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Blood utilization efficiency using the crossmatch-to-transfusion ratio in preoperative and non-preoperative patients

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Abstract

Inefficiencies in blood procurement remain a challenge in transfusion services, potentially leading to unnecessary resource utilization. However, comparative studies on the efficiency of blood use among preoperative and non-preoperative patients remain limited. This study aims to evaluate and compare the efficiency of blood use using the crossmatch-to-transfusion (C/T) ratio indicator in both patient groups at a regional hospital. This study employed a retrospective analytical design based on secondary data from the hospital's blood bank registry. A total of 16,554 units of blood collected over 20 months were used as the sample, selected through a total sampling approach. Data analysis employed descriptive statistics and the paired samples t-test to identify differences between groups. The results indicated that blood usage in preoperative patients tended to be less efficient, with the majority of C/T ratios exceeding the recommended efficiency threshold. In contrast, the C/T ratios for non-preoperative patients remained consistently within the efficient category. Statistical analysis also confirmed significant and meaningful differences between the two groups. The findings underscore the need to implement evidence-based blood ordering strategies, such as the Maximum Surgical Blood Order Schedule (MSBOS) and type-and-screen protocols, to improve efficiency and optimize transfusion practices in clinical care.

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1. Introduction

Blood transfusion services play a crucial role in modern healthcare systems, particularly in supporting high-risk clinical procedures such as surgery, trauma care, and certain hematological conditions. However, limited blood availability is not the only issue. In daily practice, how blood is ordered, processed, and used rationally often becomes a critical factor determining the overall efficiency of the transfusion system (World Health Organization, 2021; Cohn et al., 2020; Shander et al., 2016; Mueller et al., 2019; Clevenger et al., 2015).

Excessive over-ordering still frequently occurs in preoperative patients. Blood that has undergone crossmatching does not always result in a transfusion; rather, it often remains unused and must be returned to the blood inventory system. This situation increases the laboratory's workload and may disrupt blood availability for other patients with more urgent needs (Mahfouz et al., 2019; Kour et al., 2019; Naomi et al., 2021; World Health Organization, 2021; Al-Riyami et al., 2020; Anwar & Shafi, 2018; Berhe et al., 2019). This practice reflects an imbalance between actual clinical needs and decision-making patterns in blood ordering.

To evaluate the efficiency of blood utilization, the Crossmatch-to-Transfusion (C/T) ratio has been used in various studies and transfusion service policies. This ratio compares the amount of blood crossmatched with the amount actually transfused. Values ≤ 2.5 are generally considered an acceptable efficiency threshold. A high C/T ratio often indicates disproportionate ordering relative to clinical needs, leading to inefficiency in the blood service system (Karaca et al., 2020; Kementerian Kesehatan Republik Indonesia, 2014; Kementerian Kesehatan Republik Indonesia, 2015; Golea et al., 2022; Mahar et al., 2021; Saraswati et al., 2019).

Several studies across various countries indicate that this inefficiency is more pronounced in surgical settings. A study in Egypt reported a C/T ratio of 3.5 in preoperative patients, indicating a high level of wastage due to suboptimal implementation of policies such as the Maximum Surgical Blood Order Schedule (MSBOS) and Type and Screen (Mahfouz et al., 2019; International Society of Blood Transfusion, 2021). Similar findings were reported in India, where the overall C/T ratio reached 2.33 and rose to 5.14 in certain departments, reflecting still-significant over-ordering practices (Joon et al., 2024). On the other hand, a study in Nigeria showed more efficient results with a C/T ratio of 1.3, confirming alignment between demand and actual transfusion needs (Anigbogu et al., 2023). These variations suggest that the efficiency of blood use is determined not only by clinical factors but also by institutional policies and healthcare providers' decision-making behaviors. Unfortunately, most previous studies have tended to focus on specific patient groups, particularly preoperative patients, without directly comparing them to non-preoperative groups within the same context. Nevertheless, such comparisons could provide a more comprehensive picture of how clinical contexts influence blood ordering and utilization patterns.

In Indonesia, studies specifically examining efficiency differences between these two groups within a single institution remain relatively limited, although some research has shown variations in C/T ratios by procedure type or patient condition (Naomi et al., 2021). Indicator-based evaluations, such as the C/T ratio, are becoming increasingly relevant amid efforts to promote the implementation of Patient Blood Management (PBM). The WHO (2024) emphasizes the importance of using this indicator as part of a strategy to improve efficiency, reduce waste, and ensure that transfusions are administered appropriately. The issue of efficiency is no longer merely operational but has become part of the agenda for systemic improvement in healthcare quality (World Health Organization, 2024; Kementerian Kesehatan Republik Indonesia, 2014; Kementerian Kesehatan Republik Indonesia, 2015). This study aims to evaluate and compare the efficiency of blood use between preoperative and non-preoperative patients at Buleleng Regional General Hospital using the C/T ratio indicator. This approach is expected to provide an empirical picture of blood usage patterns at the institutional level and also offer a deeper understanding of the dynamics of clinical practices that influence the efficiency of the transfusion system. The study results can serve as a basis for policy development to optimize blood ordering and strengthen patient blood management implementation in hospitals.

2. Method

2.1 Research Design and Participants

This study employed a quantitative, retrospective, cross-sectional design. This design was chosen to describe actual blood usage patterns and to compare two different clinical groups within the same context. The study data were derived from secondary sources, specifically the Blood Service Registry at the Hospital Blood Bank (BDRS) of Buleleng Regional General Hospital, covering the period from February 2024 to September 2025. The study population consisted of all blood products recorded as having undergone crossmatching during that period, totaling 16,554 units. The sample size was determined using a total sampling approach, considering that the entire population could be operationally reached (Subhaktiyasa, 2024b). This approach also provides a more comprehensive picture of blood usage patterns at the institutional level. The 16,554 units of blood products meeting the inclusion criteria were analyzed as the study sample. Inclusion criteria included all blood products recorded as crossmatched with a clear request status, whether for preoperative or non-preoperative preparation. Incomplete data or data lacking information regarding transfusion status were excluded from the analysis to maintain data consistency and validity.

2.2 Instruments and Data Collection

Instrument used retrospective observational data from secondary sources. The variables studied included the number of blood products that underwent crossmatching and the number that were transfused.

These blood product counts were used to calculate the Crossmatch-to-Transfusion (C/T) ratio for each group. The data source was the official blood service registry at the BDRS of Buleleng Regional General Hospital, which is routinely used in transfusion service operations. This data has high validity because it is part of a standardized medical record system. Nevertheless, a verification process was still conducted by comparing the consistency of records across periods to minimize potential administrative errors (Subhaktiyasa, 2024a). Data collection was conducted by the researcher in January 2026, with the researcher's official permission from the hospital. This process took place within the BDRS environment under the supervision of authorized staff, ensuring that data access remained in accordance with applicable institutional procedures. The recorded data included monthly aggregates of the number of crossmatches and transfusions for both preoperative and non-preoperative patients over 20 months.

2.3 Data Analysis

Data analysis was conducted using both descriptive and inferential methods. Descriptive statistics were used to characterize the data, including the total number of crossmatches, the number of transfusions, and the distribution of C/T ratios, with mean, median, standard deviation, minimum, and maximum values reported (Subhaktiyasa et al., 2025). The C/T ratio was calculated as the ratio of the volume of blood products crossmatched to the volume transfused. Subsequently, these values were categorized according to national standards: ≤2.5 as efficient and >2.5 as inefficient (Kementerian Kesehatan Republik Indonesia, 2015). Analysis of differences between the preoperative and non-preoperative groups was conducted using inferential statistical tests. Results of the Shapiro–Wilk test indicated that the data distribution met the assumption of normality; therefore, the analysis proceeded using a paired t-test (Seltman, 2018; van de Schoot & Miočević, 2020). Effect sizes were calculated using Cohen's d to indicate the strength of the observed differences (Cohen, 1988). All analyses were performed using SPSS version 27.

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2.4 Ethical Considerations

Ethical approval was obtained from the Health Research Ethics Committee of Buleleng Regional Hospital under number 005/EC/KEPK-RSB/II/2026. All data used is anonymized secondary data. Personal identifiers, such as patient names and medical record numbers, were removed and replaced with codes to ensure confidentiality. Access to the data was conducted officially with institutional permission. The data is kept confidential and used solely for research purposes.

3. Results and Discussion

3.1 Results

A total of 16,554 units of blood products that underwent crossmatching at the Buleleng Regional General Hospital Blood Bank (BDRS) during the study period were analyzed in this study. 4,063 units (24.5%) were requested for preoperative preparation, while 12,491 units (75.5%) fell into the non-preoperative category. The Crossmatch-to-Transfusion (C/T) ratio was calculated monthly. The results of the descriptive analysis of the C/T ratio are presented in Table 1.

Table 1. Descriptive analysis of C/T ratio values

Variable	Mean	SD	Median	Min	Max
Preoperative C/T ratio	3.33	0.90	3.40	1.50	4.93
Non-Preoperative C/T ratio	1.08	0.05	1.08	1.02	1.17

Table 1 describes that the non-preoperative group had a mean C/T ratio of 1.08 with a relatively small standard deviation. The narrow range of values indicates consistency in the data across observation periods. All recorded values fell within a low range with minimal variation. In contrast, the preoperative group had a higher mean C/T ratio (3.33) and a larger standard deviation. The minimum and maximum values showed a much wider range than in the non-preoperative group. This variation reflects fluctuations in C/T ratios in the preoperative group during the observation period. Furthermore, the distribution of efficiency levels based on compliance with the C/T ratio threshold (≤2.5) is presented in Table 2.

Table 2. Comparison of blood request efficiency levels

Category	Efficient (Months)	Efficient (%)	Inefficient (Months)	Inefficient (%)
Preoperative C/T ratio	3	15	17	85
Non-Preoperative C/T ratio	20	100	0	0

Table 2 shows that in the preoperative group, only a small portion of the observation period met the efficiency criteria. Most of the observation months fell outside the established efficiency limits. In contrast, the non-preoperative group exhibited a different pattern, in which the entire observation period met the efficiency criteria. To test the differences between the two groups, an inferential statistical analysis was conducted and is presented in Table 3. The Shapiro–Wilk normality test indicates that the data are normally distributed ($p > 0.05$).

Table 3. Results of the paired samples t-test and effect size

Mean Difference	SD of Difference	effect size (Cohen's d)	95% Confidence Interval	t-value	df	Sig. (2-tailed)
2.24550	0.91294	2.46	1.818–2.673	11	19	0.000

Table 3 confirms a difference in the mean C/T ratio between the two groups. The p-value is below the set threshold ($p < 0.05$), and the 95% confidence interval does not cross zero. Furthermore, the effect size indicates a large magnitude of difference. The confidence interval range demonstrates the consistency of the difference between groups throughout the observation period. The temporal development of the C/T ratio values during the study period is presented in Figure 1.

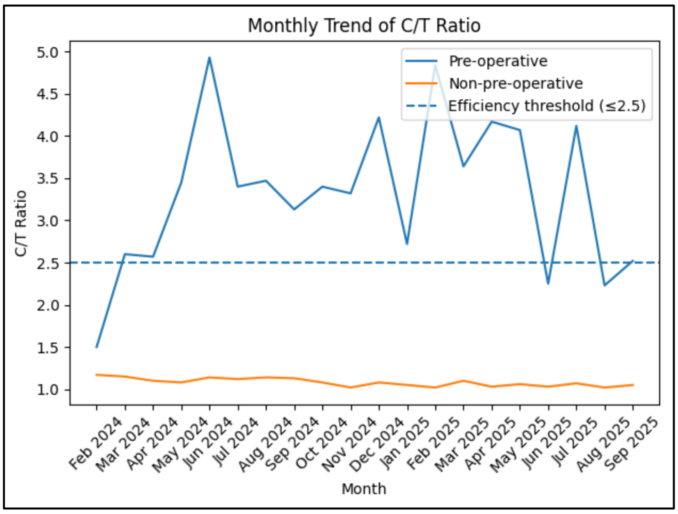

Figure 1. Monthly trends in the C/T ratio in the preoperative and non-preoperative groups

Figure 1 shows that the C/T ratio values in the non-preoperative group tended to remain within a narrow range throughout the observation period. Fluctuations from month to month are relatively small. Meanwhile, the preoperative group shows greater variation with several increases in values during specific periods. This pattern reveals differences in the distribution of values between the groups throughout the observation period.

3.2 Discussion

The study aimed to evaluate and compare blood utilization efficiency between the preoperative and non-preoperative groups using the Crossmatch-to-Transfusion (C/T) ratio as an indicator. The findings revealed consistent differences between the two groups, indicating that the clinical context plays a significant role in determining blood ordering and utilization patterns. The non-preoperative group exhibited a relatively stable pattern of blood use with minimal variation throughout the observation period. This better aligns clinical needs with blood ordering decisions. In practice, non-preoperative situations are often associated with acute conditions or clearer indications for transfusion, leading to more targeted clinical decisions. These findings align with previous reports indicating that blood use in non-elective settings tends to be more rational, as it is based on immediate, measurable needs (Anigbogu et al., 2023). Conversely, the patterns observed in the preoperative group appear more complex. Wider variations in C/T ratio values indicate fluctuations in blood ordering practices. Some cases indicate that blood requests during the preoperative phase are made as a precaution against potential bleeding during surgery. However, not all surgical procedures actually require transfusion, so some of the crossmatched blood goes unused. This phenomenon has been widely reported in the literature as a form of over-ordering influenced by a risk-averse clinical approach (Mahfouz et al., 2019; Kour et al., 2019; Kaur et al., 2013).

The patterns of inefficiency in the preoperative setting in this study are consistent with those observed across various countries. A study in Egypt reported relatively high C/T ratios in surgical patients due to suboptimal implementation of policies such as the Maximum Surgical Blood Order Schedule (MSBOS) (Mahfouz et al., 2019). Similarly, a study in India demonstrated significant variation across departments, reflecting differences in clinical practices and local policies regarding blood ordering (Joon et al., 2024). These similarities suggest that the issue of blood use efficiency is not merely a local concern but part of a systemic challenge in transfusion services (Mueller et al., 2019).

Differences between preoperative and non-preoperative groups can also be understood within the framework of clinical decision-making behavior. Uncertainty regarding potential bleeding often prompts healthcare providers to order blood in quantities exceeding actual needs. While this approach aims to enhance patient safety, in practice, it can contribute to systemic inefficiencies. These conditions reinforce the view that behavioral and institutional policy aspects play a role just as important as clinical factors in determining the efficiency of blood use (World Health Organization, 2021; Naomi et al., 2021; Mulyantari & Yasa, 2016).

Furthermore, the results of this study have important implications for strengthening the implementation of Patient Blood Management (PBM). The WHO emphasizes that optimizing blood use depends not only on resource availability but also on the healthcare system's ability to manage unnecessary demand through evidence-based approaches (World Health Organization, 2024). Therefore, indicators such as the C/T ratio can serve as effective evaluation tools to identify areas requiring improvement in blood ordering practices (Vibert & Spahn, 2017; Clevenger et al., 2015).

These findings also highlight the critical role of Hospital Blood Banks (HBBs) in managing the efficiency of blood use. Crossmatching procedures that are not followed by a transfusion not only increase the laboratory's workload but also impact reagent usage, working hours, and blood stock management. This understanding underscores the need for more structured strategies, such as the implementation of the Maximum Surgical Blood Order Schedule (MSBOS) and "type and screen" policies, to ensure that every blood request truly aligns with clinical needs (Kementerian Kesehatan Republik Indonesia, 2015; Cohn et al., 2020). Findings indicate that the clinical context and prevailing ordering practices significantly influence the efficiency of blood use. Consistent differences between the preoperative and non-preoperative groups underscore the importance of a more targeted approach to managing blood requests, particularly in elective settings. In the long term, these efforts contribute to the efficiency of the transfusion service system and also to improved healthcare quality.

4. Conclusion

The study suggests that blood use efficiency, as measured by the Crossmatch-to-Transfusion (C/T) ratio, shows consistent differences between the preoperative and non-preoperative groups. This pattern points to variations in blood ordering practices across different clinical settings. The findings confirm an imbalance between blood demand and utilization in the preoperative setting. Efficiency is not only determined by medical needs but is also influenced by decision-making approaches and institutional policies. The results also reinforce the importance of implementing Patient Blood Management (PBM) and using indicators such as the C/T ratio as evaluation tools to improve the quality and efficiency of blood transfusion services. This understanding can serve as a basis for developing hospital policies, particularly to optimize blood ordering procedures through a more rational, evidence-based approach. However, this study has limitations related to the use of secondary data from a single institution. Therefore, future research is recommended to explore more specific clinical factors, including types of surgical procedures and patient characteristics, as well as to involve multi-center studies to obtain a more comprehensive picture of the efficiency of blood use across various healthcare services.

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Conflict of Interest

The authors declare no conflict of interest.

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