Cureus
Part of SPRINGER NATURE

Open Access Original Article

Assessment of Bone Marrow Iron Stores and Correlation of Bone Marrow Iron Grading With Biochemical Parameters in Various Types of Anemia With Special Reference to Serum Ferritin Levels: A Prospective Observational Study

Chhaya Shevra [1], Saumya Singh [1], Mandavi Agarwal [2], Zaki Siddiqui [2]

1. Pathology, Maharani Laxmi Bai Medical College, Jhansi, IND 2. Medicine, Maharani Laxmi Bai Medical College, Jhansi, IND

Corresponding author: Saumya Singh, saumyasinghgsvm@gmail.com

Review began 07/23/2026
Review ended 11/20/2026
Published 11/25/2026

© **Copyright** 2026
Shevra et al. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 4.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

DOI: 10.7759/cureus.120226

Abstract

Background: Anemia is a common hematological disorder and a major public health problem, especially in developing countries such as India. Iron deficiency is the most frequently encountered type of anemia. Iron status is commonly evaluated using biochemical parameters such as serum iron, serum ferritin, total iron-binding capacity (TIBC), and transferrin saturation. However, these parameters may be influenced by inflammation, infection, liver disease, and other chronic illnesses, which can make interpretation difficult. Bone marrow iron assessment using Perls' Prussian blue staining remains the gold standard method for assessing body iron stores.

Aims and objectives: This study aimed to assess bone marrow iron stores and to correlate bone marrow iron grading with biochemical parameters in patients with various types of anemia with special reference to serum ferritin.

Materials and methods: The present prospective observational study was conducted on 100 patients with anemia in the Department of Pathology in collaboration with the Department of Medicine at Maharani Laxmi Bai Medical College, Jhansi, India. Bone marrow aspiration was performed in all cases, and iron stores were graded according to Gale's grading system using Perls' Prussian blue stain. Biochemical parameters including serum iron, serum ferritin, TIBC, and transferrin saturation were estimated and correlated with bone marrow iron grading. Statistical analysis was done using Spearman's correlation coefficient and chi-squared test.

Results: Among the 100 patients studied, females constituted 56% of cases and males 44% of cases. The majority of patients belonged to the 11-20-year age group (27%). Microcytic hypochromic anemia was the most common type of anemia, seen in 39% of cases, followed by dimorphic anemia in 35% and megaloblastic anemia in 19%. Bone marrow examination revealed absent iron stores in all cases of microcytic hypochromic anemia, whereas megaloblastic and hemolytic anemia cases showed normal to increased marrow iron stores. Serum ferritin (ρ=0.696) showed a significant positive correlation with bone marrow iron grading. The correlations were statistically significant ($p<0.001$). Severe anemia was the most common presentation observed in the study population.

Conclusion: Bone marrow iron assessment shows significant correlation with biochemical parameters and provides a reliable evaluation of body iron stores. It is particularly useful in patients where biochemical parameters are inconclusive or affected by chronic inflammatory conditions. Combined assessment of bone marrow iron stores with biochemical markers helps in the accurate diagnosis and appropriate management of various types of anemia.

Categories: Hematology, Pathology, Internal Medicine
Keywords: anemia, bone marrow iron stores, perls prussian blue stain, serum ferritin, transferrin saturation

Introduction

Anemia is a common health problem with higher prevalence in developing countries due to poor nutrition, poverty, and limited healthcare facilities. It is not a disease but a symptom of deranged hemoglobin and oxygen-carrying capacity. Hence, even mild anemia should be properly evaluated [1].

The evaluation of anemia includes clinical assessment and basic investigations such as complete blood count, red cell indices, and peripheral smear examination. Iron status is frequently evaluated using biochemical measures such as serum iron, serum ferritin, total iron-binding capacity (TIBC), and transferrin saturation [2].

How to cite this article
Shevra C, Singh S, Agarwal M, et al. (November 25, 2026) Assessment of Bone Marrow Iron Stores and Correlation of Bone Marrow Iron Grading With Biochemical Parameters in Various Types of Anemia With Special Reference to Serum Ferritin Levels: A Prospective Observational Study. Cureus 18(11): e120226. DOI 10.7759/cureus.120226

Serum ferritin is one of the most reliable indicators of body iron stores under normal physiological conditions, whereas ferritin also functions as an acute-phase reactant, and its levels may rise in diseases including cancer, liver disease, inflammation, and infections [3].

When peripheral blood results and biochemical tests are insufficient to provide a definitive diagnosis, bone marrow examination is a crucial diagnostic process in the assessment of hematological illnesses. In anemia, it provides direct information about blood cell production, marrow cellularity, iron stores, and the presence of abnormal cells or dysplastic changes.

Bone marrow examination helps in assessing erythropoiesis, myelopoiesis, megakaryopoiesis, and iron storage in the reticuloendothelial system. Examination of marrow smears, along with special stains like Perls' Prussian blue, allows accurate evaluation of iron stores and helps in differentiating different types of anemia [4].

When normal tests, such as peripheral smears and biochemical markers, do not yield a definitive diagnosis for unexplained anemia, bone marrow aspiration is recommended [5].

The correlation between bone marrow iron stores and biochemical parameters is essential not only for diagnosing specific types of anemia but also for the accurate therapeutic management of anemia [6].

Materials And Methods

The present study is a prospective study and was conducted in the Department of Pathology and Medicine at Maharani Laxmi Bai Medical College, Jhansi, India, from January 2025 to April 2026. A total of 100 anemic patients were taken from both inpatients and outpatients of the Department of Medicine.

This hospital-based prospective observational study was conducted using a consecutive sampling technique. All patients fulfilling the predefined inclusion and exclusion criteria during the study period were assessed for eligibility. Eligible patients were enrolled consecutively until the predetermined sample size of 100 patients was achieved. Patients who did not meet the inclusion criteria or fulfilled any of the exclusion criteria were not enrolled in the study.

The sample size was calculated for correlation analysis assuming a moderate correlation coefficient (r=0.30), with a 95% confidence level and an 80% statistical power. The minimum required sample size was estimated to be 85 subjects. To improve the reliability of the study findings, a total of 100 patients were included in the study. Written informed consent was obtained from all participants, and the study was granted ethical approval by the Institute Ethics Committee (Human Studies) of Maharani Laxmi Bai Medical College (approval number: 7056/IEC/PG-23-32/2026/SC-1). Bone marrow aspiration was performed as part of the routine clinical evaluation of patients with anemia based on clinical indications. The procedure was not performed solely for research purposes. The bone marrow samples obtained during clinical evaluation were also used for the assessment of iron stores as part of this study.

The present study included anemic patients belonging to different age groups ranging from 2 to 66 years and of either sex. Both pediatric and adult patients were included because the aim of the study was to evaluate bone marrow iron stores and their correlation with biochemical parameters in various types of anemia. A total of 100 patients were enrolled during the study period, of which 18 were pediatric patients and 82 were adults. Patients with hematological malignancies, recent iron therapy, severe bleeding, and clotting disorders and those who declined consent were excluded from the study.

Peripheral blood samples were collected in ethylenediaminetetraacetic acid (EDTA) tubes for the analysis of hematological parameters, including hemoglobin, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). Serum samples were used for the analysis of biochemical parameters, including serum iron, serum ferritin, TIBC, and transferrin saturation. All biochemical parameters were done in a five-part analyzer using standardized laboratory kits.

Bone marrow aspiration was performed from the posterior superior iliac crest under aseptic precautions. The aspirated material was used to prepare bone marrow smears. Air-dried smears were fixed in methanol. The stain was prepared by mixing equal volumes of 2% potassium ferrocyanide and 2% hydrochloric acid, and the slides were stained for 20-30 minutes. After washing with distilled water, slides were counterstained with safranin, air-dried, and examined under light microscopy. Bone marrow iron stores were assessed according to Gale's grading system (Table *1*).

Grade	Description of iron staining
Grade 0	No iron granules seen
Grade 1	Small granules in reticulum cells, visible only under oil immersion
Grade 2	Few small granules visible under low-power objective
Grade 3	Numerous small granules present in all marrow particles
Grade 4	Large granules arranged in small clumps
Grade 5	Dense clumps of large iron granules
Grade 6	Very large iron deposits obscuring marrow cells

TABLE 1: Gale's grading system for the assessment of bone marrow iron stores

For analysis, grade 0 was considered decreased iron stores, grades 1-3 were considered normal iron stores, and grades 4-6 were considered increased iron stores. The bone marrow iron findings were then correlated with biochemical parameters in different types of anemia. Each bone marrow smear was examined by three pathologists. The final grading was based on microscopic assessment by the pathologists, with disagreements resolved through discussion and consensus.

For statistical analysis, the collected data were entered into Microsoft Excel (Microsoft Corporation, Redmond, Washington, United States) and analyzed. Continuous variables were expressed as mean±standard deviation, while categorical variables were expressed as frequency and percentage. Correlation between bone marrow iron stores and biochemical parameters was assessed using Spearman's rank correlation coefficient. A p-value of less than 0.05 was considered statistically significant.

Results

Table *2* shows the baseline demographic characteristics of the study population (N=100), including age distribution, sex, and residence status. The age of patients ranged from 2 to 66 years with a median age of 30 years. Most patients belonged to the 11-20-year age group (27%), followed by 31-40 years (24%) and 21-30 years (20%). Female patients were more common (56%) than males (44%). Fifty-four percent were from rural areas, while 46% were from urban areas. This denotes that anemia is more prevalent in rural areas due to low socioeconomic conditions and limited healthcare awareness.

Variable	Category	Frequency	Percentage
Age group (years)	1-10	4	4%
	11-20	27	27%
	21-30	20	20%
	31-40	24	24%
	41-50	13	13%
	51-60	9	9%
	61-70	3	3%
Residence	Rural	54	54%
	Urban	46	46%
Sex	Female	56	56%
	Male	44	44%
Median age	30 years	-	-

TABLE 2: Baseline demographic characteristics of the study population (N=100)

Table *3* shows the distribution of different types of anemia. In this study, microcytic hypochromic anemia was the most common morphological type, accounting for 39% of cases, and bone marrow aspiration findings showed erythroid hyperplasia with micronormoblastic maturation and decreased iron stores. Dimorphic anemia was seen in 35% of samples, in which bone marrow smear showed both micronormoblast and megaloblast maturation and that iron stores were decreased to normal (grades 0-3). In megaloblastic anemia (19%), the marrow showed hypercellular marrow with megaloblastic maturation and normal to increased iron grades (grades 2-5). In aplastic anemia (5%), the bone marrow cellularity was reduced and showed few mature lymphocytes and that iron stores were normal to increased (grades 2-4). Two cases were from hemolytic anemia which showed normoblastic maturation with increased iron stores. In one patient with thalassemia, the iron stores were markedly increased (grade 6) due to multiple transfusions. However, a total of 11 discordant cases were identified between serum ferritin levels and bone marrow iron grading. These included six cases with normal serum ferritin despite absent marrow iron stores, three cases with low serum ferritin despite normal marrow iron stores, and two cases with elevated serum ferritin despite absent marrow iron stores.

Types of anemia	No. of cases	Bone marrow aspiration findings	Iron grade
Microcytic hypochromic anemia	39	Erythroid hyperplasia with predominantly micronormoblastic maturation	0
Dimorphic anemia	35	Erythroid hyperplasia with micronormoblastic and megaloblastic maturation	0-3
Megaloblastic anemia	19	Hypercellular marrow, erythroid hyperplasia with megaloblastic changes along with features of dyserythropoiesis	2-5
Aplastic anemia	5	Hypocellular marrow; a few number of lymphocytes are seen	2-4
Hemolytic anemia (1 case of thalassemia)	2	Normoblastic erythropoiesis	4-6

TABLE 3: Distribution of different types of anemia with bone marrow aspiration findings and iron store grading

Bone marrow aspirate findings and Perls' Prussian blue staining patterns demonstrating different grades of bone marrow iron stores are shown in Figure *1*.

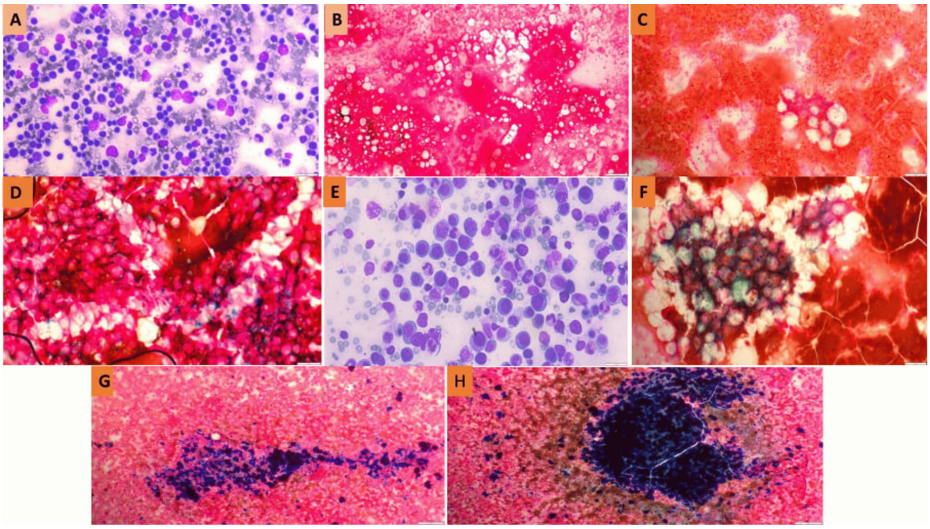

FIGURE 1: (A) Microcytic hypochromic anemia (MGG stain, ×40). (B) Grade 0 (Perls' stain, ×10). (C) Grade 2 (Perls' stain, ×10). (D) Grade 3 (Perls' stain, ×10). (E) Megaloblastic anemia (MGG stain, ×20). (F) Grade 4 (Perls' stain, ×10). (G) Grade 5 (Perls' stain, ×10). (H) Grade 6 (Perls' stain, ×10)

MCG: May-Grünwald-Giemsa

Table *4* shows that serum ferritin levels correlated with bone marrow iron stores in different types of anemia. Microcytic hypochromic anemia was the most common type (39%). Serum ferritin levels ranged from decreased to increased, and iron stores were absent (grade 0) in all cases except for one patient who showed a very high ferritin level (1330 ng/mL) despite absent marrow iron stores due to underlying inflammation. In dimorphic anemia (35%), serum ferritin values ranged from normal to increased, and iron stores were reduced to normal (grades 0-3) except for one patient who had a high ferritin value (307 ng/mL) despite grade 0 marrow iron stores due to chronic kidney disease. In megaloblastic anemia (19%), serum ferritin values ranged from normal to increased, and iron stores were normal to increased (grades 2-5) except for one male patient who showed an exceptionally high serum ferritin value (2356.9 ng/mL) due to underlying infection or inflammation. In aplastic anemia (5%), the bone marrow showed a hypocellular marrow; however, serum ferritin levels were normal to increased, and iron stores were normal to increased (grades 2-4). In hemolytic anemia, serum ferritin values ranged from normal to increased, and iron stores were increased (grades 4-6).

Serum ferritin (ng/mL)	Sex	Normal iron grade (1-3)	High iron grade (4-6)	Low iron grade (0)
Normal	Female (15-200)	15	2	6
	Male (15-300)	13	5	0
High	Female (>200)	6	1	2
	Male (>300)	9	4	0
Low	Female (<15)	3	0	21
	Male (<15)	0	0	13

TABLE 4: Comparison between serum ferritin levels and bone marrow iron grading

Table *5* shows the correlation between bone marrow iron stores and serum ferritin. A positive correlation was observed between serum ferritin and bone marrow iron grading with Spearman's correlation coefficient (ρ=0.696), which was statistically significant ($p<0.001$). However, a discrepancy between ferritin levels and actual marrow iron reserve was observed in 11 patients.

Biochemical marker	Spearman's rho (ρ)	P-value	Direction	Significance
Serum ferritin	0.696	<0.001*	Positive	Significant

TABLE 5: Correlation between bone marrow iron grade (Perls' grade) and serum ferritin

*Statistically significant (p<0.05)

Table *6* shows the correlation between bone marrow iron stores and serum iron. A positive correlation was observed between serum iron and bone marrow iron grading with Spearman's correlation coefficient (ρ=0.6985), which was statistically significant (p<0.001).

Biochemical marker	Spearman's rho (ρ)	P-value	Direction	Significance
Serum iron	0.6985	<0.001*	Positive	Significant

TABLE 6: Correlation between bone marrow iron grade (Perls' grade) and serum iron

*Statistically significant (p<0.05)

Table *7* shows the correlation between bone marrow iron stores and TIBC. A statistically significant negative correlation was observed between bone marrow iron grading and TIBC values (ρ=-0.5625; p<0.001).

Biochemical marker	Spearman's rho (ρ)	P-value	Direction	Significance
Total iron-binding capacity	-0.5625	<0.001*	Negative	Significant

TABLE 7: Correlation between bone marrow iron grade (Perls' grade) and total iron-binding capacity

*Statistically significant (p<0.05)

Table *8* shows the correlation between bone marrow iron stores and transferrin saturation. A positive correlation was observed between transferrin saturation and bone marrow iron grading with Spearman's correlation coefficient (ρ=0.638), which was statistically significant (p<0.001).

Biochemical marker	Spearman's rho (ρ)	P-value	Direction	Significance
Transferrin saturation	0.638	<0.001*	Positive	Significant

TABLE 8: Correlation between bone marrow iron grade (Perls' grade) and transferrin saturation

*Statistically significant (p<0.05)

Discussion

In the present study, patients belonged to an age range of 2-66 years with a median age of 30 years. The highest number of patients was observed in the 11-20-year age group (27%), followed by 31-40 years (24%) and 21-30 years (20%). The higher frequency of anemia in younger age groups is related to increased nutritional requirements, growth, menstrual blood loss, and reproductive demand, similar to the findings of Patel et al. [7]. The majority of patients were from rural areas (54%), while 46% belonged to the urban population. Higher prevalence of anemia in rural patients may be due to poor socioeconomic status, inadequate nutritional intake, chronic infections, poor sanitation, lack of awareness regarding a balanced diet and iron supplementation, and limited healthcare access. Similar findings were reported by Let et al.,

who also observed a higher prevalence of anemia in rural areas of India [8]. Fifty-six percent of patients were female, and 44% were male, showing a slightly higher number of anemia cases among females. Similar findings were observed by Gupta et al., who also reported a higher proportion of female patients in their studies [9]. The findings suggest that females formed a larger proportion of anemic patients.

In this study, microcytic hypochromic anemia (39%) was the most common type of anemia, followed by dimorphic anemia (35%), megaloblastic anemia (19%), aplastic anemia (5%), and hemolytic anemia (2%). A similar finding was also observed by Patel et al., who also reported microcytic hypochromic anemia as the most common anemia type in their study [7]. The findings of the present study were comparable to their study and indicate that microcytic anemia continues to represent an important cause of anemia.

In microcytic hypochromic anemia, the bone marrow showed erythroid hyperplasia with micronormoblastic maturation, and all patients had absent marrow iron stores (grade 0). Pujara et al. also reported similar findings [10]. In dimorphic anemia, the bone marrow showed both micronormoblast and megaloblast maturation. Marrow iron stores ranged from grade 0 to grade 3, but most patients had grade 1 and grade 2 iron stores, suggesting that iron stores were normal in the majority of cases. Only one patient had grade 0 marrow iron because of low serum ferritin (7 ng/mL), suggesting associated iron deficiency. Saxena et al. also reported similar findings [11]. In megaloblastic anemia, the marrow showed erythroid hyperplasia with megaloblastic changes and dyserythropoiesis, with iron stores from normal to increased (grades 2-5). Saxena et al. also observed the same findings [11].

In our study, there were five patients with aplastic anemia. The bone marrow was hypocellular, showing only lymphocytes and plasma cells, whereas iron stores remained grades 2-4. Deka et al. also reported hypocellular bone marrow in patients with aplastic anemia [12]. Also, there were two cases of hemolytic anemia including thalassemia. The bone marrow showed normoblastic erythropoiesis with increased marrow iron stores. The patient with thalassemia had grade 6 marrow iron, indicating increased iron accumulation.

In the present study, serum ferritin showed an overall positive correlation with bone marrow iron grading across different types of anemia. In microcytic hypochromic anemia, most patients had grade 0 marrow iron stores. However, six discordant cases were identified in which serum ferritin remained normal or markedly elevated despite absent marrow iron stores. Similar observations were reported by Guyatt et al., who suggested that serum ferritin may not always accurately reflect iron status because it can be influenced by factors other than iron deficiency [13]. In dimorphic anemia, most patients showed grade 1-3 marrow iron stores. However, five discordant cases were observed including patients with elevated ferritin despite depleted marrow iron and patients with low ferritin despite normal marrow iron stores. Similar findings were reported by Bableshwar et al., who noted that mixed nutritional deficiencies and altered iron metabolism can affect the relationship between serum ferritin and actual marrow iron stores [14].

In megaloblastic anemia, aplastic anemia, and hemolytic anemia, serum ferritin generally showed better correlation with marrow iron grading and was commonly associated with normal to increased iron stores. Similar observations have been described by Birare et al., who reported that ineffective erythropoiesis, reduced iron utilization, and increased iron turnover may contribute to higher ferritin levels in these anemia subtypes [1]. Pujara et al. also noted that ferritin values may not always represent actual marrow iron stores in every patient [10]. The findings of the present study suggest that serum ferritin alone may occasionally give an incomplete assessment of iron status. In patients where clinical features and laboratory findings do not fit together, bone marrow iron grading may provide a better understanding of actual body iron stores and support more accurate evaluation of anemia.

In the current study, serum ferritin showed a significant positive correlation with bone marrow iron grading (ρ=0.696; $p<0.001$). Similar positive correlations were observed with serum iron (ρ=0.699; $p<0.001$) and transferrin saturation (ρ=0.638; $p<0.001$), while TIBC showed a significant negative correlation (ρ=-0.563; $p<0.001$). These findings suggest that biochemical parameters generally reflect bone marrow iron stores. A comparable observation was reported by V et al., who also found a strong positive correlation between serum ferritin and bone marrow iron stores (ρ=0.83; $p<0.01$) and concluded that serum ferritin levels tend to increase with increasing marrow iron stores [15].

The present study has some limitations. Bone marrow aspiration is an invasive procedure and may cause pain and discomfort to the patient. Although complications are uncommon, there is a small risk of bleeding and infection. The procedure also involves additional cost and requires trained personnel and laboratory facilities. Another limitation is the subjective nature of Gale's grading system, which may lead to variation in assessment by different pathologists. Despite these limitations, bone marrow iron assessment remains useful, particularly in patients showing discrepancies between biochemical parameters and bone marrow findings.

Overall, the present study shows that biochemical parameters alone are not always sufficient for the accurate assessment of iron stores because they may be affected by inflammatory conditions, infections, nutritional status, liver disorders, and recent therapy. Bone marrow iron grading provides direct assessment of marrow iron stores and remains an important diagnostic tool, especially in patients with discrepant biochemical

findings. Combined evaluation of hematological parameters, biochemical profile, and bone marrow iron grading improves diagnostic accuracy in patients with various types of anemia.

Conclusions

This study highlights the importance of correlating serum ferritin and other biochemical parameters with bone marrow iron stores in the evaluation of various types of anemia. Although serum ferritin is a useful marker of iron stores, its levels may be influenced by inflammation, infection, and liver disorders, which can lead to discrepancies between biochemical findings and bone marrow iron grading. Bone marrow iron assessment using Perls' Prussian blue staining provides direct evidence of iron stores and remains valuable, particularly in cases with discordant biochemical findings. Therefore, combined assessment of biochemical parameters and bone marrow iron stores may improve the evaluation of iron status in patients with anemia.

Microcytic hypochromic anemia was the most common type of anemia and was mainly associated with reduced marrow iron stores along with biochemical features suggestive of iron deficiency. On the other hand, patients with dimorphic, megaloblastic, aplastic, and hemolytic anemia generally had normal to increased marrow iron stores.

The study also demonstrated that hematological and biochemical parameters vary across different anemia groups and can help in understanding the underlying pattern of anemia. Serum ferritin, serum iron, and transferrin saturation showed significant positive correlations with bone marrow iron grading, whereas TIBC showed a significant negative correlation. These findings suggest that biochemical parameters are useful indicators of iron status and marrow iron stores.

However, some patients showed differences between biochemical parameters and actual marrow iron stores, indicating that biochemical findings may not always represent the true iron stores of the body.

Therefore, bone marrow iron grading continues to remain an important method for direct assessment of iron stores, especially in patients where clinical findings and biochemical parameters do not match. Combined interpretation of hematological findings, biochemical profile, and bone marrow iron assessment may lead to more accurate diagnosis and better management of patients with anemia.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Saumya Singh, Chhaya Shevra, Mandavi Agarwal, Zaki Siddiqui

Acquisition, analysis, or interpretation of data: Saumya Singh, Chhaya Shevra, Mandavi Agarwal, Zaki Siddiqui

Drafting of the manuscript: Saumya Singh, Chhaya Shevra, Mandavi Agarwal, Zaki Siddiqui

Critical review of the manuscript for important intellectual content: Saumya Singh, Chhaya Shevra, Mandavi Agarwal, Zaki Siddiqui

Supervision: Saumya Singh, Chhaya Shevra, Mandavi Agarwal, Zaki Siddiqui

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Institute Ethics Committee (Human Studies) of Maharani Laxmi Bai Medical College issued approval 7056/IEC/PG-23-32/2026/SC-1. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Acknowledgements

The authors sincerely thank Dr. Meher Bano, Department of Social and Preventive Medicine, for helping with statistical analysis and also Mr. Prakash Kesarwani and Mr. Sintoo Yadav for the technical support.

References

1. Birare SD, Jain N, Abhange RS: A study of hematological indices and bone marrow morphology in patients presenting with anemia. Indian J Pathol Oncol. 2019, 6:266-74. 10.18231/j.ijpo.2019.052
2. Kumar V, Abbas AK, Aster JC: Robbins and Cotran Pathologic Basis of Disease . 10th (ed): Elsevier, Philadelphia (PA); 2020.
3. Ganz T, Nemeth E: Iron homeostasis in host defence and inflammation . Nat Rev Immunol. 2015, 15:500-10. 10.1038/nri3863
4. Bain BJ, Clark DM, Wilkins BS: Bone Marrow Pathology. Wiley-Blackwell, Hoboken (NJ); 2019.
5. Weiss G, Ganz T, Goodnough LT: Anemia of inflammation. Blood. 2019, 133:40-50. 10.1182/blood-2018-06-856500
6. Waters HM, Seal LH: A systematic approach to the assessment of erythropoiesis . Clin Lab Haematol. 2001, 23:271-83. 10.1046/j.1365-2257.2001.00406.x
7. Patel K, Hathila RN, Patel PR: A study of iron store in bone marrow and its correlation in various anemia . IP J Diagn Pathol Oncol. 2022, 7:18-21. 10.18231/j.jdpo.2022.004
8. Let S, Tiwari S, Singh A, Chakrabarty M: Prevalence and determinants of anaemia among women of reproductive age in Aspirational Districts of India: an analysis of NFHS 4 and NFHS 5 data. BMC Public Health. 2024, 24:437. 10.1186/s12889-024-17789-3
9. Gupta I, Kour B, Jandial R, Bhardwaj S: Assessment of bone marrow iron stores using Gale's grading and its correlation with iron deficiency anemia. J Med Sci. 2022, 42:160-5. 10.4103/jmedsci.jmedsci_420_20
10. Pujara K, Bhalara R, Dhruva G: A study of bone marrow iron storage in hematological disorder . Int J Health Allied Sci. 2014, 3:221-4.
11. Saxena R, Mahajan S, Pati HP, Choudhry VP: Bone marrow examination in megaloblastic and dimorphic anemia. Indian J Hematol Blood Transfus. 2001, 7-10.
12. Deka RR, Saikia DK, Kakati S, Das BK: Importance of Perls' stain as a routine test in anaemia in adults . Ann Pathol Lab Med. 2017, 4:A342-8. 10.21276/APALM.1067
13. Guyatt GH, Oxman AD, Ali M, Willan A, McIlroy W, Patterson C: Laboratory diagnosis of iron-deficiency anemia: an overview. J Gen Intern Med. 1992, 7:145-53. 10.1007/BF02598003
14. Bableshwar RS, Roy M, Bali A, Patil PV, Inumella S: Intensive method of assessment and classification of the bone marrow iron status: a study of 80 patients. Indian J Pathol Microbiol. 2013, 56:16-9. 10.4103/0377-4929.116142
15. V AK, Rao PS, Adappa S, Balanthimogru P, Mahabala C: Correlation between serum ferritin and bone marrow iron stores. Trop Doct. 2017, 47:217-21. 10.1177/0049475516678478