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Investigating the Influence of Pre-Donation Haematological Parameters on Haematocrit and the Haemoglobin Content in Packed Red Blood Cell Units

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Abstract

Objective: This study aimed to evaluate the impact of pre-donation hematological parameters, specifically hemoglobin and hematocrit levels, on the quality of packed red blood cell (PRBC) units after 21 days of storage.

Methodology: A cross-sectional, analytical study was conducted at the Armed Forces Institute of Transfusion, Rawalpindi from February 2024 to July 2024, involving 384 voluntary whole blood donors who met specific inclusion criteria. Pre-donation hematological parameters were measured using an automated hematology analyzer. PRBC units were processed according to standard protocols and evaluated on Day 21 for volume, hematocrit, and total hemoglobin content. Data analysis was performed using SPSS software, applying descriptive statistics, Pearson correlation, and multiple regression analysis to assess the relationship between pre-donation variables and PRBC quality.

Results: At Day 21, PRBC units exhibited significant changes compared to initial post-donation values. Pre-donation hemoglobin and hematocrit levels showed weak correlations with Day 21 PRBC hemoglobin content and hematocrit levels. The integrity of PRBC units appeared more influenced by storage conditions than donor-specific hematological parameters. While hemoglobin content remained relatively stable, hematocrit levels showed variability, indicating that additional biochemical and environmental factors during storage play a critical role in maintaining PRBC quality.

Conclusion: Pre-donation hematological parameters have a limited role in predicting PRBC quality after 21 days of storage. Factors such as donor conditions and processing parameters may significantly influence PRBC integrity, highlighting the need for comprehensive donor screening and optimized storage practices.

Keywords: PRBC transfusion, Hematocrit, Hemoglobin, Donor factors, Blood storage, Transfusion therapy, Blood quality, Total Hemoglobin Content.

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Introduction

The quality of packed red blood cells (PRBC) is a key determinant to blood transfusion, which is an important intervention in many medical processes such as surgeries, trauma and treatment of anemias among others. PRBC units are prepared from whole blood collection and the RBC strength is raised, so to facilitate oxygen delivery in patients requiring transfusion. The effectiveness of the above-mentioned transfusions highly depends on the quality of the PRBC units in which the quality depends on donor factors, processing methods and storage conditions. [1,2]

Hemoglobin and hematocrit measurements potential pre-donation tests that are often taken in evaluating donors have variations depending on agencies' policies. These parameters are used in determination of the compatibility of a donor as well as determination of compatibility, safety and effectiveness of blood in case of transfusion. Hemoglobin is an oxygen-carrying protein found in red blood cells and hematocrit is the quantity of the blood which is comprised by the red blood cell. Both are indices related to red blood cell mass and are likely to be potential mediators of the quality of PRBC units.[3,4]

A range of concerns regarding the relation has been published on how effective pre-donation hematological parameters of PRBC quality are in terms of prediction. Thus, increased pre-donation hemoglobin and hematocrit concentrations have been considered highly appropriate for producing higher quality of PRBCs, recent analysis proved inadequate in supporting this hypothesis. PRBC

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units go through processing and storage which can create variability that could neutralize the effect of pre-donation parameters.[5,6] This variability includes such factors as variation in Red Blood Cell shape and shifts in the biochemical characteristics of the blood during storage.

These changes can result to the deterioration of their performance. For instance, low ATP and reduced 2,3-DPG levels may alter red blood cell function and therefore may reduce the impact of the transfer.[7] As these changes arise, the oxygen-carries of red blood cells is reduced and this may well have a bearing on the general success rate of blood transfusions.[8,9]

Based on these findings, it is therefore necessary to examine the associations of pre-donation hematologic indices and PRBC quality more vigorously. The knowledge of these relationships may therefore assist in the evaluation and recruitment of blood donors and also improve on the quality of blood being used in transfusion services. The result of this study will be used to determine the effect of pre-donation, Hemoglobin and Hct levels on the quality of PRBC units especially the Post donation hematological parameters including PRBC Hb content and Hct levels.[10]

This research will also analyse whether the quality of PRBC units is influenced by the storage process, including the interaction between the donor characteristics and the storage conditions. For this reason, the current research will aim at scrutinizing these factors in a bid to offer an understanding of the various factors that influence PRBC quality with the view of enhancing better transfusion outcomes. Based on pre-donation and post-donation data, this study intends to establish the level of first donor characteristics in determining the PRBC quality at the end, which will help in formulation of blood donation procedures and storage methods.[11,12]

Methodology

This was a cross-sectional study done on blood donors attending the Armed Forces Institute of Transfusion (AFIT) Rawalpindi Pakistan from February 2024 to July 2024. The purpose of the study was to assess how donor's attributes and pre-donation laboratory values affect the qualification of the PRBC units on Day 21 of storage. The research was conducted over the six months following the approval from the Institutional Review Board (IRB) including protocol was reviewed and approved

The subjects were 384 voluntary whole blood donors who were aged 20 to 50 years of age. Donors were selected based on specific inclusion criteria: As well, the children and adolescents had no chronic diseases, were not infected recently and, therefore, had to be healthy. First-time and multiple donors were recruited for the study to the ensure a general representation of the donor population. Patients with past health problems, recent surgery, or in case of female volunteer, pregnancy was a criterion for exclusion from the study. The study was to be carried out in compliance with the ethical standards thus before participating in it, the participants were required to read and understand the information furnished to them before they agreed to be part of the study by giving their written informed consent.

All the donors were requested to complete detailed questionnaire to obtain data on age, gender and weight, smoking status, diet history, alcohol consumption and drug intake history. This was taken by asking the frequency of past donations and the time elapsed before the last donation from them through the questionnaire. These data were used in eliminating confounding factors and made sure that all the factors influencing PRBC quality were considered.

The different areas of the study were explained to the respondents and they willingly participated in the study Informed consent was obtained from all respondents Oral and written information was sought from all the respondents after explaining the different areas of the study. From all the participant's, informed consent was sought and received before participant inclusion into the study. The participants were told of the nature of the study, the activities that would be conducted and the participant's liberty to pull out of the study at any time without any reason being provided for it. To ensure data confidentiality participants were given identification numbers only and only grouped data was used in the analysis.

Blood samples were taken from all respondents after they had completed the questionnaire. This was done using the Sysmex XP 100 hematology analyzer to determine pre-donation hematological parameters, including hemoglobin (g/dL), hematocrit (%) and RBC

Count. All of these measurements were taken for each donor prior to blood donation. The parameters of the PRBC units were then measured on Day 21 of storage under the optimal conditions in accordance with the Departmental Standard Operating Procedures (SOPs).

The collected blood units were therefore processed into PRBC units within 24 hours adopting a standardized method of centrifugation. PRBC units were kept at 2-6°C in a controlled environment. Other hematological parameters that were estimated post-donation included PRBC hemoglobin content and hematocrit levels and these were done using the same techniques as those described above. These parameters were used to describe the quality of the PRBC units being issued out to the various facilities.

The statistical analysis of the data was conducted in SPSS 27.0 version. To analyse the demographic characteristics of the donors and the hematological parameters, descriptive tool was applied. Continues variables were summarized by Arithmetic mean and Standard deviation while categorical variables were summarized by frequencies and percentages.

Pearson coefficient correlation was employed to analyse the connection existing between pre-donation haematologic characteristics (haemoglobin, haematocrit, RBC Count and packed-cell volume) and post-donation PRBC quality characteristics @ Day 21 (PRBC haemoglobin content, haematocrit content, Total Hb Content and PRBC packed-cell volume). Using multiple regression analysis, therefore, the significance of pre-donation hemoglobin and hematocrit as PRBC quality predictors were ascertained. According to conventional statistical analysis, a p-value of less than 0. 05 was deemed to be statistically significant.

They were organized in tables and figures to assist in interpretation in addition to providing comparisons with other studies. This cross-sectional study was designed to identify how accurately the pre-donation haematologic indexes reflect the PRBC unit quality and can be used to enhance blood donation and transfusion strategies.

Results

The mean age of the donors was 30.65 ± 6.25 years having a weight range of 50 to 89 kg (mean 70.42 ± 5.49 kg). The gender distribution was predominantly male having 307 male donors (79.9%) and 77 female donors (20.1%) (Table I).

Table I: Detailed Demographics and Hematological Parameters of the Study Population .n=(384)

Characteristic	Min	Max	Mean ± SD
Age (years)	20	50	30.65 ± 6.25
Weight (kg)	50	89	70.42 ± 5.49
Hemoglobin (g/dL)	13.00	18.50	14.804 ± 0.899
Hematocrit (%)	36.3	49.5	43.715 ± 2.899
RBC Count (x 10^12/L)	3.70	7.40	5.046 ± 0.534
Mean Corpuscular Volume (fL)	59.9	103.7	85.161 ± 5.854
Mean Corpuscular Hemoglobin (pg.)	17.1	35.1	29.807 ± 2.333
Mean Corpuscular Hemoglobin Conc. (g/dL)	28.5	37.6	33.936 ± 1.150

The pre-donation hemoglobin levels varied from 13.00 to 18.50 g/dL having a mean of 14.804 ± 0.899 g/dL. The pre-donation hematocrit levels ranged from 36.3% to 49.5% having a mean of 43.715 ± 2.899%. The average RBC count was 5.046 ± 0.534 x 10^12/L.

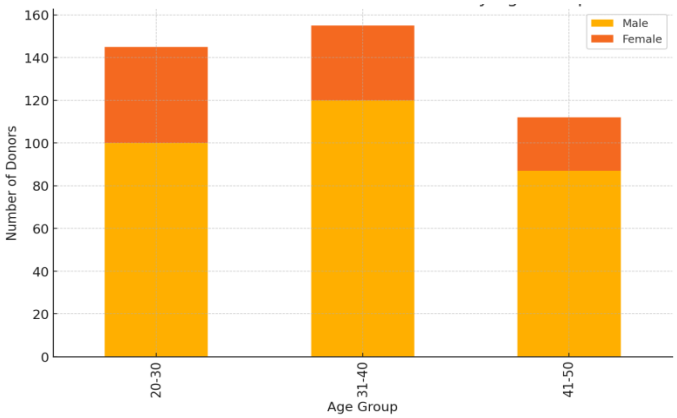

Figure 1. Distribution of Donor Characteristics by Age Group and Gender.

Post-donation hemoglobin levels increased slightly giving a mean of 16.360 ± 2.476 g/dL as compared to the pre-donation mean of 14.804 ± 0.899 g/dL. Also, the post-donation hematocrit level showed a significant increase to 58.217 ± 12.342% from a pre-donation mean of 43.715 ± 2.899% (Table II).

Hematological alterations predict that blood donation affects these measures in the mentioned manner. It postulated that the pre-and post-donation values may show compensatory mechanisms or measurement variations due to the increase in the values after the

donation as the whole blood is processed as red blood cells unit.

Table III lists the regression analysis by looking on the pre-donation hematological parameter as an independent variable to its ability to predict the quality of PRBC unit at Day 21 of storage. Hemoglobin and hematocrit pre-donation did not influence content of the PRBC Unit when measured at the Day 21 as indicated by the coefficients obtained from the beta test.

The obtained low levels of R^2 and high levels of p- value suggest that there is a low measure of explanation for pre-donation hematological parameters that could significantly influence the quality of PRBC. These findings imply that perhaps other factors are more influential in defining PRBC quality or that the roles of these parameters in defining PRBC quality are more intricate than what has been captured by a linear regression model.

The findings in relation to the correlation analysis are presented in Table IV hence show that some pre-donation parameters are significantly related with PRBC quality indicators. In subjecting the pre-donation hemoglobin levels to correlation analysis, it was observed that this variable had a weak positive relation with the pre-donation hematocrit ($r = 0.123$; $p < 0.05$) and a weak but negative relation with total hemoglobin content of the PRBC units ($r = -0.039$). These correlation values were very low and indicative of very weak correlation between pre-donation hematocrit and PRBC hematocrit ($r = 0.034$) or total hemoglobin content ($r = 0.028$). However, the total hemoglobin content of PRBC units showed only moderate positive correlation with PRBC hematocrit, though statistically significant, ($r = 0.197$, $p < 0.01$).

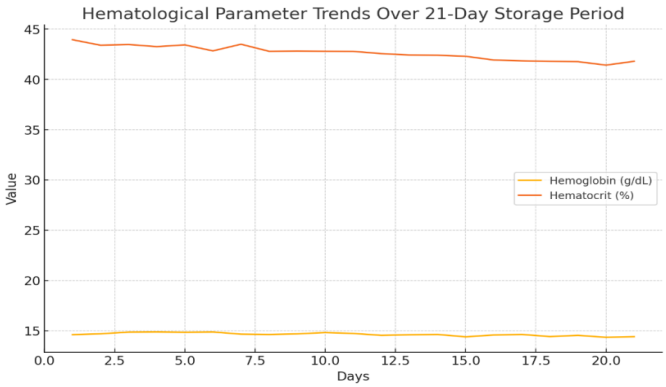

Figure 3a. Hematological Parameter Trends Over a 21-Day Storage Period.

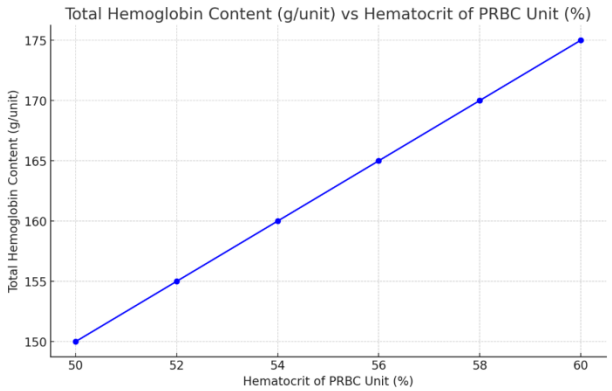

Figure 3b. Relationship between Total Hemoglobin Content (g/unit) and Hematocrit of PRBC Unit (%) at Day 21 of Storage.

Discussion

The hematologic analyses of this study suggest that preparatory for donation, hemoglobin and hematocrit values do have little bearing on the quality of PRBC units,

Table II: Pre-Donation Haematological Parameters and PRBC Quality Parameters..

Parameter	Pre-Mean ± SD	Post Mean ± SD	Pre-Range	Post Range
Hemoglobin (g/dL)	14.804 ± 0.899	16.360 ± 2.476	13.00 - 18.50	12.80 - 24.50
Hematocrit (%)	43.715 ± 2.899	58.217 ± 12.342	36.3 - 49.5	20.8 - 93.3
RBC Count (x 10^12/L)	5.046 ± 0.534	4.60 ± 0.48	3.70 - 7.40	211.0 - 371.0
Mean Corpuscular Volume (fL)	85.161 ± 5.854	84.90 ± 5.80	59.9 - 103.7	59.0 - 102.7
Mean Corpuscular Hemoglobin (pg.)	29.807 ± 2.333	29.70 ± 2.30	17.1 - 35.1	17.0 - 34.1
Mean Corpuscular Hemoglobin Conc. (g/dL)	33.936 ± 1.150	33.80 ± 1.12	28.5 - 37.6	28.0 - 37.0

Table III: Regression Analysis for Pre-Donation Hematological Parameters Predicting PRBC Quality.

Independent Variable	Dependent Variable	Pre-Donation Beta Coefficient (β)	PRBC @Day 21 Beta Coefficient (β)	R^2	p-Value
Hemoglobin (g/dL)	PRBC Hemoglobin (g/dL)	-0.043	-0.032	0.003	0.404
Hematocrit (%)	PRBC Hemoglobin (g/dL)	0.034	0.029	0.003	0.514
Hemoglobin (g/dL)	PRBC Hematocrit (%)	0.012	0.009	0.001	0.816
Hematocrit (%)	PRBC Hematocrit (%)	0.033	0.028	0.001	0.528

Table IV: Correlation Analysis of Pre-Donation and PRBC Parameters.

Parameter	Hemoglobin (g/dL) Pre-donation	Hematocrit (%) Pre-Donation	Hematocrit of PRBCUnit @Day 21 (%)	Total Hemoglobin Content @ Day 21 (g/unit)
Hemoglobin (g/dL) Pre-Donation	1.000	0.123*	0.016	-0.039
Hematocrit (%) Pre-Donation	0.123*	1.000	0.034	0.028
Hematocrit of PRBC Unit @ 21 (%)	0.016	0.034	1.000	0.197**
Total Hemoglobin Content @ 21 (g/unit)	-0.039	0.028	0.197**	1.000

based on the very low correlation coefficients and regression coefficients obtained in this analysis. These findings are also in accordance with other authors who have indicated that it is difficult to estimate PRBC quality depending on pre-donation parameters only.[1,2] This highlights the problems of clinicians, and blood banks, in using basic hematological indices to assess the safety and quality of blood products especially packed red blood cells, which are central to transfusions.

This is in concordance with other studies where weak direct relationship between pre-donation hemoglobin and PRBC Quality indicators including the hemoglobin quality of PRBC units (r = -0. 039) has also been observed.[3,4] This means that although the results of the hemoglobin levels are useful to identify which donors are acceptable and what blood is convenient for donation, they might not be enough to inform about the final likelihood of the good quality PRBC units. In practical terms, this finding could have a bearing on the fact that, when screening for potential PRBC donors, using just the hemoglobin level indices; we may miss other indicators that may influence the quality of the PRBCs that are produced at the end of the entire donation process.

As in the above findings the correlation coefficient of pre-donation hematocrit and PRBC hematocrit was 0. 034 and with total hemoglobin content was 0. 028, which further confirms earlier studies that have addressed that pre-donation hematocrit alone is not a strong predictor of PRBC quality.[5,6] Hematocrit refers to the percentage of total blood volume that can be occupied by RBCs, and though it has been used undeniably to quantify the red cell mass in donors and hence PRBC availability, there is only a modest association of hematocrit data with PRBC quality especially post-donation; this brings into question other variables that seem to have significant effects on the final quality of the product more so those in the production line

The correlation obtained in the study that indicated PRBC units wherein the hemoglobin content had a moderate positive association with the PRBC hematocrit on positive correlation coefficient test (r = 0. 197, p < 0. 01) and RBC unit volume (r = 0. 262, p < 0. This finding is in concordance with the extent of literature, which points out that, despite the fact that the pre-donation tests may give some essential data, the methods of blood processing and storage greatly affect the quality of PRBCs.[7-9] Maximum and minimum amounts of volume and hemoglobin content reviewed suggests that increases blood volume is associated with high hemoglobin levels which is important in making sure that the PRBC units meet the clinical levels of transfusion. Still, these associations are not sufficiently strong and, because of that, it is possible to conclude that there are other aspects connected to blood processing and storage which contribute to variability of these quality parameters.

Some researchers have established that blood processing methods, storage period or temperature environments may in some way influence the Pre-donation parameter – PRBC quality correlations.[10- 12] For example, the method of red cell separation, the type of additive used and the time taken for storage can affect the survival and viability which in turn affects the level of hemoglobin and hematocrits in the PRBC units. In light of the results of the present study, the processes underlying the preparation of PRBCs for storage may interact with donor factors at the time of donation and thereby introduce extra sources of variation that have not been previously captured based solely on the donor's pre-collection status.

It has been suggested that other factors such as post donation hemodilution and alterations in red cell morphology during storage are additional factors that have brought slight correlations to the identified PRBC quality indicators.[13,14] Such characteristics indicate that, although there is some connection between all the pre-donation parameters and the quality of PRBC, it is probably masked by some factors that transpire before, during, and after the blood donation process. This

becomes of special importance when it comes to analyse the part that storage conditions play when forming storage lesions – biochemical and morphological changes occurring in red blood cells during the storage phase. These lesions can impact on the life span of the red cells with consequently influence the oxygen delivery capacity as well as the efficiency of the transfusion which in turn determines the clinical results attached to the PRBC transfusion.[17]

The weak correlation established in the present study for pre-donation hematological parameters compared to what has been suggested in earlier studies that these parameters could effectively predict quality of PRBC.[15,16] Another limitation of this study is the subjectivity of the variability of donors, such as age, gender, or weight, which affects hematological parameters but not PRBC quality in a consolidated manner over time. Besides, the study did not consider the storage duration other than ordinally 21 days after which several biochemical and morphological changes occur in rat RBCs. These changes, or storage lesions, can reduce the effect of the donor-related factors, thus complicating the assessment of pre-donation hematological measures.

It is suggested to assess various factors, such as detailed medical check-up of donors, assessment and monitoring of the process of donation in progress, or investigation of the impact of difference storage environments on the final guess.[18] These models could therefore facilitate the capacity of blood banks to assure the quality of PRBC units, which would in turn serve patients' benefits by offering superior quality blood products for transfusion.[19,20]

Further research into understanding the relationship between donor characteristics and storage conditions could result into creation of new storage schedules or additive solutions that reduce the effects of the storage lesions hence of increased PRBC shelf life. This would become particularly important in cases of a shortage of blood available or where preservation is called for, say in military or for disasters.

Conclusion

The study conducted revealed that the pre donation hematological parameters including the hemoglobin, hematocrit levels were not very useful to ascertain the quality of PRBC units as evident from the regression and correlation analysis done. Analyzing the correlation table, it was noted that, although there was some positive correlation of pre-donation parameters with PRBC quality indicators but these correlations were relatively low. This is an apparent sign that the direct impacts of these pre-donation parameters may not be profound in defining the PRBC quality over the storage period of 21 days that comes out of donation hence there is a need to look for other variables or even interactions that might greatly shape the final quality of PRBC product.

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