International Science and Technology Journal
المجلة الدولية للعلوم والتقنية
Volume 37 العدد
Part 2 المجلد
المجلة الدولية للعلوم والتقنية
International Science and Technology Journal
ISTJ

http://www.doi.org/10.62341/smat4919

Received	**2025/11/15**	**تم استلام الورقة العلمية في**
Accepted	**2025/12/01**	**تم قبول الورقة العلمية في**
Published	**2025/12/03**	**تم نشر الورقة العلمية في**

The Link between Maternal ABO and Rh blood Traits and Anaemia and Blood Transfusion Status

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Abstract

Anemia during pregnancy is the pinnacle of concern for the World Health Organization (WHO) in low- and middle-income countries (LMICs). In these settings, where anemia is often most severe, blood transfusion serves as an important, life-saving intervention for the management of obstetric emergencies and severe cases. Therefore, this emphasizes the need for regular prenatal follow-up and regular screening during pregnancy for early detection and prompt treatment of anemia, thereby preventing progression to critical stages requiring complex interventions. The study objective is to investigate the association of maternal blood traits (ABO and Rh) with anemia and blood transfusion during childbirth. The survey was a retrospective cross-sectional study conducted on 4,919 pregnant women at Al-Wahda Hospital in Derna, Libya, between 2020 and 2023. Venous blood samples were collected for blood type and hemoglobin studies, and the results were statistically analyzed using SPSS for descriptive statistics, chi-square tests, and ANOVA tests. The results of the analysis of 4,919 maternal records revealed a significant association ($p = 0.027$) between blood characteristics and hemoglobin status, with A-negative characteristics having the highest prevalence of anemia (61.8%). In the group, 527 postpartum women (10.71%) received a total of 1153 blood transfusion units.

http://www.doi.org/10.62341/smat4919

Mean units transfused increased with the severity of anemia, reaching 3.00 ± 0.816 units for A-positive women with severe anemia. However, inferred statistics using two-way ANOVA showed that neither maternal blood characteristics (P = 0.565), hemoglobin status (P = 0.621), nor their interaction (P = 0.507) had a statistically significant effect on transfusion requirements. The distribution of transfusions is carefully reflected in the cohort, 527 parturient women (10.71%) received a total of 1,153 blood transfusion units. The mean transfusion units increased with anemia severity, peaking at 3.00 ± 0.816 units for severely anaemic A-positive women. However, inferential statistics using two-way ANOVA showed that neither maternal blood trait (P=0.565), haemoglobin status (P=0.621), nor their interaction (P=0.507) had a statistically significant effect on transfusion requirements. The distribution of transfusions closely mirrored the population prevalence of blood traits (O+ 30.17%, A+ 31.67%, B+ 21.25%). Furthermore, the mode of delivery did not significantly influence transfusion rates (P=0.219). The evidence supports implementing universal anaemia screening and management as a priority in prenatal care. Consequently, blood bank inventories require alignment with the population's blood trait distribution (A+ > O+ > B+ > O- > AB+ > A- > B- > AB-). Moreover, clinically, the focus is advised to remain on preventing and managing anaemia and its complications rather than blood traits-based predictions.
Key words: Maternal ABO, Rh, Anaemia, Blood Transfusion.

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية
Volume 37 العدد
Part 2 المجلد
http://www.doi.org/10.62341/smat4919

العلاقة بين فصائل دم الأمهات *Rh, ABO* وفقر الدم واحتياج نقل الدم

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الملخص

تُعَدُّ مُشكلة فقر الدم أثناء الحمل بؤرة التركيز الأساسية لمنظمة الصحة العالمية (*WHO*)، لا سيَّما في البلدان المنخفضة والمتوسطة الدخل (*LMICs*)، حيث يصل العبء الوبائي لفقر الدم إلى أعلى مستوياته، ويُمثِّل نقل الدم تدخلاً حاسماً لإنقاذ الأرواح، في مواجهة حالات الطوارئ التوليدية والمضاعفات الصحية الشديدة. لذلك، يؤكد على ضرورة المتابعة المنتظمة قبل الولادة والفحوصات الروتينية طوال الحمل للكشف المبكر والعلاج الفوري لفقر الدم، مما يمنع بالتالي التقدم إلى مراحل حرجة تستلزم تدخلات معقدة. الهدف من الدراسة هو التحقق من العلاقة بين فصائل الدم الأمومية *ABO* و *Rh*مع فقر الدم ونقل الدم أثناء الولادة. وقد كان هذا البحث دراسة مقطعية بأثر رجعى أُجريت على 4919 امرأة حامل في مستشفى الوحدة في درنة، ليبيا، بين عامي 2020 و2023. تم جمع عينات دم وريدية لدراسة فصيلة الدم والهيموجلوبين واجراء اختبارات المطابقة لنقل الدم كأحد الإجراءات الروتيني، وتم تحليل النتائج إحصائياً باستخدام برنامج *SPSS* للإحصاء الوصفي واختبارات كاي مربع واختبارات *ANOVA* كشفت نتائج تحليل 4919 سجلاً أمومياً عن وجود ارتباط ذي دلالة إحصائية *(P=0.027)* بين مجموعة الدم وحالة الهيموجلوبين، حيث كانت مجموعة *A-* السلبي أعلى معدل انتشار لفقر الدم (61.8%) في المجموعة، وتلقت 527 امرأة (10.71%) ما مجموعه 1153 وحدة نقل دم. وازداد متوسط وحدات النقل مع شدة فقر الدم، ليصل إلى ذروته عند 3.00 ± 0.816 وحدة للنساء المصابات بفقر الدم الشديد من فصيلة *A+* الموجب. ومع ذلك، أظهرت الإحصائيات الاستدلالية باستخدام تحليل التباين ثنائي الاتجاه *(two-way ANOVA)*

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أنه لا فصيلة الدم الأمومية *(P=0.565)*، ولا حالة الهيموجلوبين*(P=0.621)* ، ولا تفاعلهما *(P=0.507)* كان لها تأثير ذو دلالة إحصائية على متطلبات نقل الدم. وقد انعكس توزيع عمليات النقل بدقة تقريباً مدى انتشار فصائل الدم بين الأمهات *O+ 30.17%*، *A+ 31.67%*، *B+ 21.25%* علاوه على ذلك، لم يؤثر نمط الولادة بشكل كبير على معدلات النقل *(P=0.219)*. يلخص البحث لتركيز الاولوية لفحص وإدارة فقر الدم بشكل عالمي في الرعاية ومتابعة الحمل. ولذلك، فانة ينصح توفير مخزون بنوك الدم المحلية على النحو *(A+ > O+ > B+ > O− > AB+ > A− > B− > AB−)*، وهذا بالإضافة الى التركيز السريري على منع فقر الدم وإدارة مضاعفاته بدلاً من التنبؤات القائمة على فصيلة الدم.

الكلمات الدالة *:*فصائل الدم الأمومية، *ABO*، *Rh*، فقر الدم، نقل الدم.

Introduction

Anaemia during pregnancy is a significant global health concern and is associated with adverse maternal and fetal outcomes, including preterm birth, low birth weight, postpartum haemorrhage (PPH), and increased maternal mortality. [1] Anaemia affects about 42% of pregnant women worldwide [1, 2]. In low- and middle-income countries, maternal anaemia contributes to 12% of low-birth-weight cases, 19% of preterm births, and 18% of perinatal mortality.[3] The World Health Organisation (WHO) defines anaemia in obstetrics as a haemoglobin (Hb) level <11.0 g/dL, with some guidelines adjusting thresholds to <10.5 g/dL in the second trimester [1, 4-7]. The primary cause is largely iron deficiency (ID), driven by increased physiological demands, inadequate dietary intake, and haemodilution due to plasma volume expansion. [2, 8]. Other contributing factors include folate or vitamin B12 deficiency, chronic inflammation, and hemoglobinopathies (e.g., sickle cell disease, thalassemia) [4, 9]. Excessive haemorrhaging, such as postpartum haemorrhage (PPH), defined as more than 1000 ml of blood loss after delivery, also causes anaemia. [10]

In 2023, the world witnessed a heart-breaking statistic: more than 700 women lost their lives every day due to preventable causes related to pregnancy and childbirth. Shockingly, over 90% of these maternal deaths occurred in low and lower-middle-income

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countries. One of the leading causes of maternal mortality is blood loss before, during, and after childbirth[11].

Blood transfusions are employed for lifesaving[12, 13]. In obstetrics, two primary reasons necessitating prompt blood transfusion to avert maternal death are severe anaemia during the prenatal period and partum haemorrhage.[13, 14] . Obstetric haemorrhage 31% and extreme anaemia 15% are primary contributors to maternal mortality. And access to blood transfusions decreases mortality by 40–60%.[15]

Mortality among women from severe postpartum haemorrhage was roughly 27-31%, whereas fatalities resulting from consequences of severe anaemia during pregnancy were 10-15%. Consequently, significant haemorrhaging throughout gestation and postpartum, together with acute anaemia, was addressed with blood infusions to preserve the mother's life, achieving a success rate of 60-80% for postpartum haemorrhage and 15-30% to manage the complication of severe anaemia during pregnancy.[16-18]

The management of anaemia during pregnancy and postpartum haemorrhage, particularly through relevant blood transfusion protocols, is of paramount importance. This study was undertaken in an attempt to enhance healthcare system through guiding blood transfusion policy and improving resource allocation. The outcome of this research should provide valuable insight into blood inventory management and volunteer donor recruitment strategies by identifying the most frequently requested blood types and analysing the impact of severity of anemia on blood transfusion demands.

Materials and Methods

Study area and design

The present research work was conducted in the obstetrics and gynaecology ward of Al Wahda Teaching Therapeutic Hospital, situated in Derna, Eastern Libya. The study is designed as a retrospective cross-sectional study. Data for 4921 term labour women were extracted from patient documents and registration manual books at the delivery room. The cases attended to the gynaecology and obstetrics ward at Al Wahda Hospital from first of January 2020 to thirty first of December 2023, to induce normal and lower caesarean section deliveries.

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Methods

Maternal whole blood EDTA samples was drawn from labour women at admission to deteinvolve group traits (ABO and Rh), haemoglobin (Hb) concentration, and performance of blood transfusion requirements involvement blood compatibility test. The principle of determining ABO and Rh traits is based on erythrocytes cell-slide method consistent with the Association for the Advancement of Blood & Biotherapies (AABB). Haemoglobin concentration was determined using the Nihon Kohden MEK-6550 3-part Diff Haematology Analyser.

Statistics analysis

Data were analysed using SPSS Version 29. Descriptive statistics (frequencies and percentages) summarized the distributions of maternal blood groups and haemoglobin status. The Chi-Square test assessed the association between these two categorical variables. A one-way ANOVA compared mean blood transfusion units across delivery modes, while a two-way ANOVA examined the individual and interactive effects of maternal blood group and WHO-classified haemoglobin severity on transfusion units. This multi-test approach ensured comprehensive analysis.

Results

A total of 4,919 mothers were included in the analysis of maternal blood traits distribution and its association with haemoglobin and blood transfusion status. Regarding haemoglobin status, 47.1% of mothers had normal haemoglobin levels, while 52.9% exhibited abnormal haemoglobin levels. The proportion of mothers with abnormal haemoglobin concentration was highest among those with the A-negative blood trait (61.8%), followed by O-negative (54.4%), B-positive (54.5%), and A-positive (54.1%) blood traits. In contrast, the AB-negative blood trait had the highest proportion of mothers with normal haemoglobin concentration (61.5%). The difference in the distribution of haemoglobin status across blood traits was statistically significant ($P = 0.027$). These findings show a significant association between maternal blood traits and haemoglobin status among certain blood traits, particularly A-negative, showing a higher prevalence of abnormal haemoglobin levels compared to others, as illustrated in Table 1.

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This was confirmed by the calculated chi-square value of 15.783, with 7 degrees of freedom. The tabular value at the same degrees of freedom is 14.07. Since the calculated value exceeds the tabular value, this suggests a statistically significant difference in mean transfusion requirements among the groups at this stage.

Table 1 Distribution of Maternal Blood Traits According to Haemoglobin Status and Their Association(N=4919)

			Maternal haemoglobin		Total	P-value
			normal	abnormal		
Maternal Blood Groups	A Positive	No.	667	785	1452	0.027
		Percentage (%)	45.9%	54.1%	100.0%	
	A Negative	No.	68	110	178	
		Percentage (%)	38.2%	61.8%	100.0%	
	B Positive	No.	446	534	980	
		Percentage (%)	45.5%	54.5%	100.0%	
	B Negative	No.	59	54	113	
		Percentage (%)	52.2%	47.8%	100.0%	
	AB Positive	No.	172	165	337	
		Percentage (%)	51.0%	49.0%	100.0%	
	AB Negative	No.	24	15	39	
		Percentage (%)	61.5%	38.5%	100.0%	
	O Positive	No.	775	817	1592	
		Percentage (%)	48.7%	51.3%	100.0%	
	O Negative	No.	104	124	228	
		Percentage (%)	45.6%	54.4%	100.0%	
Total		No.	2315	2604	4919	
		Percentage (%)	47.1%	52.9%	100.0%	

χ^2 15.783 Degrees of freedom 7 critical value 14.07

Analysis of 4,919 maternal blood trait records, alongside 1,153 units of blood transfused to 527 parturient women, revealed that the distribution of blood transfusions closely aligns with the prevalence of maternal blood traits and maternal haemoglobin concentration, as defined by the WHO for maternal anaemia, as explored in Table 2. The descriptive statistics were explain comparing means across blood traits when show variability in mean blood transfusion requirements across different maternal blood traits and haemoglobin status categories ((mean ±SD (2.19+1.28 units)) a total each blood haemoglobin concentration cross each all blood traits categories the normal haemoglobin concentration (2.32±1.38), mild (2.09±1.16), moderate (2.16±1.29), Sever (2.64±0.81) For instance, The mean ± standard deviation (SD) for blood transfusion units in the group A Positive with severe anemia is 3.00 ± 0.816 units. This means that,

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on average, women in this blood trait received three units of blood transfusion, with most individuals' transfusion amounts falling within approximately 0.816 units above or below this mean (i.e., roughly between 2.18 and 3.82 units). The mean transfusion increases with the severity of 8, peaking at 3.0 units for severe anaemia. Similar trends, though with different magnitudes, are observed in other blood traits. The standard deviations indicate moderate variability of blood transfusion within blood traits, with some blood traits categories e.g., B negative with mild anaemia (mean ± SD, 3.67± 3.055) showing higher dispersion, likely due to small sample population sizes Table 2

Despite these observed differences in means, the two-way ANOVA results indicate that neither maternal blood trait (F = 0.827, P = 0.565) nor maternal haemoglobin status (F = 0.592, P = 0.621), nor their interaction (F = 0.947, P = 0.507), have a statistically es, indicating a potentially greater demand for these rarer blood traits in clinical settings.

Significant effect on blood transfusion requirements. All p-values are well above the conventional threshold of 0.05, suggesting that the observed differences in means are not statistically significant and may be attributed to random variation rather than actual trait effects. Explained as a table 3

The R-squared value (0.045) further suggests that only about 4.5% of the variance in blood transfusion requirements can be explained by the combination of maternal blood trait and haemoglobin status, indicating a weak explanatory power of the model. Explained in Table 3

In summary, while descriptive statistics hinted at potential differences in transfusion needs among maternal blood traits and haemoglobin categories, the inferential statistics (ANOVA) do not support a significant association. This implies that, within this sample, neither maternal blood trait nor haemoglobin status is a strong determinant of blood transfusion requirements during the studied period.

Table 2 Association between Maternal Blood Traits, Anaemia

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Severity, and Blood Transfusion Requirement (Mean Units)

Descriptive Statistics: the mean transfusion for each blood group						
		Maternal Haemoglobin WHO				
Maternal Blood Groups	Descriptive Statistics	Normal Haemoglobin	Mild Anemia	Moderate Anemia	Severe Anemia	Total
A Positive	Mean	2.6	2.13	2.23	3	2.31
	Std. Deviation	1.735	1.264	1.334	0.816	1.411
	N	35	32	91	4	162
A Negative	Mean	1.25	1.75	1.93	-	1.77
	Std. Deviation	0.5	0.5	1.207	-	1.02
	N	4	4	14	-	22
B Positive	Mean	1.86	2.14	1.98	2.75	2.05
	Std. Deviation	0.663	1.099	0.892	0.5	0.937
	N	14	36	55	4	109
B Negative	Mean	1.67	3.67	2	-	2.33
	Std. Deviation	0.577	3.055	1.095	-	1.723
	N	3	3	6	-	12
AB Positive	Mean	2.5	2	1.87	-	2
	Std. Deviation	1.291	0.632	1.06	-	1
	N	4	6	15	-	25
AB Negative	Mean	-	-	1	-	1
	Std. Deviation	-	-	-	-	-
	N	-	-	1	-	1
O Positive	Mean	2.33	1.97	2.35	2	2.26
	Std. Deviation	1.185	1.066	1.582	1	1.387
	N	40	30	82	3	155
O Negative	Mean	2.67	1.88	1.94	-	2.07
	Std. Deviation	1.862	0.835	0.998	-	1.172
	N	6	8	16	-	30
Total	Mean	2.32	2.09	2.16	2.64	2.19
	Std. Deviation	1.377	1.164	1.299	0.809	1.279
	N	106	119	280	11	516

Table 3 Two-Way ANOVA of Maternal Blood Traits and Haemoglobin Status on Blood Transfusion

Tests of Between-Subjects Effects		
Dependent Variable: Blood transfusion		
Source	F	Sig.
Maternal blood group	0.827	0.565
Maternal haemoglobin	0.592	0.621
Maternal blood group * Maternal haemoglobin	0.947	0.507
a. R Squared = .045 (Adjusted R Squared = -.001)		

Figure 1 describes the analysis of 4,919 maternal blood trait records, alongside 1,153 units of blood, for 527 parturient blood transfusion recipients. The results reveal that the distribution of blood transfusions closely aligns with the prevalence of maternal blood traits. With the A positive blood trait demonstrated on received blood transfusions at a rate of 31.67%, also showed O positive and B positive with transfusion rates of 30.17% and 21.25%, respectively. Conversely, AB-positive, who had a relatively lower transfusion rate of 4.74%.

Negative blood traits were found to be less in both maternal delivery and transfusion cases. O negative, A negative, B negative, and AB

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negative collectively represented a smaller segment of the population, with AB negative being the rarest at 0.78% of maternal blood traits and only 0.02% of transfusions. Interestingly, some negative blood traits, such as O negative and A negative, exhibited slightly higher transfusion rates compared to their population frequencies, suggesting a potentially greater demand for these rarer blood traits in clinical settings.

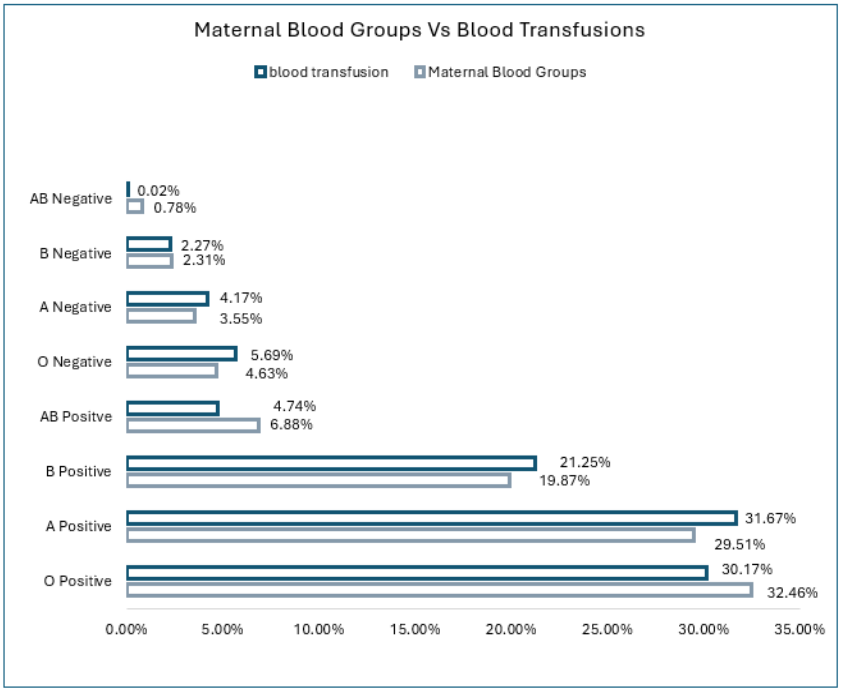

Figure 1 Comparison of Maternal Blood trait Distribution and Blood Transfusion Frequencies

Table 5 presents the results of a one-way ANOVA examining the mean blood transfusion units required according to mode of delivery among 527 participants. The mean blood transfusion units for women who delivered vaginally (Normal delivery) was 2.12 (SD = 1.01, N = 121). For those who underwent elective caesarean section, the mean was 2.10 (SD = 1.115, N = 183), while the mean for urgent caesarean section was 2.30 (SD = 1.499, N = 223). The overall mean for the study population was 2.19 units (SD = 1.273).

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The ANOVA results indicated no statistically significant difference in blood transfusion rates between the different modes of delivery ($F = 1.522$, $P = 0.219$). The calculated F value was lower than the tabular value (2.9957). The P-value exceeded the conventional threshold for significance ($P > 0.05$), suggesting that the mode of delivery whether normal, elective cesarean, or urgent caesarean there not a significant effect on the likelihood of requiring a blood transfusion in this cohort.

These findings suggest that, within this study population, the need for transfusion is not significantly influenced by the mode of delivery, highlighting the importance of considering other clinical factors when assessing transfusion risk.

Table 4 One-Way ANOVA of Blood Transfusion Units by Mode of Delivery

Mode of Delivery		N	Mean	Std. Deviation	Sum of Squares	Mean Square	P-value
normal		121	2.12	1.01	4.923	2.461	0.219
caesarean	Elective	183	2.1	1.115			
	Urgent	223	2.3	1.499	847.48	1.617	
	Total	527	2.19	1.273	852.402		

Calculated value 1.522 Degrees of freedom 2, 524 Tabular value 2.9957

Discussion

The previously completed cohort study, published in early 2025, summarised the prevalences of maternal blood traits in the studied population as follows: proved that blood type O+ was dominant in the study group at 1627 (32.5%), followed by A+ at 1479 (29.5%). B+ was offered to 996 individuals (19.9%), while AB+ accounted for 345 individuals (6.9%).[19] The Rh-negative blood traits were lowered frequencies: O- was identified in 232 (4.6%), A- in 178 (3.6%), B- in 116 (2.3%), and very low frequencies to AB- (0.8%).[19]

These findings lead us to deduce that O+ and A+ are the predominant maternal blood traits in the cohort, collectively representing over 60% of the population, This aligns with global population proportions documented in the literature. [1, 2]. For instance, a large cohort study conducted at Tobruk Medical Center found that O blood type is most prevalent (38.3%) in pregnant women, less than A (33.4%), which is similar to the distribution presented in the group.[20]

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An additional study of over 2,300 births reported 46.9% O and 37.5% A blood traits, demonstrating the global dominance of these traits in maternal communities.[21] In contrast, AB- is the least common blood trait among the mothers studied, comprising less than 1% of the sample.[19]

This study investigated the effect of maternal blood traits on haemoglobin concentration and the requirement for blood transfusion during labour in a large-scale cohort of 4,919 women, with detailed analysis on 527 transfusion cases. Globally, Anaemia is a significant risk factor for requiring blood transfusion during labour and postpartum. The Royal College of Obstetricians and Gynaecologists (RCOG) guidelines highlight that severe anaemia before or after delivery increases transfusion risk, mainly when bleeding occurs.[22]

The prevalence of anaemia, defined as hemoglobin concentration less tahn11 g/dL according to WHO criteria, [23] was significant, affecting approximately 52.9% of mothers, with higher rates observed in A-negative and O-negative blood groups ($P = 0.027$), indicating a statistically significant relationship between blood status and hemoglobin. This who is supported by some on the other hand not all literature. For example, a study in Indian rural pregnant females found anaemia most prevalent in B-positive blood trait, with A-positive also common nevertheless without a statistically significant association across all traits.[24]

Another survey from Tobruk Medical Centre announced that A+ and O+ women were more prone to anaemia, though the association was statistically insignificant ($P > 0.05$).[25] This suggests that the strength of association varies depending on the population and sample size. Some research suggests that individuals with blood trait O may be relatively resistant to anaemia, despite their high frequency in populations. Kumar and Kaushik (2024) reported that individuals with blood trait O had a lower prevalence of anaemia compared to those with traits A, B, and AB, indicating a possible protective effect.[26] This corresponds with our observation of heightened anaemia rates in O-negative among the study population, which suggests that Rh factor negativity may modify this causality or that geographical and nutritional factors play a role.

A study conducted on pregnant women from the city of Sabratha in western Libya showed that blood haemoglobin and haematocrit

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concentrations begin to gradually decrease from the first to the third trimester of pregnancy; This is despite, no association was established between these levels and maternal blood traits. Despite this, no explicit link was found. However, the observed decreases in haemoglobin and haematocrit strongly suggest that the anaemia has stages of development that are most likely to occur at the end of pregnancy.[27] Another study conducted in the city of Al-Bayda in eastern Libya also supported this finding, showing a general prevalence of anaemia among pregnant women at 57%, with the majority of cases occurring in the third trimester. This prevalence of anaemia is closely consistent with the findings of the current study, indicating a significant risk of anaemia affecting pregnant Libyan women, and also confirming that anaemia is a major public health concern in the geographical area.[28, 29]

In this investigation, the blood transfusions were administered to 10.71% of all women at birth, a very high rate compared to a previous study conducted in Germany that targeted more than 6 million pregnant women, where transfusions of packet red blood cells (RBCs) constituted 1.23%. It was also observed that severe anaemia was prevalent among women who received blood transfusions.[1]

In addition, the study corresponds to consistent with findings that anaemia is closely correlated to the requirement to blood transfusions during childbirth. Similarly, a Ugandan study found that moderate and severe anaemia is associated with increased rates of maternal blood transfusions, at a rate of 12% among women with anaemia.[30] This underscores the elevated risk of blood transfusions for mothers with anaemia during childbirth, which is often accompanied by complications in women who receive blood transfusions. There, anaemia and blood transfusions in women with placenta accreta syndrome have been strongly linked to an increased risk of postpartum complications, such as renal and heart failure. [9] Our analysis infers about 1153 units of blood were donated to 527 parturient recipients, likely reflecting a similar clinical burden, where anaemia and blood group-related risks may contribute to transfusion requirements and associated morbidity. European studies, particularly in Germany, also meta-analyse more extended hospital stays and higher rates of comorbidities (e.g., hypertension,

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diabetes) in transfused women, emphasising the complex interplay between anaemia, transfusion, and maternal health. [9]

The mean number of blood transfusion units elevated with anaemia severity across all blood traits, peaking at 3.00 ± 0.816 units in the A-positive trait with severe anaemia. This trend aligns with the pathophysiological understanding that severe anaemia, often due to iron deficiency or blood loss, necessitates greater transfusion support to restore oxygen-carrying capacity and prevent maternal morbidity. [9, 26] The study discovered which maternal blood traits are most frequently to receiving blood during labour, and this is considered that one of the almost of clinically significant application. The investigation deduced that the most prevalent maternal blood trait is the nearly predominant transfusion blood categories, the A+ blood trait; otherwise, the O positive dominates on the maternal blood trait distribution phenotypes.[19] The moderate variability among standard deviations within traits reflects clinical heterogeneity and individualised transfusion practices.

However, data estimated using two-way ANOVA not observed a statistically significant effect of maternal blood characteristics ($F = 0.827$, $P = 0.565$), haemoglobin status ($F = 0.592$, $P = 0.621$), or their interaction ($F = 0.947$, $P = 0.507$) on transfusion requirements. This suggests that while descriptive data show trends, blood traits alone are not a strong independent predictor of transfusion necessitated. This finding confirms previous studies emphasizing that clinical factors such as severity of anemia and bleeding, rather than blood traits, primarily drive transfusion decisions in obstetrics. [4, 31]

The distribution of blood transfusions closely reflected the prevalence of maternal blood traits, with O-positive, A-positive and B-positive accounting for the majority of transfusions, reflecting population frequencies rather than differential risk. In particular, rare Rh-negative blood syndromes, such as AB-negative, had extremely low transfusion rates, highlighting potential challenges in blood bank management and the necessitate for targeted donor recruitment.[1, 14]

Furthermore, the mode of delivery (normal vaginal, elective caesarean, or immediate caesarean) nevertheless without significantly affect the rate of transfusion (ANOVA, $P = 0.219$), suggesting that the requirements for transfusion is more closely

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associated with maternal anemia and bleeding complications than type of delivery alone. This is in line with WHO recommendations which advocate individual risk assessment for transfusion rather than reliance on the method of delivery..[32]

The high prevalence of anemia and its strong association with transfusion warrant highlighting the critical importance of prenatal anemia screening and treatment, including iron supplementation and nutritional interventions to reduce transfusion requirements and improve maternal outcomes. The lack of significant association between blood trait and transfusion suggests that universal anemia prevention strategies should be prioritized over blood traits -targeted approaches.

The findings of this study of the association between maternal blood traits, anemia and blood transfusion during labour are consistent with widespread evidence that anemia significantly increases the risk of blood transfusion in pregnant women. The predominance of O+ and A+ blood traits and the high prevalence of anemia in Rh-negative traits add a new dimension to understanding transfusion requirements.

Other large studies confirm the strong association between anemia and blood transfusions and highlight the increased morbidity in women receiving blood transfusions. These data underscore the importance of targeted anemia screening and management strategies, based on blood traits, to collectively reduce transfusion rates and improve maternal health outcomes.

Given the challenges of rare blood traits in transfusion logistics, health systems should strengthen and promote blood donation programs and inventory management to ensure availability of all blood traits, especially Rh-negative trait.[14]

Conclusion

The purpose of this study was to provide reliable data to rationalize the use of human resources and blood donation. The findings confirm that the value of a donated blood unit is only realized when it is adapted to actual and expected needs. Random donations or storage of large, non-priority quantities represent a significant waste of volunteer effort.

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This research provides actionable information for the blood bank and volunteer management at Al Wahda Teaching and Therapeutic Hospital, specifically for the gynaecology and obstetrics ward. Accordingly, blood units should be stored in the following priority order based on demand: A+ > O+ > B+ > O- > AB+ > A- > B- > AB-, with approximate storage ratios of 32:31:22:6:5:5:3:1.

Furthermore, enhancing national standard operating procedures (SOPs)and regulatory guidelines for blood bank management can be achieved by implementing a donation and storage system guided by scientific demand research, as demonstrated here. This approach ensures the optimal utilisation of donations and directs donor efforts toward meeting patients' actual requirements. Ultimately, this maximises the return on these vital human resources and provides the effectiveness and efficiency of the entire blood supply chain.

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