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Original Research Article

Association Between Maternal Anemia During Pregnancy and Developmental Outcomes in Infants: A Retrospective Cohort Study

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Abstract:

Background: Maternal anemia during pregnancy remains a major public health issue in India and is linked to adverse fetal and neonatal outcomes, including impaired growth and development.

Aim: To assess the association between maternal anemia and developmental outcomes in infants, particularly low birth weight (LBW) and developmental delay.

Methodology: A retrospective cohort study was conducted on 84 mother–infant pairs at Samarpan Multi-Speciality Hospital, Surat, India. Maternal hemoglobin levels were classified as non-anemic or varying degrees of anemia. Infant outcomes, including birth weight and developmental status at 12 months (assessed via standardized tools), were analyzed using chi-square tests and logistic regression.

Results: Among participants, 73.8% of mothers were anemic, with moderate anemia most common (44%). LBW (46.4%) and developmental delay (23.8%) were prevalent. Anemic mothers had significantly higher rates of LBW (54.8% vs. 22.7%, p=0.002) and developmental delay (30.6% vs. 4.5%, p=0.001). Risk increased with anemia severity; severe anemia showed highest LBW (75%) and delay (50%). Moderate (OR 2.8) and severe anemia (OR 4.5), along with LBW (OR 3.2), were significant predictors of developmental delay.

Conclusion: Maternal anemia is strongly associated with adverse infant outcomes, highlighting the need for early detection and effective antenatal interventions.

Keywords: Maternal Anemia, Low Birth Weight, Developmental Delay, Infant Outcomes, Pregnancy, Retrospective Cohort.

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Introduction

Pregnancy anemia is a major worldwide population health problem especially in low- and middle-income nations like India. According to World Health Organization (WHO), anemia during pregnancy is a concentration of hemoglobin less than 11.0 g/dL [1]. It has always been high in India with national surveys reporting around 50 percent. This burden is a multifaceted combination of nutritional deficiencies (mainly iron and folate) and other factors, including malaria, helminthic infections, and poor maternal nutrition [2]. These problems are even more aggravated in the socioeconomically disadvantaged groups, particularly in rural and semi-urban areas where access to quality antenatal care is scarce. Inequality in healthcare infrastructure, literacy and nutrition awareness in states such as Rajasthan, increases the risk and impact of maternal anemia.

Maternal anemia is not just a hematological disorder but a complex disease with extensive consequences on maternal, fetal, and neonatal health. In pregnancy, there should be sufficient hemoglobin to promote maximum oxygen delivery to the placenta and the developing fetus [3]. The decreased hemoglobin level undermines oxygen supply and placental perfusion that may have negative effects on fetal growth and development. As a result, maternal anemia has always been linked to poor pregnancy outcomes, such as low birth weight (LBW), preterm birth, intrauterine growth retardation (IUGR), and high perinatal morbidity and mortality. Such consequences do not only have short-term impacts on the survival of the neonate but also long-term consequences on the growth trajectory and developmental potential of the child [4].

Low birth weight, which is a birth weight of less than 2.5 kilograms, is a very important indicator of neonatal health, and a significant predictor of infant morbidity and mortality. It is usually caused by

maternal undernutrition, chronic disease or poor prenatal care. Children with low birth weights are at increased risks of infections, retarded growth, and impaired cognitive abilities [5] when they are born. The initial year of life is especially significant in terms of brain development as it is during this time that there is rapid neurobiological growth and synaptic formation. Long-term neurodevelopment effects can be caused by any disturbance of the intrauterine environment, including hypoxia caused by maternal anemia or inadequate provision of nutrients.

Infancy developmental outcomes refer to various milestones, such as motor skills, language acquisition, cognitive abilities, and social interactions. Prenatal hypoxia, in-uterine nutritional deficiencies, and a deficiency of anemia during early years can be very detrimental towards achieving these milestones [6]. Slowness in the attainment of the basic developmental milestones like sitting, crawling, walking and speaking do not only point to the immediate health issues but are also a predictive of future difficulties in learning, behavior and general thinking. New data indicates that maternal health in pregnancy is critical to determining these developmental courses of action, and thus the need to identify and treat it early is significant [7,8].

Although extensive literature has on the relationship between maternal anemia and poor pregnancy outcomes, there is an acute necessity to investigate this relationship in regional settings, especially in rural and semi-urban India. With a large and diverse demographic and socioeconomic population, Rajasthan is a state with unique challenges in terms of maternal nutrition, healthcare access, and awareness. Lack of antenatal care use, cultural beliefs, and poverty are usually some of the reasons why anemia in pregnant women in the area is prevalent. Moreover, information investigating the long-term developmental results of infants born to anemic mothers in these environments is scarce.

In this context, the present retrospective cohort study aims to investigate the association between maternal anemia during pregnancy and key developmental outcomes in infants in Rajasthan, India. The research is based on 93 mother-infant pairs in 1-year of follow-up and has two main outcomes, including low birth weight and infant developmental delay. Through these associations, the study aims to give an insight into the possible long-term impacts of untreated maternal anemia and emphasize the relevance of timely and effective antenatal interventions.

Methodology

Study Design and Setting: This study was designed as a retrospective cohort study conducted in the Department of Paediatrics, Samarpan Multi-Speciality Hospital, Surat, India.

Study Duration: The study was carried out over a period of one year from December 2024 to November 2025.

Study Population and Sample Size: The study included a total of 84 mother–infant pairs selected from hospital records. These participants were included based on the availability of complete antenatal, delivery, and pediatric follow-up information necessary for assessing both maternal anemia status and infant developmental outcomes.

Inclusion Criteria

- Mothers with documented hemoglobin levels during the third trimester.
- Mothers who had complete antenatal records.
- Live singleton births with recorded birth details.
- Infants with documented developmental assessment up to 12 months of age.
- Availability of pediatric follow-up records including developmental screening.

Exclusion Criteria

- Mothers with chronic medical conditions such as hypertension, diabetes mellitus, renal disease, or infections affecting fetal outcomes.
- Preterm births (<37 weeks of gestation).
- Infants with congenital anomalies or genetic disorders.
- Cases with incomplete or missing maternal or neonatal records.

Data Collection: Data were retrospectively collected from hospital obstetric and pediatric records using a standardized data abstraction form. Maternal variables included age, parity, number of antenatal visits, and hemoglobin levels measured during the third trimester, which were classified according to World Health Organization criteria into non-anemic, mild, moderate, and severe anemia categories. Neonatal variables included birth weight, with low birth weight defined as less than 2.5 kg, gestational age, APGAR scores, and developmental status assessed at 12 months.

Assessment of Developmental Outcomes: Developmental outcomes were assessed based on pediatric follow-up records using the Denver Developmental Screening Test (DDST) or equivalent standardized screening tools. Developmental delay was defined as the failure to achieve two or more age-appropriate developmental milestones in domains such as gross motor, fine motor, language, or social skills by the age of 12 months.

Procedure: Eligible medical records were identified and reviewed systematically. Data were extracted using a structured format to ensure consistency. Mothers were categorized into anemic and non-anemic groups, and further classified based on the severity of anemia. Infant outcomes, including birth

weight and developmental status at 12 months, were then compared across these groups to determine any associations.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 25.0. Descriptive statistics such as mean and standard deviation were used for continuous variables, while frequencies and percentages were calculated for categorical variables. The Chi-square test was applied to assess the association between maternal anemia and outcomes such as low birth weight and developmental delay. Logistic regression analysis was performed to identify predictors of developmental delay while controlling for confounding factors such as birth weight and maternal hemoglobin levels. A p-value of less than 0.05 was considered statistically significant."

Result

Table 1 shows the distribution of maternal hemoglobin levels among the study subjects (N=84). The majority of mothers had moderate anemia, accounting for 37 cases (44%), followed by non-anemic mothers with 22 cases (26.2%). Mild anemia was observed in 17 mothers (20.2%), while severe anemia was the least common, seen in 8 cases (9.5%). Overall, a substantial proportion of the study population was anemic, with moderate anemia being the most prevalent category.

Table 1: Distribution of Maternal Hemoglobin Levels (N = 84)

Maternal Hemoglobin Category	Number of Mothers (n)	Percentage (%)
Non-anemic (≥11.0 g/dL)	22	26.2
Mild Anemia (10.0–10.9 g/dL)	17	20.2
Moderate Anemia (7.0–9.9 g/dL)	37	44
Severe Anemia (<7.0 g/dL)	8	9.5
Total	**84**	**100**

Table 2 shows birth outcomes according to maternal hemoglobin categories among the study subjects (N=84). Among non-anemic mothers (22), 5 (22.7%) had low birth weight (LBW) babies and only 1 (4.5%) showed developmental delay. In mild anemia (17 cases), LBW was seen in 7 (41.2%) and developmental delay in 3 (17.6%). In moderate anemia (37 cases), both LBW (21, 56.8%) and developmental delay (12, 32.4%) were more frequent. The highest proportions were observed in severe anemia (8 cases), where 6 (75%) had LBW and 4 (50%) had developmental delay. Overall, 39 (46.4%) babies had LBW and 20 (23.8%) showed developmental delay. This demonstrates a clear increasing trend, with worsening maternal anemia associated with higher rates of both low birth weight and developmental delay.

Table 2: Birth Outcomes by Maternal Hemoglobin Category (N = 84)

Maternal Hemoglobin Category	Number of Mothers	LBW Cases (n)	LBW (%)	Developmental Delay Cases (n)	Developmental Delay (%)
Non-anemic	22	5	22.7	1	4.5
Mild Anemia	17	7	41.2	3	17.6
Moderate Anemia	37	21	56.8	12	32.4
Severe Anemia	8	6	75	4	50
Total	**84**	**39**	**46.4**	**20**	**23.8**

Table 3 shows the association between maternal anemia and low birth weight among the study subjects (n=84). Among non-anemic mothers, 5 out of 22 babies (22.7%) had low birth weight, whereas among anemic mothers, a much higher proportion, 34 out of 62 (54.8%), had low birth weight. Overall, 39 babies had low birth weight and 45 had normal birth weight. The association was statistically significant ($\chi^2 = 9.86$, $p = 0.002$), indicating that maternal anemia is significantly associated with an increased risk of low birth weight.

Table 3: Association Between Maternal Anemia and Low Birth Weight

Maternal Anemia Status	LBW (n)	Normal Birth Weight (n)	Total	Percentage LBW (%)
Non-anemic	5	17	22	22.7
Anemic	34	28	62	54.8
Total	**39**	**45**	**84**	

Chi-square (χ^2) = 9.86, p = 0.002

Table 4 shows the association between maternal anemia and developmental delay among the study subjects (n=84). Among non-anemic mothers, only 1 out of 22 children (4.5%) had developmental delay, whereas among anemic mothers, 19 out of 62 children (30.6%) exhibited developmental delay. Overall, 20 children had developmental delay while 64 showed normal development. The association was statistsically significant ($\chi^2 = 10.72$, $p = 0.001$), indicating that maternal anemia is strongly associated with a higher risk of developmental delay in children.

Table 4: Association Between Maternal Anemia and Developmental Delay

Maternal Anemia Status	Developmental Delay (n)	Normal Development (n)	Total	Percentage Delay (%)
Non-anemic	1	21	22	4.5
Anemic	19	43	62	30.6
Total	**20**	**64**	**84**	

Chi-square (χ^2) = 10.72, p = 0.001

Table 5 presents the logistic regression analysis identifying predictors of developmental delay. Moderate anemia was significantly associated with increased risk, with an odds ratio (OR) of 2.8 (95% CI: 1.2–6.5, p=0.014), while severe anemia showed an even higher risk (OR 4.5, 95% CI: 1.5–13.2, p=0.006). Low birth weight was also a significant predictor (OR 3.2, 95% CI: 1.4–7.4, p=0.005). In contrast, maternal age >30 years was not significantly associated with developmental delay (OR 1.3, 95% CI: 0.6–3.1, p=0.412). Overall, increasing severity of anemia and low birth weight were significant predictors of developmental delay.

Table 5: Logistic Regression Analysis for Predictors of Developmental Delay

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
Moderate Anemia	2.8	1.2 – 6.5	0.014
Severe Anemia	4.5	1.5 – 13.2	0.006
Low Birth Weight	3.2	1.4 – 7.4	0.005
Maternal Age (>30 years)	1.3	0.6 – 3.1	0.412

Table 6 shows the association between severity of maternal anemia and developmental delay. Among mild anemia cases, 3 out of 17 children (17.6%) had developmental delay. In moderate anemia, 12 out of 37 cases (32.4%) showed developmental delay. The highest proportion was observed in severe anemia, where 4 out of 8 cases (50%) had developmental delay. This indicates a clear increasing trend, with higher severity of maternal anemia associated with a greater proportion of developmental delay.

Table 6: Developmental Delay by Severity of Maternal Anemia

Severity of Anemia	Developmental Delay (n)	Total Cases	Percentage (%)
Mild	3	17	17.6
Moderate	12	37	32.4
Severe	4	8	50

Discussion

The results of the current study indicate that there is a high rate of maternal anemia with almost three-fourths of mothers having anemia and moderate anemia being the most prevalent type. This trend is in line with the wider national and regional data. An example is that the World Health Organization has indicated that anemia is a significant public health issue in low- and middle-income countries and especially amongst pregnant women and this is mainly due to nutritional deficiency and inadequate access to antenatal care (World Health Organization, 2011) [1]. This has been found to be similarly prevalent in Indian contexts with studies like Kumar et al. (2018) [9] finding high prevalence of anemia in pregnancy with the most prevalence in socioeconomically disadvantaged groups. The prevalence has however been found to be lower in some studies conducted in hospitals, which are located in more urbanized areas, implying that geographic and socioeconomic influences can be significant in defining maternal hemoglobin status".

The correlation between low birth weight (LBW) and maternal anemia in the current study is quite consistent with previous studies. We found a definite dose-response trend, with LBW progressively becoming non-anemic to severely anemic mothers. This coincides with the research established by Lone et al. (2004) [10] that shows that the reduction in hemoglobin concentrations was strongly correlated with the risk of LBW, thus supporting the biological plausibility of the fact that impaired oxygen delivery resulted in intrauterine growth restriction (IUGR). In a similar finding, Kumar et al. (2018) [9] discovered

that anemia, especially during the second and third trimesters, was significantly correlated with low birth weight and preterm delivery. Conversely, some of the studies have found weaker associations but when confounding variables, including maternal nutrition and socioeconomic status, were considered, indicating that anemia can be both a risk factor in its own right and a reflection of maternal health status as a whole.

The statistically significant correlation between maternal anemia and LBW in our study ($p = 0.002$) further adds to the evidence base to support this relationship. Similar results were also cited by Lone et al. (2004) [10] when they found maternal anemia to be a significant determinant of poor perinatal outcome. The fact that the same results are obtained in various populations shows the strength of this association. Nevertheless, a degree of variation in magnitude has been noted between studies, which could be the result of study design, sample size, and diagnostic criteria of anemia and LBW. As an example, in high-resource areas, studies are more likely to have smaller effect sizes, possibly because of the improved nutritional supplementation and access to healthcare.

Measured in terms of developmental outcomes, the current research revealed that there was a strong statistically significant relationship between maternal anemia and developmental delay and a significant escalation in risk as severity of anemia increased. This observation is in line with Lozoff et al. (2006) [11] who have shown that early iron deficiency may lead to cognitive, motor, and behavioral impairments in the long run. On the same note, Georgieff (2008) [12] pointed out the importance of iron in brain development especially in myelination, neurotransmitter production. Our observed gradient, between 4.5% developmental delay in non-anemic mothers and 50% in those with severe anemia, is highly consistent with these previous results, as it confirms the idea that there is a dose effect in terms of neurodevelopment.

Our study logistic regression analysis is another strong point that supports literature in that moderate and severe anemia are strong predictors of developmental delay. These higher odds (2.8 times moderate anemia and 4.5 times severe anemia) are similar to the results of Rao and Georgieff (2007) [13] who highlight that fetal iron deficiency has long-term neurodevelopmental effects, despite correction of postnatal iron status. Moreover, the fact that low birth weight is an independent predictor of developmental delay (OR = 3.2) is not new as a number of previous studies indicated that low birth weight infants are at risk of delayed cognitive and motor development both because of biological susceptibility and environmental conditions.

Although in our study there was no significant association between maternal age and developmental delay, other researchers have given mixed results. Other researchers postulate that maternal advanced age might raise the risk of adverse outcomes because of comorbidities whereas other researchers, like our findings, point out that maternal age alone might not be a good predictor in the presence of other factors like anemia and nutrition. This comparison reflects the multifactorially of developmental outcomes and the importance of taking a wider array of maternal and environmental factors into account.

In general, the correlation of our results with previous research indicates the importance of maternal hemoglobin levels in birth weight and early childhood development. Some slight differences in studies can be explained by the differences in the population, access to healthcare, and approaches to studies. However, the high congruence in proving a dose-response relationship between the severity of anemia and the presence of adverse outcomes in mothers highlights the need to detect and treat maternal anemia early in life. These results are added to the existing body of research that highlights the importance of enhancing maternal nutrition and anemia management as a way of not only decreasing perinatal morbidity, but also as a way of ensuring optimal neurodevelopmental outcomes in children.

Conclusion

The research concludes that maternal anemia in pregnancy is strongly correlated with poor infant outcomes, especially low birth weight and developmental delays. Results show that there is a definite trend such that the more severe anemia, the higher the chances of such adverse events. Infants born by anemic mothers had a higher likelihood of being born with a low weight and slow development, than their non-anemic mothers. In addition, moderate and severe anemia, and low birth weight were also significant predictors of developmental delay, whereas maternal age did not play a significant role. In general, the findings demonstrate maternal anemia as a significant and possibly modifiable risk factor to early childhood development.

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