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Socio-Demographic Determinants and Clinical Spectrum of Moderate-to-Severe Anemia and Inherited Haemoglobinopathies in Pregnant Women of Central India

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Abstract

Background and Objectives: Anemia remains a pervasive public health challenge during pregnancy in developing countries, significantly affecting maternal and perinatal outcomes. While nutritional deficits dominate, the overlapping presence of inherited haemoglobinopathies complicates the clinical and demographic spectrum. This study evaluates the socio-demographic and clinical factors associated with moderate-to-severe anemia and haemoglobinopathies among pregnant women in Madhya Pradesh, India.

Methodology: A prospective cross-sectional study was conducted involving 375 pregnant women presenting with hemoglobin (Hb) levels less than 10 gm/dl across three trimesters at Gandhi Medical College, Bhopal, Madhya Pradesh. Demographic information, obstetric history, and clinical parameters were analyzed against anemia grades (moderate vs. severe) and haemoglobinopathy profiles confirmed via High-Performance Liquid Chromatography (HPLC).

Results: Iron Deficiency Anemia (IDA) was the predominant diagnosis across all cohorts, accounting for 93.3% of cases, while haemoglobinopathies were identified in 6.7%, with beta-thalassemia trait being the most common genetic variant. No statistically significant correlations were observed between haemoglobinopathy distribution and maternal age(Chi-square(4) = 5.302, p = 0.258), education(Chi-square(15) = 8.248, p = 0.913), socioeconomic status (Chi-square(6) = 3.481, p = 0.746), booking status(Chi-square(3) = 2.247, p = 0.523), obstetric history (Chi-square(3) = 0.643, p = 0.886), religious communities (Chi-square(6) = 4.538, p = 0.604). However, a highly significant statistical association was established between consanguineous

marriage and anemia severity (Chi-square (1) = 5.874, p = 0.015), with 32.6% of severely anemic patients reporting consanguinity compared to 17.2% in the moderate cohort. Furthermore, 38% of patients diagnosed with beta-thalassemia arose from consanguineous unions.

Conclusion: While nutritional iron deficiency remains the overwhelming driver of maternal anemia, a significant subset carries inherited hemoglobin disorders. The strong correlation between severe maternal anemia, beta-thalassemia, and consanguineous marriages underscores the critical necessity for targeted community counseling, pre-pregnancy screening, and routine antenatal surveillance in regional public health strategies.

Keywords: Moderate anemia, Severe anemia, Haemoglobinopathies, Iron Deficiency Anemia, Beta-thalassemia, Sickle cell anemia

Introduction

Anemia is the most prevalent nutritional deficiency worldwide, acting as a profound public health concern in developing nations like India. Despite easily accessible treatments, preventable etiologies, and decades of dedicated national eradication initiatives operating since independence, anemia remains the most frequent medical complication encountered during pregnancy. It is deeply tied to adverse maternal and perinatal morbidity and mortality[1]. To mitigate this burden, structural frameworks like the National Nutritional Anemia Prophylaxis Program under the RMNCH-A campaign were instituted in 1972 [2], alongside supplementary global and national initiatives such as the 12*12 program spearheaded by the Federation of Obstetrics and Gynecology Society of India (FOGSI) in collaboration with the WHO and UNICEF [3].

According to the World Health Organization (WHO), the global prevalence of gestational anemia ranges from a mere 14% in wealthy developed nations to a staggering 65% to 75% across India [4]. More recently, the National Family Health Survey (NFHS-5) confirmed that 52.2% of pregnant Indian women remain anemic 5. The baseline diagnostic physiological threshold for anemia in pregnant individuals is defined by the WHO as hemoglobin values below 11g/dl irrespective of gestational age, whereas the Centers for Disease Control and Prevention (CDC) utilizes trimester-specific criteria as hemoglobin below 11g/dl in the first and third trimesters, and hemoglobin below 10.5 g/dl in the second trimester[6].

Anemia refers to a condition in which the hemoglobin (Hb) content of the blood is lower than normal for a person's age, gender, and environment, resulting in the blood's capacity to carry oxygen being diminished [7]. In developing ecosystems, its multi-factorial presentation stems from inadequate dietary habits, poor iron bioavailability, hookworm infestation, chronic infections (such as tuberculosis and malaria), and underlying genetic hemoglobin disorders like sickle cell anemia and thalassemia syndromes [7]. Furthermore, maternal factors including age, high parity, short inter-pregnancy intervals, and broader socio-demographic and lifestyle characteristics aggressively dictate its development. Mild anemia often causes chronic fatigue and exhaustion. However, progression to moderate or severe grades can provoke maternal tachycardia, hypotension, postpartum hemorrhage, and severe systemic infections [8,9]. Postpartum hemorrhage is intimately tied to pre-labor hemoglobin levels; when unmanaged, severe bleeding remains a fatal consequence, driving up to 23% of maternal deaths in developing regions [8-11].

Crucially, inherited haemoglobinopathies often mimic or coexist with Iron Deficiency Anemia (IDA), clouding clinical differentiation. The WHO estimates that 5.2% of the global population carries a significant hemoglobin variant, surging past 7% when isolating pregnant cohorts

[12]. In India, thalassemia and sickle cell disease represent the primary variants, with an estimated 7500 – 12000 babies born annually with beta-thalassemia major [13]. The national carrier burden sits at 3% to 4% [14], while sickle cell traits exhibit a mean frequency of 4.3%, displaying dense clustering across central states like Madhya Pradesh, Gujarat, Maharashtra, and Chhattisgarh [15,16]. Given the acute physiological iron demands of pregnancy, differentiating nutritional deficits from genetic traits is critical: IDA demands aggressive iron supplementation, whereas genetic carrier states require strict counseling to prevent homozygous inheritance in the progeny and avoid hazardous secondary iron overload. Because localized epidemiological profiles detailing these interactions within the Madhya Pradesh region remain scarce, this study delineates the socio-demographic and clinical dynamics shaping moderate-to-severe gestational anemia and haemoglobinopathies.

Materials and Methods

After approval from the institutional ethical committee this prospective cross-sectional study was executed from October 2022 to March 2024 within the Department of Obstetrics and Gynecology at Gandhi Medical College (GMC), Bhopal, Madhya Pradesh, India.

Inclusion and Exclusion Criteria: Pregnant women exhibiting confirmed Hb less than 10gm/dl were enrolled. Conversely, individuals maintaining Hb more than 10gm/dl or those declining to provide explicit informed consent were excluded.

Methodology

Study population comprised of 375 pregnant women presenting with hemoglobin levels less than 10gm/dl who were attending the antenatal outpatient or inpatient services of the participating centers during the active study timeline. Comprehensive clinical, obstetric, and socio-demographic profiling was conducted via structured clinical evaluation, capturing variables including maternal age, educational background, socioeconomic status (SES), booking registration status, obstetric parity (primigravida vs. multigravida), Body Mass Index (BMI), religious community background, and history of consanguineous marriage. Participants were stratified according to their anemia status (Group 1: Moderate IDA with Hb less than 10 mg/dl; Group 2: Severe IDA with Hb less than 7 mg/dl; Group 3: BTT (with or without iron deficiency) with HbA2 >3.5%. Gestational anemia was classified according to standard operational severity thresholds: Moderate Anemia was mapped at Hb 7-10 mg/dl, while Severe Anemia was defined as Hb < 7 mg/dL. Collected venous blood (4 mL) was partitioned, utilizing 2 mL in an EDTA matrix for automated complete blood counts (CBC) and peripheral blood smears, while the remaining 2 mL was evaluated via high-performance liquid chromatography (HPLC) to establish definitive hemoglobin profiles where Beta-Thalassemia Trait confirmed at HbA2 >3.5%.

Statistical Analysis: Quantitative and qualitative indicators were entered into Microsoft Excel 2010 and processed through SPSS version 20.0. Prevalence metrics were assessed via 95% confidence intervals. Categorical associations exploring socio-demographic drivers against anemia severities and verified hemoglobinopathy categories were analyzed using parametric and non-parametric test of significance i. e; Pearson's Chi-Square test, T-Test, Z Test, U Test with statistical significance assigned at a threshold of P value less than 0.05.

Results

The clinical and demographic characteristics of the 375 pregnant participants were rigorously cross-examined against anemia severity grades (Moderate vs. Severe) to unearth localized socio-demographic correlations.

The overwhelming majority of the study population fell within the 26–30 years age bracket (51.2%), followed by 24.5% in the 31–35 years range. When evaluating age against anemia severity, the 26–30 age group contributed the highest relative proportion of both moderate anemia cases (50.0%) and severe anemia cases (60.5%); however, this distribution lacked statistical significance (Chi-square (4) = 5.302, p = 0.258).

Socio-demographic parameters—including maternal education levels, socioeconomic status (SES), antenatal booking registration status, baseline obstetric parity, and maternal Body Mass Index (BMI) categories—demonstrated no statistically significant correlation with verified haemoglobinopathy statuses or anemia patterns. Iron Deficiency Anemia emerged consistently as the most frequent diagnostic presentation across all educational strata (Chi-square (15) = 8.248, p = 0.913), across all socioeconomic tiers (Chi-square (6) = 3.481, p = 0.746), across both booked and unbooked clinical presentations (Chi-square (3) = 2.247, p = 0.523), across multigravid and primigravid cohorts (Chi-square (3) = 0.643, p = 0.886). Similarly, distribution across regional religious communities (Hindu, Muslim, and Sindhi) showed no distinct clustering relative to hemoglobin disorder prevalence (Chi-square (6) = 4.538, p = 0.604).

In stark contrast, a highly significant statistical correlation was uncovered between a history of consanguineous marriage and clinical anemia severity (Chi-square (1) = 5.874, p = 0.015). Patients manifesting moderate anemia were significantly less likely to report consanguineous unions (17.2%) compared to the cohort suffering from severe anemia, where the prevalence of consanguineous marriage rose sharply to 32.6%. Conversely, a greater proportion of individuals presenting with moderate anemia (82.8%) reported non-consanguineous marriages relative to those with severe anemia (67.4%).

When analyzing the distribution of underlying conditions, Iron Deficiency Anemia (IDA) was confirmed as the primary driver for both moderate (95.4%) and severe (76.7%) anemia presentations. However, the severe anemia cohort displayed a substantially higher prevalence of underlying beta-thalassemia traits (23.2%) compared to the moderate anemia group (3.3%), an imbalance that was highly significant (Chi-square (3) = 28.987, p < 0.001). Out of the total 375 participants, 71 (18.9%) were involved in consanguineous marriages. Crucially, 8 out of the 21 participants diagnosed with beta-thalassemia trait (38%) reported a history of consanguinity, a proportion that is substantially higher than the 18% (63 out of 350) recorded among patients with pure nutritional iron deficiency.

Table 1: Graph showing association of age with moderate to severe anemia

Age Group		Anemia Grades		Total
		Moderate Anemia	Severe Anemia	
<=20 Years	Count	11(3.3%)	0(0%)	11(2.9%)
21-25 Years	Count	70(21.1%)	4(9.3%)	74(19.7%)
26-30 Years	Count	166(50.0%)	26(60.5%)	192(51.2%)
31-35 Years	Count	80(24.1%)	12(27.9%)	92(24.5%)
36-40 Years	Count	5(1.5%)	1(2.3%)	6(1.6%)
	Count	332(100%)	43(100%)	375(100%)
Pearson Chi-Square	Value	df	P Value	Result
	5.302a	4	0.258	Non Sig

Table 2: Association between Education status and types of haemoglobinopathies

Education	INTERPRETATION				Total
	BETA THALASSEMIA	BETA THALASSEMIA + SICKLE CELL ANEMIA	IRON DEFICIENCY ANEMIA	SICKLE CELL ANEMIA	
GRADUATE & ABOVE	0	0	1[100%]	0	1
GRADUATE	2[14.28%]	0	12[85.7%]	0	14
HIGH SCHOOL	4[6.4%]	0	58[93.5%]	0	62
ILLITERATE	11[6.5%]	0	156[92.30%]	2[1.1%]	169
MIDDLE SCHOOL	4[3.8%]	1[0.97%]	98[94.2%]	1[0.97%]	104
PRIMARY SCHOOL	0	0	25[100%]	0	25
Total	21	1	350	3	375
Pearson Chi-Square	Value	Df	P Value	Result	
	8.248[a]	15	0.913	Non-sig	

Table 3: Association between Socioeconomic Status and types of haemoglobinopathies

Social Economic Status	INTERPRETATION				Total
	BETA THALASSEMIA	BETA THALASSEMIA + SICKLE CELL ANEMIA	IRON DEFICIENCY ANEMIA	SICKLE CELL ANEMIA	
LOWER CLASS	8[5.40%]	0	139[93.9%]	1[0.6%]	148
MIDDLE CLASS	6[6.7%]	0	83[93.25%]	0	89
UPPER LOWER CLASS	7[5.0%]	1[0.7%]	128[92.7%]	2[1.4%]	138
Total	21	1	350	3	375
Pearson Chi-Square	Value	Df	P Value	Result	
	3.481	6	0.746	Non-sig	

Table 4: Association between Booking status and types of haemoglobinopathies

BOOKED	INTERPRETATION				Total
	BETA THALASSEMIA	BETA THALASSEMIA + SICKLE CELL ANEMIA	IRON DEFICIENCY ANEMIA	SICKLE CELL ANEMIA	
BOOKED	8[6.1%]	0	123[93.8%]	0	131
UNBOOKED	13[5.3%]	1[0.4%]	227[93.0%]	3[1.2%]	244
Count	21	1	350	3	375
Pearson Chi-Square	Value	Df	P Value	Result	
	2.247	3	0.523	Non-sig	

Table 5: Association between OBST History and types of haemoglobinopathies

OBST HISTORY	INTERPRETATION				Total
	BETA THALASSEMIA	BETA THALASSEMIA + SICKLE CELL ANEMIA	IRON DEFICIENCY ANEMIA	SICKLE CELL ANEMIA	
Multigravida	13[5.3%]	1[0.4%]	229[93.4%]	2[0.8%]	245
PRIMI	8[6.1%]	0	121[93.0%]	1[0.7%]	130
Count	21	1	350	3	375
Pearson Chi-Square	Value	Df	P Value	Result	
	0.643	3	0.886	Non-sig	

Table 6: Association between Community and types of haemoglobinopathies

Community	INTERPRETATION				Total
	BETA THALASSEMIA	BETA THALASSEMIA + SICKLE CELL ANEMIA	IRON DEFICIENCY ANEMIA	SICKLE CELL ANEMIA	
HINDU	8[4.1%]	1[0.5%]	183[94.8%]	1	193
MUSLIM	8[6.8%]	0	106[91.3%]	2[1.7%]	116
SINDHI	5[8.1%]	0	61[92.4%]	0	66
Total	21	1	350	3	375
Pearson Chi-Square	Value	Df	P Value	Result	
	4.538	6	0.604	Non-sig	

Table 7: Association between Anemia Grades and Consanguineous marriage

CONSANGUINEOUS MARRIAGE		Anemia Grades		Total
		Moderate Anemia	Severe Anemia	
YES	Count	57(17.2%)	14(32.6%)	71(18.9%)
NO	Count	275(82.8%)	29(67.4%)	304(81.1%)
	Count	332(100%)	43(100%)	375(100%)
Pearson Chi-Square	Value	Df	P Value	Result
	5.874a	1	0.015	Sig

Discussion

This cross-sectional investigation highlights the clinical and socio-demographic factors associated with moderate-to-severe gestational anemia and underlying haemoglobinopathies within the central Indian landscape of Madhya Pradesh. Socio-demographic evaluation revealed that over half of the anemic antenatal patients clustered within the peak reproductive age bracket of 26–30 years (51.2%), followed by 92 (24.5%) lies in 31-35 years range, 43 (11.5%) were diagnosed with severe anemia. In a study by Laspal P et al. 157 (46.2%) of the pregnant women were in the age group of 20-25 years and 69 (20.3%) had severe anemia[7]. In the present study majority of the participants in all the categories of haemoglobinopathies were illiterate which account for a total of 169 (45%) participants followed by 104 (27.7%) who were educated till middle school. In a study conducted by G. D. Maiti et al. 143 (71.5%) of the participants were graduate, followed by 33 (16.5%) were post-graduate [17].

In the current study majority of the participants were from lower socio-economic class accounting for 148 (39.5%) from all the classes of women followed by 138 (36.8%) belong to upper lower class. Sushruti Kaushal et al. conducted similar study and majority 97 (56.39%) of the participants were from low Socio-economic status which is similar to the study finding[18].

In the current study more than half 193 (51.5%) of the participants were Hindu followed by muslims 116 (30.9%) followed by sindhis 66(17.6%). Among hindus, maximum number of cases were for IDA (94.8%) & 4.1% for beta-thalassemia. Whereas among muslims 91.3% were IDA & 6.8% were beta-thalassemia. Debasis Mukhopadhyay et al. 2022, conducted similar study among 10407 participants in West Bengal observed that majority 8451 (81.2%) of them were Hindu, followed by 1898(18.2%) were Muslim[19]. Sumedha Dharmarajan et al. in 2021 in their study found majority of the participants were Hindu[20].

In the current study most of the participants from all the categories of haemoglobinopathies were booked which together comprises of 244 (65.1%). Sushruti Kaushal et al. conducted study etiology of anemia among pregnant women found 166 (96.5%) were booked[18].

In the present study, majority of the participants 245 (65.3%) were multigravida across all the categories of anemia and various haemoglobinopathies. Laspal P et al. 2022 nearly half 172 (50.6%) of the participants were multigravida[7].

G. D. Maiti et al. conducted the study among 200 pregnant females found that majority 102 (51%) of the participants were primigravida which is different from our study finding [17].

In the present study 71 (18.9%) of the participants were in consanguineous marriage, in which 8(11.2%) women were having beta-thalassemia compared to non-consanguineous marriage, in which only 13(4.2%) women were having beta-thalassemia. Sumedha Dharmarajan el al in 2021 conducted a similar study found 20% of the participants were in consanguineous marriage which is in congruence with the current study[20].

Conclusion

This study demonstrates that while Iron Deficiency Anemia remains the primary driver of low hemoglobin levels in pregnant women within Madhya Pradesh, inherited haemoglobinopathies represent a distinct sub-population (6.7%) that is heavily concentrated within severe anemia presentations. The significant association between severe gestational anemia, beta-thalassemia traits, and consanguineous marriages provides clear direction for public health policy. Managing maternal anemia effectively requires a dual approach: combining nutritional support with pre-pregnancy counseling and early screening for hemoglobin disorders.

Limitations

The findings of this study should be considered within the context of certain limitations. The sample size, while sufficient for localized analysis, may not fully represent the broader national population. Sociodemographic variables like socioeconomic status, education, and obstetric parity relied on self-reported data, which introduces the potential for recall bias. Given the cross-sectional design, it is not possible to infer direct causality regarding the observed associations. Additionally, this study did not account for other contributing factors such as concurrent micronutrient deficiencies or chronic environmental conditions. Finally, the high proportion of severe anemia cases may be affected by referral bias, as complicated or severe cases are more frequently directed to tertiary care institutions.

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