

Association of Maternal Anemia with Adverse Pregnancy Outcomes: A Prospective Cohort Study

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ABSTRACT

Background: Maternal anemia remains a common pregnancy complication and has been associated with preterm birth, low birth weight, postpartum hemorrhage, and neonatal morbidity. The strength of these associations varies according to anemia severity, gestational timing, and population characteristics. **Objective:** To evaluate the association between maternal anemia and adverse maternal, fetal, and neonatal outcomes among pregnant women receiving antenatal care at Government Medical College Handwara. **Materials and Methods:** This prospective cohort study was conducted from September 20, 2025 to September 20, 2026. Six hundred pregnant women with singleton pregnancies were followed from enrollment at or before 20 weeks of gestation until delivery and the early neonatal period. Maternal anemia was defined using trimester-specific World Health Organization hemoglobin thresholds. The primary endpoint was a composite adverse pregnancy outcome. Secondary outcomes included preterm birth, low birth weight, small for gestational age, hypertensive disorders, premature rupture of membranes, cesarean delivery, postpartum hemorrhage, blood transfusion, stillbirth, low five-minute Apgar score, and neonatal intensive care unit admission. Risk ratios and multivariable-adjusted risk ratios were estimated with 95% confidence intervals. **Results:** Of 600 women, 318 (53.0%) were classified as anemic and 282 (47.0%) as non-anemic. The composite adverse pregnancy outcome occurred in 145 (45.6%) anemic women and 78 (27.7%) non-anemic women (RR 1.65, 95% CI 1.32-2.06; $p < 0.001$). Maternal anemia was associated with higher risks of preterm birth (19.2% vs. 11.0%), low birth weight (24.8% vs. 12.8%), small-for-gestational-age birth (17.3% vs. 8.9%), premature rupture of membranes (16.0% vs. 8.5%), postpartum hemorrhage (9.7% vs. 3.9%), low five-minute Apgar score (8.8% vs. 3.9%), and NICU admission (20.1% vs. 9.9%). After multivariable adjustment, anemia remained independently associated with the composite endpoint, preterm birth, low birth weight, small for gestational age, premature rupture of membranes, postpartum hemorrhage, low Apgar score, and NICU admission. A graded increase in adverse outcomes was observed with increasing anemia severity. **Conclusions:** Maternal anemia was associated with a substantially higher risk of adverse pregnancy outcomes, particularly preterm birth, low birth weight, small-for-gestational-age birth, postpartum hemorrhage, and neonatal morbidity. Early identification, correction of anemia, and risk-based obstetric surveillance may improve maternal and perinatal outcomes.

Keywords: maternal anemia, pregnancy, preterm birth, low birth weight, postpartum hemorrhage, neonatal intensive care, prospective cohort

INTRODUCTION

Anemia in pregnancy is a major global maternal health problem and remains especially important in low- and middle-income settings. Physiological plasma-volume

expansion lowers hemoglobin concentration during gestation, but values below trimester-specific thresholds represent clinically relevant anemia. In 2024, the World Health Organization (WHO) reaffirmed trimester-

specific hemoglobin cutoffs of <11.0 g/dL in the first and third trimesters and <10.5 g/dL in the second trimester [1].

Pregnancy increases iron requirements because of expansion of maternal red-cell mass, placental development, fetal growth, and anticipated blood loss at delivery. Iron deficiency is therefore a major contributor to maternal anemia, although folate deficiency, vitamin B12 deficiency, infections, inflammation, hemoglobinopathies, and chronic disease may also contribute. WHO recommends daily oral supplementation with 30-60 mg elemental iron and 400 micrograms folic acid during pregnancy to reduce maternal anemia and adverse birth outcomes [2].

The clinical importance of maternal anemia extends beyond the hemoglobin value itself. Reduced oxygen-carrying capacity may impair placental oxygenation and fetal growth, while severe anemia can reduce maternal physiological reserve at delivery. A 2025 systematic review and meta-analysis of 31 cohort studies reported higher risks of postpartum hemorrhage, premature rupture of membranes (PROM), preterm delivery, low birth weight, cesarean delivery, gestational hypertension, and neonatal asphyxia among pregnancies complicated by anemia [3]. Earlier meta-analyses similarly identified associations between low maternal hemoglobin and preterm birth, low birth weight, and other adverse maternal and neonatal outcomes [4,5].

South Asian data are particularly relevant because the burden of anemia, nutritional vulnerability, and access to antenatal services differ substantially from many high-income populations. A prospective cohort of more than 92,000 deliveries in India and Pakistan found markedly higher risks of stillbirth, neonatal mortality, low birth weight, preterm birth, and postpartum hemorrhage among women with severe anemia [6]. Cohort studies from Assam and eastern Maharashtra have also linked maternal anemia with postpartum hemorrhage, low birth weight, small-for-gestational-age birth, and perinatal mortality [7,8].

Despite the importance of this problem, region-specific prospective data from North Kashmir remain limited. The present study therefore evaluated the association between maternal anemia and adverse pregnancy outcomes among women receiving antenatal care at Government Medical College Handwara, with particular attention to anemia severity and clinically relevant maternal and neonatal endpoints.

MATERIALS AND METHODS

Study design and setting

A prospective cohort study was conducted in the Department of Obstetrics and Gynaecology, Government Medical College Handwara, Jammu and Kashmir, India, from September 20, 2025 to September 20, 2026. Pregnant women attending the antenatal clinic were screened consecutively for eligibility and were followed prospectively through delivery and the early neonatal period.

Sample size

The sample size was calculated for comparison of adverse pregnancy outcome rates between anemic and non-anemic women. Assuming event rates of 28% among anemic women and 18% among non-anemic women, 80% power, a two-sided alpha of 0.05, and an approximately 1:1 exposure ratio, the minimum required sample was approximately 550 participants (275 per group). Allowing for incomplete records and potential loss to follow-up, the target sample was increased to 600 women.

Eligibility criteria

Women were eligible if they were 18-45 years of age, had a viable singleton pregnancy, presented at or before 20 weeks of gestation, intended to continue antenatal care and delivery at the study institution, and provided written informed consent. Women with multiple gestation, major fetal congenital anomaly, known hemoglobinopathy, chronic renal or hepatic disease, active major bleeding, recent blood transfusion, hematologic malignancy or bone-marrow disorder, or serious systemic illness expected to independently influence hemoglobin concentration or pregnancy outcome were excluded.

Exposure definition and anemia severity

Venous blood was collected at enrollment for a complete blood count. Maternal anemia was classified using WHO 2024 trimester-specific hemoglobin cutoffs [1]. In the first and third trimesters, anemia was defined as hemoglobin <11.0 g/dL; in the second trimester, it was defined as hemoglobin <10.5 g/dL. Severity was categorized as mild, moderate, or severe using the corresponding WHO thresholds shown in Table 1.

Table 1. Trimester-specific hemoglobin thresholds used to classify maternal anemia [1].

Gestational period	No anemia	Mild anemia	Moderate anemia	Severe anemia
First trimester	>=11.0 g/dL	10.0-10.9	7.0-9.9	<7.0
Second trimester	>=10.5 g/dL	9.5-10.4	7.0-9.4	<7.0
Third trimester	>=11.0 g/dL	10.0-10.9	7.0-9.9	<7.0

Baseline and follow-up variables

At enrollment, maternal age, residence, socioeconomic status, educational level, occupation, body mass index (BMI), gravidity, parity, prior obstetric history, interpregnancy interval, dietary pattern, iron-folic acid supplementation, tobacco exposure, gestational age, and relevant medical conditions were recorded. Hemoglobin and red-cell indices were documented at enrollment. Participants received standard antenatal management; treatment of anemia was not withheld for study purposes. Follow-up visits recorded pregnancy complications, repeat hemoglobin testing when clinically indicated, delivery details, and neonatal outcomes.

Outcome definitions

The primary endpoint was a composite adverse pregnancy outcome, defined as the occurrence of at least one major prespecified maternal, fetal, or neonatal event. Secondary maternal outcomes included hypertensive disorders of pregnancy, PROM, cesarean delivery, postpartum hemorrhage, blood transfusion, and maternal

intensive-care requirement. Fetal and neonatal outcomes included preterm birth before 37 completed weeks, low birth weight below 2500 g, small-for-gestational-age birth, stillbirth, five-minute Apgar score <7, and neonatal intensive care unit (NICU) admission.

Statistical analysis

Continuous variables were summarized as mean $\pm$ standard deviation and categorical variables as number and percentage. Student t-test was used for continuous variables and the chi-square test or Fisher exact test for categorical variables, as appropriate. Crude risk ratios (RRs) with 95% confidence intervals (CIs) were calculated for adverse outcomes. Multivariable Poisson regression with robust standard errors was used to estimate adjusted risk ratios (aRRs) after controlling for maternal age, BMI, parity, rural residence, socioeconomic status, gestational age at enrollment, and iron-folic acid supplementation. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

Participant characteristics

A total of 612 eligible women were approached; 12 declined participation and 600 were enrolled and completed follow-up (Figure 1). Of these, 318 (53.0%) met criteria for anemia at enrollment and 282 (47.0%) were non-anemic. Among the 318 anemic women, 179 (56.3%) had mild anemia, 112 (35.2%) had moderate anemia, and 27 (8.5%) had severe anemia.

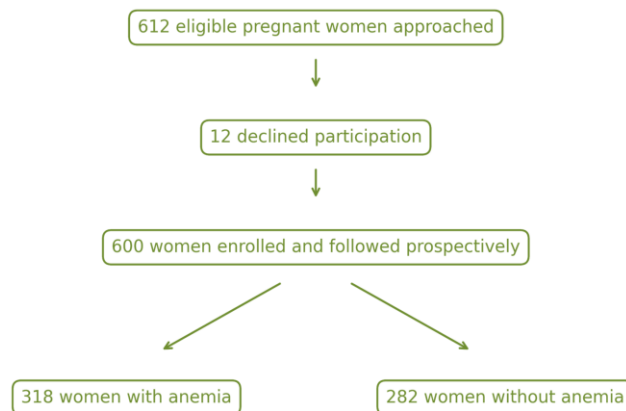


Figure 1. Participant flow through the prospective cohort.

Baseline demographic and obstetric characteristics were broadly comparable between groups (Table 2). Mean maternal age was 27.4 $\pm$ 4.7 years among anemic women and 27.1 $\pm$ 4.5 years among non-anemic women ($p=0.425$). Adequate iron-folic acid supplementation before enrollment was less frequent among anemic women (35.2% vs. 44.7%; $p=0.018$). Mean enrollment hemoglobin was 9.4 $\pm$ 1.1 g/dL in the anemic group compared with 11.8 $\pm$ 0.7 g/dL in the non-anemic group ($p<0.001$).

Table 2. Baseline maternal characteristics according to anemia status. Values are mean $\pm$ SD or n (%).

Characteristic	Anemic (n=318)	Non-anemic (n=282)	p-value
Maternal age, years	27.4 $\pm$ 4.7	27.1 $\pm$ 4.5	0.425
BMI, kg/m ²	22.6 $\pm$ 3.1	23.1 $\pm$ 3.2	0.053
Primigravida	137 (43.1%)	128 (45.4%)	0.570

Rural residence	216 (67.9%)	172 (61.0%)	0.076
Lower socioeconomic status	131 (41.2%)	98 (34.8%)	0.105
Adequate iron-folic acid use before enrollment	112 (35.2%)	126 (44.7%)	0.018
Gestational age at enrollment, weeks	14.1 +/- 3.2	14.0 +/- 3.1	0.698
Hemoglobin at enrollment, g/dL	9.4 +/- 1.1	11.8 +/- 0.7	<0.001

Maternal, fetal, and neonatal outcomes

The composite adverse pregnancy outcome was significantly more frequent among anemic women than non-anemic women (45.6% vs. 27.7%; RR 1.65, 95% CI 1.32-2.06; $p < 0.001$). Anemic women had higher risks of preterm birth, low birth weight, small-for-gestational-age birth, PROM, postpartum hemorrhage, blood transfusion, low five-minute Apgar score, and NICU admission (Table 3). Differences in hypertensive disorders, cesarean delivery, and stillbirth did not reach conventional statistical significance in the crude analysis.

Table 3. Maternal, fetal, and neonatal outcomes according to anemia status. RR, risk ratio; CI, confidence interval; PROM, premature rupture of membranes; NICU, neonatal intensive care unit.

Outcome	Anemic n/N (%)	Non-anemic n/N (%)	Crude RR (95% CI)	p-value
Composite adverse pregnancy outcome	145/318 (45.6)	78/282 (27.7)	1.65 (1.32-2.06)	<0.001
Preterm birth <37 weeks	61/318 (19.2)	31/282 (11.0)	1.74 (1.17-2.61)	0.005
Low birth weight <2500 g	79/318 (24.8)	36/282 (12.8)	1.95 (1.36-2.79)	<0.001
Small for gestational age	55/318 (17.3)	25/282 (8.9)	1.95 (1.25-3.04)	0.002
Hypertensive disorders	42/318 (13.2)	24/282 (8.5)	1.55 (0.96-2.50)	0.066
PROM	51/318 (16.0)	24/282 (8.5)	1.88 (1.19-2.98)	0.005
Cesarean delivery	117/318 (36.8)	89/282 (31.6)	1.17 (0.93-1.46)	0.178
Postpartum hemorrhage	31/318 (9.7)	11/282 (3.9)	2.50 (1.28-4.88)	0.005
Blood transfusion	18/318 (5.7)	5/282 (1.8)	3.19 (1.20-8.49)	0.013
Stillbirth	10/318 (3.1)	3/282 (1.1)	2.96 (0.82-10.63)	0.081
Five-minute Apgar score <7	28/318 (8.8)	11/282 (3.9)	2.26 (1.14-4.45)	0.015
NICU admission	64/318 (20.1)	28/282 (9.9)	2.03 (1.34-3.07)	<0.001

Outcome gradient according to anemia severity

A dose-response pattern was observed across anemia severity categories. The composite adverse pregnancy outcome increased from 27.7% among non-anemic women to 36.9% with mild anemia, 53.6% with moderate anemia, and 70.4% with severe anemia (overall $p < 0.001$). Similar graded increases were seen for preterm birth, low birth weight, postpartum hemorrhage, and NICU admission (Table 4).

Table 4. Selected adverse outcomes according to anemia severity. Values are n (%).

Outcome	No anemia (n=282)	Mild (n=179)	Moderate (n=112)	Severe (n=27)
Composite adverse outcome	78 (27.7%)	66 (36.9%)	60 (53.6%)	19 (70.4%)
Preterm birth	31 (11.0%)	25 (14.0%)	27 (24.1%)	9 (33.3%)
Low birth weight	36 (12.8%)	35 (19.6%)	32 (28.6%)	12 (44.4%)
Small for gestational age	25 (8.9%)	21 (11.7%)	25 (22.3%)	9 (33.3%)
Postpartum hemorrhage	11 (3.9%)	10 (5.6%)	13 (11.6%)	8 (29.6%)
NICU admission	28 (9.9%)	26 (14.5%)	28 (25.0%)	10 (37.0%)

Multivariable analysis

After adjustment for maternal age, BMI, parity, rural residence, socioeconomic status, gestational age at enrollment, and iron-folic acid supplementation, maternal anemia remained independently associated with the composite adverse outcome, preterm birth, low birth weight, small-for-gestational-age birth, PROM, postpartum hemorrhage, low five-minute Apgar score, and NICU admission (Table 5 and Figure 2).

Table 5. Multivariable-adjusted associations between maternal anemia and adverse pregnancy outcomes.

Outcome	Adjusted RR	95% CI	p-value
Composite adverse pregnancy outcome	1.52	1.23-1.88	<0.001
Preterm birth	1.58	1.08-2.31	0.018
Low birth weight	1.76	1.25-2.48	0.001

Small for gestational age	1.70	1.11-2.60	0.014
PROM	1.69	1.09-2.61	0.019
Postpartum hemorrhage	2.18	1.14-4.15	0.019
Five-minute Apgar score <7	1.94	1.01-3.72	0.047
NICU admission	1.78	1.20-2.64	0.004
Hypertensive disorders	1.35	0.85-2.14	0.200
Cesarean delivery	1.10	0.89-1.35	0.380

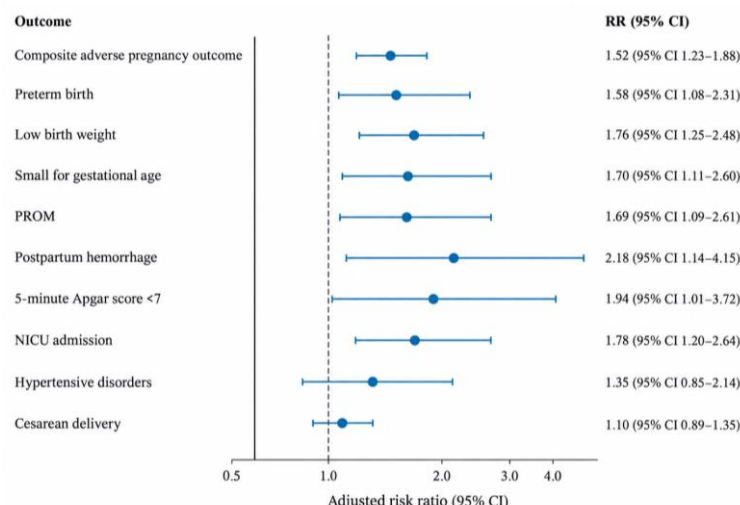


Figure 2. Adjusted risk ratios for major adverse pregnancy outcomes associated with maternal anemia.

DISCUSSION

Maternal anemia was associated with a higher frequency of adverse maternal and neonatal outcomes in this prospective cohort. The composite adverse pregnancy outcome occurred in 45.6% of anemic women compared with 27.7% of non-anemic women, corresponding to a crude risk ratio of 1.65 and an adjusted risk ratio of 1.52. Significant associations were observed for preterm birth, low birth weight, small-for-gestational-age birth, premature rupture of membranes (PROM), postpartum hemorrhage, low five-minute Apgar score, and neonatal intensive care unit (NICU) admission. Adverse outcomes also increased progressively with anemia severity.

These findings are consistent with recent meta-analytic evidence. Wang et al. reported increased risks of postpartum hemorrhage, PROM, preterm delivery, low birth weight, cesarean delivery, gestational hypertension, and neonatal asphyxia among pregnancies complicated by anemia [3]. In the present study, postpartum hemorrhage showed one of the strongest associations with maternal anemia, with a crude RR of 2.50 and an adjusted RR of 2.18. Reduced hematologic reserve among anemic women may increase vulnerability to the clinical consequences of obstetric blood loss.

Preterm birth was also significantly more frequent among anemic women. Similar findings have been reported by Jung et al. [4], who demonstrated an association between low maternal hemoglobin concentrations and adverse maternal and infant

outcomes. Haider et al. [5] likewise reported increased risks of preterm birth and low birth weight in women with anemia during early or mid-pregnancy. Potential mechanisms include reduced maternal oxygen-carrying capacity, placental hypoxia, nutritional deficiencies, oxidative stress, and increased susceptibility to infection. Maternal anemia remained independently associated with both low birth weight and small-for-gestational-age birth after adjustment for major confounders. The adjusted risk of low birth weight was 76% higher and that of small-for-gestational-age birth was 70% higher among anemic women. These observations are consistent with South Asian evidence. Rahman et al. [9] reported increased risks of low birth weight and preterm birth among anemic pregnant women, while Parks et al. [6] found that severe maternal anemia was associated with low birth weight, preterm delivery, stillbirth, and neonatal mortality in a large prospective cohort from India and Pakistan.

The findings are also relevant to Indian clinical practice. Nair et al. [7] reported associations between severe maternal anemia and postpartum hemorrhage, low birth weight, small-for-gestational-age birth, and perinatal mortality in Assam. Patel et al. [8], in a cohort from rural Maharashtra, similarly observed increased risks of low birth weight, stillbirth, and neonatal mortality, particularly among women with moderate-to-severe anemia.

NICU admission was approximately twice as frequent among infants born to anemic women, and the

association remained significant after multivariable adjustment. This may reflect the higher frequencies of preterm birth, low birth weight, small-for-gestational-age birth, and low Apgar scores in the anemia group. Although stillbirth was more frequent among anemic women, the confidence interval was wide and the difference was not statistically significant, likely because of the relatively small number of events.

Not all outcomes showed statistically significant associations. Cesarean delivery and hypertensive disorders were numerically more frequent among anemic women, but these differences were not significant after adjustment. Published evidence regarding these outcomes remains heterogeneous. The 2025 meta-analysis by Wang et al. [3] reported modest associations between anemia and both cesarean delivery and gestational hypertension, whereas South Asian pooled evidence has not consistently demonstrated significant associations with cesarean delivery or preeclampsia [9]. Differences in anemia definitions, timing of hemoglobin measurement, underlying maternal characteristics, and obstetric practice may contribute to this variability.

A clear severity-response relationship was observed. The composite adverse-outcome rate increased from 27.7% among women without anemia to 36.9% with mild anemia, 53.6% with moderate anemia, and 70.4% with severe anemia. Similar graded increases were observed for preterm birth, low birth weight, postpartum hemorrhage, and NICU admission. Parks et al. [6] also demonstrated substantially poorer fetal and neonatal outcomes among women with severe anemia. These findings support closer surveillance and more intensive management of women with moderate and severe anemia.

WHO recommends daily supplementation with 30-60 mg elemental iron and 400 µg folic acid during pregnancy [2]. Antenatal care should therefore include early hemoglobin assessment, nutritional counseling, appropriate iron supplementation, and evaluation of treatment response. Women with persistent moderate or severe anemia should be assessed for additional causes such as nutritional deficiency, chronic inflammation, infection, malabsorption, or hemoglobinopathy.

The strengths of this study include its prospective design, clearly defined comparison groups, trimester-specific anemia classification, follow-up through delivery, evaluation of both maternal and neonatal outcomes, and multivariable adjustment for important confounders. Assessment according to anemia severity also permitted evaluation of a dose-response relationship.

Several limitations should be considered. This was a single-center study, which may limit generalizability to the wider North Kashmir population. Hemoglobin concentration alone cannot determine the etiology of

anemia, and ferritin and inflammatory markers were not uniformly available. Treatment initiated after enrollment may have modified subsequent risk and attenuated associations between baseline anemia and later outcomes. Residual confounding related to diet, infection, socioeconomic factors, and adherence to supplementation is also possible. Severe anemia was relatively uncommon, resulting in wider confidence intervals for infrequent outcomes such as stillbirth. In addition, serial hemoglobin trajectories were not incorporated into the primary exposure definition. Future studies should evaluate whether persistent or newly developed anemia during pregnancy predicts adverse outcomes more accurately than a single enrollment measurement.

Future multicenter studies should evaluate the causes and severity of maternal anemia using serial hemoglobin, ferritin, and other relevant biomarkers. Further research should assess treatment adherence and response to iron-folic acid therapy and determine whether early correction of anemia reduces adverse maternal and neonatal outcomes. Larger prospective studies from different regions are also needed to improve generalizability and identify women at highest risk.

CONCLUSIONS

Maternal anemia was associated with a higher risk of adverse pregnancy outcomes, particularly preterm birth, low birth weight, small-for-gestational-age birth, PROM, postpartum hemorrhage, low five-minute Apgar score, and NICU admission. The burden of adverse outcomes increased with anemia severity, with the highest rates among women with severe anemia. These findings support early antenatal screening, timely correction of anemia, assessment of treatment response, and intensified obstetric surveillance for women with moderate or severe anemia. Larger multicenter cohorts incorporating ferritin, anemia etiology, serial hemoglobin measurements, and treatment-response data are warranted.

DECLARATIONS

Ethics Approval and Consent to Participate

The study was conducted after approval from the Institutional Ethics Committee of Government Medical College Handwara. Written informed consent was obtained from all participants before enrollment.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

All authors contributed to the conception and design of the study, data collection, analysis and interpretation of findings, manuscript preparation and critical revision, and approved the final version of the manuscript.

Data Availability

The data generated and analyzed during this study are available from the corresponding author on reasonable request, subject to institutional and ethical restrictions.

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AI Use Disclosure

The authors declare that no generative artificial intelligence tools were used to generate or substantially modify the scientific content of this manuscript.

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