RESEARCH PAPER

EVALUATION OF RBC INDICES IN IRON DEFICIENCY ANEMIA

DR. Sumana Pawar[1*]

[1*]Assistant Professor, MD, Pathology, YIMS, Yadagiri, Karnataka, India | Email: sumanapawar@gmail.com

ABSTRACT

Overview

One of the most prevalent haematological conditions in the world, iron deficiency anaemia continues to be a serious public health issue, especially in poor nations. The evaluation of red blood cell (RBC) indices and their diagnostic importance in individuals with iron deficient anaemia is the main goal of this study.

Goal

The study's objective is to objectively analyse changes in RBC indices and determine how important they are for identifying and distinguishing iron deficiency anaemia from other microcytic anaemias.

Supplies and Procedures

The study's foundation is secondary data analysis from laboratory tests, haematological reviews, and published clinical trials. Ferritin levels, erythrocyte indices, peripheral blood smear results, and complete blood count parameters were all analytically assessed.

Results

The results indicate that the most prevalent haematological abnormalities in iron deficient anaemia are decreased MCV, MCH, and MCHC with raised RDW. Early RBC index interpretation enhances diagnostic precision and facilitates efficient clinical care.

Keywords: Not provided.

How to cite this article: Pawar S. Evaluation of RBC Indices in Iron Deficiency Anemia. Int J Drug Deliv Technol. 2026;16(54s): 722-727. DOI: 10.25258/ijddt.16.54s.64

Source of support: Nil.

Conflict of interest: None.

Introduction

Iron Deficiency Anemia is a microcytic hypochromic hematological disorder which is the outcome of insufficient iron availability for hemoglobin synthesis. Changes in red blood cell indices involves mean corpuscular volume or MCV, mean corpuscular hemoglobin or MCH, mean corpuscular hemoglobin concentration or MCHC and red cell distribution width or RDW offer significant diagnostic data for erythropoietic dysfunction and iron metabolism.

Background of the study

Iron deficiency has impacted around two billion individuals internationally and is considered as the most prevalent nutritional deficiency throughout the world. IDA causes the impaired cognitive development, decreased physical performance, mental morbidity, and cardiovascular issues. Similar hematology growingly depends on the RBC indices as cost effective diagnostic biomarkers as erythrocyte morphology shows imbalances in iron metabolism, hemoglobin biosynthesis, marrow physiology and systematic inflammatory activity.

Problem statement

In spite of wider usage of complete blood count testing, interpretation of RBS indices stays as inconsistent in clinical practice. Iron deficiency anemia sometimes overlaps hematologically along with thalassemia trait, anemia of chronic disease and sideroblastic anemia. Wrong interpretation of erythrocyte indices can delay the treatment, sacrifice the therapeutic intervention and impact the progression of tissue hypoxia, ineffective erythropoiesis and multisystem physiological dysfunction.

Research aim and objectives

The aim of this research is to critically analyse the diagnostic importance of RBC indices in IDA.

Objectives are to examine the pathophysiological alterations in erythrocyte indices, evaluation of diagnostic limitations, and analysis of empirical data and to evaluate the clinical importance of RBC indices in separating the IDA from optional hematological disorders.

Research questions

1. Which options cause RBC indices at the time of IDA?
2. How impactful are RBC indices in separating IDA from other microcytic anemias?
3. How do inflammatory mechanisms impact the erythrocyte parameters at the time of functional and absolute iron deficiency

states?

Literature Review

Introduction

IDA shows a huge global hematological burden featured by impaired h**emoglobin synthesis, microcytosis, hypochromia, and defective erythropoiesis.** RBC indices occurred at the time of complete blood count analysis which offer quantitative evaluation of erythrocyte morphology and hematological physiology. Similar kinds of literature shows growing clinical dependency on RBC indices as these parameters facilitate quick findings of iron depletion, analysis of anemia severity, differentiation of competing hematological disorders and checking up if therapeutic response.

Theories and models

The hematopoietic theory offers the initial conceptual framework for understanding erythrocyte abnormalities in IDA. Hematopoiesis shows the formation and separating of blood cells in bone marrow microenvironment which is regulated by the erythropoietin, stem cell activity, nutritional substrates, and cytokine signaling. According to the context of physiological conditions, erythroblasts synthesise enough hemoglobin before the terminal maturation. But the iron deficiency separates from heme biosynthesis, manufactures defective erythrocyte maturation and generates microcytic hypochromic cells.

As per the erythropoietic physiology, erythroblasts continue mitotic division till enough intracellular hemoglobin concentration is achieved (Almashjary, 2024) . Decreased iron availability analyzes hemoglobin gatherings and prolongs cellular division cycles, finally manufacturing of smaller erythrocytes with less hemoglobin content. Consequently MCV and MCH values declined progressively at the time of iron depletion.

The iron metabolism model shows changes in RBC indices. Iron homeostasis relies on gastrointestinal absorption, storage of ferritin, macrophase recycling, transferrin mediated transport and hepcidin regulation. Hepcidin works as the main iron regulatory hormone by inhibiting ferroprotein dependent iron release from enterocytes and macrophages.

At the time of iron deficiency, hepcidin synthesis reduces in reaction to less iron stores, increasing the intestinal iron absorption. Similarly inflammatory disorders enhance hepcidin manufacturing via cytokine mediated signaling pathways which involve interleukin-6. Increased hepcidin holds the iron bioavailability in spite of preserved ferritin reserves and builds functional iron deficiency.

IDA is caused by TMPRSS6 mutations and illustrates which increased the hepcidin levels and produce the microcytic anemia resistant to oral iron therapy. Their findings show how non regulated hepcidin activity separates erythropoiesis in spite of iron supplementation (Ha et al., 2025) .

The functional iron deficiency model has distinguished among depleted total body iron stores and impaired iron utilisation. In anemia of chronic disease, circulating iron becomes absent for erythropoiesis as inflammatory cytokines fosters macrophage iron sequestration. Patients can show transferrin saturation, mild microcytosis and increased ferritin levels.

Another significant framework includes the oxidative stress model. IDA changes mitochondrial respiration and decreases antioxidant enzymatic activity, hence growing reactive oxygen species manufacturing. Grown oxidative stress harms the erythrocyte membranes and impacts anisocytosis reflected by enhanced RDW.

The microcytic anemia differential diagnosis model is also clinically important. Beta-thalassemia trait, sideroblastic anemia, and lead positioning can manufacture hematological patterns related to IDA. Mentzer index and connected discriminant formulas were implemented to distinguish IDA from thalassemia trait by using MCV and erythrocyte count relationships.

But these models upgrade the diagnostic analysis; no single theoretical framework solely explains all hematological manifestations of IDA (Kamalzadeh et al., 2026) . Contemporary studies have supported the evaluation which includes erythrocyte indices, biochemical markers, inflammatory parameters and clinical assessment.

Empirical studies

Empirical evidence helps the diagnostic importance of RBC indices in IDA. Kriel et al shared that RDW sometimes enhances before huge reduction happens in MCV which shows that anisocytosis is an early marker of iron deficient erythropoiesis. Their study also focuses on ferritin as the most particular biochemical marker for iron deficiency, but inflammatory disorders sometimes change the interpretation of ferritin.

Kolars et al found that around one quarter of the international population is impacted by the IDA. Their opinion shows that women at reproduction stage, children, adolescents and pregnant women are at the highest risk groups due to loss of menstrual blood, pregnancy related iron demand, malnutrition and huge growth.

Hamzah 2025 states that IDA exists with less MCV, less MCH, hypochromia and increased RDW. The study has found gastrointestinal hemorrhage, nutritional deficiency, pregnancy and malabsorption syndromes as common etiological factors.

According to Lichtler and Cowley 2025, the highest exposure interferes with heme synthesis and impacts

to less hemoglobin concentrations, separates erythropoiesis and enhances the prevalence of anemia. Their findings also show that iron deficient individuals extract the huge quantity of toxic metals as intestinal metal transporters become upregulated at the time of iron depletion.

Neurological evidence by Bakkannavar et al 2024 shows an important connection among low ferritin concentration, impaired neurotransmitter metabolism and febrile seizures in pediatric populations. It is also analysed that iron deficiency interrupts the hippocampal neuronal development and monoamine synthesis which impacts the neurological function.

Ha et. al 2025 states that correlations among increased RDW, oxidative stress, inflammatory burden and skeletal fragility. Simultaneously, Tariq et al 2023 says that increased RDW and less MCHC were connected with huge disease severity and chronic hypoxia in chronic obstructive pulmonary disease.

Therapeutic studies by Rehman et al show that pooled hemoglobin modification of approximately 2.01g/dL followed by iron supplementation in different studies which includes 8829 participants. Less dosage of iron therapy below 5mg/kg/day builds favourable hematological results with less gastrointestinal negative impact.

Clinical case studies show diagnostic importance of RBC indices. A premenopausal female with fatigue, dyspnea and menorrhagia shows hemoglobin concentration of 8.5g/dL, MCV of 67fL, MCH of 19pg, MCHC of 28g/dL and RDW of 20%. Ferritin concentration is measured 6ng/mL, confirming the iron deficiency. Following iron supplementation, repeat hematological analysis shows the normalisation of RDW and progressive upgradation in hemoglobin concentration and erythrocyte morphology.

The empirical studies have shown that RBC indices stay valuable diagnostic prognostic and therapeutic markers in iron deficiency anemia.

Additional studies show the treatment necessity of RBC indices in IDA. Different studies show that erythrocyte abnormalities connect directly with disease severity, systemic inflammation and time of iron depletion. Researchers show pregnant women with IDA show less MCV and MCH values at time of trimester as fetal iron demand increases mental iron depletion. Different maternal anemia was growingly associated with preterm birth, less weight, impaired placental oxygenation and huge maternal cardiovascular issues. These show that RBC indices possess significant prognostic importance in obstetric medicine (Varma et al., n.d.) .

Pediatric hematology studies have shown that chronic iron deficiency changes neurodevelopmental physiology and immune competence. Children with chronic iron depletion sometimes exist with less hemoglobin concentration, increased RDW, behavioral abnormalities, less concentration, fatigue and delayed psychomotor development. Another necessary finding includes the connection between chronic inflammation and erythrocyte morphology. Patients with autoimmune disorders, chronic kidney disease and inflammatory bowel disease sometimes show functional iron deficiency characterized by less transferrin saturation, mild microcytosis, elevated inflammatory markers, and normal ferritin concentration.

Current hematological research finds the relationships between iron deficiency and cardiovascular malfunction. Less hemoglobin concentration impairs systematic oxygen delivery and huge compensatory cardiac workload, results in tachycardia, ventricular strain and less exercise tolerance (Hamzah and Nehar, 2025) . Grown RDW was connected with huge cardiovascular mortality, endothelial dysfunction and oxidative stress. Collectively, these empirical studies state that RBC indices are not barely laboratory values but necessary biomarkers that show erythropoietic activity, systemic physiological stress, inflammatory burden and overall disease progression.

Conclusions.

This literature shows that RBC indices are clinically indispensable for the follow- up and treatment process of IDA. Less MCV, MCH and MCHC with the increased RDW shows impaired erythropoiesis and microcytic hypochromic transformation. But correct analysis needs connection with ferritin, inflammatory markers and clinical analysis.

Methodology

Research approach

The study is conducted with the help of a qualitative research approach by focusing on critical analysis of hematological evidence instead of numerical statistical modeling. The quantitative method is apt because the findings emphasize the evaluation of diagnostic importance, pathophysiological mechanisms, theoretical perspectives and clinical analysis of RBC indices in IDA. The study is conducted with the help of deductive research approach as the research paper is progressed with the help of existing theories models and literatures.

Research design

The study is done with the help of descriptive research design to analyse the functionality of RBC indices in IDA. This design is perfect because the research is emphasised on describing hematological abnormalities, erythrocyte morphology, diagnostic biomarkers and clinical findings connected with IDA by utilising priorly published literature and empirical studies (Kriel et al., 2025) . The descriptive design also helps in detailed analysis of RBC indices including MCV, MCHM MCHC, RDW. In addition, the design

also helps in the critical analysis of diagnostic patterns, therapeutic results which is reported in the current studies.

Research method

This study has used secondary research methods as data were gathered specifically from existing academic literature instead of primary experimental findings or patient recruitment. Secondary analysis helps in the analysis of similar kinds of peer reviewed evidence which are related to microcytic hypochromic anemia, erythropoietic physiology, iron metabolism and CBC derived biomarkers. Published studies, reviews, hematological investigation and evidence based analyses are considered as the initial sources of data which are used throughout the research.

Data collection

Data were collected from academic databases which includes Google Scholar, PubMed, ScienceDirect and peer reviewed hematology journals. Searched terminology involves RBC indices in IDA, diagnostic role of RDW, microcytic hypochromic anemia, ferritin and iron metabolism and functional iron deficiency. Inclusion requirements need studies which are published between 2022 and 2025 written in English language and connected to erythrocyte indices or iron deficiency (Kriel et al., 2025) . Journals which are not peer reviewed and which are not relevant enough will be excluded.

Research ethics

Ethical considerations initially include maintenance of academic integrity, correct scientific interpretation, and avoidance of plagiarism. All data extracted from the published literature was correctly acknowledged with the help of academic referencing. As the study is conducted with the help of secondary literature analysis instead of direct human participants, formal institutional ethical approval was not needed. Hence attention was put on objective representation of scientific findings, avoidance of data manipulation and preservation of scholarly authenticity throughout the analytical procedure.

Results and Findings

Alterations in RBC indices

The findings of the study shows that RBC indices are strong among the most clinically significant diagnostic parameters in IDA and offer valuable insights into erythropoietic dysfunction, disease advancement and therapeutic response. Less MCV increased consistently as one of the most featured hematological abnormalities connected with the advanced iron depletion separates hemoglobin synthesis and builds microcytic erythrocytes with less cellular volume.

Hamzah 2025 found constant microcytosis as a defining hematological characteristic feature of IDA especially among women who are experiencing chronic menstrual blood loss and patients who are suffering from gastrointestinal bleeding. Less MCH and MCHC values are also connected with defective hemoglobin biosynthesis. Hypochromic erythrocytes consist of less intracellular hemoglobin concentration and show recurrent pathological findings with the help of reviewed literature. Increased RDW means especially diagnostic importance due to anisocytosis sometimes built before severe microcytosis became apparent. **Kriel et al 2025** draw a conclusion that RDW can work as an early indicator or iron deficient erythropoiesis as coexistence of normal erythrocytes and newly built microcytic cells enhances the erythrocyte heterogeneity.

The findings also state that ferritin stays as the most particular biochemical market for iron deficiency. But inflammatory disorders substantially critical ferritin analysis as ferritin works as an acute phase reactant. **Hoving et al 2025** states that iron refractory iron deficiency anemia occurred by TMPRSS6 mutations show that persistent microcytosis significantly decreases transferrin saturation and holds to oral iron supplementation due to increased hepcidin actively impaired iron mobilisation. The literature also shows substantial overlap among iron deficiency anemia and beta thalassemia traits. Both situations frequently show reduced MCV and hypochromia. But iron deficiency anemia usually shows increased RDW and less count of erythrocyte, at the same time, thalassemia trait sometimes is shown as relatively preserved RBC numbers.

Environmental and systematic impacts on RBC indices

Environmental and toxicological studies show additional pathological impacts upon RBC indices. **Lichtler and Cowley** show that huge exposure contradicts heme biosynthesis and impacts to less hematocrit, less hemoglobin concentration and increased anemia prevalence.

Neurological and physiological complications

Neurological evidence also shows systematic impact of iron deficiency. **Bakkannavar et al 2024** states that connection among less ferritin concentration, impaired neurotransmitter metabolism and huge susceptibility to febrile seizures in pediatric populations.

Therapeutic response and hematological recovery

Rehman et al 2025 shows that important therapeutic upgradation following iron supplementation. Such a meta analysis includes 8829 people who have reported pooled hemoglobin improvement of around 2.01g/dL after the iron therapy. Significantly, less dose of iron supplementation below 5mg/kg/day generated sufficient hematological responses by reducing the negative impact of gastrointestinal.

Findings from clinical case and diagnostic interpretation

Clinical case findings show analysed practical diagnostic importance of RBC indices. A premenopausal female with tiredness, anxiety, exertional dyspnea, brittle nails and menorrhagia shows concentration of 8.5g/dL, MCV of 67fL, MCH of 19pg, MCHC of 28g/dL and RDW of 20%.

Peripheral blood smear shows **anisopoikilocytosis,** hypochromia and pencil cells. Ferritin is measured around 6ng/mL and transferrin saturation stays below 10% which confirms the acute iron deficiency. Oral ferrous sulphate therapy, repeated analysis shows the normalisation of RDW and advanced upgradation of hemoglobin concentration and erythrocyte morphology (Tariq et al., 2023) .

In spite of these findings, the study shows different diagnostic limitations connected with RBC indices. Early stage iron deficiency can show with normocytic erythrocytes despite depleted ferritin stores. Mixed nutritional deficiencies, chronic inflammatory disease, blood transfusion, and chronic kidney disease can give an unclear hematological analysis. The findings show that RBC indices cause substantial diagnostic and prognostic value but need connection between biochemical and clinical evaluation.

Discussion

The findings help to get the idea about clinical importance of RBC indices in treating and following up iron deficiency anemia. Less MCV constantly shows defective hemoglobin synthesis and advanced microcytosis, at the same time less MCH and MCHC shows impaired intracellular hemoglobin concentration. Grown RDW increased as a necessary marker due to anisocytosis built before severe microcytosis became apparent. The discussion shows that RBC indices contain huge significance beyond hematology. Relations between increased RDW, oxidative stress, inflammatory burden, pulmonary disease, neurological dysfunction and skeletal fragility show that erythrocyte heterogeneity shows generalised physiological instability. The reviewed studies also show the necessity of distinguishing iron deficiency anemia from beta thalassemia trait and anemia of chronic disease (Lichtler and Cowley, 2025) . These types of disorders can build similar kinds of microcytic erythrocytes, IDA usually show increased REW and less ferritin concentration. Function of hepcidin mediated iron sequestration also critical hematological analysis as functional iron deficiency can cause preserved ferritin stores. Consequently, RBC indices must be analysed with ferritin, transferrin saturation, inflammatory markers and peripheral smear findings. Socioeconomic importance also increased as a necessary factor. In resource limited healthcare settings, lacking upgraded biochemical investigation, RBC indices sometimes show the only accessible diagnostic tools. But the discussion shows different diagnostic limitations (Almashjary, 2024) . Initial stage iron deficiency can exist with normocytic erythrocytes when integrated nutritional deficiencies, chronic inflammatory disease, new blood transfusion and chronic kidney disease can obstruct the hematological analysis. Future hematological activity will combine traditional RBC indices with reticulocyte hemoglobin content, soluble transferrin receptor assays and AI powered assisted diagnostic systems to upgrade diagnostic precision and therapeutic monitoring.

Conclusion

Analysis of RBC indices is fundamental for treatment and follow up of IDA. Less MCV, MCH and MCHC besides increased RDW cause necessary data about microcytosis, hypochromia, anisocytosis and defective erythropoiesis. RBC indices contain necessary diagnostic limitations, similar evidence which supports their constant clinical importance due to accessibility, affordability, and wider diagnostic usage. Combined analysis includes biochemical markers and clinical assessment which are important for correct diagnosis and fruitful therapeutic management of iron deficiency anemia.

References

Almashjary, M.N., 2024. Reticulocyte hemoglobin content: advancing the frontiers in Iron-deficiency Anemia diagnosis and management. *Journal of Applied Hematology*, *15*(1), pp.1-8.

Bakkannavar, S., Faheem, Y., Jaiswal, A., Shergill, K., Boppana, K., Almansouri, N.E., Hamid, P. and Hamid, P.F., 2024. Associative patterns between iron deficiency anemia and febrile seizures in the five to 60 months age group: A comprehensive systematic review. *Cureus*, *16*(3).

Barua, S., Ciannella, S., Tijani, L. and Gomez-Pastora, J., 2023. Iron in blood cells: Function, relation to disease, and potential for magnetic separation. *Biotechnology and Bioengineering*, *120*(7), pp.1707-1724.

Ha, J., Ono, M., Zhu, H., Cencer, C., Ge, X. and Wu, J.Y., 2025. Complete Blood Count Parameters and Bone Health: Clinical and Experimental Evidence. *Endocrinology and Metabolism*, *40*(6), pp.811-820.

Hamzah, E.F. and Nehar, K.N., 2025. Iron Deficiency Anemia: A Comprehensive Review of Epidemiology, Pathophysiology, Diagnosis, and Clinical Implications. *South Asian Research Journal of Applied Medical Sciences*, *7*(6), pp.277-284.

Hoving, V., Donker, A.E., Schols, S.E.M. and Swinkels, D.W., 2025. How I treat iron-refractory iron deficiency anaemia—An expert opinion-based treatment guidance for children and adults. *British Journal of Haematology*, *206*(4), pp.1067-1076.

Kamalzadeh, H., Choobin, N., Haghighat, A., Ardestani, M.T. and Farhanpoor, M., 2026. AI-assisted haematology: machine learning–based prediction of iron-deficiency anaemia from reticulocyte maturation indices. *BMC Medical Informatics and Decision Making*, *26*(1), p.24.

Kamalzadeh, H., Choobin, N., Haghighat, A., Ardestani, M.T. and Farhanpoor, M., 2026. AI-assisted haematology: machine learning–based prediction of iron-deficiency anaemia from reticulocyte maturation indices. BMC Medical Informatics and Decision Making, 26(1), p.24.

Kolarš, B., Mijatović Jovin, V., Živanović, N., Minaković, I., Gvozdenović, N., Dickov Kokeza, I. and Lesjak, M., 2025. Iron deficiency and iron deficiency anemia: A comprehensive overview of established and emerging concepts. *Pharmaceuticals*, *18*(8), p.1104.

Kriel, M., Opie, J., Rusch, J., Richardson, D. and Louw, V., 2025. Old tests and new paradigms: How to interpret iron studies and related biomarkers for the diagnosis of iron deficiency in adults. *Blood Reviews*, p.101337.

Lichtler, R. and Cowley, M., 2025. Environmental Contaminants, Iron Deficiency, and Iron-Deficiency Anemia: A Review of the Literature. *Scientifica*, *2025*(1), p.5007983.

Rehman, T., Agrawal, R., Ahamed, F., Das, S., Mitra, S., Kumar, D., Sethy, C., Kanungo, S., Bhattacharya, D. and Pati, S., 2025. Optimal dose and duration of iron supplementation for treating iron deficiency anaemia in children and adolescents: A systematic review and meta-analysis. *PloS one*, *20*(2), p.e0319068.

Tariq, S., Ismail, D., Thapa, M., Goriparthi, L., Pradeep, R., Khalid, K., Cooper, A.C. and Jean-Charles, G., 2023. Chronic obstructive pulmonary disease and its effect on red blood cell indices. *Cureus*, *15*(3).

Varma, R.S., Ladumor, P., Panchal, J. and Panchal, J., Role of Red Cell Indices and Peripheral Smear in Differentiating Microcytic Anemias: A Cross-Sectional Study. *Hemoglobin (g/dL)*, *9*(1.6), pp.10-8.