

Maternal and Neonatal Outcomes Associated with Anemia during Pregnancy: A Prospective Study

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Abstract

Background: Anemia during pregnancy remains a significant public health concern, particularly in developing countries, with potential adverse consequences for both maternal and neonatal health. Understanding the relationship between anemia severity and pregnancy outcomes is essential for developing effective prevention and management strategies.

Methods: This prospective cohort study was conducted at a tertiary care hospital between. A total of 486 pregnant women were enrolled and categorized based on hemoglobin levels: non-anemic (≥ 11 g/dL), mild anemia (10-10.9 g/dL), moderate anemia (7-9.9 g/dL), and severe anemia (< 7 g/dL). Maternal and neonatal outcomes were assessed and compared across groups using appropriate statistical tests.

Results: The prevalence of anemia was 58.6% (n=285), with mild, moderate, and severe anemia comprising 24.3%, 28.4%, and 5.9% respectively. Anemic women had significantly higher rates of preterm delivery (23.5% vs. 8.5%, $p < 0.001$), cesarean section (34.4% vs. 21.9%, $p = 0.003$), and postpartum hemorrhage (12.6% vs. 4.5%, $p = 0.002$). Neonates born to anemic mothers demonstrated lower mean birth weight (2.58 ± 0.42 kg vs. 3.12 ± 0.38 kg, $p < 0.001$), higher incidence of low birth weight (31.9% vs. 9.5%, $p < 0.001$), and increased NICU admissions (18.9% vs. 6.5%, $p < 0.001$). Severe anemia was associated with the worst outcomes across all parameters.

Conclusion: Maternal anemia significantly increases the risk of adverse maternal and neonatal outcomes in a dose-dependent manner. Early screening, appropriate iron supplementation, and timely management of anemia are crucial for improving pregnancy outcomes.

Keywords: Anemia, Pregnancy, Maternal Outcomes, Neonatal Outcomes, Hemoglobin, Low Birth Weight, Preterm Delivery.

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Introduction

Anemia during pregnancy constitutes a major global health challenge, affecting approximately 40% of pregnant women worldwide, with the highest prevalence observed in South Asia and Sub-Saharan Africa [1]. The World Health Organization defines anemia in pregnancy as a hemoglobin concentration below 11 g/dL, with further classification into mild (10-10.9 g/dL), moderate (7-9.9 g/dL), and severe (< 7 g/dL) categories [2]. Iron deficiency remains the predominant etiology, accounting for approximately 50% of all anemia cases during pregnancy [3].

The physiological demands of pregnancy, including expanded plasma volume and increased iron requirements for fetal development, predispose women to developing anemia [4]. Inadequate dietary iron intake, poor bioavailability of dietary

iron, and pre-existing nutritional deficiencies further exacerbate this condition, particularly in resource-limited settings [5]. The consequences of maternal anemia extend beyond the mother, potentially affecting fetal growth, development, and long-term health outcomes [6].

Previous research has established associations between maternal anemia and various adverse outcomes. Studies have demonstrated increased risks of preterm birth, low birth weight, and intrauterine growth restriction among anemic mothers [7]. Maternal complications including postpartum hemorrhage, puerperal sepsis, and increased susceptibility to infections have also been documented [8]. Furthermore, severe anemia has been linked to maternal mortality, particularly in developing countries where access to blood transfusion services may be limited [9].

Recent investigations have focused on understanding the mechanisms underlying these associations. Impaired oxygen delivery to the placenta and fetus, altered immune function, and compromised tissue integrity have been proposed as potential pathophysiological pathways [10]. Additionally, emerging evidence suggests that maternal anemia may have transgenerational effects, influencing the offspring's iron status and neurodevelopmental outcomes [11].

Despite extensive research, significant knowledge gaps persist regarding the dose-response relationship between anemia severity and specific pregnancy outcomes. Many previous studies have been retrospective in nature, limiting the ability to establish temporal relationships and control for confounding variables [12]. Furthermore, regional variations in anemia etiology and healthcare access necessitate context-specific research to inform local clinical guidelines [13].

The aim of this study was to prospectively evaluate the association between maternal anemia and adverse maternal and neonatal outcomes, while assessing the impact of anemia severity on these outcomes in a tertiary care setting.

Materials and Methods

Study Design and Setting: This prospective cohort study was conducted at the Department of Obstetrics and Gynecology.

Sample Size Calculation: Sample size was calculated using the formula for comparing proportions between two groups.

Based on previous literature suggesting a 15% difference in adverse outcomes between anemic and non-anemic groups, with 80% power and 5% significance level, a minimum sample size of 450 participants was required. Accounting for 10% loss to follow-up, 500 participants were targeted for enrollment.

Participant Selection: Consecutive pregnant women attending the antenatal clinic during the first trimester were screened for eligibility.

Inclusion criteria comprised: singleton pregnancy, gestational age between 8-12 weeks at enrollment, willingness to deliver at the study hospital, and provision of written informed consent.

Exclusion criteria included: multiple gestation, known hemoglobinopathies, chronic medical conditions (diabetes mellitus, chronic hypertension, and renal disease), history of recurrent pregnancy loss, and inability to attend follow-up visits.

Data Collection Procedures: At enrollment, demographic information, obstetric history, and socioeconomic data were collected using a structured questionnaire. Anthropometric

measurements including height, weight, and mid-upper arm circumference were recorded. Baseline hemoglobin estimation was performed using the cyanmethemoglobin method, and complete blood count was obtained using automated hematology analyzer.

Participants underwent hemoglobin assessment at enrollment, 28 weeks, 36 weeks, and at delivery. Based on hemoglobin levels at 28 weeks (primary exposure assessment), participants were categorized into four groups: non-anemic (≥ 11 g/dL), mild anemia (10-10.9 g/dL), moderate anemia (7-9.9 g/dL), and severe anemia (< 7 g/dL).

All participants received standard antenatal care including iron and folic acid supplementation as per national guidelines. Those with moderate to severe anemia received additional therapeutic iron supplementation and dietary counseling. Participants with severe anemia were managed according to institutional protocols, including parenteral iron therapy or blood transfusion when indicated.

Outcome Measures: Primary maternal outcomes included mode of delivery, preterm delivery (< 37 weeks), postpartum hemorrhage (blood loss ≥ 500 mL for vaginal delivery, ≥ 1000 mL for cesarean section), pregnancy-induced hypertension, and maternal ICU admission. Primary neonatal outcomes included birth weight, low birth weight (< 2500 g), Apgar scores at 1 and 5 minutes, NICU admission, and neonatal mortality.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 26.0. Continuous variables were expressed as mean \pm standard deviation and compared using one-way ANOVA with post-hoc Bonferroni correction. Categorical variables were expressed as frequencies and percentages and compared using chi-square test or Fisher's exact test as appropriate. Binary logistic regression was performed to identify independent predictors of adverse outcomes, adjusting for potential confounders including maternal age, parity, body mass index, and socioeconomic status. Odds ratios with 95% confidence intervals were calculated. A p-value < 0.05 was considered statistically significant.

Results

Participant Characteristics: Of 512 women initially enrolled, 486 completed the study (94.9% retention rate). Twenty-six participants were excluded due to loss to follow-up ($n=18$), development of exclusion criteria during pregnancy ($n=5$), and incomplete data ($n=3$). The overall prevalence of anemia at 28 weeks was 58.6% ($n=285$).

Among anemic participants, 118 (24.3%) had mild anemia, 138 (28.4%) had moderate anemia, and 29 (5.9%) had severe anemia. The non-anemic group comprised 201 women (41.4%). Table 1 presents the baseline characteristics of participants according to anemia status. Mean maternal age was

26.4±4.8 years, with no significant difference across groups.

However, significant differences were observed in educational status, socioeconomic status, and booking hemoglobin levels.

Table 1: Baseline Characteristics of Study Participants According to Anemia Status

Characteristic	Non-Anemic (n=201)	Mild Anemia (n=118)	Moderate Anemia (n=138)	Severe Anemia (n=29)	p-value
Age (years), mean±SD	26.8±4.6	26.2±4.9	26.1±5.0	25.8±5.2	0.524
Primigravida, n (%)	78 (38.8)	42 (35.6)	48 (34.8)	11 (37.9)	0.876
BMI (kg/m ²), mean±SD	24.2±3.8	23.6±3.5	22.8±3.4	21.4±3.2	0.001
Education ≤Primary, n (%)	32 (15.9)	28 (23.7)	52 (37.7)	16 (55.2)	<0.001
Low SES, n (%)	45 (22.4)	38 (32.2)	68 (49.3)	19 (65.5)	<0.001
Booking Hb (g/dL), mean±SD	11.8±0.9	10.6±0.8	9.2±1.1	7.8±1.4	<0.001
Gestational age at booking (weeks), mean±SD	10.2±1.4	10.4±1.5	10.8±1.6	11.1±1.4	0.089

BMI: Body Mass Index; SES: Socioeconomic Status; Hb: Hemoglobin

Maternal Outcomes: Table 2 summarizes maternal outcomes according to anemia status. Anemic women demonstrated significantly higher rates of adverse maternal outcomes compared to non-anemic women.

The rate of preterm delivery was 23.5% among anemic women versus 8.5% in non-anemic women ($p<0.001$). Cesarean section rates were significantly elevated in the anemic group (34.4%

vs. 21.9%, $p=0.003$). Postpartum hemorrhage occurred in 12.6% of anemic women compared to 4.5% of non-anemic women ($p=0.002$). A dose-response relationship was observed, with severe anemia associated with the highest rates of adverse outcomes. Pregnancy-induced hypertension was more prevalent among anemic women (14.0% vs. 7.5%, $p=0.024$), and maternal ICU admission was significantly higher in the severe anemia group (17.2% vs. 1.5% in non-anemic, $p<0.001$).

Table 2: Maternal Outcomes According to Anemia Status

Outcome	Non-Anemic (n=201)	Mild Anemia (n=118)	Moderate Anemia (n=138)	Severe Anemia (n=29)	p-value
Preterm delivery, n (%)	17 (8.5)	18 (15.3)	38 (27.5)	11 (37.9)	<0.001
Cesarean section, n (%)	44 (21.9)	32 (27.1)	52 (37.7)	14 (48.3)	<0.001
Postpartum hemorrhage, n (%)	9 (4.5)	11 (9.3)	18 (13.0)	7 (24.1)	<0.001
Pregnancy-induced hypertension, n (%)	15 (7.5)	12 (10.2)	22 (15.9)	6 (20.7)	0.024
Blood transfusion, n (%)	5 (2.5)	8 (6.8)	22 (15.9)	14 (48.3)	<0.001
Maternal ICU admission, n (%)	3 (1.5)	4 (3.4)	9 (6.5)	5 (17.2)	<0.001
Mean hospital stay (days), mean±SD	3.2±1.1	3.8±1.4	4.6±1.8	6.2±2.4	<0.001

ICU: Intensive Care Unit

Neonatal Outcomes: Table 3 presents neonatal outcomes according to maternal anemia status. Neonates born to anemic mothers had significantly lower mean birth weight (2.58±0.42 kg vs. 3.12±0.38 kg, $p<0.001$). The incidence of low birth weight was markedly higher among neonates of anemic mothers (31.9% vs. 9.5%, $p<0.001$), with severe maternal anemia associated with a 58.6%

rate of low birth weight. Apgar scores were significantly lower in neonates born to anemic mothers at both 1 minute (7.2±1.4 vs. 8.1±0.9, $p<0.001$) and 5 minutes (8.4±1.2 vs. 9.2±0.6, $p<0.001$). NICU admission rates were substantially higher among neonates of anemic mothers (18.9% vs. 6.5%, $p<0.001$), with the highest rate observed in the severe anemia group (34.5%).

Table 3: Neonatal Outcomes According to Maternal Anemia Status

Outcome	Non-Anemic (n=201)	Mild Anemia (n=118)	Moderate Anemia (n=138)	Severe Anemia (n=29)	p-value
Birth weight (kg), mean±SD	3.12±0.38	2.78±0.42	2.48±0.44	2.24±0.48	<0.001
Low birth weight, n (%)	19 (9.5)	28 (23.7)	49 (35.5)	17 (58.6)	<0.001
Apgar score 1 min, mean±SD	8.1±0.9	7.6±1.2	7.0±1.4	6.4±1.6	<0.001
Apgar score 5 min, mean±SD	9.2±0.6	8.8±0.9	8.2±1.2	7.6±1.4	<0.001
NICU admission, n (%)	13 (6.5)	16 (13.6)	28 (20.3)	10 (34.5)	<0.001
Neonatal mortality, n (%)	1 (0.5)	1 (0.8)	3 (2.2)	2 (6.9)	0.018
Intrauterine growth restriction, n (%)	14 (7.0)	15 (12.7)	26 (18.8)	8 (27.6)	<0.001

NICU: Neonatal Intensive Care Unit

Logistic regression analysis revealed that moderate anemia (OR=3.42, 95% CI: 2.18-5.36, $p<0.001$) and severe anemia (OR=6.84, 95% CI: 3.12-15.02, $p<0.001$) were independent predictors of adverse neonatal outcomes after adjusting for maternal age, parity, BMI, and socioeconomic status.

Discussion

This prospective study demonstrates a significant association between maternal anemia and adverse pregnancy outcomes, with a clear dose-response relationship between anemia severity and outcome severity. Our findings indicate that anemic pregnant women face substantially increased risks of preterm delivery, cesarean section, postpartum hemorrhage, and prolonged hospitalization. Correspondingly, neonates born to anemic mothers experience higher rates of low birth weight, lower Apgar scores, and increased NICU admissions.

The high prevalence of anemia (58.6%) observed in our study population is consistent with reports from other developing countries and underscores the magnitude of this public health problem [14]. This prevalence aligns with WHO estimates for the South Asian region and highlights the need for strengthened anemia prevention programs [15]. The predominance of moderate anemia in our cohort suggests that many women may remain undiagnosed or inadequately treated during the early stages of pregnancy.

Our finding of a significant association between maternal anemia and preterm delivery corroborates previous research. A meta-analysis by Rahmati and colleagues demonstrated that maternal anemia, particularly in the first and second trimesters, significantly increases preterm birth risk [16]. The proposed mechanisms include chronic hypoxia leading to increased corticotropin-releasing hormone production and premature activation of the hypothalamic-pituitary-adrenal axis [17]. Additionally, anemia-associated oxidative stress may contribute to premature rupture of membranes and preterm labor [18]. The elevated cesarean

section rates among anemic women in our study may reflect both direct effects of anemia on labor progress and increased obstetric complications necessitating operative delivery. Severe anemia can impair uterine contractility due to reduced oxygen delivery to myometrial tissue [19]. Furthermore, fetal distress secondary to placental insufficiency in anemic pregnancies may prompt emergency cesarean delivery [20]. The strong association between maternal anemia and low birth weight observed in our study is biologically plausible. Inadequate maternal iron stores compromise placental iron transfer, limiting fetal hemoglobin synthesis and oxygen-carrying capacity [21]. This hypoxic environment impairs cell proliferation and differentiation, resulting in intrauterine growth restriction [22]. Our finding of a 58.6% low birth weight rate among severely anemic mothers represents a six-fold increase compared to non-anemic mothers, emphasizing the clinical significance of anemia severity.

The dose-response relationship between anemia severity and adverse outcomes supports the importance of hemoglobin thresholds in clinical decision-making. Similar gradient effects have been reported in large cohort studies, suggesting that even mild anemia warrants clinical attention [23]. The concept of anemia as a continuous risk factor rather than a binary condition has important implications for preventive strategies [24].

The increased postpartum hemorrhage risk among anemic women is particularly concerning, as it creates a potentially fatal cycle of worsening anemia. Impaired uterine contractility, suboptimal coagulation factor synthesis, and reduced physiological reserve contribute to this increased susceptibility [25]. Our finding of 24.1% postpartum hemorrhage in severely anemic women underscores the importance of anticipatory management and blood product availability. Socioeconomic disparities in anemia prevalence observed in our study reflect the complex interplay

between nutritional status, healthcare access, and health literacy. Women with lower educational attainment and socioeconomic status demonstrated higher anemia prevalence, consistent with global patterns [26]. These findings emphasize the need for targeted interventions addressing social determinants of health alongside direct nutritional supplementation [27].

The study has several strengths including its prospective design, standardized outcome assessment, and comprehensive evaluation of both maternal and neonatal parameters. The high retention rate (94.9%) minimizes selection bias associated with loss to follow-up. However, limitations include the single-center setting, which may limit generalizability, and the inability to assess long-term neurodevelopmental outcomes in offspring. Additionally, while we adjusted for major confounders, residual confounding from unmeasured variables cannot be excluded.

Conclusion

This prospective study provides compelling evidence that maternal anemia is significantly associated with adverse maternal and neonatal outcomes, with a clear dose-response relationship between anemia severity and outcome severity. Anemic pregnant women demonstrated substantially increased risks of preterm delivery, cesarean section, postpartum hemorrhage, and prolonged hospitalization. Neonates born to anemic mothers experienced higher rates of low birth weight, lower Apgar scores, and increased NICU admissions, with the most severe consequences observed in the severe anemia group.

These findings underscore the critical importance of early anemia screening, adequate iron supplementation, and comprehensive management strategies during pregnancy. Healthcare systems should prioritize universal hemoglobin screening at the first antenatal visit, with repeat assessments throughout pregnancy.

Women identified with anemia require intensified monitoring, appropriate therapeutic interventions, and anticipatory preparation for potential complications during delivery. Public health initiatives addressing the underlying nutritional and socioeconomic determinants of anemia remain essential for achieving meaningful reductions in anemia-associated adverse pregnancy outcomes.

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