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Original Article

Biochemistry Section

Association Between Maternal Blood Group and Anaemia in First-trimester Pregnancy: A Cross-sectional Study from Tamil Nadu, India

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ABSTRACT

Introduction: Iron Deficiency Anaemia (IDA) is a significant public health concern among first-trimester pregnant women in India, particularly in Tamil Nadu. Given the dual burden of maternal anaemia and the potential role of blood group as a biological determinant, exploring this relationship is essential. Elucidating such relationships may strengthen antenatal care by enabling risk based screening, improved antenatal care practices, personalised interventions, and ultimately better maternal and neonatal outcomes.

Aim: To assess the association between maternal blood group and iron deficiency anaemia among pregnant women in their first trimester attending a hospital in Tamil Nadu, India.

Materials and Methods: This hospital-based, cross-sectional study was conducted at the Department of Obstetrics and Gynaecology of SRM Medical College and Hospital, Faculty of Medicine and Health Sciences, S.R.M. Institute of Science and Technology, Kattankulathur, Chengalpattu, Chennai, Tamil Nadu, India, for six months, from July 2025 to December 2025, among 280 pregnant women in their first trimester. Initial obstetric evaluation included basic analytes such as iron, Transferrin Iron Binding Capacity (TIBC), % Transferrin Saturation (TSAT), haemoglobin and blood group. Iron profile was evaluated in a Beckman Coulter DXC700 analyser. Subjects were categorised as Group A with mild anaemia, Group B with moderate anaemia and Group C with severe anaemia. Normality of the variables was evaluated by applying the Shapiro-Wilk test, and it was demonstrated as skewness, non parametric methods were employed. Descriptive statistics were expressed as median values with interquartile ranges, while categorical variables were summarised as frequencies and percentages.

Results: A total of 280 women in the first trimester of pregnancy were enrolled in this study. The mean age of the participants was 26.86±4.52 years. The distribution of ABO blood groups among participants was as follows- group O- 120 (43%), Group A- 53 (18.92%), group B- 92 (33%), group AB- 15 (5.36%). This distribution highlights the predominance of group O, followed by group B, consistent with population level data. Out of 280 participants, the majority of participants were Rh positive 246 (87.86%), while a smaller proportion were Rh negative 34 (12.14%). The AB+ group had the lowest median haemoglobin concentration among the blood groups studied; however, between-group statistical comparisons were not performed/reported. Participants with Hb less than 11 g/dL were 131 (46.78%), and haemoglobin levels more than 11 g/dL were 149 (53.22%). About 3 (2.29%) had severe anaemia with Hb less than 8 g/dL, 58 (44.27%) had moderate anaemia with Hb levels ranging between 8 and 9.9 g/dL and 70 (53.44%) had mild anaemia with Hb levels between 10 and 10.9 g/dL.

Conclusion: Blood group typing may serve as a supplementary biological marker for identifying vulnerable populations, but effective prevention and management should prioritise evidence based strategies with routine iron supplementation, early haematologic screening, and structured nutritional education to reduce the burden of anaemia, particularly in pregnancy.

Keywords: Blood group antigens, Haemoglobin, Iron profile, Serum ferritin

INTRODUCTION

Pregnancy is a critical physiological state that places increased demands on maternal haematologic and nutritional reserves. Among the complications during gestation, anaemia remains one of the most prevalent and significant public health concerns [1]. The World Health Organisation (WHO) reports that 30% of non pregnant and more than 42% of pregnant women have survived with anaemia [1]. In pregnancy, haemoglobin levels below 11 g/dL are a threshold frequently exceeded in early gestation due to haemodilution and increased iron requirements [2]. Globally, anaemia affects nearly 37% of pregnant women, with higher prevalence reported in less economically developed countries [3].

During pregnancy, maternal blood volume expands by 30-50%, driven by a significant increase in plasma volume and a 20-30% rise in red cell mass [4]. This expansion supports the growing uterus, placenta, and foetal demands, with the disproportional increase in plasma leading to physiologic anaemia (dilution) and improved placental perfusion. Thus, leads to a fall in the concentration of Hb in the blood, despite an increase in the total number of red cells [5]. Deficiencies at this stage are associated with outcomes such as preterm birth, intrauterine growth restriction, and low birth weight [6]. Therefore, it's ideal to identify, early in the first trimester of pregnancy, women at risk of developing iron deficiency anaemia in late pregnancy in order to initiate the target iron supplementation.

Human blood types vary among individuals and are classified into four main groups: A, B, AB, and O. Each group is associated with specific antigens on red blood cells and corresponding antibodies in the plasma. Variations in red cell antigens and immune responses across ABO and Rh blood groups have been linked to differences in haemoglobin levels and iron metabolism. Maternal IgG antibodies, specifically anti-A or anti-B, cross the placental barrier to target the foetus's incompatible red blood cells. Such incompatibility occurs most frequently when a mother with blood type O carries a foetus

with blood type A, B, or AB, and IgG antibodies play a key role in mediating this response [7].

However, findings remain inconsistent across populations, and limited data exist from South India, where anaemia prevalence is particularly high. Tamil Nadu, Telangana, Andhra Pradesh, and Kerala generally fall into the category of moderate to high prevalence of anaemia, which reveals the requirement of a nutritional supplementation programme [8]. Iron deficiency anaemia is commonly identified using haemoglobin levels along with serum indicators such as iron concentration, TIBC, and TSAT. Assessing these parameters during the first trimester of pregnancy may be advantageous, as it allows clinicians to identify women at risk. Understanding which early pregnancy blood markers can predict the development of anaemia in the third trimester is therefore important for timely intervention [9].

The association between blood group and iron deficiency anaemia will provide valuable insights for risk stratification, targeted interventions, and improved care in the first trimester of pregnancies. Iron deficiency is a global epidemic; as per the Indian Council of Medical Research (ICMR), the National guidelines for control of iron deficiency anaemia. Emphasise the importance of early detection and management of iron deficiency anaemia [10]. Understanding which blood group can predict the anaemic status is advantageous as it allows clinicians to identify women at risk [11]. Therefore, this hospital-based study was undertaken in Tamil Nadu to evaluate the relationship between maternal blood group and anaemia prevalence in first-trimester pregnant women, with the aim of contributing region-specific evidence to the growing body of literature on maternal health. Hence, the study aimed to assess the association between maternal blood group and iron deficiency anaemia among pregnant women in their first trimester attending a hospital in Tamil Nadu. The objectives were to determine the distribution of haemoglobin levels across different blood groups in first-trimester pregnant women. Also to assess anaemia severity (mild, moderate, and severe) and examine iron indices across different ABO and Rh blood groups.

MATERIALS AND METHODS

This hospital-based cross-sectional study was conducted at the Department of Obstetrics and Gynaecology of SRM Medical College and Hospital, Faculty of Medicine and Health Sciences, S.R.M. Institute of Science and Technology, Kattankulathur, Chengalpattu, Chennai, Tamil Nadu, India, for six months, from July 2025 to December 2025, Following approval by the Institute's Ethics Committee (Ethical clearance number: ST0525-2532), the study started by recruiting individuals in accordance with the predetermined inclusion and exclusion criteria. The ethical principles were closely followed outlined in the Declaration of Helsinki (2013 revision) and those set forth by pertinent regulatory agencies, ensuring that each participant provided informed consent and that the study was conducted with respect for human dignity and safety.

Inclusion criteria: Women with singleton pregnancy aged 18 to 40 years in their first trimester (up to 12 weeks of gestation) who consented to participate in the study were included.

Exclusion criteria: Women with known haematological disorders (e.g., thalassaemia, sickle cell disease), chronic medical conditions affecting haemoglobin levels (e.g., renal disease, liver disease), and women already on iron therapy before pregnancy were excluded.

Sample size calculation: According to the National Family Health Survey (NFHS-5, 2019-21), as quoted in an original research article, the prevalence of anaemia among pregnant women in India is approximately 48-52% [12].

Using this prevalence estimate (p=0.48), the sample size was calculated with the standard formula for single-proportion studies:

$n = Z^2 p (1-p)/d^2$

Where:

z= 1.96 (for 95% confidence level)

p= 0.48 (prevalence of anaemia in pregnancy)

d= 0.05 (margin of error, 5%); n = 384

The required sample size was calculated as 384 based on an assumed anaemia prevalence of 48%, 95% confidence level and 5% absolute precision. Due to non response, refusal and incomplete records, 280 eligible participants were included in the final analysis using a convenience sampling approach. This method was chosen due to its feasibility in a clinical setting and the accessibility of pregnant women attending antenatal clinics.The reduced sample size may have reduced the precision and statistical power of the association analysis.

Study Procedure

Blood group determination: ABO and Rh typing was performed using standard agglutination techniques [13]. Haemoglobin concentrations were determined using an automated Sysmex haematology analyser [14]. Anaemia was defined based on WHO guidelines as a haemoglobin level below 11 g/dL [15]. Participants were categorised based on haemoglobin levels, with Hb less than 8 g/dL as severe anaemia, Hb between 8 to 9.9 g/dL as moderate anaemia, and Hb between 10 to 10.9 g/dL as mild anaemia [16]. Pregnant women with haemoglobin less than 11g/dL, low iron (<40 µg/dL) and high TIBC (>400 µg/dL) were classified as having iron deficiency anaemia [17]. Participants with TSAT <15% were considered to have low transferrin saturation, consistent with reduced circulating iron availability. Serum iron levels, TIBC, and TSAT were also assessed using Beckman Coulter DXC 700 autoanalyser [18].

STATISTICAL ANALYSIS

All the collected data were coded and analysed using Statistical Package for Social Sciences (SPSS) software version 21.0. Normality of the variables was assessed using the Shapiro-Wilk test. Since the data demonstrated skewness, non parametric methods were applied. Descriptive statistics are presented as median values with interquartile ranges, while categorical variables are summarised as frequencies and percentages. The Mann-Whitney U test was employed to compare distributions between two groups and to evaluate statistical differences. The Chi-square test was used to examine the association between blood group and anaemia status.

RESULTS

A total of 280 women in the first trimester of pregnancy were enrolled in the study. The mean age of participants was 26.86 ± 4.52 years, indicating that the majority of women were in their mid-twenties, a critical reproductive age group in the regional population. The distribution of ABO blood groups among participants was: Group O positive n=99 (35.36%), Group O negative, 21 (7.5%), Group A positive, 46 (16.43%), Group A negative, 7 (2.5%), AB positive, 15 (5.36%); B negative, 6 (2.14%), B positive, 86 (30.71%).

With respect to Rh factor, the majority of participants were Rh positive, 246 (87.86%), while a smaller proportion were Rh negative, 34 (12.14%). This finding aligns with established epidemiological trends, where Rh positivity is more common globally, but Rh negativity remains clinically significant due to its implications in haemolytic disease of the newborn.

Median haemoglobin levels across blood groups ranged between 10.5 g/dL (AB+) and 11.45 g/dL (B-), respectively. Serum iron concentrations varied from 41 µg/dL (AB+) to 63 µg/dL (A-), with most groups showing reduced levels compared to reference ranges. TIBC was elevated across all groups, ranging from 363 µg/dL (A-) to 514.5 µg/dL (B-), consistent with iron deficiency states.

TSAT was markedly reduced, ranging from 9.0% (B-) to 12% (as observed in B+, O+, O- blood group). The majority of blood groups demonstrated values below the normal threshold (20-50%), confirming iron deficiency as the predominant aetiology of anaemia as presented in [Table/Fig-1].

The study categorised participants into three levels of anemia severity as severe, moderate, and mild. In the category of severe anaemia, O+ blood group presented Hb of 6.4 g/dL exhibited the lowest with serum iron as low as 17 µg/dL and transferrin saturation levels 3%. Moderate anemia (Hb 8 to 9.9 g/dL), out of

Parameters	Group A- n=7 (2.5%)	Group A+ 46 (16.43%)	Group AB+ 15 (5.36%)	Group B- n=6 (2.14%)	Group B+ 86 (30.71%)	Group O- n=21 (7.5%)	Group O+ n=99 (35.36%)
Hb (g/dL)	11.2 (10.7-11.85)	11.1 (10.32-11.77)	10.5 (9.85-11.9)	11.45 (11.02-14.45)	10.98 (10.2-11.8)	11.1 (10.2-12)	10.95 (10-11.9)
Iron (µg/dL)	63 (45.5-87)	48.5 (36-73.5)	41 (30-69)	43 (40.25-49.5)	52 (38.5-75)	44 (32-76.5)	51 (39-63)
TIBC (µg/dL)	363 (305.25-389.25)	441.5 (390-479)	414 (349-502)	514.5 (393.75-552.75)	418 (377-496)	443 (347-508)	440 (378-511)
% Transferrin Saturation (TSAT)	10.05 (11.75-28.25)	11 (8-20.3)	11 (6.3-19)	9 (8-10)	12 (9-17.6)	12 (6.88-20.5)	12 (8-17.7)
IDA present/absent %	n=1 (0.35%)	n=21 (7.5%)	n=8 (2.85 %)	n=1 (0.35%)	n=38 (12.5%)	n=9 (3.21%)	n=53 (18.92%)

[Table/Fig-1]: Haemoglobin, iron, TIBC and % Transferrin Saturation (TSAT) levels and blood group in first-trimester pregnant women.
Results are expressed in median and inter-quartile range; Hb: Haemoglobin; TIBC: Transferrin iron binding capacity; Blood groups – A-, A+, B-, B+, AB+, B-, B+, O-, O+

The anaemic group (Hb < 11 g/dL) showed lower serum iron and TSAT, along with higher TIBC, which is the classical biochemical profile of iron deficiency anaemia [Table/Fig-2]. The reported p<0.001 confirms that these differences are statistically significant. Based on haemoglobin levels, the participants were categorised as Hb < 11 g/dL, 131 (46.78%) and haemoglobin levels ≥ 11g/dL, 149 (53.22%).

Parameters	Hb < 11g/dL (n=131)	Hb ≥ 11g/dL (n=149)	p-value
Iron (µg/dL)	40 (29-58)	61 (45-79)	<0.001**
TIBC (µg/dL)	465 (403-517)	402 (364-465)	<0.001**
% Transferrin saturation (TSAT)	9 (6-12)	16 (11-21)	<0.001**

[Table/Fig-2]: Serum iron, TIBC and % Transferrin Saturation (TSAT) levels in first-trimester pregnant women.
Hb: Haemoglobin; TIBC: Transferrin iron binding capacity; (Mann-Whitney U test): Results are expressed in median and interquartile range, ** p<0.001 - highly significant

Out of 131 pregnant women, about 3 (2.29 %) had severe anaemia with Hb less than 8 g/dL, 58 (44.27%) had moderate anaemia with Hb levels ranging between 8 and 9.9 g/dL and 70 (53.43%) had mild anaemia with Hb levels between 10 and 10.9 g/dL. Blood group distribution in anaemic women is categorised as seen in [Table/Fig-3] and revealed the detailed data of median and interquartile range of Hb, iron, TIBC and % TSAT with respect to the blood groups and severity of anaemia.

58 participants in this category, the O+ blood group was the most prevalent with n=24 (41.38%), followed by B+ with n=16 (27.59%). Iron levels in this group ranged from a mean of 27 µg/dL (O-) to 46.5 µg/dL (O+). TIBC remained high, peaking at 535 µg/dl in the O- blood group.

The mild anaemia category had the highest number of participants (n=70) with haemoglobin levels between 10 and 10.9 g/dL. Again, the O+ blood group was the most common 28 (48.28%), followed by B+ with 21 (36.21%). Iron profiles compared to the severe and moderate groups were observed, with serum iron reaching 57.83 µg/dL in A+ participants and TSAT levels generally exceeding 8% [Table/Fig-3].

In the present study, the Chi-square test (χ^2=296.317, df=312, p=0.730) revealed no statistically significant association between blood group and iron deficiency anaemia among the 280 participants. Symmetric measures (Phi=1.029, Cramer's V=0.420, p=0.730) further confirmed the absence of meaningful association.

DISCUSSION

Anaemia during pregnancy continues to be a major public health challenge, particularly in low- and middle-income countries. It is associated with the increased risks of maternal morbidity, preterm delivery, and low birth weight. Recent evidence highlights that maternal blood group may play a role in the prevalence and severity

Blood group	n (%)	Hb g/dL	Iron (µg/dL)	TIBC (µg/dL)	%Transferrin saturation (TSAT)
Severe anaemia (Hb < 8 g/dL)					
O+	1 (33.33%)	6.4	17	574	3
B+	2 (66.67%)	7.25(6.9 - 7.6)	19 (16.17 - 21.83)	566 (482.56 - 649.44)	4 (2.59 - 5.41)
Moderate anaemia (Hb 8 to 9.9 g/dL)					
A+	9 (15.52%)	9.37 (8.94 -9.8)	35.33 (27.52 -43.14)	487.4 (421.44 -553.25)	9.84 (2.14 -17.54)
AB+	4 (6.90%)	9.12 (8.27 -9.97)	28.5 (19.21 -37.79)	489.5 (407.67 -571.33)	6.5 (3.86 - 9.14)
B+	16 (27.59%)	9.67 (9.18 -10.16)	37.38 (21.17 -53.59)	483.31 (394.18 -572.44)	8.13 (4.13 -12.13)
O-	5 (8.62%)	9.38 (9.05 -9.71)	27 (17.54 -36.46)	535 (414.8 -655.2)	5.48 (2.04 -8.92)
O+	24 (41.38%)	9.51 (9.08 - 9.37)	46.5 (15.57 -77.43)	479.75 (415.25-544.25)	10.07 (2.58 -17.56)
Mild anaemia (Hb 10 to 10.9 g/dL)					
A+	12 (17.14 %)	10.55 (10.35 -10.75)	57.83 (40.33 -75.33)	443.58 (366.74 -520.42)	13.73 (3.77 -23.69)
AB+	4 (6.90%)	10.37 (10.15 -10.59)	46.5 (29.37 -63.63)	455 (364.87 -545.13)	10.15 (7.1 -13.2)
B+	21 (36.21%)	10.44 (10.21 -10.67)	52.47 (24.77 -80.17)	407.09 (346.7 -467.48)	13.65 (5.27 -22.03)
B-	1 (1.72%)	10.5	35	390	9 (8-10)
O-	4 (6.90%)	10.72 (10.6 -10.84)	40 (29.14 -50.86)	471 (444.46 -497.54)	8.69 (6.27 -11.11)
O+	28 (48.28%)	10.55 (10.3 -10.8)	53.42 (26.61 -80.02)	476.17 (389.5 -562.84)	11.91 (5.15 -18.67)

[Table/Fig-3]: Category of anaemia and percentage of blood group distribution.
Median and interquartile range; Hb: Haemoglobin; TIBC: Transferrin iron binding capacity

of anaemia, though findings remain mixed and context-specific [19]. The current study highlighted the different blood group and severity of anaemia in pregnant women in the first trimester of pregnancy. About 43% of participants had O positive blood group and also presented with severe anaemia.

Several investigations have explored the link between maternal blood group and anaemia during pregnancy. Reported that the severity of anaemia correlated with maternal complications and neonatal outcomes [20]. Found high anaemia prevalence among pregnant women, with associations to dietary and socioeconomic factors. Blood group was noted as a potential biological determinant but not consistently predictive [21]. An observational study conducted by Sharma YC et al., found that women with B+ve and O+ve blood groups exhibited a higher prevalence of moderate anaemia compared to those with A or AB groups. These findings suggest that blood group antigens may influence susceptibility to anaemia, potentially through genetic or immunological mechanisms. Such evidence underscores the importance of incorporating blood group profiling into risk stratification and targeted screening strategies for pregnant women [22].

The World Health Organisation (WHO) defines anaemia in pregnancy as haemoglobin (Hb) levels < 11g/dL. The finding that 46.78% of women fell below this threshold indicates a high burden of anaemia, underscoring the need for targeted interventions in antenatal care. A 2024 prospective study in India reported similar prevalence rates, with nearly half of pregnant women presenting Hb <11 g/dL, confirming anaemia as a persistent challenge in maternal health [22]. Overall, values clustered close to the WHO cut-off of 11 g/dL, indicating a high burden of borderline or mild anaemia among participants.

The WHO 2025 global estimates show that anaemia remains widespread among women of reproductive age, particularly during pregnancy, with significant consequences for maternal and neonatal outcomes. These findings are consistent across diverse populations, suggesting that anaemia in pregnancy is not only region-specific but also a global public health issue.

Similarly, systematic reviews have reinforced that anaemia in pregnancy is multifactorial, but blood group differences may contribute to variations in haemoglobin levels [23]. These findings align with earlier literature that linked ABO blood groups to differences in red cell morphology and susceptibility to haemolysis.

Iron status indicators were evaluated across varying degrees of anaemia severity. Participants classified with moderate to severe anaemia demonstrated that the markedly reduced serum iron concentrations (<50 µg/dL), elevated TIBC >400 µg/dL, and TSAT values below 16%, when compared to individuals with mild anaemia. These findings are consistent with established diagnostic criteria for iron deficiency anaemia, as outlined by the WHO and corroborated by previous haematological studies [24,25].

Importantly, the WHO does not recognise blood group as a risk factor for iron deficiency anaemia. WHO guidelines emphasise dietary iron intake, absorption efficiency, pregnancy, childhood growth demands, and chronic disease as the primary determinants of anaemia prevalence. This underscores that while blood group may show population-specific associations, it is not a globally validated predictor. Several studies have reported varying associations between ABO blood groups and anaemia prevalence [26,27]. For instance, retrospective analyses in Turkish populations suggested that individuals with blood group O exhibited a higher prevalence of anaemia compared to other groups [27].

The ABO blood groups are known to influence susceptibility to certain infections and diseases, which may indirectly affect iron metabolism. For example, chronic parasitic infections or gastrointestinal blood loss could vary by blood group, thereby altering iron status. In this study, the participants with AB and O positive were found to present with an iron-deficient state. It is reported that women with O blood group tend to present with lower haemoglobin levels compared to other blood groups. The proposed mechanisms include: (i) Red cell antigenic differences that may affect iron metabolism and haemolysis; (ii) Immune-mediated variations in susceptibility to infections, which indirectly influence iron status [27]. These findings suggest that O-positive blood group may predispose individuals to iron deficiency anaemia, as reflected in altered iron indices.

In the present study, the Chi-square test did not reveal a statistically significant association between blood group and anaemia status. This finding suggests that blood group does not play a major role in determining susceptibility to iron deficiency anaemia in the studied population. In contrast, one of the studies conducted in rural India found only weak associations, emphasising that dietary intake and socioeconomic status were stronger determinants of anaemia risk than blood group type [28]. Shaik H et al., found blood group A to be significantly associated with anaemia among young adults in Andhra Pradesh [29], while Venkatesan D et al., highlighted possible interactions between blood group, iron status, and genetic polymorphisms in pregnant women [30]. The discrepancy between our findings and earlier reports may be due to differences in sample size, population characteristics, or methodological limitations such as low expected cell counts in the contingency table. Overall, the present study contributes to the growing body of evidence suggesting that the relationship between blood group and anaemia is not universal and may vary across populations. Larger, multicentric studies with robust statistical power are recommended to clarify this association.

Limitation(s)

Despite promising findings, several limitations must be acknowledged. Firstly, sample size and regional bias, as many other studies are region-specific, limiting generalisability. Not included the confounding factors such as nutritional status, socioeconomic conditions, and infections (e.g., malaria, hookworm) often overshadow blood group effects.

CONCLUSION(S)

The present study demonstrated that there is no statistically significant association between blood group and anaemia. However, the role of blood group as a supplementary marker warrants consideration. Blood group typing is universally performed, cost-effective, and documented in routine clinical practice, making it a readily available parameter for integration into broader risk assessment frameworks. Inclusion of blood group alongside established determinants such as nutritional status, socioeconomic conditions, and comorbidities does enhance screening efficiency and supports individualised patient care. From a public health perspective, incorporating blood group data into antenatal care programmes may support more efficient resource allocation, particularly in regions with a high burden of anaemia.

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Authors' contribution: SP: Data collection; RJ: Literature review, data scrutiny and preparation of figures/tables; KAAS: Statistical analysis, interpretation of results and conceptualisation; VMV: Supervision, project administration, critical review; PR: Methodology design, editing of the manuscript.

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