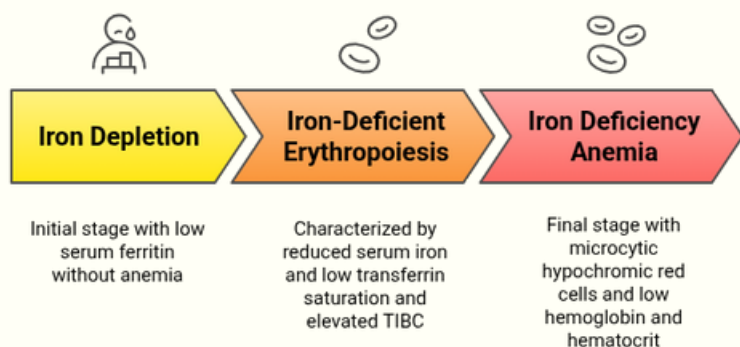


Introduction

Iron deficiency anemia (IDA) is the most prevalent nutritional disorder globally, with India bearing a disproportionate burden. According to the National Family Health Survey-5 (NFHS-5), 67.1% of children under five and 57% of women of reproductive age (15–49 years) in India are anemic, with stark disparities across states—79.7% in Gujarat vs. 39.4% in Kerala [1]. Socio-economic inequities persist: 52% of women in the wealthiest quintile are anemic compared to 64% in the poorest [1]. IDA contributes to 20% of maternal deaths and a 28% higher incidence of low birth weight in infants born to anemic mothers [2]. Despite initiatives like Anemia Mukt Bharat (AMB) (2018–2023), which allocated ₹3,400 crore (~\$470 million) primarily for iron supplementation (75% of the budget), systemic gaps in addressing non-nutritional causes (e.g., malaria, hemoglobinopathies) hinder progress [3,4].

Pathophysiology of Iron Deficiency Anemia

IDA develops in three stages:



In India, key contributors include low dietary heme iron, hookworm infections (15–20% prevalence in rural areas), and chronic blood loss from gastrointestinal disorders [5].

Diagnosis

Clinical Features

Pediatric IDA often presents with subtle yet critical symptoms that impact growth and development. Key clinical signs include:

- **General Symptoms:**
 - **Fatigue & Irritability** – Children may appear less active or become easily tired.
 - **Pallor** – Visible in the conjunctiva, palms, and nail beds.
- **Neurodevelopmental Effects:**
 - **Cognitive Impairments** – Reduced attention span, delayed language skills.
 - **Behavioral Changes** – Increased restlessness, poor school performance.

Growth and Immunity:

- **Growth Delays** – Slower weight and height gain in infants/toddlers.
- **Frequent Infections** – Recurrent respiratory, GI, or skin infections due to weakened immunity.

Unusual or Severe Presentations:

- **Pica (Craving for Non-Food Items)** – Eating dirt, ice, or chalk.
- **Glossitis & Angular Cheilitis** – Swollen tongue, painful mouth sores.
- **Tachycardia or Systolic Murmur** – Seen in moderate-to-severe anemia.

Clinical Red Flags: If anemia persists despite iron therapy or presents with splenomegaly, persistent jaundice, or severe developmental delays, consider alternative diagnoses like thalassemia, lead poisoning, or chronic disease-related anemia.

Laboratory Investigations

- **Routine Tests:** CBC reveals microcytic hypochromic cells.
- **Iron Studies:** Confirmatory markers include serum ferritin, TIBC, and transferrin saturation [5].

Emerging Biomarkers:

- sTfR (>28.1 nmol/L) and hepcidin (<5 ng/mL) differentiate IDA from anemia of chronic disease [6].

AI-powered tools:

- Mobile apps like “Hb-Optimize” reduce diagnostic errors by 30% in rural Maharashtra [7].

Point-of-Care Testing

- HemoCue devices cut screening delays by 40% in high-burden states like Bihar [8].

Case-Based Learning: Diagnostic Challenges in Pediatric IDA

Pediatricians often encounter challenging anemia presentations where IDA mimics or coexists with other conditions. Below are two case studies illustrating the role of emerging biomarkers like hepcidin and sTfR.

Case 1: Atypical IDA vs. Anemia of Chronic Disease (ACD)

- **Patient:** 2-year-old boy with recurrent respiratory infections, pallor, and mild hepatomegaly.
- **Initial Lab Results:**
 - **Hb:** 9.0 g/dL, MCV: 72 fL (microcytic), Ferritin: 35 ng/mL (borderline normal).
 - **CRP:** Elevated (15 mg/L), suggesting inflammation.

Iron Deficiency Anemia Unlocked: Emerging Biomarkers, Precision Diagnosis, and Tailored Therapies

- **Differential Diagnosis:**
 - Iron Deficiency Anemia (IDA)? But ferritin is borderline normal.
 - Anemia of Chronic Disease (ACD)? Common in chronic infections.
- **Diagnostic Breakthrough:**
 - **Hepcidin:** <5 ng/mL → Confirms IDA (hepcidin is suppressed in IDA but elevated in ACD).
 - **sTfR:** Elevated (>28.1 nmol/L) → IDA confirmed.
- **Conclusion:** Despite normal ferritin, low hepcidin indicated iron deficiency, guiding appropriate iron therapy.

Case 2: IDA vs. Thalassemia Trait

- **Patient:** 4-year-old girl with pallor, mild splenomegaly, and no dietary iron deficiency risk.
- **Lab Findings:**
 - **Hb:** 8.5 g/dL, MCV: 62 fL, Ferritin: Low (8 ng/mL).
 - **RDW:** High (19%) → Suggestive of IDA.
- **Differential Diagnosis:**
 - IDA? Fits microcytic hypochromic anemia.
 - Thalassemia Trait? Also presents as microcytosis.
- **Key Differentiator:**
 - **Mentzer Index (MCV/RBC count):**
 - >13 in IDA ($72/4.8 = 15$)
 - <13 in thalassemia trait (e.g., $60/6.5 = 9.2$)
 - **Hb Electrophoresis:** Normal → Confirms IDA, excluding thalassemia trait.
- **Conclusion:** High RDW and Mentzer Index guided the pediatrician toward IDA over thalassemia trait, ensuring correct treatment.

Iron Dosing Guide for Pediatric Patients

Pediatricians need weight-based dosing for safe iron supplementation. Below is an age-specific dosage table:

Age Group	Oral Iron Dose (mg/kg/day)	IV Iron Criteria
<6 months	2 mg/kg/day	Not recommended
6–24 months	3 mg/kg/day	Hb <7 g/dL or severe malabsorption
2–5 years	2–3 mg/kg/day	Poor adherence to oral therapy
>5 years	2 mg/kg/day	Chronic inflammation cases

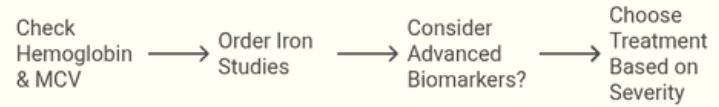
Oral iron options:

- Ferrous sulfate (cheapest, most effective).
- Ferric maltol (better tolerated, but expensive).

IV iron indications:

- Severe anemia with intolerance to oral therapy.
- Malabsorption (e.g., celiac disease).

Pediatric Anemia Workup



Step 1: Check Hemoglobin & MCV

- Microcytic anemia (MCV <80 fL)? → Continue workup.
- Normocytic anemia? → Consider hemolysis or ACD.

Step 2: Order Iron Studies (Ferritin, TIBC, Transferrin Saturation)

- Low ferritin (<12 ng/mL)? → Confirmed IDA.
- Normal ferritin but high TIBC (>400 µg/dL)? → Possible IDA.
- Normal ferritin with low TIBC? → Consider ACD.

Step 3: Consider Advanced Biomarkers

- Low hepcidin + high sTfR? → IDA confirmed.
- High hepcidin + normal sTfR? → Likely ACD.

Step 4: Choose Treatment Based on Severity

- Mild (Hb 9–11 g/dL)? → Oral iron therapy.
- Moderate (Hb 7–9 g/dL, poor oral adherence)? → Parenteral iron (IV).
- Severe (Hb <7 g/dL, symptomatic)? → Consider transfusion + IV iron

Recent Advances

Diagnosis

- Omics-based approaches: Proteomic profiling detects subclinical IDA with 92% accuracy [13].
- AI integration: Predictive algorithms identify high-risk populations using NFHS-5 data [7].

Treatment

- Hypoxia-inducible factor (HIF) stabilizers: Boost endogenous erythropoietin in chronic kidney disease patients [14].
- Liposomal iron: 90% bioavailability vs. 10–15% for ferrous sulfate [10].

Summary

Iron deficiency anemia (IDA) is a major health issue in India, affecting over half of women and children, with regional and socio-economic disparities. Despite initiatives like Anemia Mukt Bharat, non-nutritional causes remain overlooked. Diagnosis involves clinical signs, hematological tests, and biomarkers like hepcidin. Pediatric cases require differentiation from other anemias using tools like the Mentzer Index. Treatment includes oral iron, with IV options for severe cases.

For References Scan the QR code

