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ORIGINAL ARTICLE

TERTIARY CARE HOSPITAL REALITY CHECK: HEMOGLOBIN CHANGE AFTER TRANSFUSING 1 UNIT OF FRESH WHOLE BLOOD IN A CROSS-SECTIONAL STUDY

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Abstract

Background: Anemia is a typical clinical disorder which often necessitates blood transfusion, especially in hospitalized patients. Even though it is usually believed that the transfusion of a unit of blood raises the hemoglobin levels about 1 g/dL, the response of hemoglobin can differ according to the patient traits and clinical conditions. However, limited evidence exists regarding the real-world hemoglobin increment after transfusion of fresh whole blood in tertiary care settings and the influence of comorbidities on this response.

Objective: To determine the change in hemoglobin level following transfusion of one unit of fresh whole blood (450 mL) in anemic patients and to assess whether comorbid conditions influence the hemoglobin response.

Material and Methods: This cross-sectional study was conducted in the Department of Medicine, Benazir Bhutto Shaheed Teaching Hospital (DHQ), Abbottabad, Pakistan, from 15 April 2024 to 14 April 2025. A total of 159 hemodynamically stable anemic patients (hemoglobin <11 g/dL) receiving one unit of fresh whole blood were included after informed consent. Pre-transfusion (HBBT) and 24-hour post-transfusion (HBAT) hemoglobin levels were measured using the Sahli method. Data on demographics, anemia type, comorbidities, and clinical features were collected. Analysis included descriptive statistics, subgroup comparisons, and multivariable linear regression (SPSS v22).

Results: Mean age was 42.23 ±19.74 years; 62.9% were female. Microcytic anemia was most common 86(54.1%). The mean increase in hemoglobin was 1.65 ± 0.70 g/dL (mean percentage change: 32.29 ± 25.80%), which was a statistically significant improvement after transfusion of fresh whole blood. Females showed greater increase than males. Patients with vague bleeding had lower increment (1.49±0.63 g/dL vs 1.71±0.71 g/dL in non-bleeding). Regression analysis identified female gender as a positive predictor (B = 0.24, p = 0.047) and vague bleeding as a negative predictor (B= −0.29, p = 0.024) of hemoglobin change.

Conclusion: One unit of fresh whole blood transfusion produced a clinically meaningful hemoglobin rise of approximately 1.65 g/dL in anemic patients. Female gender enhanced response, while vague bleeding attenuated it. Comorbidities like hypertension, diabetes, and chronic kidney disease showed no significant impact.

Keywords: Anemia, Blood Transfusion, Hemoglobin, Whole Blood Transfusion, Comorbidity

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Introduction:

Anemia is a significant community health issue worldwide and is linked to various forms of medical and surgical conditions, which play a significant role in morbidity and healthcare burden on a global basis [1]. It is characterized by the concentration of hemoglobin being below 13 g/dL in men and 12 g/dL in women [2]. The condition is especially common in hospitalized patients, and in this case, it is frequently required to intervene clinically.

Blood transfusion is a widely practiced medical intervention across the globe and has been termed as a form of organ transplantation that is specialized because of its biological and immunological nature[3,4]. The demand of whole blood and blood components is on the increase, and the supply of voluntary blood donors is not sufficient to meet the growing demand [4].

Authorship Contribution: [1,6]Substantial contributions to the conception or design of the work; or the acquisition, Data analysis, Literature review, [2]Drafting the work or revising it critically for important intellectual content, [3,4,6]Final approval of the version to be published, Topic Selection & Supervision

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The type of blood products transfused depends on the needs of individual patients, but the most common aspects of blood transfusion in clinical practice are whole blood and packed red blood cells.

It is widely believed that one unit of blood transfusion leads to the approximate 1 g/dL rise in hemoglobin level[4,5]. It is anticipated that hemoglobin levels will stabilize within about 24 hours after transfusion, but past research has shown that it can happen sooner when patients are clinically stable with no recent or ongoing bleeding [6]. These results imply that there is variability in the response of hemoglobin after transfusion.

Before transfusing a hospitalized patient, the potential benefits must clearly outweigh the associated risks. The decisions regarding transfusion must be personalized and based on both hemoglobin levels along with the physiological condition of the patient, his or her clinical condition, and comorbidities [7]. One of the indicators that are concerned with the transfusion practice and forecast of clinical outcome is the hemoglobin concentration. Thus, precise measurement of the hemoglobin levels is necessary to streamline the transfusion procedures and maximize the patient care [8].

There are several ways of estimating hemoglobin, which differ in their accuracy, cost, and practicability. Outpatient treatment usually needs faster and cheaper screening procedures, but inpatient treatment demands more precise techniques when it comes to treatment monitoring and decision-making[9]. Sahli method is one of the most common and most popular methods of hemoglobin estimation especially in a resource-deprived environment as it is cheap, simple to do, and materials are readily available. It enables the hemoglobin determination through the venous or capillary blood [10].

Although fresh whole blood transfusion is commonly used, there is a paucity of evidence on the magnitude of hemoglobin change that is actually achieved following transfusion of one unit of fresh whole blood in the clinical setting, specifically in its association with underlying comorbid conditions. It is important to learn how hypertension, diabetes mellitus, chronic kidney disease, liver disease, and bleeding tendencies affect hemoglobin response to make evidence-based decisions related to transfusion. Thus, this research was designed to test how hemoglobin level changes after transfusion of one unit of fresh whole blood in patients with anemia and to determine whether comorbid conditions influence the change in hemoglobin or not.

Material and Method:

Study setting & design: This cross-sectional study was conducted at Medical Ward of Benazir Bhutto Shaheed Teaching Hospital (DHQ), between 15 April 2024 and 14 April 2025.The Institutional Review Board of the Benazir Bhutto Shaheed Teaching Hospital (DHQ), Abbottabad in Pakistan granted the ethical approval (Ref. No/Approval No: ERC-BBS-2024/05).

Sample size: The sample size was calculated using the standard single-population proportion formula at a 95% confidence level and 5% margin of error, assuming a population proportion of 10%, which yielded a minimum required sample of 139 participants. To improve precision and account for possible exclusions or incomplete data, 159 patients were ultimately included (Figure 1).

Inclusion criteria: Patients aged >14 years of either gender with clinically diagnosed anemia (hemoglobin <11 g/dL), who were hemodynamically stable, received one unit (approximately 450 mL) of fresh whole blood, and provided written informed consent were included.

Exclusion criteria: Patients aged <14 years, those who refused consent, received multiple transfusions within 24 hours, were discharged before the 24-hour post-transfusion assessment, received red cell concentrate instead of fresh whole blood, or had incomplete clinical data were excluded.

Data collection procedure: Eligible patients were enrolled consecutively after informed consent. Demographic, clinical, and laboratory data were recorded using a structured questionnaire. Hemoglobin was measured before transfusion and again 24 hours after transfusion using the Sahli method by a single trained observer.

Data analysis: Data were analyzed using SPSS version 22.0. Continuous variables were summarized as mean ± SD or median (IQR), while categorical variables were presented as frequencies and percentages. Appropriate statistical tests and multivariable linear regression were used to identify predictors of hemoglobin change. A p-value <0.05 was considered statistically significant.

Participants:

Eligible participants included patients older than 14 years of age, of either gender, who were clinically anemic with laboratory-confirmed hemoglobin levels below 11 g/dL as measured by the hospital's automated complete blood count analyzer. Only hemodynamically stable (SBP ≥90 mmHg, heart rate ≤100 beats/min, absence of vasopressin or inotropic support, and no clinical evidence of shock or ongoing active hemorrhage at the time of transfusion) patients were included, defined as those who were conscious, not requiring emergency interventions other than transfusion, able to eat and drink, and capable of providing informed consent. Patients receiving transfusion of fresh whole blood and willing to participate after full explanation of the study were included. In our institution, one unit of fresh whole blood corresponds to approximately 450 mL, which is

the standard volume collected and transfused. Patients younger than 14 years, those who refused consent, those who received multiple transfusions within 24 hours, patients discharged from the ward before completion of 24 hours post-transfusion assessment, and patients receiving red cell concentrate were excluded from the study.

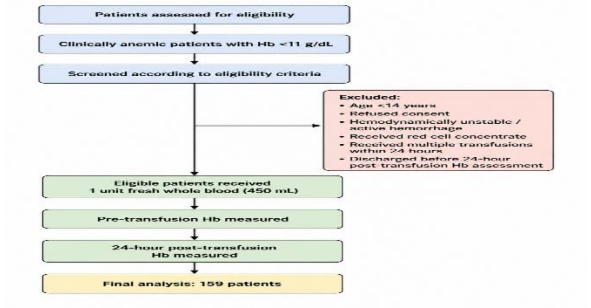

Figure 1: Study flow chart.

Variables:

The change in hemoglobin concentration in g/dL after transfusion was the main outcome variable. Post-transfusion hemoglobin level and percentage change in hemoglobin were the secondary outcomes. Demographic variables which included age, gender, marital status, education level, residence, lifestyle and socioeconomic status were also used as independent variables. The clinical variables were the type of anemia, blood group, history of addiction such as smoking, alcohol and naswar use, comorbid conditions such as hypertension, diabetes mellitus, coronary artery disease, malignancy, liver disease, chronic kidney disease, chronic obstructive pulmonary disease, hyperthyroidism, and rheumatologic diseases. Other variables were vague bleeding (presence of clinically suspected or patient-reported minor, intermittent, or occult blood loss without overt active hemorrhage. This included conditions such as positive occult blood in stool, mild epistaxis, microscopic hematuria, or abnormal uterine bleeding not causing hemodynamic instability), acute infection, family history of transfusion and baseline hemoglobin level.

Data Sources and Measurement;

A structured and pre-designed questionnaire was used to obtain data on demographic, clinical, and laboratory data. Sahli method was used to measure the hemoglobin levels pre and post transfusion. All the hemoglobin measurements were conducted by a single trained observer to reduce the inter-observer variability. Pre-transfusion hemoglobin was measured prior to transfusion whereas post-transfusion hemoglobin was measured 24 hours after transfusion had been completed.

Statistical Methods:

Data analysis was performed using SPSS version 22.0. Normality of continuous variables was assessed prior to analysis. Continuous variables with normal distribution were analyzed using independent t-tests, whereas non-normally distributed variables were analyzed using the Mann–Whitney U test. Categorical variables were summarized descriptively. The association between clinical factors and hemoglobin change was evaluated by calculating paired differences between post-transfusion and pre-transfusion hemoglobin values. A multivariable linear regression model was constructed to identify independent predictors of hemoglobin change, incorporating age, gender, hypertension, diabetes mellitus, malignancy, liver disease, kidney disease, vague bleeding, and baseline hemoglobin as covariates. A p-value of less than 0.05 was considered statistically significant.

Results:

Sociodemographic variables revealed that there was a higher number of female patients. The most prevalent type of anemia was microcytic followed by macrocytic and normocytic anemia (Table 1).

The average percentage increase in hemoglobin was 1.65 g/dL, which was a statistically significant improvement in hemoglobin after transfusion of fresh whole blood. Subgroup comparisons showed that there were differences in hemoglobin response among various clinical conditions. In hypertensive patients, the mean hemoglobin response was 1.54 ± 0.60 g/dL in comparison with 1.67 ± 0.71 g/dL in non-hypertensive patients. Patients who appeared with vague bleeding had a relatively low mean rise of hemoglobin of 1.49 ± 0.63 g/dL and those with no vague bleeding had a mean rise of 1.71±0.71 g/dL (Table 2, Figure 2).

In the multivariate linear regression analysis, female gender was found to be an important independent variable that predicted a higher hemoglobin change after transfusion, and females showed a higher increase in hemoglobin than males (B = 0.24, p = 0.047). Conversely, vague bleeding was significantly negatively related to the hemoglobin change, which means that the hemoglobin response is reduced in these patients (B = -0.29, p = 0.024). Other factors such as age, hypertension, diabetes mellitus, malignancy, liver disease, chronic kidney disease and baseline hemoglobin level were not significantly related to change in hemoglobin (Table 3).

This regression model indicated that 10.1 percent of the variance in hemoglobin change (R2 = 0.101) was explained, with an adjusted R 2 = 0.046. The general model was close to statistical significance (F(9,149) = 1.855, p = 0.063).

Table 1. Baseline Characteristics of Study Participants (n = 159).

Variables		N(%)
Age (Years); Mean ± SD		42.23 ± 19.74
Gender	Male	59 (37.1)
	Female	100 (62.9)
Education	Educated	71 (44.7)
	Uneducated	88 (55.3)
Residence	Rural	95 (59.7)

	Urban	64 (40.3)
Marital Status	Married	113 (71.1)
	Unmarried	46 (28.9)
Lifestyle	Sedentary	127 (79.9)
	Active	32 (20.1)
Hemoglobin Before Transfusion (g/dL); Mean ± SD		6.07 ± 1.89
Hemoglobin After Transfusion (g/dL); Mean ± SD		7.72 ± 1.93
Change In Hemoglobin (g/dL); Mean ± SD		1.65 ± 0.70
Percentage Change In Hemoglobin; Mean ± SD		32.29 ± 25.80
Anemia	Microcytic	86 (54.1)
	Macrocytic	43 (27.0)
	Normocytic	30 (18.9)
Blood Group	A	50 (31.4)
	O	49 (30.8)
	B	42 (26.4)
	AB	18 (11.3)
Addiction History	No Addiction	134 (84.3)
	Smoking	11 (6.9)
	Naswar/Tobacco Use	6 (3.8)
	Smoking And Naswar Use	8 (5.0)
Socioeconomic Status	Poor	14 (8.8)
	Lower-Middle	116 (73.0)
	Middle	28 (17.6)
	Upper	1 (0.6)
Comorbidities	Hypertension	26 (16.4)
	Diabetes Mellitus	16 (10.1)
	Coronary Artery Disease	1 (0.6)
	Chronic Kidney Disease	11 (6.9)
	Malignancy	7 (4.4)
	Chronic Obstructive Pulmonary Disease	2 (1.3)
	Rheumatologic Disease	4 (2.5)
	Liver Disease	2 (1.3)
Other Clinical Features	Vague Bleeding	43 (27.0)
	Acute Infection	51 (32.1)
	Family History Of Transfusion	17 (10.7)

Values are presented as n (%), unless otherwise indicated.

Abbreviations: Hb, hemoglobin; CAD, coronary artery disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease.

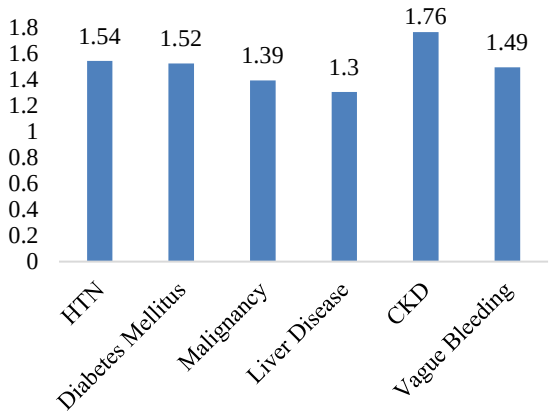

Figure 2: Bar chart of mean hemoglobin change (g/dL) across key subgroups.

Table 2: Change in Hemoglobin after Transfusion and Subgroup Analysis.

Variable	Group	Mean Change	Median	Statistical Test	p-value
		(g/dL)			
HTN	No	1.67±0.71	1.6	U = 1863.5	0.532
	Yes	1.54±0.60	1.4		
Diabetes Mellitus	No	1.66±0.71	1.6	U = 1284.5	0.422
	Yes	1.52±0.56	1.4		
Malignancy	No	1.66±0.70	1.6	U = 629.0	0.417
	Yes	1.39±0.52	1.3		
Liver Disease	No	1.65±0.70	1.6	U = 216.0	0.365
	Yes	1.30±0.14	1.3		
CKD	No	1.64±0.70	1.6	U = 734.5	0.591
	Yes	1.76±0.69	1.4		
Vague Bleeding	No	1.71±0.71	1.6	t = 1.892	0.062
	Yes	1.49±0.63	1.2		

HTN = Hypertension.DM = Diabetes Mellitus. CKD = Chronic Kidney Disease.SD = Standard Deviation. U = Mann–Whitney U statistic.t = Independent samples t-test statistic. p-value< 0.05 considered statistically significant

Table 3: Multiple Linear Regression Analysis of Factors Associated with Change in Hemoglobin.

Variable	Unstandardized Coefficient (B)	Std. Error	t-value	p-value	95% CI
Intercept	2.01	0.24	8.36	<0.001	1.54 to 2.49
Age	–0.004	0.003	–1.31	0.193	–0.010 to 0.002
Female	0.24	0.12	2.00	0.047	0.003 to 0.48
HTN	–0.08	0.16	–0.52	0.607	–0.41 to 0.24
DM	–0.12	0.20	–0.59	0.555	–0.50 to 0.27
Malignancy	–0.33	0.28	–1.18	0.240	–0.88 to 0.22
Liver disease	0.22	0.51	0.43	0.667	–0.79 to 1.23
CKD	0.43	0.24	1.83	0.069	–0.04 to 0.90
Vague bleeding	–0.29	0.13	–2.28	0.024	–0.54 to –0.04
Pre-transfusion Hb	–0.04	0.03	–1.40	0.164	–0.10 to 0.02

HTN = Hypertension. DM = Diabetes Mellitus. CKD = Chronic Kidney Disease. Hb = Hemoglobin. CI = Confidence Interval. B = Unstandardized regression coefficient.

Discussion:

This study provides local evidence from a tertiary care setting in Pakistan on the actual haemoglobin increment following one unit of fresh whole blood transfusion, which is still commonly used in resource-limited environments despite global shifts toward component therapy. By identifying predictors such as gender and vague bleeding, it contributes to more rational, patient-centered transfusion practices, potentially reducing unnecessary transfusions, optimizing blood resource utilization, and improving outcomes in anemic patients with comorbidities. The findings highlight variability from the conventional "1 g/dL per unit" rule and support evidence-based guidelines tailored to South Asian populations.

In this study, anemic adult patients who received transfusion of one unit of fresh whole blood demonstrated a mean haemoglobin (Hb) rise of 1.65 ± 0.70 g/dL. This is a clinically meaningful response to baseline anemia, with mean Hb increasing from 6.07 g/dL pre-transfusion to 7.72 g/dL post-transfusion. In our setting, one unit of fresh whole blood corresponds to approximately 450 mL, which may partly explain the observed haemoglobin increment. The recorded increase is generally in line with the conventional expectation that one unit of blood raises haemoglobin by about 1 g/dL. Previous studies have reported similar findings, with average increases ranging from 1.0–1.5 g/dL[11,12]. This relatively greater haemoglobin response may be attributable to population-specific factors such as smaller body size and a higher proportion of female patients. Importantly, these findings suggest that in similar clinical settings, a single unit of transfused blood may be more effective than traditionally anticipated, highlighting the need for cautious transfusion practices to avoid potential over-transfusion.

The magnitude of haemoglobin increase after transfusion is influenced by several factors, including patient body size, ongoing blood loss, total blood volume, and underlying clinical conditions. A study conducted in a tertiary healthcare facility in Nepal reported a lower average Hb rise of approximately 0.75 g/dL following transfusion of one unit of whole blood or packed red cells. The authors explained this variability by such factors as chronic illness, acute hemorrhage, fluid administration, and donor-related characteristics [12,13]. In the present study, patients presenting with vague bleeding demonstrated a lower mean haemoglobin increase compared to those without bleeding. This observation is in line with earlier studies which revealed that, continuous or occult blood loss could also weaken the anticipated haemoglobin reaction following transfusion [12].

Although vague bleeding showed a borderline association with hemoglobin change in univariable analysis ($p = 0.062$), it became statistically significant in the multivariable regression model ($p = 0.024$). This difference likely reflects the effect of confounding, as regression analysis adjusts for multiple covariates simultaneously. After controlling for factors such as gender, baseline hemoglobin, and comorbidities, the independent negative impact of vague bleeding on hemoglobin response became more apparent.

Moreover, we observed was a higher increase in hemoglobin levels in female patients as opposed to male patients. This observation is consistent with the emerging evidence indicating that donor and recipient factors, such as sex, body mass index (BMI), and body surface area (BSA), could determine hemoglobin responsiveness to transfusion. It has been reported that transfusion in individuals with smaller body size may raise hemoglobin concentration by a disproportionately greater percentage [12].

A small statistically nonsignificant negative correlation was observed between age and change in hemoglobin following transfusion in the present study. On the same note, baseline hemoglobin level showed a weak negative correlation with post-transfusion hemoglobin change, which means that patients with high baseline Hb were more likely to experience smaller incremental increases. Even though these correlations were not significant, they are in line with the clinical expectations and with previous results, which have found less hemoglobin gains in older and those patients with higher baseline levels of hemoglobin, whereas less baseline hemoglobin is typically related to a higher post-transfusion response [12,14].

In our cohort, females constituted the majority of participants (62.9%), and microcytic anemia was the most prevalent anemia subtype (54.1%). These findings are consistent with international data showing a higher prevalence of anemia among females (56.1%), with microcytic anemia being the most common form observed (40.7%). Similarly, local studies have reported a predominance of anemia among females, with microcytic anemia accounting for approximately 48.2% of cases [15,16]. Moreover, it is shown in the international evidence that microcytic anemia, mainly iron deficiency, is exceedingly widespread in low-income states. Most of the microcytic anemia patients in our study were in lower-middle socioeconomic class (73.0%), which can be compared to the regional data giving prevalence of 73.6% [16,17.]

In terms of the distribution of blood groups, the most prevalent were blood groups A (31.4), O (30.8), then B (26.4), and AB (11.3). These results demonstrate some minor difference with respect to the regional data in which blood group B has been identified as the most common (34.1%), followed by group O (28.1%), group A (26.6%), and group AB (11.2%) [18]. These differences may be genetic and geographic peculiarities of the population.

All participants in the present study received fresh whole blood, which is considered a standard transfusion product in many clinical settings. There is an emerging body of evidence that whole blood transfusion is possibly linked to better outcomes (such as decreased mortality), especially in targeted patient groups [19,20]. Notably, the study participants did not receive any previous anemia treatment, which reduced the possibility of any confounding factors on the post-transfusion changes in hemoglobin. Past studies have shown that iron supplementation or any other treatment of anemia may confound the actual impact of transfusion [21].

In the current analysis, hemoglobin response did not show any significant correlation with other frequent

comorbidities like high blood pressure, diabetes mellitus, cancer, or liver diseases. The multivariable regression model predicted nearly ten percent variability of hemoglobin response implying that there are other unmeasured variables that might affect post-transfusion hemoglobin variations. These results support the idea that the individualized approach to transfusion decisions must be observed considering patient-specific clinical presentation and hemodynamic status instead of only using hemoglobin thresholds [22, 23].

Conclusion:

One unit of fresh whole blood transfusion resulted in a clinically significant rise in hemoglobin, with a mean of 1.65g/dL. Female gender was associated with a greater hemoglobin response, while vague bleeding was linked to a reduced post-transfusion increase. Age, baseline hemoglobin level, and chronic kidney disease showed non-significant associations, and other comorbidities had no measurable impact. The small percentage of variance explained by the model indicates that there are other clinical factors that affect hemoglobin response.

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CONFLICT OF INTEREST:
The authors declare no conflicts of interest.

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