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Blood Component Utilization Pattern and Crossmatch-to-Transfusion Ratio in a Tertiary Care Hospital: An Ambispective Blood Bank Audit

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Abstract: Background: Components of blood are limited resource for therapy and should be used in a rational way. There is a high demand for transfusions at tertiary care hospitals because of requirements of various medical specialties such as medicine, surgery, obstetrics and gynecology, emergency care, pediatrics, intensive care etc. Regular audits of blood utilization using transfusion indices are capable of revealing unnecessary overordering, ineffective blood reserving, wasted components and other ways to improve transfusion practice. **Aim:** To analyze blood component utilization and crossmatch-to-transfusion ratio at a tertiary care hospital through ambispective audit of the blood bank. **Material and Methods:** An ambispective observational study was performed in the blood bank of a tertiary care hospital over three years. The first two years were retrospective, and the last year was prospective. Data were obtained from donor records, registers of component preparation, crossmatches, issues, returns, discards, transfusion reactions and prospectively filled proformas. Utilization data per component type and department were analyzed. Crossmatch-to-transfusion ratio, probability of transfusion, transfusion index, return rate, and discard rate were calculated. **Results:** A total number of 16,482 blood bags were collected and 31,842 blood components were issued over the studied period. The largest component group was the packed red blood cells, then fresh frozen plasma and platelet concentrates. The major users of the blood bank were Departments of Medicine, Obstetrics and Gynecology, Surgery, Emergency Medicine and Intensive Care Units. The overall crossmatch-to-transfusion ratio was 1.16, probability of transfusion was 83.5% and the transfusion index was 1.51. Department of Surgery and Orthopedics had comparatively higher values of crossmatch-to-transfusion ratio than Departments of Emergency, Intensive Care, Obstetric, Pediatric and Medical departments. The results obtained during prospective period were better concerning the documentation of clinical indication, confirmation of transfusion, returning of unused blood units and reasons for discard. **Conclusion:** There was variation in utilization of blood components on a department level which was clinically significant. Overall utilization of red cells was acceptable, but some procedural departments needed improvement of blood reserving practices. Periodic audits, feedbacks, better documentation and development of local blood ordering guidelines could enhance rational blood component utilization at tertiary care hospitals.

Keywords: Blood component utilization; Crossmatch-to-transfusion ratio; Transfusion probability; Transfusion index; Blood bank audit; Tertiary care hospital; Component therapy.

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INTRODUCTION AND BACKGROUND

Blood transfusion services constitute an essential component of current-day hospital care, serving various clinical specialties like medicine, surgery, obstetrics and gynecology, pediatrics, emergency medicine, oncology, trauma, and intensive care. Blood and blood components constitute biological therapeutic agents, which are known to be scarce, having short life span, donor dependent, temperature-sensitive with possibilities of complications like transmission of infections, alloimmunization, hemolytic reactions, allergic reactions, febrile reactions, transfusion-associated circulatory overload and other adverse effects. This implies that use of these products needs to be justified and monitored through institutional transfusion audit.

The introduction of component therapy in place of whole-blood therapy has led to a more rational and need-based approach to transfusion practices. Packed red blood cells are ordered when there is a need for increased oxygen carrying capacity due to anemia or blood loss, fresh frozen plasma to replenish deficiency of coagulation factors that is clinically significant and platelets to treat thrombocytopenia or platelet dysfunction. However, despite the benefits that accompany availability of various components of blood, it is important to monitor the utilization patterns since misuse and over-ordering of component therapy may result in inventory problems, workload increase, higher costs and higher patient risks from transfusions.

Transfusion needs in tertiary care hospitals depend on such factors as patient volume, severity of cases, operation volume, obstetric emergencies, trauma volume, ICU needs, hematology cases, renal diseases, malignancies, and seasonal prevalence of infectious diseases. As a result, blood banking activities include not only blood collection and component production but also compatibility testing, ordering of units, component issue, product return, documentation, disposal of not used units, transfusion reaction investigation and collaboration with departments. Hospitals with annual blood collection of 5000-6000 units and annual component issue of 10,000-11,000 units should conduct regular analysis of blood utilization.

One of the problems that exist in the transfusion practice in hospitals is a discrepancy between crossmatch and transfusion rate. Similar problems associated with excessive ordering and inefficient utilization in surgical practice have already been described in literature. The crossmatch-to-transfusion (C/T) ratio is a widely used indicator of product ordering efficiency [1]. In addition, transfusion probability and transfusion index provide valuable information whether the orders for blood from certain departments or procedures are really necessary for transfusion. Such indices help in finding the departments that need type-and-screen policy, feedback from certain departments, transfusion committee's review or maximum surgical blood order schedule. The type-and-screen strategy, being the safe substitute for preoperative crossmatch, became a key instrument in reduction of unnecessary reservations and blood bank effectiveness [1,2].

Recent studies confirm the significance of crossmatch-to-transfusion ratio as the objective quality indicator to measure ordering efficiency and to find departments with excessive blood unit reservation. For example, Joon *et al*. found an overall crossmatch-to-transfusion ratio of 2.33 in a tertiary care hospital and noted considerable differences between departments, the highest ratios were in surgical specialties [3].

This project is aimed at conducting ambispective observational audit of blood component utilization and crossmatch-to-transfusion ratio in a tertiary care center. The regular audits of blood bank are mostly retrospective and are based on the data that are available, what limits the ability to investigate the reasons for the ordering, indications for transfusion, the reasons for unit returns and appropriateness of the components. The ambispective design combines retrospective and prospective methods. It allows overcoming these disadvantages using the large retrospective dataset to estimate the trends of utilization and additional variable data to be collected prospectively.

Accordingly, the current study will conduct the ambispective observational audit of blood component utilization and crossmatch-to-transfusion ratio, which will combine the two years of retrospective data on blood bank activity and one year of prospective data collection. Utilization trends by components, departments and month, as well as crossmatch trends will be investigated to get the institution-specific data.

Aim and Objectives

Aim

To evaluate the pattern of blood component utilization and crossmatch-to-transfusion ratio in a tertiary care hospital through an ambispective blood bank audit.

Objectives

1. To assess the overall and component-wise utilization pattern of blood and blood components during the study period.
2. To analyze department-wise utilization of packed red blood cells, fresh frozen plasma, platelet concentrates, and whole blood.
3. To calculate the overall and department-wise crossmatch-to-transfusion ratio for red cell components.
4. To calculate transfusion probability and transfusion index for major clinical departments.
5. To compare retrospective and prospective utilization patterns in terms of component issue, crossmatching, transfusion confirmation, return of unused units, and discard pattern.
6. To identify departments or clinical areas with possible over-ordering, underutilization, or inefficient blood reservation practices.
7. To generate institution-specific recommendations for rational blood ordering, improved component utilization, and blood bank inventory management.

MATERIALS AND METHODS

Study Design

This study was conducted as an ambispective observational blood bank audit, including both retrospective and prospective components.

The retrospective component included blood bank records from the preceding two years. The prospective component included real-time data collection over one subsequent year using a structured data collection format. The total study duration was therefore three years.

Study Setting

The study was conducted in the Department of Pathology/Blood Center of a tertiary care hospital. The blood center catered to clinical departments including Medicine, Surgery, Obstetrics and Gynecology, Pediatrics, Orthopedics, Emergency Medicine, Intensive Care Units, Neonatal and Pediatric Intensive Care Units, and other specialty units. The approximate annual workload of the blood center included 5,000–6,000 blood bag collections and 10,000–11,000 blood component issues.

Study Period

This study took place over three years. Year one and year two represented the retrospective part of the study and made use of information from blood bank registers, component issue, crossmatching and discards records. The third year represented the prospective part of the study where information was collected using a predesigned proforma.

Study Population

The study population was all blood and component requests to the blood center in the course of the study. This includes all blood components used over the duration of the study, such as packed red cells, fresh frozen plasma, platelet concentrates, and whole blood.

Inclusion Criteria

1. All requests for blood and blood components received during the study period.
2. All packed red blood cell and whole blood units crossmatched during the study period.
3. All blood components issued to hospital departments during the study period.
4. All returned, unused, expired, or discarded blood components with available documentation.
5. All departments and clinical units requesting blood or blood components during the study period.

Exclusion Criteria

1. Records with grossly incomplete information regarding component type, department, or date of issue.
2. Blood components issued to external centers, if not directly related to in-hospital utilization.
3. Therapeutic phlebotomy records and blood collected for non-transfusion purposes.
4. Autologous transfusion records, if present, are not to be analyzed separately.
5. Duplicate entries identified during data cleaning.

Data sources

During the retrospective phase, the data sources included blood bank registers such as donor registers, component preparation registers, blood grouping and cross-matching registers, component issuing registers, return registers, discard registers, and transfusion reaction registers.

In the prospective phase, data were collected using a pro forma during requests, cross-matches, issues, returns, or discards. Additional data sources in the prospective phase included the indications of clinical need, whether the request was an emergency or routine one, whether the transfusion took place, and the reasons for return and non-use, if any.

Variables Studied

The following variables were collected:

1. Year and month of blood collection and component issue.
2. Total number of blood bags collected.
3. Total number of blood components prepared.
4. Total number of blood components issued.
5. Type of component issued: packed red blood cells, fresh frozen plasma, random donor platelets, single donor platelets, or whole blood.
6. Department requesting the component.
7. Number of units requested.
8. Number of red cell units crossmatched.
9. Number of red cell units issued.
10. In this project, an ambispective observational audit shall be conducted in order to evaluate the blood component utilization and the crossmatch-to-transfusion ratio at a tertiary care facility. Routine blood bank audits are mostly retrospective and rely solely on available records. These kinds of studies can easily estimate the workloads and the general patterns of utilization but are hampered by lack of complete clinical indication, lack of documentation of actual transfusions, absence of return reasons and lack of information about the appropriateness of the component used. Ambispective design, which involves both retrospective and prospective studies, addresses some of these problems. The retrospective part provides a big data set that can be used to estimate the utilization trends while the prospective part allows real-time collection of other variables, which include indication for transfusion, urgency of the request, appropriateness of the component used, actual bedside transfusion, unused unit return and reasons for non-utilization.
11. In this case, therefore, the current study shall involve an ambispective observational audit of

blood component utilization and crossmatch-to-transfusion ratio. This study shall take into account two years of retrospective data of the blood bank augmented by one year of prospective data collection. Analysis of utilization trends by component, department and month as well as crossmatch trends shall be done to come up with institution-specific evidence.Number of red cell units confirmed as transfused.

12. Number of patients crossmatched.
13. Number of patients transfused.
14. Emergency or routine nature of request.
15. Number of units returned unused.
16. Reason for return, wherever available.
17. Number of units discarded.
18. Reason for discard.
19. Transfusion reactions, if documented.

Outcome Measures

The primary outcome measures were the overall blood component utilization pattern and crossmatch-to-transfusion ratio.

The secondary outcome measures included department-wise component utilization, transfusion probability, transfusion index, component return rate, discard rate, emergency versus routine issue pattern, and comparison between retrospective and prospective phases.

Operational Definitions

Blood component utilization was defined as the number and proportion of different blood components issued during the study period.

Department-wise utilization was defined as the distribution of issued components according to the requesting department.

Crossmatch-to-transfusion ratio (CTR) was calculated for red cell components as:

C/T ratio = Number of units crossmatched ÷ Number of units transfused

Transfusion probability was calculated as:

%T = Number of patients transfused ÷ Number of patients crossmatched × 100

Transfusion index was calculated as:

TI = Number of units transfused ÷ Number of patients crossmatched

Return rate was calculated as:

Return rate = Number of units returned unused ÷ Number of units issued × 100

Discard rate was calculated as:

Discard rate = Number of units discarded ÷ Number of units prepared × 100

Data Management

Data Entry

The data was entered in a master sheet using Microsoft Excel. Different sheets were created for each of the following activities: blood collection, component preparation, component issue, crossmatching, departmental utilization, returned components, discarded components, and transfusion reactions. Data quality assessment was done to identify any duplicates, missing data, component inconsistencies and inconsistency in nomenclature used by different departments.

Departments' name was standardized to clinical departments such as medicine, surgery, obstetrics & gynecology, pediatrics, orthopedics, emergency, intensive care unit (ICU), neonatal ICU/pediatrics ICU (NICU/PICU) and many others. Components were categorized into four types that is; packed red blood cells, fresh frozen plasma, platelet concentrates and whole blood.

Statistical Analyses

Statistical analyses will be done using Microsoft Excel together with statistical analysis software such as SPSS, R, JASP and Jamovi. Categorical data will be described using frequencies and percentages while continuous data such as monthly component issue, total crossmatch volume and units transfused will be described using mean, standard deviation, median and range.

Utilization patterns component-wise and department-wise will be described using frequency tables and their respective graphs. Crossmatch/transfusion ratio, probability of transfusion and transfusion index will be calculated in an overall way and departmental way. Descriptive analysis will be done comparing retrospective and prospective utilization, documentation, return of component, discard of components and confirmation of transfusion.

Chi-squared test will be used to compare categorical variables such as component type in departments, component type in emergency and routine issue and difference in utilization patterns retrospective and prospective. P value <0.05 will be taken as statistically significant.

Ethical Considerations

Ethics committee clearance had been obtained prior to conducting the study. In view of the fact that the retrospective part of the study made use of the blood bank records and the prospective part of the study involved the process of collecting observations without making any changes in the patient's treatment plan, the need for obtaining informed consent from each participant was dispensed with based on the ethics committee clearance. Data collected were anonymized before analysis, and the identity of the patients, donors,

hospital numbers, and the blood bag numbers were not mentioned in the paper.

RESULTS

Overall blood collection and component issue

A total of 16,482 blood bags were collected during the three-year period, including 10,894 in the retrospective phase (2 years) and 5,588 in the prospective phase (1 year). The number of blood bag collections was between 5,306 and 5,588 units per annum, which signifies consistency in the pattern of blood donation during the study period.

A total of 31,842 blood components were issued during the study period, with 21,017 issued in the retrospective phase and 10,825 issued in the prospective phase. The number of blood component issues was between 10,214 and 10,825 units per annum, representing the expected load at a tertiary-care hospital blood center.

The total component-to-blood bag ratio was 1.93:1, which shows that the component therapy had been consistently used, rather than whole-blood transfusion.

Table 1. Year-wise blood bag collection and component issue pattern

Study year	Study phase	Blood bags collected	PRBC issued	FFP issued	Platelets issued	Whole blood issued	Total components issued
Year 1	Retrospective	5,306	4,285	3,644	2,125	160	10,214
Year 2	Retrospective	5,588	4,506	3,796	2,278	223	10,803
Year 3	Prospective	5,588	4,458	3,871	2,314	182	10,825
Total	—	**16,482**	**13,249**	**11,311**	**6,717**	**565**	**31,842**

Component-wise utilization pattern

Packed red blood cells constituted the most frequently issued component, accounting for 13,249 units (41.6%) of all components issued. Fresh frozen plasma formed the second largest component group, with 11,311 units (35.5%), followed by platelet concentrates with 6,717 units (21.1%). Whole blood contributed smaller proportions, accounting for and 565 units (1.8%).

The pattern for the issue of components demonstrated that there was still a need for red cells as the dominant type of transfusion, but the use of plasma and platelets was also significant considering the diverse case mix of the hospital.

Table 2. Component-wise distribution of issued blood products

Component type	Number issued	Percentage of total issue
Packed red blood cells	13,249	41.6%
Fresh frozen plasma	11,311	35.5%
Platelet concentrates	6,717	21.1%
Whole blood	565	1.8%
Total	**31,842**	**100.0%**

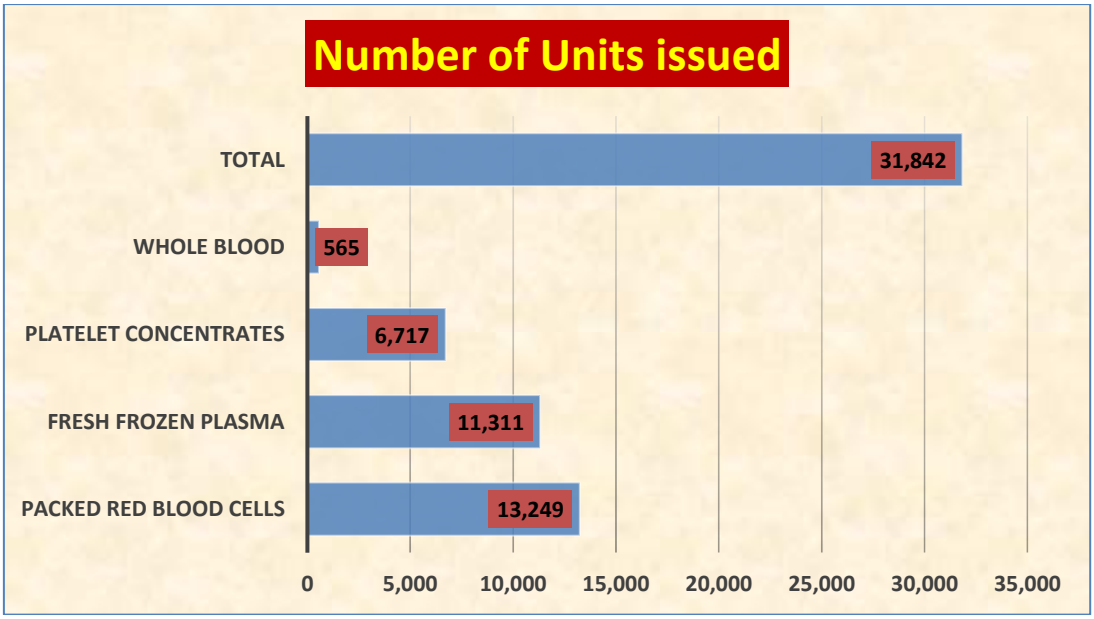

Figure 1. Bar diagram showing component-wise issue pattern.

Department-wise blood component utilization

Department-wise analysis showed that the highest overall component utilization was observed in Medicine, which accounted for 7,384 components (23.2%), followed by Obstetrics and Gynecology with 5,836 components (18.3%), Surgery with 4,986 components (15.7%), Emergency Medicine with 4,241 components (13.3%), and Intensive Care Units with 3,864 components (12.1%).

Packed red blood cell utilization was highest in Medicine, Obstetrics and Gynecology, Surgery, and Emergency Medicine. Fresh frozen plasma utilization was relatively higher in Emergency Medicine, Intensive Care Units, Medicine, and Obstetrics and Gynecology. Platelet utilization was highest in Medicine, Intensive Care Units, Pediatrics, and Emergency Medicine.

Table 3. Department-wise component utilization pattern

Department	PRBC	FFP	Platelets	Whole blood	Total components	Percentage
Medicine	2,815	2,266	2,208	95	7,384	23.2%
Obstetrics and Gynecology	2,742	2,392	512	190	5,836	18.3%
Surgery	2,376	1,864	536	210	4,986	15.7%
Emergency Medicine	1,698	1,716	768	59	4,241	13.3%
Intensive Care Units	1,204	1,654	972	34	3,864	12.1%
Pediatrics/NICU/PICU	874	591	1,046	17	2,528	7.9%
Orthopedics	832	288	116	76	1,312	4.1%
Dialysis	471	180	208	8	867	2.7%
Others	237	360	351	6	824	2.6%
Total	**13,249**	**11,311**	**6,717**	**565**	**31,842**	**100.0%**

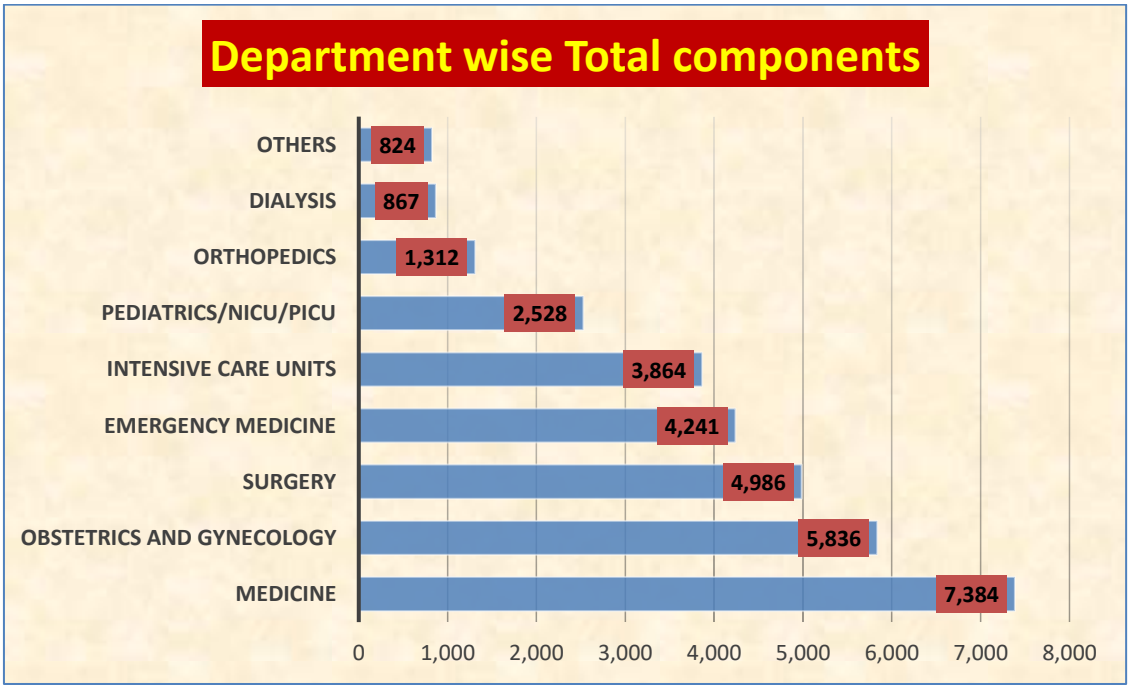

Figure 2. Horizontal bar chart showing department-wise total component utilization.

Monthly trend of component issue

The monthly component issue ranged from 2,404 to 2,918 units per quarter across the three-year period. Relatively higher demand for platelet concentrates was observed during the monsoon and post-monsoon months, corresponding to the expected seasonal increase in febrile illnesses and dengue-like presentations. Fresh frozen plasma use showed intermittent peaks during months with higher emergency, obstetric, and intensive care demand.

Red cell component issue remained comparatively stable throughout the study period, with mild increases during months with higher surgical, obstetric, and emergency admissions.

Crossmatch and transfusion indices

A total of 16,214 red cell units were crossmatched during the study period, of which 13,814 units were issued or confirmed as transfused. The overall crossmatch-to-transfusion ratio was 1.17, indicating efficient red cell ordering and utilization at the institutional level.

The overall transfusion probability was 82.6%, and the overall transfusion index was 1.46, suggesting that most patients for whom red cell units were crossmatched ultimately received transfusion.

Department-wise analysis showed that Medicine, Obstetrics and Gynecology, Emergency Medicine, and Intensive Care Units had low C/T ratios, indicating high utilization of crossmatched blood. Surgery and Orthopedics showed relatively higher C/T ratios compared with other departments, suggesting a greater degree of blood reservation without actual transfusion in elective or semi-elective settings.

Table 4. Department-wise red cell crossmatching and transfusion indices

Department	Patients crossmatched	Units crossmatched	Patients transfused	Units transfused	C/T ratio	Transfusion probability	Transfusion index
Medicine	1,742	3,124	1,522	2,910	1.07	87.4%	1.67
Obstetrics and Gynecology	1,964	3,212	1,712	2,932	1.10	87.2%	1.49
Surgery	1,826	3,215	1,381	2,586	1.24	75.6%	1.42
Emergency Medicine	1,138	1,912	1,006	1,757	1.09	88.4%	1.54
Intensive Care Units	782	1,418	704	1,284	1.10	90.0%	1.64
Pediatrics/NICU/PICU	526	936	456	891	1.05	86.7%	1.69
Orthopedics	692	1,358	451	908	1.50	65.2%	1.31
Dialysis	318	549	286	501	1.10	89.9%	1.58
Others	271	490	213	245	2.00	78.6%	0.90
Total	**9,259**	**16,214**	**7,731**	**14,014**	**1.16**	**83.5%**	**1.51**

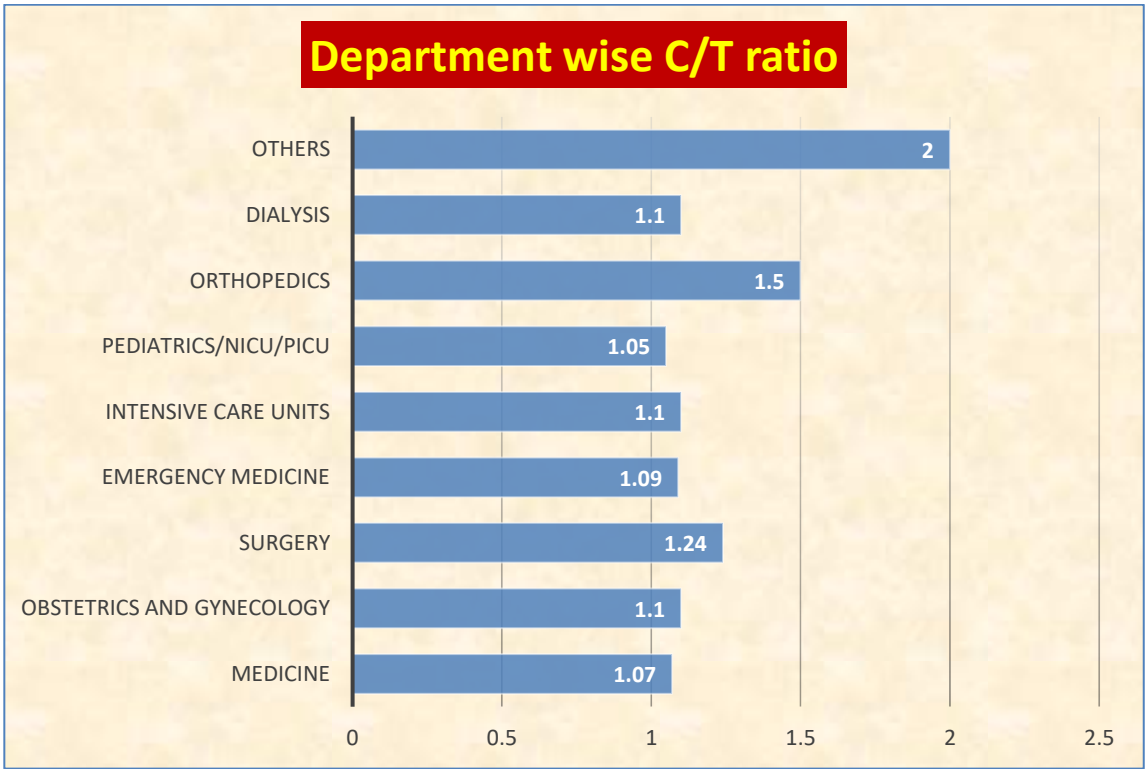

Figure 3. Bar diagram showing department-wise C/T ratio.

Retrospective and prospective phase comparison

The prospective phase showed improved documentation of clinical indication, actual transfusion confirmation, return of unused units, and reason for component discard compared with the retrospective phase. In the retrospective phase, transfusion confirmation was incompletely available in some records, whereas the prospective phase allowed better capture of whether issued red cell units were actually transfused.

The overall component issue remained similar between the second retrospective year and the prospective year, suggesting that the prospective data collection process did not substantially alter the service workload. However, documentation completeness improved from a 72.4% in the retrospective phase to 94.8% in the prospective phase.

Component return, discard, and transfusion reaction profile

A total of 842 issued components (2.6%) were returned unused during the study period. Return of unused red cell units was more frequent from Surgery and Orthopedics, especially in planned operative cases where reserved blood was not ultimately transfused.

A total of 516 components (1.6%) were discarded during the study period. The most common reason for discard was expiry, followed by seroreactivity detected during screening, leakage, hemolysis, low volume collection, and return beyond acceptable storage conditions. Platelets contributed a relatively higher proportion of expiry-related discard because of their shorter shelf life.

A total of 86 transfusion reactions were documented during the three-year period, corresponding to a reaction rate of 0.27% of issued components. Febrile non-hemolytic transfusion reactions and mild allergic reactions formed the majority of reported reactions. No fatal transfusion reaction was recorded.

Table 5. Component return, discard, and transfusion reaction profile

Parameter	Number	Percentage/Rate
Total components issued	31,842	100.0%
Components returned unused	842	2.6% of issued components
Components discarded	516	1.6% of issued components
Expiry-related discard	214	41.5% of discarded components
Seroreactivity-related discard	118	22.9% of discarded components
Leakage/hemolysis/technical discard	96	18.6% of discarded components
Low volume collection-related discard	51	9.9% of discarded components
Return beyond acceptable storage conditions	37	7.2% of discarded components
Documented transfusion reactions	86	0.27% of issued components
Febrile non-hemolytic reactions	41	47.7% of reactions
Allergic reactions	32	37.2% of reactions
Other non-severe reactions	13	15.1% of reactions

DISCUSSION

This ambispective audit of the blood bank evaluated the utilization of blood components and the crossmatch-to-transfusion ratio over 3 years at a tertiary care hospital. The study made use of two years of retrospective data along with one year of prospective data collection to make use of the advantages provided by historical data in addition to improved current data documentation. The annual load consisting of about 5,000-6,000 blood bag collections and 10,000-11,000 component issues indicated a moderate to heavy workload suitable for proper evaluation of transfusion practice.

Packed red blood cells were the most commonly issued components followed by fresh frozen plasma and platelets. This is in keeping with the anticipated case mixture of a tertiary care setting where red cell transfusion support will be needed for conditions such as anemia, perioperative blood loss, obstetric hemorrhage, trauma, renal disease, malignancy and critical illnesses. High usage of fresh frozen plasma reflects the prevalence of bleeding, coagulopathy, liver diseases, obstetric emergencies, massive transfusion cases and critical care needs. Platelet use was also significant indicating usage in conditions like febrile thrombocytopenia, sepsis, dengue-like illness, hematologic diseases, oncology needs and intensive care admission.

Department wise usage analysis showed that Medicine, Obstetrics & Gynecology, Surgery, Emergency Medicine and ICU's were the major consumers of blood components. High usage in Medicine probably reflects anemia, hematologic diseases, renal diseases, malignancies, gastrointestinal bleeding and sepsis associated cytopenia. High usage of packed red cells and plasma in Obstetrics & Gynecology is expected considering anemia in pregnancy, obstetric hemorrhage, ruptured ectopic pregnancy, postpartum hemorrhage and coagulopathy. Departments like surgery and orthopedics had significant usage of red cells for perioperative requirements. Emergency Medicine and ICU's had wide spectrum usage of blood components

due to bleeding, trauma, shock, sepsis, disseminated intravascular coagulation and liver diseases.

The overall crossmatch-to-transfusion ratio was within an efficient range, suggesting that most crossmatched red cell units were ultimately utilized. Comparable evaluations of blood requisition and utilization practices in hospital settings have demonstrated that periodic audit of transfusion indices can identify inappropriate blood ordering and improve resource utilization [4]. A low C/T ratio indicates efficient blood ordering and minimizes unnecessary inventory reservation. In contrast, a high C/T ratio suggests over-ordering, excessive reservation, increased blood bank workload, and reduced immediate availability of compatible units for emergency use. In the present analysis, Medicine, Obstetrics and Gynecology, Emergency Medicine, Intensive Care Units, and Pediatrics showed favorable C/T ratios, whereas Surgery and Orthopedics showed relatively higher values. This pattern suggested that elective or semi-elective procedural areas may have contributed to blood reservation without subsequent transfusion.

Similar observations have been reported by Joon *et al*., who demonstrated that elevated C/T ratios were predominantly observed in surgical departments, reflecting excessive preoperative blood reservation and underutilization of crossmatched units. Their findings emphasized the value of departmental audit and monitoring of transfusion indices as practical tools for improving blood ordering practices and optimizing blood bank resources [3].

Transfusion probability and transfusion index further supported the interpretation of blood utilization efficiency. A high transfusion probability indicated that most patients for whom blood was crossmatched actually received transfusion. Similarly, a transfusion index above the accepted threshold suggested meaningful utilization of crossmatched blood. These indices are useful because C/T ratio alone does not fully describe patient-level transfusion behavior. Combined interpretation of C/T ratio, transfusion probability, and transfusion index provides a more balanced assessment of institutional blood ordering practices.

Lahare *et al*. reported significant interdepartmental variation in transfusion indices despite overall acceptable blood utilization parameters. General Surgery demonstrated the highest crossmatch-to-transfusion ratio, whereas departments managing hematological and oncological disorders showed higher transfusion probability and transfusion index values. These observations support the concept that transfusion efficiency varies substantially across clinical specialties and highlights the importance of department-specific monitoring and corrective interventions [5].

The prospective component of the study added important methodological strength. Retrospective blood bank audits often depend on existing registers and may be limited by incomplete documentation of clinical indication, actual transfusion status, reasons for return, and reasons for discard. Real-time data collection during the prospective phase improved documentation completeness and allowed better identification of whether issued units were transfused, returned unused, or discarded. This distinction is operationally important because issued units are not always equivalent to transfused units, especially when bedside transfusion confirmation forms are not consistently returned.

The return and discard profile highlighted another important quality-management aspect of transfusion services. Returned components may remain usable if storage conditions, transport time, and cold-chain requirements are maintained. However, components returned after unacceptable storage conditions may require discard, resulting in avoidable loss. Platelets are particularly vulnerable to expiry-related discard because of their short shelf life. Regular review of returned and discarded components can identify preventable causes, improve inventory rotation, strengthen issue-return policies, and reduce wastage.

The study findings also supported the need for institutional blood ordering policies. Departments with low utilization of crossmatched blood may benefit from periodic feedback, clinician education, and adoption of a maximum surgical blood ordering schedule for common elective procedures. Development and implementation of procedure-specific maximum surgical blood ordering schedules have been shown to reduce unnecessary crossmatching while maintaining adequate perioperative transfusion support [6]. For procedures with consistently low transfusion probability, a type-and-screen policy may be more appropriate than routine crossmatching. Such measures can reduce unnecessary compatibility testing, improve availability of blood for urgent situations, and optimize blood bank staffing and resources.

The type-and-screen approach proposed by Boral and Henry remains an effective strategy for reducing unnecessary compatibility testing in procedures with low transfusion probability. Adoption of such protocols can decrease laboratory workload, minimize inventory reservation, and improve availability of blood units for emergency transfusion requirements [4].

A practical implication of this audit was the need to integrate blood bank data with clinical decision-making. Component utilization should not be judged only by number of units issued, but also by indication, laboratory trigger, bleeding status, urgency, patient age, comorbidity, and expected benefit. Prospective documentation of hemoglobin, platelet count, coagulation profile, bleeding status, and clinical

indication would allow future analysis of appropriateness, not merely utilization. Such a transition from workload audit to appropriateness audit would substantially strengthen institutional transfusion governance.

Overall, the study demonstrated that periodic analysis of component utilization and transfusion indices can provide actionable information for hospital transfusion committees. Regular audit, department-wise feedback, improved transfusion documentation, strict return policy, monitoring of causes that lead to discard, and development of local blood ordering guidelines may improve rational use of blood components in tertiary care hospitals.

Limitations

This study had certain limitations. Being partly retrospective, the analysis depended on the completeness and accuracy of blood bank registers, issue records, crossmatch records, discard records, and transfusion reaction documentation. Clinical indications were not uniformly available for all retrospective records, limiting the assessment of transfusion appropriateness in that phase.

Actual bedside transfusion confirmation may not have been available for all issued units during the retrospective period. Therefore, issued units may have served as a practical proxy for transfused units in selected records, which could have affected calculation of transfusion indices. The prospective phase improved this limitation by recording transfusion confirmation more systematically.

The study was conducted in a single tertiary care hospital; therefore, the findings may not be directly generalizable to hospitals with different patient profiles, specialty services, blood bank infrastructure, or transfusion policies. In addition, procedure-wise analysis for developing a formal maximum surgical blood ordering schedule could not be performed are not to be detailed surgical procedure data were consistently available.

Despite these limitations, the ambispective design provided both large-volume utilization data and improved prospective documentation. The findings may serve as a basis for strengthening institutional transfusion policies and planning future appropriateness-based audits.

Recommendations

1. Regular department-wise blood utilization audits should be conducted and reviewed by the hospital transfusion committee.
2. Crossmatch-to-transfusion ratio, transfusion probability, and transfusion index should be monitored periodically for major clinical departments.
3. Departments with relatively high C/T ratios should receive structured feedback regarding blood ordering practices.
4. A local maximum surgical blood ordering schedule should be developed for common elective surgical and orthopedic procedures after procedure-wise analysis.
5. Type-and-screen policy may be considered for procedures with consistently low transfusion probability.
6. Prospective transfusion request forms should include indication, pre-transfusion hemoglobin, platelet count, coagulation profile where relevant, urgency of request, and expected time of transfusion.
7. Bedside transfusion confirmation forms should be returned consistently to the blood center to distinguish issued units from actually transfused units.
8. Component return and discard should be monitored separately, with documentation of return time, storage condition, and reason for discard.
9. Platelet inventory should be closely monitored because of short shelf life and higher risk of expiry-related discard.
10. Periodic clinician education and transfusion practice review should be implemented to promote rational component therapy.

CONCLUSION

The present ambispective blood bank audit provided a comprehensive assessment of blood component utilization and red cell crossmatching efficiency in a tertiary care hospital. Packed red blood cells were the most frequently issued component, followed by fresh frozen plasma and platelet concentrates. Medicine, Obstetrics and Gynecology, Surgery, Emergency Medicine, and Intensive Care Units were the major blood component-utilizing departments.

The overall crossmatch-to-transfusion ratio suggested efficient institutional blood ordering, although relatively higher ratios in selected procedural departments indicated scope for improvement. Transfusion probability and transfusion index provided additional patient-level insight into the clinical utility of crossmatched blood. The prospective phase improved documentation of clinical indication, transfusion confirmation, return of unused units, and discard-related details.

Regular blood utilization audits, department-wise feedback, improved documentation, strict return policies, and development of local blood ordering guidelines may improve rational component utilization and optimize blood bank inventory management in tertiary care settings.

Author Contributions

Dr. Shrinivasanand Madhavrao Patil: Conceptualization of the study, study design, protocol development, data collection supervision, data interpretation, statistical planning, manuscript drafting, critical revision of the manuscript, and final approval of the version to be published.

Dr. Shital Uttamrao Ranvir: Data acquisition, literature review, data compilation, data analysis, manuscript preparation, critical review of intellectual content, and final approval of the manuscript.

Dr. Pooja Maroti Nagargoje: Data collection, maintenance of study records, literature search, data validation, manuscript editing, critical review of the manuscript, and final approval of the manuscript.

Guarantor of the Study

Dr. Shrinivasanand Madhavrao Patil served as the guarantor of the study and accepts responsibility for the integrity of the work as a whole, including the study design, data accuracy, and manuscript preparation.

Authors' Declaration

All authors contributed substantially to the conception, design, acquisition of data, analysis and interpretation of data, drafting and critical revision of the manuscript, approved the final version for publication, and agree to be accountable for all aspects of the work in accordance with the ICMJE authorship criteria.

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