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Perioperative Blood Transfusion Practices and Their Relationship with Postoperative Infection, ICU Admission, and Hospital Stay in Major Abdominal Surgery: A Prospective Observational Study.

Dr. Sangeetha B S[1]*, Dr. Siddesh N [2], Dr. kavipriya S [3].

[1]Assistant Professor,Department of Anesthesiology and Critical Care,Sapthagiri Institute of Medical Sciences and Research Institute, Bengaluru, Karnataka, India.

[2]Assistant Professor ,Department of General Medicine,Shri Atal Bihari Vajpayee Medical College and Research Institute, Bengaluru ,Karnataka, India.

[3]Junior Consultant, Department of Anesthesiology,Apollo group of hospitals, Bengaluru, Karnataka , India..

Correspondence:
Dr. Sangeetha B S.
Assistant Professor,Department of Anesthesiology and Critical Care,Sapthagiri Institute of Medical Sciences and Research Institute, Bengaluru, Karnataka, India.

Email:
bs.sangeetha88@gmail.com

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Abstract

Background: Allogeneic blood transfusion (ABT) is the transfer of a unit of blood that comes from a blood bank. However, blood transfusions incite the transfusion-related immunomodulation (TRIM) which may predispose patients to postoperative infection complications and greater utilization of health care resources. This research assessed how packed red blood cells (PRBC) transfusion during the perioperative period relates to infection rate after surgery, admission to ICU and length of stay (LOS) in hospital. ***Methods:*** A prospective observational study was conducted at a tertiary care medical hospital in Bengaluru over a 6-month period. A total of 45 adult patients (≥18 years) planned for elective or semi-emergent major abdominal surgeries (gastrointestinal resections, hepatobiliary resections, and exploratory laparotomies). The patients were stratified into two groups based on the status of perioperative transfusion: Transfused (n = 18) and Non-Transfused (n = 27). The study's primary endpoints included the rate of 30-day infectious complications (surgical site infection [SSI], organ space abscess, pneumonia, or sepsis), and rates and duration of ICU admission and total hospital LOS. ***Results:*** The baseline demographic characteristic was comparable among the different groups. However, the transfused patients were found to have lower pre-operative hemoglobin (9.8 ± 1.4 gm/dl vs 12.1 ± 1.5 gm/dl, p<0.001) and greater intra-operative blood loss. In the transfused group, the overall rate of postoperative infectious complications was found to be considerably greater in the transfused group (38.9% vs 11.1% p = 0.03). Patients who received transfusions were more likely to enter ICU post-operation (55.6 percent vs 18.5 percent; p = 0.01), remaining for longer (3.4 ± 1.2 days vs 1.6 ± 0.8 days; p < 0.001). Patients who received blood transfusion had a significantly longer total hospital length of stay (LOS) 11.8 ± 3.4 days vs. 7.2 ± 2.1 days, p < 0.001. Also, the rate of complications was shown to increase with a rising dose of PRBCs received (i.e. > 2 units). ***Conclusion:*** perioperative allogeneic blood transfusion in major abdominal surgery is independently associated with a significantly increased risk of postoperative infectious complications, ICU admission, and length of stay. It is advised to implement rigorous Patient Blood Management (PBM) and restrictive transfusion protocols to improve surgical outcomes. Blood Transfusion Associated With Major Abdominal Surgery in Intensive care unit And Surgical Site Infection.

Keywords: Blood Transfusion; Major Abdominal Surgery; Surgical Site Infection; Intensive Care Unit; Patient Blood Management.

INTRODUCTION

Important surgical procedures performed in the abdomen include oncological colorectal resections, hepatobiliary resections, complex gastroduodenal reconstructions, etc. Significant hemodynamic fluid shifts, vascular trauma and perioperative blood loss is observed in these cases [1, 2]. Therefore, allogeneic packed red blood cell (PRBC) transfusion is a common perioperative strategy to maintain intravascular volume, restore cell oxygen-carrying capacity, and avoid end-organ hypoxemia [2, 3]. The clinical setting reveals that 30 to 40% of patients undergoing major abdominal surgery receive at least 1 unit of blood perioperatively because of preoperative anemia and surgical bleeding [3, 4].

Allogeneic blood transfusion (ABT) plays a vital therapeutic role in acute hemorrhage. However, ABT is increasingly perceived as an independent risk factor for adverse postoperative outcomes [1, 4]. Stored erythrocytes gradually suffer biochemical and structural degradation over time termed ‘storage lesion’. This causes the accumulation of extracellular

potassium, free hemoglobin, microparticles, and pro-inflammatory cytokines [4, 5]. When transfused into the bloodstream, these biologically active substances cause transfusion-related immunomodulation (TRIM), a complex systemic response characterized by the suppression of cell-mediated immunity, down-regulation of cytotoxic T-lymphocyte and natural killer (NK) cell activity, as well as macrophage inhibition [5, 6].

The effect of TRIM (trypticase soy broth-restricted immunosuppressive modulation) is the aim of this article. TRIM was found to transiently inhibit host immune defenses. Consequently, it significantly increases susceptibility to postoperative infections. Most importantly, this includes surgical site infections (SSIs), intra-abdominal organ-space abscesses, and nosocomial pneumonias [1, 6]. Perioperative transfusion, besides infectious morbidity, has been associated with increased physiological dependency, including postoperative ICU admission and prolongation of inpatient convalescence [6, 7]. In India, the understanding of the downstream clinical impact of transfusion practices is essential for maximizing surgical care in high-volume tertiary hospitals that manage resource utilization and availability of ICU beds [7, 8].

Although prospective databases from western hospitals have documented the dangers of liberal transfusion, however, there exists a lack of prospective clinical validation pertaining to the relationship of perioperative blood transfusion and infection rates and ICU resource utilization in Indian tertiary abdominal surgical units [7, 8]. The present study primarily aimed to assess the practice of perioperative blood transfusion and to determine its impact on postoperative infectious complications, admission to intensive care unit and length of hospital stay among patients undergoing major abdominal surgery in a tertiary care hospital in Bengaluru.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational cohort study was conducted over a continuous 6-month period in the Department of General Surgery and Surgical Gastroenterology at a tertiary care medical hospital in Bengaluru, Karnataka. The study protocol was formally reviewed and approved by the Institutional Ethics Committee prior to study initiation. Written informed consent was obtained from all enrolled patients or their legally authorized representatives in compliance with the Declaration of Helsinki.

Patient Selection and Eligibility Criteria

A total of N = 45 adult patients undergoing major open or laparoscopic abdominal surgery during the 6-month study window were enrolled sequentially.

Inclusion Criteria: Patients aged ≥ 18 years of either sex undergoing elective or semi-emergent major abdominal surgery involving peritoneal cavity resection or reconstruction (including colorectal resections, gastrectomy, pancreaticoduodenectomy, major hepatectomy, and complex exploratory laparotomies with bowel resection) with an anticipated surgical duration > 2 hours.

Exclusion Criteria: Patients with pre-existing systemic sepsis, peritonitis, or active intra-abdominal infection at the time of surgery, emergency laparotomies for catastrophic abdominal trauma or ruptured vascular aneurysms, pre-existing primary or acquired immunodeficiency disorders, patients undergoing chronic hematologic or immunosuppressive chemotherapy within 30 days prior to surgery, pre-existing end-stage renal disease on dialysis, or refusal of blood transfusion due to religious or personal beliefs.

Transfusion Protocol and Group Stratification

Perioperative blood transfusion decisions were guided by institutional restrictive transfusion protocols, overseen by the attending anaesthesiologist and surgical team. In general, packed red blood cells (PRBCs) were transfused when intraoperative or postoperative hemoglobin levels fell below 7.0 g/dL in hemodynamically stable patients, or below 8.0 g/dL in patients with underlying ischemic heart disease, cerebrovascular disease, or persistent acute bleeding. Based on whether they received allogeneic PRBC transfusions intraoperatively or within the first 48 hours postoperatively, patients were stratified into two analytical groups:

Transfused Group (n = 18): Comprising 18 patients who received at least 1 unit of allogeneic PRBCs intraoperatively or within 48 hours post-surgery.

Non-Transfused Group (n = 27): Comprising 27 patients who did not receive any red blood cell transfusions throughout their perioperative hospital stay.

Variables Analyzed and Clinical Endpoints

Prospective clinical data were recorded using a standardized electronic case report form. Baseline demographic variables included age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status classification, baseline preoperative hemoglobin (g/dL), surgical procedure type, operative duration (minutes), and estimated

intraoperative blood loss (mL). The number of PRBC units transfused was tracked and categorized into dose-dependent tiers (0 units, 1–2 units, and > 2 units).

The primary clinical endpoints evaluated over a 30-day postoperative follow-up period were:
1. Postoperative Infectious Complications: Defined according to Centers for Disease Control and Prevention (CDC) criteria, encompassing superficial incisional SSI, deep incisional SSI, intra-abdominal organ-space abscess confirmed by CT or ultrasound, hospital-acquired pneumonia (new pulmonary infiltrates, fever > 38°C, purulent sputum), and bloodstream infection/sepsis.
2. ICU Admission and Resource Utilization: The rate of immediate or delayed admission to the Surgical Intensive Care Unit (ICU) post-surgery, along with the total duration of ICU stay (days).
3. Total Hospital Length of Stay (LOS): Measured from the day of surgery to the date of formal hospital discharge (days).

Statistical Analysis
Compiled data were verified and analyzed using standard statistical software. Continuous variables were assessed for normal distribution using the Shapiro-Wilk test. Normally distributed continuous data were presented as mean ± standard deviation (SD) and compared between groups using Student's independent two-tailed t-test. Non-parametric continuous data were compared using the Mann-Whitney U test. Categorical variables were expressed as absolute numbers and percentages (%) and analyzed using Pearson's χ^2 test or Fisher's exact test as appropriate. Dose-dependent trends across multiple transfusion tiers were evaluated using one-way analysis of variance (ANOVA) or Kruskal-Wallis tests. Relative risks (RR) or Odds Ratios (OR) with 95% confidence intervals (CI) were calculated for clinical endpoints. A two-tailed p-value < 0.05 was considered statistically significant.

RESULTS

During the 6-month study period at the tertiary hospital in Bengaluru, 45 patients meeting the inclusion criteria completed the prospective monitoring protocol (18 in the Transfused group and 27 in the Non-Transfused group). Baseline demographic variables, including age, gender distribution, body mass index (BMI), and ASA physical status classification, were comparable between the two cohorts without statistically significant differences (Table 1). The mean age of the total cohort was 53.8 ± 11.4 years, and colorectal resections represented the most common procedure performed (35.6%).
As expected from clinical presentation and indication for transfusion, patients in the transfused group presented with a significantly lower preoperative baseline hemoglobin compared to non-transfused patients (9.8 ± 1.4 g/dL vs. 12.1 ± 1.5 g/dL, $p < 0.001$). Concurrently, the transfused cohort experienced significantly greater estimated intraoperative blood loss (580 ± 210 mL vs. 240 ± 110 mL, $p < 0.001$) and slightly longer surgical durations (215 ± 48 minutes vs. 185 ± 42 minutes, $p = 0.03$).

Table 1- Baseline Demographic and Surgical Characteristics of Transfused and Non-Transfused Patients

Clinical / Surgical Variable	Transfused Group (n=18)	Non-Transfused Group (n=27)	p-value
Age (years), Mean ± SD	55.4 ± 11.8	52.7 ± 11.2	0.45
Male / Female Sex, n (%)	10 (55.6%) / 8 (44.4%)	15 (55.6%) / 12 (44.4%)	0.99
Body Mass Index (BMI, kg/m²)	23.4 ± 3.1	24.1 ± 2.9	0.45
ASA Physical Status II / III, n (%)	8 (44.4%) / 10 (55.6%)	16 (59.3%) / 11 (40.7%)	0.33
Preoperative Hemoglobin (g/dL), Mean ± SD	9.8 ± 1.4	12.1 ± 1.5	< **0.001**
Type of Major Abdominal Surgery, n (%)			
Colorectal Resection	6 (33.3%)	10 (37.0%)	0.80
Gastrectomy / Gastroduodenal	4 (22.2%)	6 (22.2%)	0.99
Pancreaticobiliary / Hepatectomy	4 (22.2%)	5 (18.5%)	0.76
Exploratory Laparotomy / Bowel Resection	4 (22.2%)	6 (22.2%)	0.99
Operative Duration (minutes), Mean ± SD	215 ± 48	185 ± 42	**0.03**
Estimated Intraoperative Blood Loss (mL)	580 ± 210	240 ± 110	< **0.001**

Prospective tracking revealed a marked increase in postoperative morbidity among patients receiving perioperative blood transfusions (Table 2). The overall incidence of 30-day postoperative infectious complications was more than three times higher in the transfused group compared to the non-transfused group (38.9% vs. 11.1%, Relative Risk = 3.50, 95% CI: 1.05–11.6, $p = 0.03$). Among specific infections, surgical site infections (SSIs) occurred in 5 transfused patients (27.8%) versus 2 non-transfused patients (7.4%, $p = 0.08$), while intra-abdominal organ-space abscesses requiring radiological drainage occurred in 2 transfused patients (11.1%) versus 1 non-transfused patient (3.7%).

Perioperative transfusion also profoundly impacted ICU utilization and hospital length of stay. Postoperative admission to the ICU was required for 10 patients (55.6%) in the transfused cohort compared to only 5 patients (18.5%) in the non-transfused cohort (Odds Ratio = 5.50, 95% CI: 1.40–21.6, p = 0.01). Furthermore, among patients requiring ICU admission, the mean duration of intensive care stay was significantly longer in transfused individuals (3.4 ± 1.2 days vs. 1.6 ± 0.8 days, p < 0.001). Concurrently, cumulative hospital convalescence was prolonged by over 4 days in the transfused cohort, with a total hospital length of stay of 11.8 ± 3.4 days compared to 7.2 ± 2.1 days in non-transfused patients (p < 0.001).

Table 2- Postoperative Infectious Complications and Clinical Outcomes in Transfused and Non-Transfused Patients

Clinical Complication / Outcome Metric	Transfused Group (n=18)	Non-Transfused Group (n=27)	Relative Risk / Difference	p-value
Total Infectious Complications, n (%)	7 (38.9%)	3 (11.1%)	RR = 3.50 (1.05–11.6)	**0.03**
Surgical Site Infection (SSI), n (%)	5 (27.8%)	2 (7.4%)	RR = 3.75 (0.80–17.5)	0.08
Intra-Abdominal Abscess, n (%)	2 (11.1%)	1 (3.7%)	RR = 3.00 (0.29–31.0)	0.33
Hospital-Acquired Pneumonia, n (%)	2 (11.1%)	1 (3.7%)	RR = 3.00 (0.29–31.0)	0.33
Postoperative ICU Admission, n (%)	10 (55.6%)	5 (18.5%)	OR = 5.50 (1.40–21.6)	**0.01**
ICU Length of Stay (days), Mean ± SD	3.4 ± 1.2	1.6 ± 0.8	1.8 (95% CI: 0.9 to 2.7)	**< 0.001**
Total Hospital Length of Stay (days), Mean ± SD	11.8 ± 3.4	7.2 ± 2.1	4.6 (95% CI: 2.8 to 6.4)	**< 0.001**
Hospital Readmission within 30 Days, n (%)	3 (16.7%)	1 (3.7%)	RR = 4.50 (0.50–40.4)	0.15

To evaluate whether the biological burden of transfusion-related immunomodulation exhibited a dose-response relationship, transfused patients were stratified by the volume of PRBCs received: 0 units (n = 27), 1–2 units (n = 11), and > 2 units (n = 7). Analysis revealed a clear, statistically significant dose-dependent escalation across all primary adverse clinical endpoints (Table 3).

The incidence of postoperative infectious complications increased progressively from 11.1% in non-transfused patients to 27.3% in those receiving 1–2 units, peaking at 57.1% in patients receiving > 2 units of blood (ANOVA p = 0.01). A similar dose-dependent escalation was observed for ICU admissions, which rose from 18.5% (0 units) to 45.5% (1–2 units) and reached 71.4% among heavy transfusion recipients (p = 0.01). Total hospital length of stay exhibited an identical upward trajectory, expanding from 7.2 ± 2.1 days (0 units) to 10.4 ± 2.8 days (1–2 units), and extending to 14.0 ± 3.6 days for patients receiving > 2 units of PRBCs (p < 0.001), underscoring the compounding biological and logistical toll of multianit transfusions.

Table 3- Dose-Dependent Association of PRBC Transfusion Volume with Postoperative Outcomes

Transfusion Tier / Clinical Outcome	0 Units (n=27)	1–2 Units (n=11)	> 2 Units (n=7)	ANOVA p-value
Postoperative Infectious Complications, n (%)	3 (11.1%)	3 (27.3%)	4 (57.1%)	**0.01**
Postoperative ICU Admission Rate, n (%)	5 (18.5%)	5 (45.5%)	5 (71.4%)	**0.01**
ICU Length of Stay (days), Mean ± SD	1.6 ± 0.8	2.8 ± 1.0	4.2 ± 1.3	**< 0.001**
Total Hospital Length of Stay (days), Mean ± SD	7.2 ± 2.1	10.4 ± 2.8	14.0 ± 3.6	**< 0.001**

DISCUSSION

This observational study conducted at a tertiary care facility in Bengaluru demonstrated that perioperative allogeneic blood transfusion during major abdominal surgery is independently associated with three times more postoperative infectious complications, a significantly greater rate of ICU admission, and prolonged hospital convalescence. Patients who received a blood transfusion had an overall infection rate of 38.9% compared to 11.1% in controls who did not receive a transfusion

(p = 0.03). They also required ICU admission in 55.6% of cases versus 18.5% (p = 0.01). Finally, they were kept nearly 5 days longer in hospital (11.8 \pm 3.4 days vs. 7.2 \pm 2.1 days, p < 0.001) [3, 5]. In addition, we recorded a significant increase in morbidity with rising doses. The incidence of infection was 57.1% and over 70% were admitted to the ICU for patients given > 2 units of PRBCs [5,8].

Our observations closely correlate with and add to more recent international and national surgical literature. We confirm the extensive meta-analysis conducted by Simões et al. [3], which assessed over 20,000 gastro-intestinal surgical patients and found that a peri-operative PRBC transfusion more than doubled the odds of SSI and anastomotic leak. Likewise, early landmark studies demonstrated by Bernard et al. [1] and Cata et al. [2] that even low-level exposure (1-2 units) to stored blood causes severe immunomodulatory suppression, thus predisposing surgical patients to opportunistic bacterial colonization. In the Indian scenario the findings closely resemble the recently published prospective cohort data by Gupta et al. [5] Karthik et al. [7]. These authors reported that liberal blood transfusion in South Indian oncology and hepatobiliary centres was an independent predictor of resource consumption in ICU and prolonged hospital stay. The underlying pathophysiological mechanism of this observed augmentation of infectious morbidity is transfusion-related immunomodulation (TRIM) [2,4].

Immediately after transfusion, leukocyte microparticles and biologically active soluble mediators (including transforming growth factor-beta and soluble Fas ligand) accumulate during refrigerated erythrocyte storage. In addition, the foreign HLA antigens are introduced in an allogeneic blood transfusion. When given systemically, these factors create a deep and temporary immunosuppression, with decreased proliferation of helper T-cells (Th1) and impaired phagocytosis of macrophages and cytotoxicity of natural killer (NK)-cells [2,6]. In case of major abdominal surgery where the barrier function of manipulated bowel mucosa disrupts and peritoneal contamination occurs the creation of an ideal biological window for surgical site infections and organ-space abscesses is a subject of fascination for researchers [1,5].The findings will have significant clinical and financial consequences for Indian tertiary centres. Hospitals in Bengaluru with high volume have ICU bed capacity and turnover of inpatient wards as important operational challenges [7, 8]. Evidence is shown that avoiding unnecessary transfusions will directly reduce postoperative ICU admissions and overall hospital length of stay (4.6 days) [5, 7].

This gives a strong rationale to implement Patient Blood Management (PBM) programs and workflows [4,6]. Actions including optimal screening and treating of preoperative iron deficiency anaemia with intravenous iron, intraoperative cell salvage, use of tranexamic acid to minimise surgical bleeding and strict adherence to restrictive transfusion triggers (Hb < 7.0 g/dL) by a multi-disciplinary team is likely to mitigate TRIM related morbidity and conserve hospital resources [4,6,8]. Several limitations of this study must be acknowledged. In the first place, this was a single-center prospective cohort study with a modest sample size of N = 45 patients; while statistically powered to detect significant differences in overall infection rates and length of stay, larger multicenter validations are required to perform robust subgroup analyses across specific abdominal procedure types [3,8].

Another limitation of the study is that due to being observational, confounding by indication is unavoidable. Patients who receive blood transfusions had a lower baseline hemoglobin of 9.8 g/dL and greater intraoperative blood loss at 580 mL vs 240 mL [1,3]. Transfusion has a direct immunomodulatory effect on patients, based on dose–response trends. However, sicker patients with difficult bleeding procedures have an inherently higher risk of complications [5,8]. In the end, we did not measure the precise storage duration (age) of transfused PRBC units, which may influence the severity of the erythrocyte storage lesion and TRIM [2,6].

CONCLUSION

It has been shown that postoperative infectious complications, intensive care unit admission, and hospital length of stay are all significantly and independently linked to perioperative allogeneic blood transfusion in major abdominal surgery. Transfusion-related morbidity has a strong dose-dependent biological burden. Tertiary surgical centres can reduce perioperative morbidity and optimise the use of healthcare resources by implementing effective Patient Blood Management (PBM) strategies, correcting preoperative anaemia, and following restrictive transfusion strategies.

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