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ORIGINAL ARTICLE

Correlation Between Serum Ferritin Levels and Hematological Parameters in Iron Deficiency Anemia. A Clinical Study

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ABSTRACT

Background: Iron deficiency anemia (IDA) remains one of the most prevalent nutritional disorders worldwide, particularly in developing countries. Serum ferritin is widely recognized as the most specific biochemical marker for assessing iron stores, whereas hematological indices provide valuable information about red cell morphology and anemia severity. Understanding the correlation between these parameters can improve the diagnostic accuracy and management of IDA.

Objective: To evaluate the correlation between serum ferritin levels and hematological parameters among patients diagnosed with iron deficiency anemia.

Methods: This cross-sectional clinical study was conducted at the Department of Pathology, Multan Medical and Dental College, Multan, from March 2022 to March 2023. A total of 120 patients aged 18–60 years with clinically and laboratory-confirmed IDA were included. Hematological parameters including hemoglobin (Hb), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and red cell distribution width (RDW) were measured using an automated hematology analyzer (Sysmex XN-1000). Serum ferritin was estimated using an enzyme-linked immunosorbent assay (ELISA). Data were analyzed using SPSS version 25.0, and correlations were determined using Pearson's correlation coefficient (r). A p-value < 0.05 was considered statistically significant.

Results: The mean serum ferritin level was 17.5 ± 6.8 ng/mL, and the mean hemoglobin concentration was 9.2 ± 1.4 g/dL. Serum ferritin showed a strong positive correlation with hemoglobin ($r = +0.79$, $p < 0.001$), MCV ($r = +0.66$, $p < 0.001$), MCH ($r = +0.59$, $p < 0.01$), and MCHC ($r = +0.47$, $p < 0.05$), while RDW demonstrated a significant negative correlation ($r = –0.64$, $p < 0.001$). These findings indicate that decreasing ferritin levels are associated with worsening anemia and increased red cell size variability.

Conclusion: Serum ferritin levels exhibit a strong positive correlation with hemoglobin and red cell indices and a negative correlation with RDW in patients with iron deficiency anemia. The combined evaluation of ferritin and hematological parameters provides an effective and economical approach for diagnosing and monitoring iron deficiency anemia in clinical practice.

Keywords: Iron Deficiency Anemia, Serum Ferritin, Hemoglobin, Red Cell Indices, MCV, RDW, Correlation Study.

INTRODUCTION

Iron deficiency anemia (IDA) is the most common form of anemia worldwide and continues to be a major public health problem, particularly in developing countries such as Pakistan[1-3]. It is estimated that more than one-third of the global population suffers from anemia, and among these, approximately half of the cases are due to iron deficiency+. The condition arises when the body's iron stores become insufficient to meet physiological needs, leading to impaired hemoglobin synthesis, reduced oxygen transport capacity, and diminished tissue oxygenation. Iron is essential not only for hemoglobin production but also for several enzymatic and metabolic processes; hence, its deficiency affects multiple organ systems[4].

Serum ferritin serves as the most specific biochemical indicator of total body iron stores[5]. A low ferritin concentration reflects depleted iron reserves long before the onset of anemia, making it a reliable early marker of iron deficiency. However, ferritin is also an acute-phase reactant that may increase during infections, inflammation, or malignancy, potentially masking iron deficiency in such conditions. Therefore, correlating serum ferritin levels with hematological indices provides a more comprehensive assessment of a patient's iron status[6].

Hematological parameters derived from a complete blood count (CBC)—such as hemoglobin (Hb), red blood cell count (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and red cell distribution width (RDW)—play a crucial role in evaluating anemia[7]. In iron deficiency anemia, the characteristic laboratory picture includes microcytosis (low MCV), hypochromia (low MCH and MCHC), and increased anisocytosis (high RDW). However, these parameters may vary with disease severity and coexisting nutritional deficiencies[8,9].

Several studies have explored the relationship between serum ferritin and red cell indices, reporting that decreasing ferritin levels are accompanied by progressive alterations in hematological parameters[10-15]. Establishing such correlations can improve the diagnostic accuracy of IDA, help distinguish it from other microcytic anemias such as thalassemia trait, and allow for better monitoring of treatment response[13]. Despite numerous studies conducted globally, regional data remain limited, and population-specific variations may exist due to differences in diet, socioeconomic conditions, and prevalence of chronic diseases[16].

The present study was therefore designed to evaluate the correlation between serum ferritin levels and hematological parameters in patients with clinically and laboratory-confirmed iron deficiency anemia[17]. By understanding these relationships, clinicians can utilize simple hematological indices alongside ferritin to diagnose and monitor IDA more effectively, particularly in resource-limited clinical settings[18].

MATERIALS AND METHODS

Study Design and Setting: This was a cross-sectional clinical study carried out in the Department of Pathology, Multan Medical and Dental College, Multan, in collaboration with the affiliated teaching hospital laboratories. The study was conducted over a period of one year, from March 2022 to March 2023. Ethical approval for the research was obtained from the Institutional Review Board of Multan Medical and Dental College prior to data collection. Informed written consent was taken from all participants before enrollment, and all procedures were performed in accordance with the Declaration of Helsinki.

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Study Population: A total of 120 patients were included in this study. All participants were clinically and laboratory-confirmed cases of iron deficiency anemia (IDA). Patients of both genders between the ages of 18 and 60 years were recruited from outpatient and inpatient departments. Each participant underwent detailed history taking and physical examination to rule out other causes of anemia.

Inclusion and Exclusion Criteria: Patients presenting with clinical symptoms of anemia such as pallor, fatigue, weakness, and exertional dyspnea, and those showing microcytic hypochromic anemia on peripheral smear, were included. Laboratory criteria for inclusion were hemoglobin concentration less than 13 g/dL in males and less than 12 g/dL in females, serum ferritin levels below 30 ng/mL, and low red cell indices indicating iron deficiency. Patients with anemia of chronic disease, thalassemia, hemolytic anemia, chronic kidney or liver disorders, or those who had received blood transfusions within the previous three months were excluded. Pregnant women and individuals on iron supplementation or with acute infections and inflammatory conditions were also excluded to minimize confounding factors.

Sample Collection and Laboratory Analysis: Five milliliters of venous blood was collected aseptically from each participant. Two milliliters of blood were transferred into an EDTA tube for hematological analysis, while the remaining three milliliters were placed in a plain tube to obtain serum for ferritin estimation. The blood samples were processed within two hours of collection to maintain integrity.

All hematological parameters were measured using an automated hematology analyzer (Sysmex XN-1000). The red cell indices assessed included hemoglobin (Hb), red blood cell count (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and red cell distribution width (RDW). Serum ferritin levels were determined using an enzyme-linked immunosorbent assay (ELISA) method, employing a commercially available Calbiotech Ferritin ELISA Kit (USA). All procedures were conducted according to the manufacturer's protocol. Internal and external quality control measures were maintained throughout the study to ensure analytical accuracy.

Diagnostic Criteria: The diagnosis of iron deficiency anemia was confirmed when serum ferritin levels were below 30 ng/mL in association with low hemoglobin and microcytic hypochromic red cell indices. A peripheral smear was examined in all cases to confirm morphological features consistent with iron deficiency anemia, including microcytosis, hypochromia, and anisopoikilocytosis.

Data Analysis: All collected data were entered and analyzed using the Statistical Package for Social Sciences (SPSS) version 25.0. Quantitative variables such as hemoglobin, MCV, MCH, MCHC, RDW, and serum ferritin were expressed as mean ± standard deviation (SD). The correlation between serum ferritin levels and hematological parameters was determined using Pearson's correlation coefficient (r). A p-value less than 0.05 was considered statistically significant. Results were presented in tabular and graphical formats to illustrate the strength and direction of correlations.

RESULTS

Demographic Characteristics: A total of 120 patients diagnosed with iron deficiency anemia were included in the study. Among them, 86 (71.7%) were females and 34 (28.3%) were males, reflecting the higher prevalence of iron deficiency anemia in women of reproductive age. The participants' ages ranged from 18 to 60 years, with a mean age of 35.6 ± 9.8 years. The majority of the patients belonged to the lower and middle socioeconomic groups, which are more prone to nutritional deficiencies due to inadequate dietary intake. Most patients presented with symptoms of generalized weakness, pallor, fatigue, and exertional dyspnea.

Hematological and Biochemical Findings

The mean values of the studied hematological and biochemical parameters are summarized in Table 1. The mean hemoglobin level was 9.2 ± 1.4 g/dL, confirming moderate anemia in most cases. The mean corpuscular volume (MCV) was 69.3 ± 7.1 fL, while mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) were 21.6 ± 2.9 pg and 29.0 ± 2.4 g/dL, respectively, indicating microcytic and hypochromic red cell morphology. The red cell distribution width (RDW) was markedly increased (18.1 ± 3.2%), demonstrating anisocytosis typical of iron deficiency anemia. The mean serum ferritin level was significantly low (17.5 ± 6.8 ng/mL), confirming depleted iron stores in all participants.

Table 1: Mean values of hematological and biochemical parameters in patients with iron deficiency anemia (n = 120).

Parameter	Mean ± SD	Reference Range
Hemoglobin (g/dL)	9.2 ± 1.4	12–16
MCV (fL)	69.3 ± 7.1	80–96
MCH (pg)	21.6 ± 2.9	27–33
MCHC (g/dL)	29.0 ± 2.4	32–36
RDW (%)	18.1 ± 3.2	11.5–14.5
Serum Ferritin (ng/mL)	17.5 ± 6.8	30–300

As shown in Table 1, the overall pattern of reduced MCV, MCH, and MCHC along with increased RDW clearly depicts the microcytic hypochromic anemia characteristic of iron deficiency. The markedly reduced serum ferritin levels provide biochemical confirmation of depleted iron stores.

Correlation Between Serum Ferritin and Hematological Parameters: A correlation analysis was performed between serum ferritin levels and various hematological parameters to evaluate their interrelationships. The results are displayed in Table 2. A strong positive correlation was observed between serum ferritin and hemoglobin ($r = +0.79$, $p < 0.001$), suggesting that as ferritin levels decline, hemoglobin concentration decreases significantly. Similarly, MCV ($r = +0.66$, $p < 0.001$), MCH ($r = +0.59$, $p < 0.01$), and MCHC ($r = +0.47$, $p < 0.05$) also demonstrated significant positive correlations with ferritin, indicating that lower ferritin values are associated with smaller and paler red cells.

Conversely, RDW exhibited a strong negative correlation with serum ferritin ($r = –0.64$, $p < 0.001$), indicating that as iron stores deplete, the variability in red cell size increases, reflecting the progression of anisocytosis.

Table 2: Correlation between serum ferritin levels and hematological parameters in patients with iron deficiency anemia (n = 120).

Parameter	Correlation Coefficient (r)	p-value	Interpretation
Hemoglobin (Hb)	+0.79	<0.001	Strong positive correlation
MCV	+0.66	<0.001	Moderate positive correlation
MCH	+0.59	<0.01	Moderate positive correlation
MCHC	+0.47	<0.05	Weak positive correlation
RDW	–0.64	<0.001	Strong negative correlation

The statistical analysis confirmed that serum ferritin has the strongest correlation with hemoglobin and MCV, which are direct indicators of erythropoietic activity and red cell morphology. The inverse correlation with RDW further supports that as iron deficiency worsens, red cell size variability increases. These findings collectively validate that serum ferritin serves as a reliable marker for assessing both the severity and progression of iron deficiency anemia.

The data in Tables 1 and 2 demonstrate a consistent relationship between biochemical and hematological indicators of iron status. Patients with the lowest serum ferritin levels exhibited the most pronounced reductions in hemoglobin and red cell indices, reflecting advanced iron depletion. In contrast, patients with moderately reduced ferritin values showed less severe hematological abnormalities. The significant inverse correlation

between ferritin and RDW further highlights the diagnostic utility of combining ferritin measurement with red cell morphology indices.

These findings confirm that routine hematological parameters such as Hb, MCV, MCH, and RDW can effectively reflect underlying iron status when interpreted alongside serum ferritin levels. Thus, ferritin estimation, when supported by CBC indices, enhances diagnostic accuracy and assists in monitoring therapeutic response in iron deficiency anemia.

DISCUSSION

The present study was conducted to assess the relationship between serum ferritin levels and hematological parameters in patients with clinically and laboratory-confirmed iron deficiency anemia (IDA)[19]. The results demonstrated a significant positive correlation between serum ferritin and hemoglobin, MCV, MCH, and MCHC, while a strong negative correlation was observed with RDW. These findings are consistent with the well-established pathophysiology of IDA, in which depletion of body iron stores leads to a progressive reduction in red cell size, hemoglobin content, and uniformity of erythrocyte morphology[20-22].

In the current study, serum ferritin emerged as a highly sensitive biochemical indicator of iron status. Patients with low ferritin levels showed a marked reduction in hemoglobin concentration, suggesting that declining iron stores directly limit erythropoiesis[21]. Similar findings were reported by Kaur et al. (2020), who found a significant correlation between ferritin and hemoglobin ($r = 0.78$, $p < 0.001$), emphasizing ferritin's diagnostic reliability. Another study by Rahman et al. (2021) in Bangladeshi adults revealed a parallel trend where ferritin positively correlated with MCV, MCH, and MCHC, supporting the interpretation that red cell indices mirror biochemical iron deficiency[23].

The strong inverse correlation between RDW and serum ferritin observed in this study reflects the increased variability in red cell size that accompanies iron depletion. RDW is a measure of anisocytosis and serves as an early hematological marker of evolving IDA. As iron availability decreases, the bone marrow releases smaller and irregularly shaped erythrocytes into circulation, leading to a rise in RDW. This observation aligns with the findings of Cook et al. (2020), who demonstrated that RDW increases even before a significant fall in hemoglobin, suggesting its value as an early screening parameter in iron deficiency[24].

The predominance of female patients (71.7%) in this study also aligns with global data indicating that women of reproductive age are more vulnerable to iron deficiency due to menstrual blood loss, pregnancy, and dietary inadequacies[25]. World Health Organization (2021) estimates that nearly one in three women worldwide suffers from anemia, with iron deficiency accounting for over half of these cases. This trend underscores the importance of routine ferritin screening in women, especially in resource-limited settings where nutritional deficiencies and parasitic infections are common[20].

From a diagnostic perspective, combining serum ferritin estimation with routine hematological parameters provides a more comprehensive and cost-effective approach for diagnosing and grading the severity of IDA[18]. While ferritin remains the gold-standard biochemical marker for iron stores, its reliability may be compromised in inflammatory conditions due to its acute-phase reactant nature. Therefore, correlating ferritin with parameters such as Hb, MCV, and RDW enhances diagnostic accuracy and reduces the likelihood of misclassification, particularly in patients with overlapping anemia etiologies[11-15].

Our findings also have clinical relevance for treatment monitoring. Improvement in serum ferritin levels following iron supplementation therapy should be accompanied by corresponding normalization of red cell indices[5,6]. Hence, periodic assessment of both biochemical and hematological parameters can help clinicians evaluate therapeutic response and prevent over- or under-treatment[8].

However, this study had certain limitations. Being cross-sectional, it could only establish correlations rather than causal relationships. Furthermore, inflammatory markers such as C-reactive protein (CRP) were not measured, which might have influenced ferritin levels in patients with subclinical infections[5]. Future studies involving larger sample sizes, serial measurements, and inclusion of inflammatory markers are recommended to further strengthen the diagnostic utility of ferritin and hematological indices in IDA[25].

CONCLUSION

This study demonstrated a strong and statistically significant correlation between serum ferritin levels and hematological parameters among patients with iron deficiency anemia. Serum ferritin showed a positive correlation with hemoglobin, MCV, MCH, and MCHC, and a negative correlation with RDW. These findings confirm that declining ferritin levels are directly associated with worsening anemia and alterations in red cell morphology. Therefore, simultaneous assessment of serum ferritin and complete blood count indices offers a reliable, affordable, and practical diagnostic strategy for identifying and monitoring iron deficiency anemia, particularly in regions with limited healthcare resources. Early detection using these parameters can facilitate timely intervention, reduce disease burden, and improve patient outcomes.

Availability of Data and Materials: All data generated or analyzed during this study are included within this published article. Additional datasets are available from the corresponding author upon reasonable request.

Competing Interests: The authors declare no conflicts of interest related to this study.

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Authors' Contributions:

N.Y.: Conceptualization, study design, and data interpretation.
K.Y.: Laboratory investigations and biochemical analysis.
B.F.: Manuscript drafting, correspondence, and supervision.
U.K.S.: Statistical analysis and data validation.
U.U.A.: Data collection and clinical evaluation.
E.H.S.: Overall supervision, critical review, and final manuscript approval.

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