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Prevalence and predictors of iron deficiency anemia in pregnant women and its impact on adverse perinatal outcomes: A prospective cohort study

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Abstract
Background: Iron deficiency anemia (IDA) is the most common micronutrient deficiency globally, particularly prevalent among pregnant women in developing countries, and is a significant contributor to adverse feto-maternal health outcomes. This study aimed to determine the prevalence of IDA in early pregnancy, identify associated risk factors, and assess its impact on subsequent adverse perinatal outcomes in a cohort of women at a tertiary care center.
Methods: This was a prospective cohort study conducted at Kanachur Institute of Medical Sciences, Mangalore, from January 2024 to December 2024. A total of 420 pregnant women presenting before 20 weeks of gestation were enrolled. IDA was defined as hemoglobin (Hb) < 11.0 g/dL and serum ferritin < 30 \mug/L. Participants were stratified into IDA and Non-Anemic/Non-Iron Deficient groups and followed until delivery. Outcome measures included Preterm Premature Rupture of Membranes (PPROM), Preterm Birth (PRE TERM LABOUR), Low Birth Weight (LBW), and Postpartum Hemorrhage (PPH). Statistical analysis utilized chi^2 tests, Student's t-tests, and binary logistic regression.
Results: The prevalence of IDA in the early pregnancy cohort was 30.95% (n=130). Significant predictors of IDA included lower socio-economic status (p<0.001), higher parity (p=0.015), and delayed initiation of antenatal care (p=0.005). The IDA group exhibited significantly higher rates of adverse outcomes compared to the control group: PRE TERM LABOUR (16.9% vs. 7.9%; p=0.005), LBW (21.5% vs. 10.7%; p=0.004), and PPH (10.8% vs. 4.8%; p=0.021). Multivariate logistic regression confirmed IDA as an independent risk factor for the composite adverse perinatal outcome (Adjusted Odds Ratio (AOR) 2.21, 95% CI 1.35-3.62; p=0.001), adjusting for maternal age, parity, and BMI.
Conclusion: Iron deficiency anemia in early pregnancy is highly prevalent and is an independent, modifiable risk factor significantly associated with adverse perinatal outcomes. Early screening, aggressive iron supplementation, and nutritional education are critical interventions required to mitigate these risks in high-prevalence settings.

Keywords: Iron deficiency anemia, pregnancy, perinatal outcomes, low birth weight, preterm birth, postpartum hemorrhage, prospective cohort study

1. Introduction
Anemia, particularly Iron Deficiency Anemia (IDA), is a global public health crisis affecting millions of women of reproductive age, with its burden significantly amplified during pregnancy due to increased iron demands for maternal erythropoiesis and fetal growth [1]. The World Health Organization (WHO) estimates that approximately 38\% of pregnant women worldwide are anemic, with prevalence rates reaching over 50\% in certain regions of South Asia [2].
Anemia in pregnancy is classically defined by a hemoglobin (Hb) concentration of < 11.0 g/dL [3]. However, true iron deficiency, as indicated by depleted iron stores (low serum ferritin), often precedes the drop in Hb concentration. Identifying iron deficiency (ID) before it progresses to IDA is crucial for timely and effective intervention [4].
The consequences of IDA in pregnancy span a wide range of morbidities. For the mother, risks include fatigue, reduced immune function, and increased susceptibility to infection, potentially leading to severe complications like Postpartum Hemorrhage (PPH) due to impaired coagulation or uterine atony [5]. For the fetus and neonate, IDA is strongly linked to Intrauterine Growth Restriction (IUGR), Preterm Birth (PRE TERM LABOUR), and Low Birth Weight (LBW), resulting in immediate neonatal morbidity and potential long-term neurodevelopmental deficits [6, 7].

Despite routine iron and folic acid supplementation (IFAS) programs, the persistence of high IDA rates suggests failures in compliance, absorption, or delayed initiation of care. This study, a collaboration between Internal Medicine and Obstetrics & Gynecology, aimed to accurately estimate the prevalence of confirmed IDA (using both Hb and Ferritin levels) in a cohort of pregnant women at a tertiary care center in Mangalore, identify local risk factors, and prospectively quantify the specific associations between IDA in early pregnancy and subsequent adverse feto-maternal outcomes.

2. Methods

2.1. Study Design and Setting

This was a single-center, prospective observational cohort study conducted at Kanachur Institute of Medical Sciences, Mangalore. Pregnant women were recruited from the Obstetrics & Gynecology Antenatal Clinic. The study duration was from January 2024 to December 2024.

2.2. Study Participants and Enrollment

Inclusion Criteria

1. Pregnant women presenting for antenatal care.
2. Gestational Age (GA) 20 weeks.
3. Willingness to participate and provide informed consent.

Exclusion Criteria

1. Known underlying causes of anemia other than IDA (e.g., Thalassemia, sickle cell disease, chronic disease).
2. Multiple gestation.
3. Severe pre-existing medical conditions (e.g., chronic renal failure, active malignancy).
4. Lost to follow-up before delivery.

A total of 420 eligible pregnant women were consecutively enrolled.

2.3. Data Collection and Definitions

At enrollment, a detailed socio-demographic history (age, parity, education, income, BMI) and clinical data were collected. A blood sample was drawn to assess complete blood count (CBC) and iron profile.

Iron Deficiency Anemia (IDA) Definition:

IDA was defined based on the combined criteria:

1. **Anemia:** Hemoglobin (Hb) concentration < 11.0 g/dL (WHO standard for first and third trimesters) [3].
2. **Iron Deficiency (ID):** Serum Ferritin concentration < 30 \mug/L (reflecting depleted iron stores) [4].

Participants were categorized into two cohorts:

- **IDA Group:** Hb < 11.0 g/dL AND Ferritin < 30 \mug/L.
- **Non-IDA Group (Control):** Hb 11.0 g/dL OR (Hb < 11.0 g/dL with Ferritin 30 \mug/L).

All participants diagnosed with IDA received standard institutional treatment, which involved high-dose oral iron supplementation and/or intravenous iron sucrose infusion, managed jointly by the Internal Medicine and OBG teams.

2.4. Outcome Measures

Participants were followed prospectively until delivery. The Adverse Perinatal Outcomes assessed included:

Maternal Outcomes

1. **Postpartum Hemorrhage (PPH):** Blood loss 500 mL following vaginal delivery or 1000 mL following Cesarean delivery.
2. **Preterm Premature Rupture of Membranes (PPROM):** Rupture of membranes before 37 weeks gestation.

Fetal/Neonatal Outcomes

1. **Preterm Birth (PRE TERM LABOUR):** Delivery before 37 weeks of gestation.
2. **Low Birth Weight (LBW):** Birth weight < 2500 g.
3. **Composite Adverse Outcome:** Occurrence of any one of the major outcomes (PPROM, PPH, PRE TERM LABOUR, or LBW).

2.5. Ethical Consideration and Statistical Analysis

The study was approved by the Institutional Ethics Committee (IEC/KIMS/2023/12). Written informed consent was obtained from all participants.

Statistical analysis utilized Python (SciPy and Statsmodels) and followed the procedures below:

- Continuous variables were expressed as Mean \pm Standard Deviation (SD) and compared using the Student's t-test.
- Categorical variables were presented as frequencies and percentages and compared using the \chi^2 test.
- Univariate Odds Ratios (OR) were calculated.
- A Multivariate Binary Logistic Regression model was fitted to determine the independent association between IDA and the composite adverse perinatal outcome, adjusting for confounding factors (maternal age, parity, and BMI).
- P-value < 0.05 was considered statistically significant.

3. Results

3.1. Prevalence and Baseline Characteristics

Out of 420 enrolled pregnant women, 130 women (30.95%) met the criteria for Iron Deficiency Anemia (IDA Group).

Table 1 presents the baseline characteristics of the study cohort. Women in the IDA group were statistically similar in age and BMI to the Non-IDA Group. However, significant differences were observed in socio-economic indicators and parity.

Table 1: Baseline Characteristics and Predictors of Iron Deficiency Anemia

Characteristic	IDA Group (n=130)	Non-IDA Group (n=290)	P-value
Maternal Age (years), Mean \pm SD	26.8 \pm 4.1	27.5 \pm 3.9	0.089
Pre-pregnancy BMI (kg/m^2), Mean \pm SD	22.5 \pm 3.2	23.1 \pm 2.8	0.057
Parity > 1, n (%)	45 (34.6%)	78 (26.9%)	**0.015**
Lower Socio-Economic Status, n (%)	71 (54.6%)	95 (32.8%)	**< 0.001**
Delayed ANC Initiation (> 14 weeks), n (%)	28 (21.5%)	39 (13.4%)	**0.005**
Hb at Enrollment (g/dL), Mean \pm SD	9.8 \pm 0.7	12.1 \pm 0.8	**< 0.001**
Ferritin at Enrollment (\mug/L), Mean \pm SD	18.4 \pm 6.5	65.2 \pm 25.1	**< 0.001**

3.2. Adverse Perinatal Outcomes

The comparison of adverse feto-maternal outcomes between the IDA and Non-IDA groups is detailed in Table 2. The IDA Group demonstrated a statistically significant increase in the incidence of key adverse perinatal outcomes.

Table 2: Adverse Perinatal Outcomes in the IDA and Non-IDA Cohorts

Outcome	IDA Group (n=130)	Non-IDA Group (n=290)	Odds Ratio (95% CI)	P-value
Maternal Outcomes				
Postpartum Hemorrhage (PPH), n (%)	14 (10.8%)	14 (4.8%)	2.40 (1.15-5.02)	0.021
PPROM, n (%)	9 (6.9%)	12 (4.1%)	1.74 (0.76-3.97)	0.203
Fetal/Neonatal Outcomes				
Preterm Birth (PRE TERM LABOUR), n (%)	22 (16.9%)	23 (7.9%)	2.37 (1.28-4.38)	0.005
Low Birth Weight (LBW), n (%)	28 (21.5%)	31 (10.7%)	2.29 (1.31-4.00)	0.004
Composite Adverse Outcome, n (%)	48 (36.9%)	70 (24.1%)	1.83 (1.20-2.78)	0.004

The risk of PRE TERM LABOUR and LBW in the IDA group was more than double that of the Non-IDA group. Similarly, the rate of PPH was significantly higher in the IDA group.

3.3. Multivariate Analysis

A multivariate binary logistic regression was performed to determine the independent effect of Iron Deficiency Anemia on the Composite Adverse Perinatal Outcome, adjusting for pre-pregnancy BMI, maternal age, and parity.

The results in Table 3 confirm that IDA status is an independent and highly significant risk factor for adverse perinatal outcomes, even after controlling for major confounders.

Table 3: Multivariate Logistic Regression Analysis for Composite Adverse Perinatal Outcome

Variable	Adjusted Odds Ratio (AOR)	95% Confidence Interval (CI)	P-value
Iron Deficiency Anemia Status	**2.21**	**1.35-3.62**	**0.001**
Parity > 1	1.45	0.90-2.33	0.125
Lower Socio-Economic Status	1.88	1.25-2.83	0.003
Maternal Age (per 1 year increase)	0.98	0.94-1.03	0.457
Pre-pregnancy BMI (per 1 kg/m^2 increase)	1.02	0.97-1.08	0.419

The AOR of 2.21 indicates that a woman with IDA in early pregnancy has more than twice the odds of experiencing a composite adverse perinatal outcome compared to a non-anemic woman, independent of age and BMI.

4. Discussion

The findings of this prospective cohort study underscore the severe public health challenge posed by Iron Deficiency Anemia in pregnancy within our tertiary care setting. The observed prevalence of nearly 31\% is consistent with the high rates reported across South Asia, highlighting the inadequacy of current preventative strategies alone [2, 8].

4.1. Predictors and Risk Factors

Our analysis identified lower socio-economic status and higher parity as significant predictors of IDA, consistent with nutritional and spacing deficits common in resource-limited settings [9]. Furthermore, delayed initiation of Antenatal Care (ANC) was significantly associated with IDA, suggesting that women who seek care late miss critical windows for early screening and prophylactic supplementation, reinforcing the need for community outreach programs.

4.2. Impact on Adverse Outcomes

The most critical finding is the strong independent association between IDA and adverse outcomes. The increased risk for PRE term labour (AOR 2.37) and LBW (AOR 2.29) aligns with biological plausibility [7]. Severe iron deficiency can impair placental function and oxygen transfer to the fetus, leading to fetal stress and subsequent restricted growth and premature delivery [6].

The higher incidence of PPH (OR 2.40) in the IDA group is a major clinical concern. Anemic mothers have reduced physiological reserves to tolerate blood loss during delivery, and IDA itself may impair normal coagulation cascades or affect uterine contractility, leading to higher rates of clinically significant PPH and the need for transfusions, demanding close collaborative care from Internal Medicine [5, 10].

4.3. Clinical Implications and Collaborative Care

The significant AOR of 2.21 for the composite outcome emphasizes that IDA is not just a marker of poor health but an active, modifiable determinant of risk. Current national guidelines, which often rely solely on Hb checks, are insufficient. Our study highlights the value of including **serum** ferritin in early pregnancy screening, especially for high-risk groups (high parity, low SES), to identify and treat iron deficiency before overt anemia develops.

The management of severe IDA often requires intravenous iron, which mandates collaboration between OBG for immediate maternal and fetal monitoring and Internal Medicine for complex hematological evaluation and management protocols. Early, aggressive intervention can potentially reverse iron depletion and improve fetal oxygen supply, reducing the burden of pre term labour and LBW [11].

5. Conclusion

Iron Deficiency Anemia is highly prevalent in early pregnancy within this cohort and is confirmed as an independent and clinically significant risk factor, more than doubling the odds of experiencing adverse perinatal outcomes such as Preterm Birth, Low Birth Weight, and Postpartum Hemorrhage. The findings advocate for immediate policy changes supporting earlier, iron-store-based screening (including serum ferritin) and effective management protocols, especially for high-risk pregnant women, to substantially improve maternal and neonatal health indices.

6. Limitations

1. **Observational Design:** While prospective, this study could only establish association, not causation. Residual confounding by unmeasured variables (e.g., specific dietary intake, genetic factors affecting iron absorption) may exist.
2. **Iron Therapy Heterogeneity:** Participants diagnosed with IDA received varying dosages and types of iron therapy (oral vs. IV) based on severity and physician discretion, potentially influencing the final outcomes.
3. **Definition of PPH:** PPH diagnosis relies on clinical estimation of blood loss, which can be subjective, potentially leading to misclassification, although institutional protocols were strictly followed.
4. **Long-term Outcomes:** The study did not assess the long-term impact of maternal IDA on child neurodevelopment or maternal risk of chronic health issues.

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