | 1.00–15.65 | |
| Blood loss (mls) Mean | 460.9 | |
| Standard deviation (SD) | 553.0 | |
| Range | 0–3300 | |
| Units of RBCs given intra-op None | 282 | 65.0% |
| 1–2 units | 99 | 22.8% |
| > 2 units (3–9 units) | 53 | 12.2% |
| POD1 Hgb (g/dl) Mean | 10.51 | |
| Standard deviation (SD) | 1.74 | |
| Range | 1.8–17.6 | |
| POD1 Anaemia No (Hgb > 13 g/dl) | 31 | 7.1% |
| Mild (Hgb = 10–13 g/dl) | 251 | 57.8% |
| Moderate (Hgb < 10 g/d) | 152 | 35.0% |
| Post-op transfusion given RBCs | 119 | 27.4% |
| Platelets | 12 | 2.8% |
| Fresh frozen plasma | 37 | 8.5% |
| Cryoprecipitate | 2 | 0.5% |
| Units of RBCs given post-op None | 315 | 72.6% |
| 1–2 units | 88 | 20.3% |
| > 2 units (3–9 units) | 31 | 7.1% |
| Overall transfusions given RBCs | 222 | 51.2% |
| Other blood products | 60 | 13.8% |

**Table 2** Post-operative complications

| | Number, *n* | Percentage, % |
|---|---|---|
| Total number of patients | 434 | 100.0% |
| Myocardial infarction | 30 | 6.9% |
| Stroke within 30 days | 2 | 0.5% |
| Deep venous thrombosis | 3 | 0.7% |
| Pulmonary embolism | 19 | 4.4% |
| Mesenteric thrombosis | 4 | 0.9% |
| Any venous thrombotic event | 15 | 3.5% |
| Death | 10 | 2.3% |
| ANY CV complication[a], excluding death | 44 | 10.1% |
| ANY CV complication, including death | 46 | 10.6% |
| # of complications[a] 0 | 388 | 89.4% |
| 1 | 28 | 6.5% |
| 2 | 14 | 3.2% |
| 3 | 1 | 0.2% |
| 4 | 1 | 0.2% |
| 5 | 2 | 0.5% |
| CV complication[a] in patients who died | 8 | 80.0% |
| CV complication[a] in patients who survived | 36 | 8.5% |

*CV* cardiovascular or thromboembolic event

**Table 3** Comparing patients who are vs. are not transfused RBCs (intra and/or post-op)

| | **Not transfused** | | **Transfused** | | **Inter-group difference** | |
|---|---|---|---|---|---|---|
| Variable | *N* | % | *N* | % | Test statistic | Significance |
| Number of patients | 231 | 53.2% | 203 | 46.8% | | |
| Age | | | | | | |
| Mean (years) | 52.8 | | 58.2 | | MWU = 0.78; df = 1 | *p* = 0.46 |
| Age categories < 20 years | 5 | 2.2% | 3 | 1.5% | χ2 = 8.40; df = 4 | *p* = 0.078 |
| 20–39 years | 50 | 21.6% | 32 | 15.8% | | |
| 40–59 years | 102 | 44.2% | 77 | 37.9% | | |
| 60–79 years | 66 | 28.6% | 84 | 41.4% | | |
| 80–99 years | 8 | 3.5% | 7 | 3.4% | | |
| Gender | | | | | | |
| Female | 93 | 40.3% | 116 | 57.1% | χ2 = 12.34; df = 1 | ***p* < 0.001** |
| Male | 108 | 46.8% | 87 | 42.9% | | OR = 1.98 (1.35, 2.90) |
| Body mass index (BMI) | | | | | | |
| Mean | 26.5 | | 24.9 | | MWU = 3.09; df = 1 | *p* = 0.11 |
| < 18.5 kg/m$^2$ | 9 | 3.9% | 21 | 10.3% | χ2 = 12.66; df = 5 | ***p* = 0.027** |
| 18.5–24.9 | 84 | 36.5% | 87 | 42.9% | | |
| 25.0–29.9 | 75 | 32.6% | 48 | 23.6% | | |
| 30–34.9 | 46 | 20.0% | 30 | 14.8% | | |
| 35.0–39.9 | 13 | 5.7% | 13 | 6.4% | | |
| ≥ 40.0 | 3 | 1.3% | 4 | 2.0% | | |
| Comorbidities | | | | | | |
| Diabetes mellitus | 55 | 23.9% | 66 | 32.5% | χ2 = 4.07; df = 1 | ***p* = 0.044** OR = 1.54 (1.01, 2.35) |
| Hypertension | 65 | 28.3% | 70 | 34.5% | χ2 = 2.03; df = 1 | *p* = 0.15 |
| Ischaemic heart dz | 11 | 4.8% | 17 | 8.4% | χ2 = 2.34; df = 1 | *p* = 0.13 |
| Heart failure | 4 | 1.7% | 3 | 1.5% | χ2 = 0.04; df = 1 | *p* = 0.83 |
| ASA status | | | | | | |
| Class I | 24 | 10.4% | 7 | 3.4% | χ2 = 21.64; df = 3 | ***p* < 0.001** |
| Class II | 140 | 60.9% | 97 | 47.8% | | |
| Class III | 63 | 27.4% | 94 | 46.3% | | |
| Class IV | 4 | 1.7% | 5 | 2.5% | | |
| Pre-op hemoglobin | | | | | | |
| Mean (g/dL) | 11.81 | | 9.78 | | *t* = 2.37; df = 432 | ***p* < 0.001** |
| ≥ 12 g/dL | 134 | 58.0% | 48 | 23.6% | χ2 = 61.39; df = 3 | ***p* < 0.001** |
| 10–11.9 g/dL | 68 | 29.4% | 79 | 38.9% | | |
| 8–9.9 g/dL | 27 | 11.7% | 67 | 33.0% | | |
| < 8 g/dL | 2 | 0.9% | 9 | 4.4% | | |
| Pathology | | | | | | |
| Benign disease | 71 | 30.7% | 34 | 16.7% | χ2 = 11.53; df = 1 | ***p* < 0.001** |
| Malignant disease | 160 | 69.3% | 169 | 83.3% | | OR = 2.21 (1.39, 3.50) |
| Type of surgery | | | | | | |
| Laparoscopic surgery | 101 | 43.7% | 44 | 21.7% | χ2 = 25.47; df = 2 | ***p* < 0.001** |
| Laparoscopic converted to open surgery | 21 | 9.1% | 17 | 8.4% | | |
| Open surgery | 109 | 47.2% | 142 | 70.0% | | |
| Scheduled for laparoscopic surgery | 122 | 52.8% | 61 | 30.0% | χ2 = 22.96; df = 1 | ***p* < 0.001** |
| Scheduled for open surgery | 109 | 47.2% | 142 | 70.0% | | OR = 2.61 (1.75, 3.87) |
| Received pre-op RBC transfusion | | | | | | |
| Yes | 19 | 8.2% | 42 | 20.7% | χ2 = 13.90; df = 1 | ***p* < 0.001** |

**Table 3** (continued)

| | Not transfused | | Transfused | | Inter-group difference | |
|---|---|---|---|---|---|---|
| No | 212 | 91.8% | 161 | 79.3% | | OR = 2.91 (1.63, 5.20) |
| Duration of surgery (minutes) Mean | 323.29 | 1.39952381 | 376.73 | 1.855812808 | MWU = 4.90; df = 1 | ***p* = 0.027** |
| Intra-operative blood loss (ml) Mean | 251.71 | | 695.32 | | *t* = 8.50; df* = 253 | ***p* < 0.001** |

The results are significant because the *p* value is less than 0.05

during or after surgery (OR = 2.61; 1.75–3.87). Patients who received a transfusion also had a much greater volume of intra-operative blood loss (695 vs. 252 ml). Patients whose pre-operative serum Hgb level was 12 g/dL or higher were more than twice as likely to not receive as receive a transfusion, while those with pre-operative Hgb levels from 8.0 to 9.9 g/dL were three times more likely than not to receive blood, and those with a pre-operative Hgb under 8.0 g/dL almost five times as likely as not. Myocardial infarction (MI) was the only complication that showed a significant difference between both groups. Of those transfused 19% (25 patients) had a post-operative MI compared to 2.8% (8 patients) who did not receive a transfusion ($p = 0.02$).

Table 4 performs the same comparisons as summarized in Table 3, but compares patients who have transfused two or fewer units of RBCs (including patients who received no transfusions) against patients who received more than two. Comparing these two groups, those receiving more than two units of RBCs also averaged a significantly lower pre-operative serum Hgb level, than patients whose pre-operative Hgb was 12 g/dL or higher. Patients with Hgb levels from 8 to 9.9 were twice as likely and under 8.0 were six times as likely to receive RBCs as not. As with any transfusion, those receiving > 2 units also were more likely to have been scheduled for open surgery and had more than three times the volume of intra-operative blood loss.

On multivariable analysis, receiving a transfusion of RBCs was statistically linked to volume of intra-operative blood loss and Hgb level (both $p < 0.001$); as well as to pre-operative body mass index (BMI), with patients who were under-weight and normal rate most at risk, and patients with a BMI between 25 and 35 less likely than not. Duration of surgery also remained in the model, with each added 5-min interval increasing the odds of a transfusion by 1%. Scheduled open surgery and patient age were the final two factors that remained in the model, with patients in the 60- to 79-year-old category at greatest risk.

The results of multivariable analysis for receiving > 2 units of RBCs found that the volume of intra-operative blood loss and pre-operative serum Hgb level were the two most significant predictors (both $p < 0.001$), with diabetes mellitus the only other predictor to remain. Having diabetes increased the odds of receiving > 2 units by roughly 140%.

Table 5 summarizes the results of the analysis comparing the 56 patients receiving RBCs whose POD1 serum Hgb level was > 11 g/dL (hence, meeting our criterion for over-transfused) against the 156 in whom it was 11 g/dL or lower. The only factor that distinguished these two groups at a Bonferroni-adjusted $p$ level < 0.001 was the pre-operative serum Hgb level, which was 1.5 g/dL higher in those who were over-transfused. The volume of blood loss did not differ significantly between these two patient groups.

## Discussion

In this study, we identified several factors that increase the risk of perioperative blood transfusion. Key patient factors include low preoperative hemoglobin, diabetes mellitus, female gender, high ASA score, malignant pathology, and a BMI below 24.9. Additionally, surgical factors such as the length of surgery, volume of blood loss, and scheduled open procedures play a significant role. While we can modify some of these factors before surgery, others remain constant. These factors can be used to develop a scoring system that guides perioperative management. Furthermore, our study findings can be used to develop intraoperative recommendations for patients at high risk of transfusion. These recommendations may include measures to improve hemostasis, such as the use of tranexamic acid, and strategies to reduce blood loss, such as minimally invasive surgery.

In our study, we found that anemia was the strongest risk factor for transfusion. Preoperative anemia affects 47–52% of patients undergoing colorectal surgery and often results from malnutrition, chronic disease, or gastrointestinal bleeding (Ristescu et al. 2019; Kwon et al. 2019). We found patients with preoperative anemia are three times more likely to need more than two units of PRBC compared to those without. Previous research shows that 59% of surgeons believe anesthetists and pre-admission clinics should manage preoperative anemia (Alamri et al. 2018). However, treating anemia in the pre-anesthesia clinic requires a multidisciplinary team, including anesthesia, surgery, hematology, and a dietitian, as well as sufficient time before the scheduled surgery. Current recommendations suggest delaying surgery

**Table 4** Comparing patients who are transfused versus not transfused > 2 units of RBCs

| | **0–2 units RBCs transfused** | | **> 2 units RBCs transfused** | | **Inter-group difference** | |
|---|---|---|---|---|---|---|
| Variable | *N* | % | *N* | % | Test statistic | Significance |
| Number of patients | 341 | | 93 | | | |
| Age Mean (years) | 53.2 | | 54.9 | | MWU = 0.018 | *p* = 0.89 |
| Age categories < 20 years | 7 | 2.1% | 1 | 1.1% | $\chi2 = 1.69$; df = 4 | *p* = 0.79 |
| 20–39 years | 68 | 19.9% | 14 | 15.1% | | |
| 40–59 years | 138 | 40.5% | 41 | 44.1% | | |
| 60–79 years | 116 | 34.0% | 34 | 36.6% | | |
| 80–99 years | 12 | 3.5% | 3 | 3.2% | | |
| Gender Female | 157 | 46.0% | 52 | 55.9% | $\chi2 = 2.85$; df = 1 | *p* = 0.090 |
| Male | 184 | 54.0% | 41 | 44.1% | | |
| Body mass index (BMI) Mean | 26.5 | | 25.6 | | MWU = 1.01 | *p* = 0.32 |
| BMI categories < 18.5 kg/m$^2$ | 20 | 5.9% | 10 | 10.8% | $\chi2 = 7.17$; df = 3 | *p* = 0.21 |
| 18.5–24.9 | 132 | 38.8% | 39 | 41.9% | | |
| 25.0–29.9 | 103 | 30.3% | 20 | 21.5% | | |
| 30–34.9 | 59 | 17.4% | 17 | 18.3% | | |
| 35.0–39.9 | 22 | 6.5% | 4 | 4.3% | | |
| ≥ 40.0 | 4 | 1.2% | 3 | 3.2% | | |
| Comorbidities Diabetes mellitus | 85 | 24.9% | 36 | 38.7% | $\chi2 = 6.90$; df = 1 | ***p* = 0.009** OR = 1.90 (1.17, 3.09) |
| Hypertension | 103 | 30.2% | 32 | 34.4% | $\chi2 = 0.60$; df = 1 | *p* = 0.44 |
| Ischaemic heart dz | 18 | 5.3% | 10 | 10.8% | $\chi2 = 3.63$; df = 1 | *p* = 0.057 |
| Heart failure | 6 | 1.8% | 1 | 1.1% | $\chi2 = 0.22$; df = 1 | *p* = 0.64 |
| ASA status Class I | 28 | 8.2% | 3 | 3.2% | $\chi2 = 14.95$; df = 3 | ***p* = 0.002** |
| Class II | 198 | 58.1% | 39 | 41.9% | | |
| Class III | 108 | 31.7% | 49 | 52.7% | | |
| Class IV | 7 | 2.1% | 2 | 2.2% | | |
| Pre-op hemoglobin Mean (g/dL) | 11.8 | | 10.5 | | *t* = 5.63; df = 432 | ***p* < 0.001** |
| Pre-op hemoglobin > 12 g/dL | 162 | 47.5% | 20 | 21.5% | $\chi2 = 33.96$; df = 3 | ***p* < 0.001** |
| 10–11.9 g/dL | 114 | 33.4% | 33 | 35.5% | | |
| 8–9.9 g/dL | 61 | 17.9% | 33 | 35.5% | | |
| < 8 g/dL | 4 | 1.2% | 7 | 7.5% | | |
| Benign disease | 91 | 26.7% | 14 | 15.1% | $\chi2 = 5.39$; df = 1 | ***p* = 0.020** |
| Malignant disease | 250 | 73.3% | 79 | 84.9% | | |
| Laparoscopic surgery | 131 | 38.4% | 14 | 15.1% | $\chi2 = 18.95$; df = 2 | ***p* < 0.001** |
| Laparoscopic converted to open surgery | 30 | 8.8% | 8 | 8.6% | | |
| Open surgery | 180 | 52.8% | 71 | 76.3% | | |
| Scheduled for laparoscopic surgery | 161 | 47.2% | 22 | 23.7% | $\chi2 = 16.63$; df = 1 | ***p* < 0.001** |
| Scheduled for open surgery | 180 | 52.8% | 71 | 76.3% | | |
| Anesthesia General only | 99 | 29.0% | 19 | 20.4% | $\chi2 = 2.73$; df = 1 | *p* = 0.098 |
| General and epidural | 242 | 71.0% | 74 | 79.6% | | |
| Received pre-op RBC transfusion Yes | 40 | 11.7% | 21 | 22.6% | $\chi2 = 7.12$; df = 1 | ***p* = 0.008** |
| No | 301 | 88.3% | 72 | 77.4% | | |
| Duration of surgery (minutes) Mean | 332.48 | 1.439307359 | 406.24 | 2.001182266 | MWU = 4.94; df = 1 | ***p* = 0.026** |
| Intra-operative blood loss (mls) Mean | 298.96 | | 1046.77 | | *t* = 8.22; df* = 97 | ***p* < 0.001** |

The results are significant because the *p* value is less than 0.05

**Table 5** Comparing outcomes in patients who are over-transfused versus not

| | Not over-transfused | | Over-transfused | | Significance |
|---|---|---|---|---|---|
| Variable | *N* | % | *N* | % | *p* |
| Demographic and clinical characteristics | | | | | |
| Number of patients | 144 | 72.0% | 56 | 28.0% | |
| Age (years) Mean | 55.84 | | 55.04 | | $p = 0.52$ |
| Females | 87 | 60.4% | 27 | 48.2% | $p = 0.12$ |
| Males | 57 | 39.6% | 29 | 51.8% | |
| Body mass index (BMI) Mean | 25.32 | | 26.41 | | $p = 0.23$ |
| Number of comorbid conditions Mean | 0.97 | | 0.80 | | $p = 0.47$ |
| Malignant disease = cause for surgery | 121 | 84.0% | 41 | 73.2% | |
| ASA grade Mean | 2.47 | | 2.52 | | $p = 0.79$ |
| Length of surgery (min) Mean | 371.77 | | 400.27 | | $p = 0.35$ |
| Pre-operative serum Hgb (g/dL) Mean | 10.26 | | 11.76 | | ***p* < 0.001** |
| Blood loss (mls) Mean | 676.74 | | 769.64 | | $p = 0.27$ |
| Peri-operative complications | | | | | |
| Myocardial infarction | 24 | 16.7% | 7 | 12.5% | $p = 0.47$ |
| Stroke within 30 days | 2 | 1.4% | 0 | 0.0% | $p = 0.38$ |
| Deep venous thrombosis | 2 | 1.4% | 1 | 1.8% | $p = 0.84$ |
| Pulmonary embolism | 6 | 4.2% | 3 | 5.4% | $p = 0.72$ |
| Mesenteric thrombosis | 1 | 0.7% | 1 | 1.8% | $p = 0.49$ |
| Any venous thromboembolic (VTE) event | 7 | 4.9% | 5 | 8.9% | $p = 0.28$ |
| Number of VTEs, mean | 0.28 | | 0.29 | | $p = 0.93$ |
| Death | 6 | 4.2% | 3 | 5.4% | $p = 0.72$ |
| Number of complications, including death | 0.33 | | 0.34 | | $p = 0.95$ |
| Length of hospital stay post-op (days) Mean | 16.74 | | 17.86 | | $p = 0.18$ |
| Course over first year post-operatively | | | | | |
| Number of ER visits in 1st year post-op Mean | 0.85 | | 1.55 | | $p = 0.11$ |
| Number of surgeries in 1st year post-op Mean | 0.58 | | 0.91 | | $p = 0.22$ |
| Rectal surgery (yes/no) (? Colorectal) | 52 | 36.1% | 17 | 30.4% | $p = 0.54$ |

The results are significant because the *p* value is less than 0.05

for 4–6 weeks, if possible, to correct anemia with parenteral or intravenous iron (Mandal et al. 2023). Yet, recent studies show mixed results on whether iron treatment reduces the transfusion rate despite improving hemoglobin levels (Richards et al. 2020; Scrimshire et al. 2020; Moon et al. 2021; McSorley et al. 2020).

Our findings align with previous studies on patient-related risk factors (Halabi et al. 2013; Nilsson et al. 2002). In addition to anemia and blood loss, diabetes was a strong predictor of blood transfusion. It increases the risk of transfusing > 2 units by 140%. Around a quarter of the Saudi population is diabetic and 78% have a poorly controlled disease (Alsuliman et al. 2006); Robert and Al Dawish 2019). This predisposes them to systemic diseases, such as ischemic heart disease, which is associated with a higher transfusion trigger. Poor glycemic control has been correlated with adverse outcomes in colorectal surgery (Nilsson et al. 2002). Additionally, our findings indicate that a normal to low BMI is highly associated with intraoperative transfusion, likely due to malnutrition. Malnutrition, in turn, exacerbates preoperative anemia and increases the risk of blood transfusion (Garcia et al. 2016; Stang and Cornell 1995). These findings strengthen our previous recommendation of a multidisciplinary team including a dietitian and internist in the perioperative planning team.

We also discovered that 28% of patients received unnecessary transfusions, with hemoglobin levels raised to above 11 mg/dl. Over-transfusion not only wastes hospital resources but also increases the risk of post-operative complications (Halabi et al. 2013; Kwon et al. 2019). We found that these patients often begin surgery with a higher hemoglobin. This over-transfusion can be explained by anesthetists' tendency to rely on patients' comorbidities, hemodynamics, and visual estimation of blood loss to make transfusion decisions. It has led to a wide variation in practice (Aquina et al. 2016). In instances of sudden massive intraoperative blood loss, anesthetists often transfuse patients without evaluating preoperative hemoglobin levels. Additionally, the excessive administration of intravenous crystalloids can cause hemodilution, which may mimic anemia and lead to unnecessary transfusions. Implementing enhanced recovery after surgery (ERAS) protocols can mitigate these issues by emphasizing point-of-care testing for blood replacement, individualized fluid management plans, and avoidance of overhydration (Peden et al. 2023; ( (Gustafsson et al. 2018).

This study has limitations due to its retrospective nature. We did not review surgical notes or anesthesia records. We therefore may have missed other factors that influence transfusion, such as tumor size, cancer stage, location, or vascular injury. Intraoperative hemoglobin is measured using the portable arterial blood gas monitor at our hospital and is not entered into the electronic patient database. Our hospital does not have a thromboelastogram or rotational thromboelastometry. We were therefore unable to include these variables in our results. These results may not apply to all settings as they reflect our surgeons' surgical techniques, hospital resources, patient population, and non-colorectal surgeries. Therefore, when applying our results to other centers, it is essential to consider these differences. In areas with a strong healthcare system, the prevalence of anemia requiring correction may be lower. In contrast, under-resourced regions may see more patients with anemia and late-stage disease, making preoperative correction less feasible. In addition, facilities with easy access to blood products can afford a lower threshold for surgical interventions, knowing that transfusions are readily available. However, in locations where blood is scarce, more conservative blood management strategies are necessary with an emphasis on preoperative optimization. More research is required to study the effect of preventive strategies on perioperative blood utilization as well as the barriers to their implementation in different populations.

In conclusion, we identified several modifiable and non-modifiable risk factors for perioperative blood transfusion in colorectal surgery. The most significant risk factors include preoperative anemia, diabetes, low BMI, and blood loss. Addressing these factors through the development of clinical pathways and protocols, starting from the preoperative clinic and optimizing intraoperative management, may help conserve blood products and reduce the need for transfusions. Further prospective research is required to confirm these results and improve transfusion risk evaluations and perioperative management.

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**Authors' contributions**
SF: sole author: Conception, data collection, analysis, writing.

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**Availability of data and materials**
Available on request.

**Data availability**
No datasets were generated or analysed during the current study.

## Declarations

**Ethics approval and consent to participate**
King Abdulaziz University Department of Research Ethics (Reference No 515-23).

**Consent for publication**
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**Competing interests**
The authors declare no competing interests.

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## Publisher's Note