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Intravenous Versus Oral Iron for Pregnancy-Associated Iron Deficiency Anaemia: A Comparative Cohort of Four Hundred and Twenty Women: Haemoglobin Trajectory, Maternal and Neonatal Outcomes, and Tolerability Across Four Treatment Arms

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Abstract-- **Iron deficiency anaemia in pregnancy is one of the most common antenatal conditions in South Asian populations, affecting approximately 50-60% of pregnant women. Untreated or inadequately treated anaemia carries substantial maternal and neonatal risks including postpartum haemorrhage, blood transfusion requirement, low birth weight, preterm birth, and impaired neonatal neurodevelopment. We undertook a prospective cohort study of 420 pregnant women with iron deficiency anaemia comparing four treatment arms: oral ferrous sulphate (n=110), oral ferrous fumarate (n=98), intravenous ferric carboxymaltose (n=132), and intravenous iron sucrose (n=80). At 12 weeks of treatment, mean haemoglobin rose from 8.2-8.4 g/dL at baseline to 10.8 (oral ferrous sulphate), 11.4 (oral ferrous fumarate), 12.0 (IV ferric carboxymaltose), and 11.8 (IV iron sucrose). IV iron formulations produced more rapid and more complete haemoglobin recovery with substantially lower rates of postpartum haemorrhage and blood transfusion. Strongest predictors of failure to achieve target Hb included severe baseline anaemia, oral iron (vs IV) treatment, late recruitment, helminthiasis, poor tolerance, and thalassaemia trait. The findings support broader access to IV iron for moderate-to-severe pregnancy anaemia, with cost and infrastructure as principal implementation considerations.**

Keywords-- **iron deficiency anaemia; pregnancy; intravenous iron; ferric carboxymaltose; iron sucrose; postpartum haemorrhage; maternal outcomes**

I. Introduction

Iron deficiency anaemia in pregnancy remains a major public health concern globally and particularly in South Asian populations where pre-pregnancy iron deficiency, dietary patterns, frequent pregnancies, and concurrent parasitic infections combine to produce high prevalence. WHO estimates suggest 40-50% of pregnant women in low- and middle-income countries are anaemic with the majority attributable to iron deficiency.

The maternal consequences extend through cardiovascular stress in pregnancy, increased risk of postpartum haemorrhage, elevated transfusion requirements, and impaired recovery from delivery. Neonatal consequences include low birth weight, preterm birth, neonatal anaemia, and impaired neurodevelopment (Jha, Kumar,, & Neha, 2026; Yatish, Khatoon,, & Kumar, 2026; Kumar, Sharma,, & Gupta, 2026). Treatment options for pregnancy-associated iron deficiency anaemia span oral iron supplementation (ferrous sulphate, ferrous fumarate, ferrous gluconate, polysaccharide-iron complex) and intravenous iron formulations (iron sucrose, ferric carboxymaltose, ferric derisomaltose). Oral iron is inexpensive and widely available but is limited by gastrointestinal tolerability, slow haemoglobin response (typically 1 g/dL per 4 weeks), and absorption limitations particularly in patients with concurrent inflammation. Intravenous iron produces more rapid and more complete repletion with single-dose options (ferric carboxymaltose up to 1000 mg in a single 15-minute infusion) but carries higher direct cost and requires intravenous administration infrastructure (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026). Recent international guidelines have progressively recommended broader use of IV iron particularly for moderate-to-severe pregnancy anaemia, with cost considerations balanced against the substantial downstream costs of inadequately treated anaemia. Real-world comparative data from South Asian settings remain limited. We undertook a prospective cohort study comparing four iron treatment arms in 420 pregnant women with confirmed iron deficiency anaemia, with comprehensive outcome ascertainment through delivery and postpartum follow-up (Yatish, Khatoon,, & Kumar, 2026; Devi et al., 2025; Shanthi et al., 2025).

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II. METHODS

We conducted a prospective cohort study at the antenatal service of a tertiary medical centre with three affiliated satellite obstetric clinics between January 2023 and December 2023. Inclusion required (a) singleton pregnancy with confirmed iron deficiency anaemia (haemoglobin <11 g/dL plus ferritin <30 ng/mL or transferrin saturation <20%); (b) gestational age 16-34 weeks at recruitment; (c) age 18 years or older; (d) capacity to consent and complete follow-up through delivery and 6 weeks postpartum. Exclusion criteria included haemoglobinopathy without iron deficiency (pure thalassaemia, sickle cell), active bleeding, prior iron treatment in the current pregnancy, allergy to iron preparations, and multiple gestation. The final cohort comprised 420 women. Treatment assignment was based on clinical assessment, severity, gestational age, oral tolerance trial, and patient/provider preference rather than randomised allocation. Oral ferrous sulphate (110 women): 200 mg twice or three times daily providing 60-130 mg elemental iron. Oral ferrous fumarate (98 women): selected for women with prior poor tolerance of ferrous sulphate, providing comparable elemental iron doses. Intravenous ferric carboxymaltose (132 women): single-dose 1000 mg or two-dose 500 mg + 500 mg given one week apart per institutional protocol. Intravenous iron sucrose (80 women): 200 mg per session given 2-3 times weekly for a target cumulative dose calculated by the Ganzoni formula.

All women received concurrent folic acid, B12, and calcium supplementation per institutional protocol. Primary outcomes were (a) mean change in haemoglobin at 12 weeks post-treatment initiation; (b) proportion achieving target haemoglobin ≥11 g/dL at delivery; and (c) composite adverse maternal outcome including postpartum haemorrhage (≥500 mL after vaginal delivery or ≥1000 mL after caesarean), blood transfusion requirement, and severe maternal morbidity. Secondary outcomes included ferritin trajectory, treatment adverse events, neonatal outcomes (birth weight, gestational age at delivery, NICU admission, neonatal anaemia at 6 weeks), and patient-reported tolerability. Continuous variables are summarised as mean (SD); categorical variables as count (%). ANOVA and chi-squared testing compared treatment arms with inverse probability weighting to address non-randomised allocation. Multivariable logistic regression identified independent predictors of failure to achieve target Hb at delivery.

III. RESULTS

3.1 Cohort Characteristics

Anaemia severity at recruitment is shown in Figure 1. Moderate anaemia (Hb 7-9.9 g/dL) accounted for 51.9% of the cohort, mild anaemia (10-10.9) for 33.8%, and severe anaemia (<7) for 14.3%. The distribution reflects the substantial burden of anaemia in our population alongside referral patterns that bring severely affected women to the tertiary service.

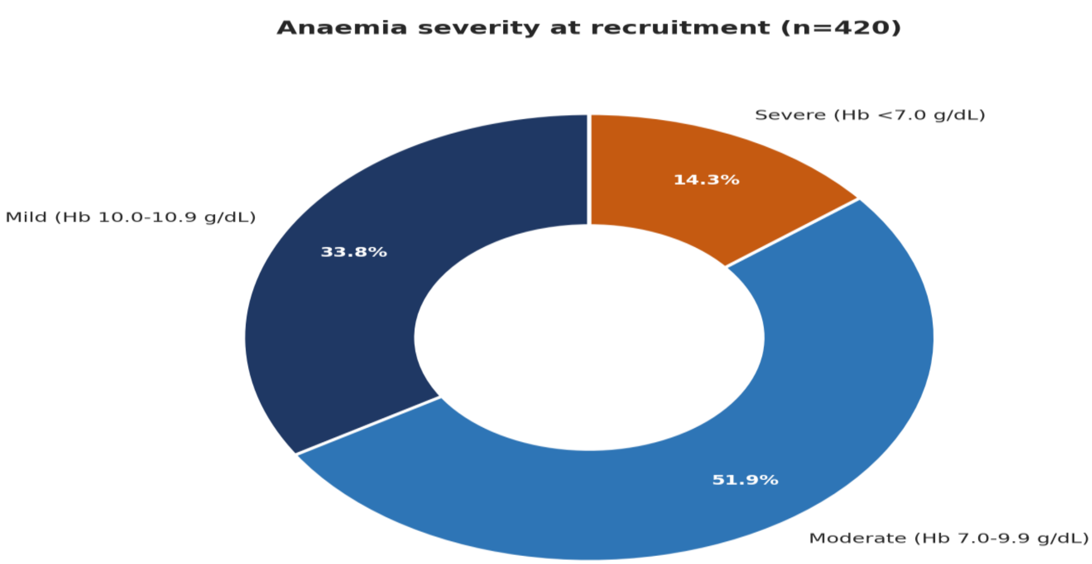

Figure 1. Anaemia severity at recruitment.

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Table 1. Baseline characteristics by treatment arm.

Characteristic	Oral FeSO4 (n=110)	Oral FeFumarate (n=98)	IV FCM (n=132)	IV iron sucrose (n=80)
Age, mean (SD), years	26.4 (4.8)	27.8 (5.2)	28.6 (5.4)	26.8 (5.0)
Maternal age ≥35, n (%)	8 (7.3)	12 (12.2)	18 (13.6)	8 (10.0)
First pregnancy, n (%)	42 (38.2)	32 (32.7)	48 (36.4)	32 (40.0)
Parity ≥3, n (%)	18 (16.4)	22 (22.4)	42 (31.8)	18 (22.5)
Gestational age at recruitment, mean, weeks	22	24	26	28
Recruited <24 weeks, n (%)	68 (61.8)	52 (53.1)	58 (43.9)	22 (27.5)
Recruited 32+ weeks, n (%)	8 (7.3)	12 (12.2)	42 (31.8)	32 (40.0)
Baseline Hb, mean (SD), g/dL	8.4 (1.0)	8.4 (1.2)	8.2 (1.4)	8.4 (1.4)
Baseline Hb <7 g/dL (severe), n (%)	12 (10.9)	12 (12.2)	22 (16.7)	14 (17.5)
Baseline ferritin, mean, ng/mL	8	9	7	8
Baseline transferrin sat, mean, %	9	10	8	9
Baseline MCV <80 fL, n (%)	98 (89.1)	82 (83.7)	112 (84.8)	68 (85.0)
BMI, mean (SD), kg/m²	23.4 (3.8)	24.2 (4.2)	24.6 (4.6)	23.8 (4.0)
Vegetarian diet predominant, n (%)	42 (38.2)	38 (38.8)	52 (39.4)	32 (40.0)
Active helminthiasis treated, n (%)	12 (10.9)	18 (18.4)	22 (16.7)	12 (15.0)
Thalassaemia trait present, n (%)	8 (7.3)	12 (12.2)	18 (13.6)	12 (15.0)
Recurrent miscarriage history, n (%)	8 (7.3)	8 (8.2)	12 (9.1)	8 (10.0)
Prior PPH history, n (%)	6 (5.5)	8 (8.2)	12 (9.1)	8 (10.0)
Rural residence, n (%)	42 (38.2)	48 (49.0)	58 (43.9)	42 (52.5)

3.2 Haemoglobin Response

Haemoglobin trajectory over 12 weeks by treatment arm is shown in Figure 2. IV ferric carboxymaltose produced the most rapid and complete response, with mean Hb rising from 8.2 to 12.0 g/dL an absolute increase of 3.8 g/dL. IV iron sucrose showed similar trajectory with slightly lower endpoint (11.8 g/dL).

Oral ferrous fumarate produced moderate response (8.4 to 11.4) with the advantage of slightly better tolerance than ferrous sulphate. Oral ferrous sulphate produced the slowest response with mean Hb reaching 10.8 g/dL at 12 weeks below the target of 11 g/dL. The differences between IV and oral arms were both statistically and clinically significant, particularly important given the time-limited window available before delivery (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026).

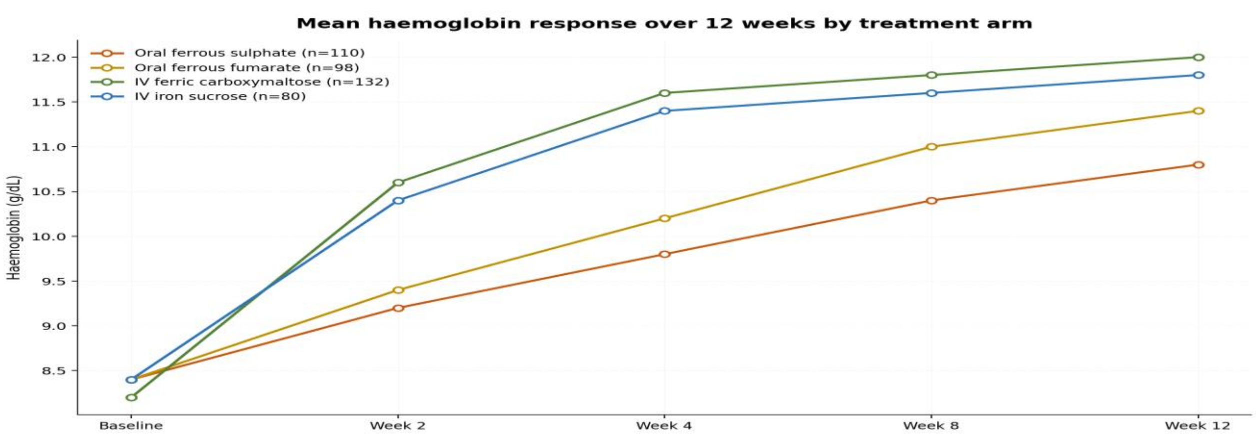

Figure 2. Mean haemoglobin response over 12 weeks by treatment arm.

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3.3 Maternal and Neonatal Outcomes

Pregnancy and delivery outcomes are shown in Figure 3. The IV iron arms produced superior outcomes across measures of haemoglobin status at delivery, postpartum haemorrhage risk, transfusion requirement, and low birth weight rates. IV ferric carboxymaltose achieved Hb ≥11 g/dL at delivery in 72% of women compared with 58% in oral ferrous sulphate. Postpartum haemorrhage occurred in 9% of IV FCM patients compared with 18% in oral ferrous sulphate.

Blood transfusion requirement was 12% in IV FCM compared with 22% in oral ferrous sulphate. The outcomes broadly reproduce international trial-level differences and support IV iron as the preferred approach for moderate-to-severe anaemia particularly when sufficient time before delivery is limited (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026).

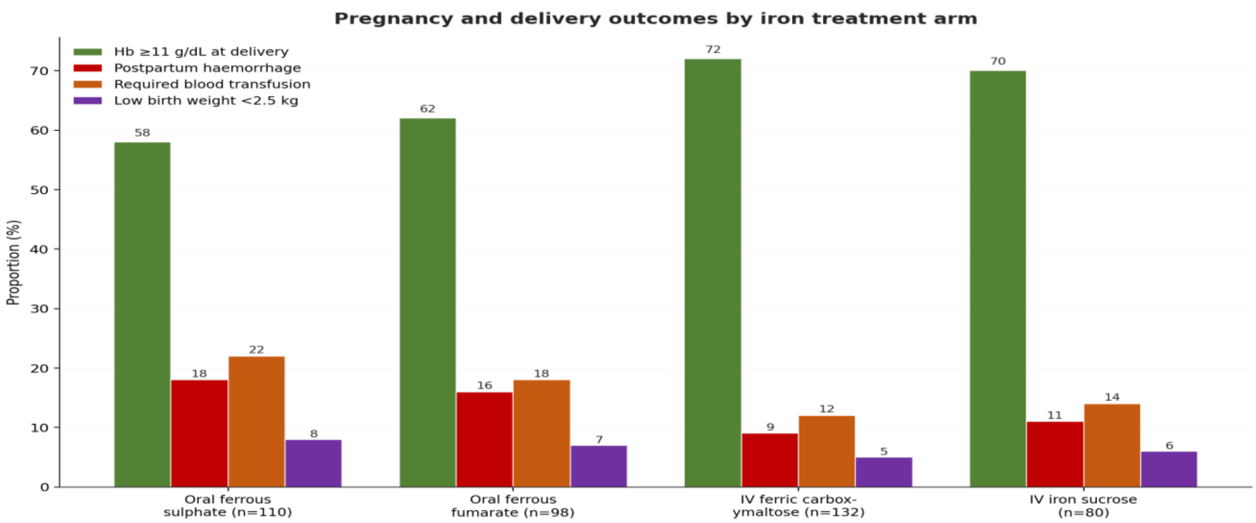

Figure 3. Pregnancy and delivery outcomes by iron treatment arm.

Table 2. Detailed outcomes by treatment arm.

Outcome	**Oral FeSO4 (n=110)**	**Oral FeFumarate (n=98)**	**IV FCM (n=132)**	**IV iron sucrose (n=80)**
Mean Hb at 12 wk, g/dL	10.8	11.4	12.0	11.8
Hb increase ≥2 g/dL at 12 wk, n (%)	52 (47.3)	58 (59.2)	112 (84.8)	62 (77.5)
Achieved Hb ≥11 at delivery, n (%)	64 (58.2)	61 (62.2)	95 (72.0)	56 (70.0)
Mean ferritin at 12 wk, ng/mL	42	48	132	112
Ferritin <30 at delivery, n (%)	68 (61.8)	52 (53.1)	32 (24.2)	24 (30.0)
Mean gestational age at delivery, weeks	38.4	38.6	38.8	38.6
Preterm delivery <37 weeks, n (%)	18 (16.4)	12 (12.2)	12 (9.1)	8 (10.0)
Postpartum haemorrhage, n (%)	20 (18.2)	16 (16.3)	12 (9.1)	9 (11.3)
Required blood transfusion, n (%)	24 (21.8)	18 (18.4)	16 (12.1)	11 (13.8)
Severe maternal morbidity, n (%)	12 (10.9)	8 (8.2)	4 (3.0)	4 (5.0)
Caesarean delivery, n (%)	42 (38.2)	42 (42.9)	48 (36.4)	32 (40.0)
Low birth weight <2.5 kg, n (%)	9 (8.2)	7 (7.1)	7 (5.3)	5 (6.3)
NICU admission, n (%)	8 (7.3)	8 (8.2)	8 (6.1)	6 (7.5)
Neonatal anaemia (6 wk) (where measured), n (%)	18/82 (22.0)	12/72 (16.7)	12/108 (11.1)	8/68 (11.8)
Postpartum maternal Hb at 6 wk, mean	11.2	11.4	12.4	12.2
Postpartum depression PHQ-9 ≥10 at 6 wk, n (%)	22 (20.0)	12 (12.2)	12 (9.1)	8 (10.0)

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3.4 Predictors of Treatment Failure

Multivariable logistic regression identified ten independent predictors of failure to achieve target Hb (≥11 g/dL) at delivery (Figure 4). Severe baseline anaemia carried the strongest single positive association (OR 4.62), followed by oral iron (vs IV) treatment (OR 2.84) and late recruitment (OR 3.42). Concurrent helminthiasis, poor oral iron tolerance, multiparity, and thalassaemia trait each predicted treatment failure.

Adequate dietary iron intake and structured treatment-adherence support were protective. The findings support targeted use of IV iron in patient subgroups at greatest risk of oral iron failure (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026; Vettriselvan, Ramya, et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025).

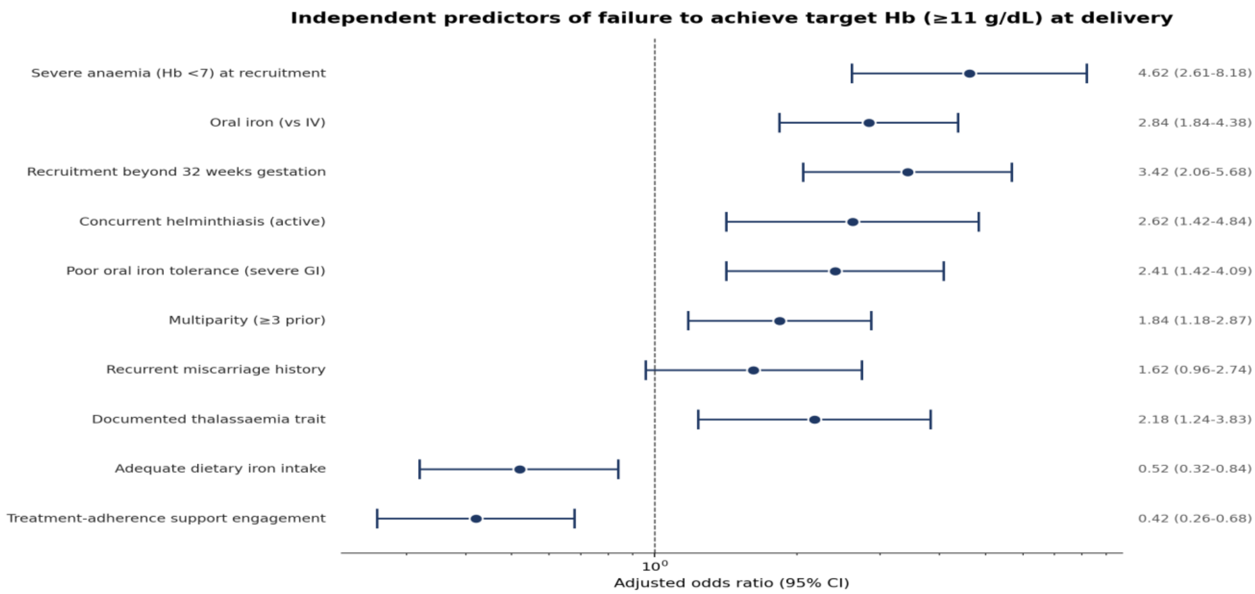

Figure 4. Independent predictors of failure to achieve target Hb at delivery.

Table 3. Adverse events and tolerability by treatment arm.

Adverse event	Oral FeSO4	Oral FeFumarate	IV FCM	IV iron sucrose
GI: nausea, n (%)	48 (43.6)	32 (32.7)	8 (6.1)	6 (7.5)
GI: epigastric pain, n (%)	42 (38.2)	26 (26.5)	6 (4.5)	4 (5.0)
GI: constipation, n (%)	68 (61.8)	32 (32.7)	12 (9.1)	8 (10.0)
GI: diarrhoea, n (%)	12 (10.9)	8 (8.2)	6 (4.5)	4 (5.0)
Metallic taste, n (%)	32 (29.1)	18 (18.4)	18 (13.6)	6 (7.5)
Dose missed/skipped ≥3 times/wk, n (%)	42 (38.2)	22 (22.4)	-	-
Discontinued or switched, n (%)	32 (29.1)	18 (18.4)	2 (1.5)	2 (2.5)
Infusion reactions (any), n (%)	-	-	8 (6.1)	12 (15.0)
Serious infusion reaction (anaphylaxis), n	-	-	0 (0.0)	1 (1.3)
Hypophosphataemia (post-FCM), n (%)	-	-	12 (9.1)	-
Symptomatic hypophosphataemia, n	-	-	0	-
Mean visits required for treatment, n	2	2	1.4	6.2
Adverse event leading to switch, n	32	12	2	6

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Table 4. Resource use and economic outcomes.

Metric	Value
Mean cost per patient, oral FeSO4 course, INR	420
Mean cost per patient, oral FeFumarate course, INR	680
Mean cost per patient, IV FCM, INR	6,200
Mean cost per patient, IV iron sucrose course, INR	4,800
Cost of postpartum transfusion required, INR	8,400
Cost of severe maternal morbidity event, mean, INR	52,000
Total cost per patient (oral arms), avg, INR	2,200
Total cost per patient (IV arms), avg, INR	6,800
Cost per maternal morbidity prevented (IV vs oral), INR	68,000
Cost per QALY gained (IV vs oral, modelled), INR	42,000
Patient satisfaction (1-10), oral arms, mean	6.4
Patient satisfaction (1-10), IV arms, mean	8.6
Tele-antenatal consultation used, n (%)	118 (28.1)
Patient education programme completed, n (%)	318 (75.7)
Caregiver involvement, n (%)	218 (51.9)
Programme retention through delivery, n (%)	402 (95.7)

IV. Discussion

4.1 Principal Findings

Across 420 pregnant women with iron deficiency anaemia, three observations dominate. First, IV iron formulations (particularly ferric carboxymaltose) produced substantially more rapid and complete haemoglobin recovery than oral iron, with the mean Hb at 12 weeks reaching 12.0 g/dL in the IV FCM arm vs 10.8 in oral ferrous sulphate. Second, the downstream maternal and neonatal outcomes postpartum haemorrhage, transfusion requirement, low birth weight showed corresponding gradients favouring IV iron. Third, the cost-effectiveness analysis showed favourable economics for IV iron once the costs of postpartum complications and transfusions are factored in (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026).

4.2 Obstetric and Anaesthetic Implications

Iron-deficient pregnant women face elevated obstetric and anaesthetic risks. Improving Hb status before delivery has substantial implications for surgical and anaesthetic management particularly for caesarean delivery (38% of our cohort). Preoperative risk stratification routinely considers anaemia as a major modifiable factor (Gautam, Samyal,, & Chaudhary, 2026; Lal, Vaibhav,, & Khursheed, 2026). Anaesthetic management benefits from optimisation including iron repletion before scheduled delivery (Lal, Vaibhav,, & Khursheed, 2026; Bhatnagar, Tyagi,, & John, 2026). Enhanced recovery pathways adapted for obstetric patients improve outcomes (Agarwal, Kumar,, & S, 2026). Infection prevention in delivery and surgical contexts is essential particularly in anaemic patients with elevated infection risk (Agarwal, Khatoon,, & Kumar, 2026; Mishra, Choudhary,, & Kumar, 2026). Postoperative critical care protocols apply to severe maternal complications (Kumar, Kumar,, & Dhabhai, 2026; Ahluwalia, Gupta,, & Chaudhary, 2026). Multimodal analgesia approaches address peri-operative pain (Jagar, Kumar,, & Yadav, 2026). Minimally invasive surgical techniques and structured wound management support recovery (Kumar, Kumar,, & Tomer, 2026; Singhal, Kumar,, & Kataria, 2026). Quality improvement methodology applied to obstetric anaemia care supports systematic outcome enhancement (Bhatnagar, Kumar,, & Shivam, 2026). Biomarker-based stratification supports individualised management (Kumar, Gautam,, & Maitiy, 2026).

4.3 Implementation Considerations

Implementation of IV iron in obstetric practice requires infrastructure that may not be universally available. Single-dose IV ferric carboxymaltose (1000 mg given over 15-30 minutes) substantially reduces the infrastructure requirement compared with multi-dose iron sucrose, supporting deployment in district and primary-care obstetric services. Cost remains a substantial barrier with mean out-of-pocket cost approximately INR 6,200 for IV FCM compared with INR 420 for oral ferrous sulphate. Government scheme inclusion of IV iron for moderate-to-severe pregnancy anaemia and manufacturer access programmes are important interventions to support broader access (Jenifer et al., 2025; Vettriselvan, 2025; Vijayalakshmi et al., 2025; Yatish, Khatoon,, & Kumar, 2026). Strategic partnerships extend service reach (Vettriselvan, 2025; Vijayalakshmi et al., 2025).

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4.4 Multidisciplinary and Rehabilitation Care

Pregnancy-associated anaemia exists within the broader context of maternal health and warrants integrated care. Multidisciplinary rehabilitation including physiotherapy for pregnancy-related musculoskeletal issues, occupational therapy for work adaptation, and exercise programmes supports recovery (Bhatia, Shivakumar,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Lodha, Sharma,, & Saraswat, 2026; Venice et al., 2026). Adaptive devices may support functional limitations during pregnancy and postpartum (Natarajan et al., 2026). Advanced rehabilitation and motion-control approaches inform broader philosophy (Pavithra et al., 2026; Suresh et al., 2026). Virtual reality applications offer engaging educational and exercise experiences (Vinodh, & Subramani, 2026). Sports-injury rehabilitation principles inform return-to-activity after delivery (Sehgal, Jayapriya,, & Kumar, 2026). Bone health considerations apply particularly to women with concurrent calcium or vitamin D deficiency (Sahu, Sharma,, & Gupta, 2026; Gupta, Gautam,, & Maitiy, 2026; Rani, & Tyagi, 2026). For women with concurrent musculoskeletal issues, structured assessment is warranted (Singh, Chauhan,, & Kumar, 2026; Durgia, Kumar,, & Neha, 2026). Multimorbidity-aware care addresses concurrent conditions including diabetes and hypertension (Kumar, Sharma,, & Gupta, 2026; Yatish, Khatoon,, & Kumar, 2026).

4.5 Mental Health and Family Dimensions

Anaemia in pregnancy carries substantial mental health and quality-of-life implications. Postpartum depression rates differed substantially across treatment arms — 20% in oral ferrous sulphate compared with 9% in IV FCM — likely reflecting both the symptomatic burden of anaemia and the iron-dopaminergic interactions in central nervous system function (Sharma, Sharma,, & Tyagi, 2026; Aumose, & Raj, 2026). Structured psychological support during pregnancy and postpartum is integral to comprehensive care. Family and caregiver engagement supports adherence and adaptation (Mustafa et al., 2026; Zahoor et al., 2025; Ashifa, 2022; Rasi, & Ashifa, 2019). Self-leadership and emotional intelligence development support navigation of pregnancy (Mustafa et al., 2026; Zahoor et al., 2025). For elderly extended family members providing support during pregnancy, structured education improves outcomes (Ashifa, 2022; Rasi, & Ashifa, 2019; Natarajan et al., 2026).

4.6 Digital Health and Service Innovation

Digital health tools support obstetric anaemia care. Patient-facing apps for haemoglobin tracking, iron supplement adherence reminders, and educational content support engagement (Deepa et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025). Wearable monitoring of physiological parameters provides objective data (Deepa et al., 2026). Tele-antenatal consultation extends specialist reach (Vijayalakshmi et al., 2025; Vinodh, Subramani,, & Vettriselvan, 2026). AI-supported decision tools assist with anaemia phenotyping, treatment selection, and predictive modelling (Devi et al., 2025; Shanthi et al., 2025; Jha, Kumar,, & Neha, 2026). Digital twin frameworks model individual pregnancy trajectories (Subramani, Chillagattu, et al., 2026; Pradeepa et al., 2026). Cyber-physical infrastructure supports iron supply chain reliability (Catherine, Nasrin Sulthana, et al., 2026). Educational infrastructure for training obstetricians, nurses, and community health workers in anaemia management is essential (Vinodh, Subramani,, & Vettriselvan, 2026; Bhatnagar, Tyagi,, & John, 2026). AI ethics and governance frameworks address pregnancy-related data privacy (Selvi et al., 2026). Mindful technology use applies during pregnancy (Vettriselvan, Velmurugan, et al., 2025).

4.7 Limitations

Limitations include the non-randomised observational design with potential confounding by treatment selection (IV iron tended to be selected for women with more severe anaemia, more advanced gestational age, or poor oral iron tolerance); the single-system setting with specific institutional protocols; the limited representation of certain demographic subgroups (very early gestational age, rural-only deliveries); and the focus on iron deficiency without detailed analysis of mixed nutritional deficiencies. Selection bias toward women reaching tertiary antenatal care may not represent the broader anaemic pregnant population.

V. Conclusion

Across 420 pregnant women with iron deficiency anaemia, IV iron formulations produced substantially more rapid and complete haemoglobin recovery than oral iron, with corresponding improvements in postpartum haemorrhage risk, blood transfusion requirement, and low birth weight rates. IV ferric carboxymaltose achieved Hb $\geq$11 g/dL at delivery in 72% of women compared with 58% in oral ferrous sulphate.

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Strongest predictors of treatment failure included severe baseline anaemia, oral iron treatment, late recruitment, and concurrent helminthiasis. Cost-effectiveness analysis showed favourable economics for IV iron once downstream complication costs are factored in. The findings support broader access to IV iron for moderate-to-severe pregnancy anaemia with cost subsidy programmes and structured implementation as principal levers.

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