

RESEARCH PAPER

A Comparative evaluation of the value of Hemoglobin and Mean Corpuscular Volume in Diagnosing Iron deficiency Anemia: A Prospective Cohort Study

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Abstract

Background: Iron Deficiency Anemia (IDA) is a widespread nutritional disorder affecting 1.88 billion people globally. Accurate diagnosis is crucial, but serum ferritin's accuracy can be compromised in inflammatory conditions, liver disease, and cancer. Mean Corpuscular Volume (MCV) and Hemoglobin (Hb) are essential markers in diagnosing IDA, but their synergistic value remains understudied.

Objective: To evaluate the diagnostic utility of combining MCV and Hb in identifying IDA, providing critical insights into their effectiveness as first-line diagnostic tools.

Methods: This prospective cohort study enrolled 190 adults (18-50 years) with anemia or low hemoglobin. Participants underwent comprehensive iron parameter analysis, including serum iron, serum transferrin, serum ferritin levels, and total iron binding capacity. Descriptive statistical analysis and correlation analysis were employed to examine relationships between MCV, Hb, and iron parameters.

Results: MCV demonstrated higher sensitivity (63-95%) and specificity (38.9-72.2%) than Hb across various iron deficiency indicators. Combining MCV with serum ferritin and transferrin saturation improved diagnostic accuracy. Notably, MCV showed higher accuracy than Hb in diagnosing IDA, especially when combined with serum ferritin and transferrin saturation.

Conclusion: This study highlights the diagnostic utility of MCV in detecting IDA, particularly when combined with serum ferritin and transferrin saturation. Hb alone has limited diagnostic accuracy. Clinicians should use a multifaceted approach to diagnose IDA accurately, considering MCV as a complementary diagnostic tool. The study's findings have significant implications for clinical practice, emphasizing the need for accurate diagnosis to prevent IDA's far-reaching consequences.

Keywords: Iron Deficiency Anemia, Mean Corpuscular Volume, Hemoglobin, Diagnostic Accuracy, Prospective Cohort Study.

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Introduction

Iron Deficiency Anemia (IDA) is a widespread nutritional disorder characterized by decreased total body iron content, leading to reduced red blood cell (RBC) production and hemoglobin (Hb) levels¹. IDA affects approximately 1.88 billion people globally, with a higher prevalence in developing countries^{2,3}. According to the World Health Organization (WHO), anemia affects approximately 40% of children aged 6-59 months, 38% of pregnant women, and 29% of women aged 15-49 years worldwide¹. In India, IDA is a significant health concern, particularly among women and children, with a prevalence of 57.2% among women aged 15-49 years and 42.5% among children aged 6-59 months^{4,5}. The consequences of IDA are far-

reaching, leading to impaired cognitive development, decreased productivity, increased risk of maternal and child mortality, poor birth outcomes, reduced immune function, and decreased physical performance^{6,7}. Current diagnostic approaches rely heavily on serum ferritin, which has high sensitivity and specificity for IDA^{8,9,10}. However, its accuracy can be compromised in inflammatory conditions, liver disease, and cancer^{9,11,12}. Mean Corpuscular Volume (MCV) and Hemoglobin (Hb) are essential markers in diagnosing Iron Deficiency Anemia (IDA), but their synergistic value in diagnosing IDA remains understudied^{9,13,14}. Studies have consistently shown that IDA is characterized by microcytic hypochromic anemia, with MCV values <80 fL and

hemoglobin levels <12 g/dL in women and <13 g/dL in men^{9,13,14}. Research has demonstrated that MCV and Hb values can effectively distinguish IDA from other forms of anemia, with MCV <76 fL having a sensitivity of 85% and specificity of 90% for IDA diagnosis^{13,15,16}. Similarly, Hb <11 g/dL had a sensitivity of 80% and specificity of 85% for IDA diagnosis in women^{15,16}. Furthermore, combining MCV and Hb values improves diagnostic accuracy for IDA, with a sensitivity of 95% and specificity of 92%^{15,17}. However, variations in MCV and Hb values have been observed across different populations, with MCV values ranging from 70-85 fL in IDA patients in India and Hb levels varying between 8-12 g/dL in IDA patients in Africa. These findings highlight the importance of considering population-specific MCV and Hb values when diagnosing IDA^{18,19,20}.

But limited data exist on optimal diagnostic thresholds for MCV and Hb in IDA diagnosis. This prospective cohort study aims to evaluate the diagnostic utility of combining MCV and Hb in identifying IDA, providing critical insights into their effectiveness as first-line diagnostic tools. By assessing the correlation between MCV, Hb, and serum ferritin levels, this study seeks to determine the optimal diagnostic threshold for MCV and Hb in IDA diagnosis.

Materials and Methods

This observational prospective study was conducted over a period of two years (January 2022 - December 2023) at Chamarajanagar Medical College, Department of Pathology. Institutional ethics committee approval was obtained. This study targeted adults aged 18-50 years presenting to the Pathology department, who met specific inclusion criteria to ensure a homogeneous study population. The criteria consisted of hemoglobin levels below 12 g/dL for women and 13 g/dL for men, as determined by automated indices, to identify individuals with anemia or low hemoglobin. Additionally, participants were required to have complete blood count and RBC indices results available to facilitate comprehensive analysis. All enrolled participants provided informed consent prior to their inclusion in the study. Participants with a history of chronic diseases, pregnancy, lactation, or recent blood transfusions were excluded.

Blood samples were collected through venipuncture using EDTA-containing vacutainers for venous blood collection. Complete blood count and RBC indices were analyzed using a differential hematology analyzer. A total of 190 participants were successfully enrolled in the study. To facilitate accurate classification, cases were re-categorized based on Mean Corpuscular Volume

(MCV) values, with MCV <80 fL indicating Iron Deficiency Anemia (IDA). Subsequently, these IDA cases underwent comprehensive iron parameter analysis, encompassing serum iron, serum transferrin, serum ferritin levels, and total iron binding capacity. Analyses were performed using a standardized enzyme-linked immunosorbent assay (ELISA) kit to ensure consistency and reliability. Descriptive statistical analysis was employed to summarize demographic and laboratory parameters, providing a comprehensive overview of the study population. To investigate the interrelationships between key hematological parameters, correlation analysis was conducted to examine the associations between hemoglobin (Hb), mean corpuscular volume (MCV), and iron parameters, including serum iron, serum transferrin, serum ferritin levels, and total iron binding capacity. Additionally, the diagnostic utility of Hb and MCV in identifying iron deficiency anemia was assessed through calculations of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy.

Results

The study population was predominantly middle-aged, with 51.57% of participants between 21-40 years old with a median age of 32.5 years. Females accounted for 60% of the study population, indicating a slightly higher prevalence of iron deficiency anemia in women. Microcytic anemia (MCV <80 fL) was present in 52.6% participants, indicating a significant burden of iron deficiency anemia. Normocytic anemia was observed in 30.5% participants, suggesting other underlying causes of anemia.

The diagnostic performance of MCV and Hb in detecting iron deficiency anemia was evaluated. MCV demonstrated higher sensitivity and specificity compared to Hb. For MCV, the sensitivity and specificity were: 95% and 38.9% for serum ferritin, 7% and 55.56% for serum iron, 70% and 72.2% for transferrin saturation, and 63% and 64.4% for Total Iron-Binding Capacity (TIBC). In contrast, Hb showed lower sensitivity (50%, 3.68%, 33.68%, and 33.16% for serum ferritin, serum iron, transferrin saturation, and TIBC, respectively) and zero specificity across all iron deficiency indicators. [Table 1]

The positive predictive values (PPV) and negative predictive values (NPV) for MCV were 63.3% and 87.5% for serum ferritin, 14.89% and 34.97% for serum iron, 73.68% and 68.42% for transferrin saturation, and 66.32% and 61.05% for TIBC respectively. Notably, Hb's PPV was 100% across all indicators, but its NPV was 0%. These findings suggest that MCV is a more reliable diagnostic tool than Hb in detecting iron deficiency anemia, particularly when combined with serum ferritin and transferrin saturation. MCV demonstrated higher

accuracy compared to Hb across most iron deficiency indicators, particularly serum ferritin (68.42% vs. 50%) and transferrin saturation (71.05% vs. 33.68%). However, Hb's accuracy was comparable to MCV's for serum iron and TIBC. MCV showed higher accuracy than Hb in diagnosing iron deficiency anemia, especially when combined with serum ferritin and transferrin saturation. However, both MCV and Hb had limitations, highlighting the need for complementary diagnostic approaches.

TABLE

Table 1: Sensitivity and Specificity of MCV and HB with respect to Serum Iron levels

Parameter	Serum Iron	
	Sensitivity	Specificity
Mean Corpuscular Volume (MCV)	07%	55.56%
Hemoglobin (Hb)	3.68%	0%

Discussion

The findings of this prospective cohort study demonstrate the synergistic value of Mean Corpuscular Volume (MCV) and Hemoglobin (Hb) in diagnosing iron deficiency anemia. Our results are consistent with previous studies highlighting the importance of MCV in detecting iron deficiency anemia. Previous studies have demonstrated the diagnostic utility of Mean Corpuscular Volume (MCV) in identifying iron deficiency anemia (IDA). Rector et al. (2015) reported a sensitivity of 92% and specificity of 67% for MCV in diagnosing IDA¹⁵. Similarly, Patel et al. (2017) found a sensitivity of 90.5% and specificity of 65.1%, while Uy et al. (2018) reported a sensitivity of 89.5% and specificity of 68.2%^{17,21}.

In the present study, we evaluated the diagnostic accuracy of MCV across various iron deficiency indicators. Our results showed that MCV sensitivity ranged from 63% to 95% and specificity ranged from 38.9% to 72.2%. These findings support the use of MCV as a diagnostic tool for IDA, although the variability in sensitivity and specificity highlights the need for careful interpretation.

Our findings indicate that Hb demonstrated relatively lower sensitivity and specificity in diagnosing iron deficiency anemia, consistent with previous research. Similarly, studies have shown

that Hb alone has limited diagnostic accuracy for iron deficiency anemia. For instance, Rector et al. (2015) and Uy et al. (2018) reported suboptimal performance of Hb as a diagnostic marker^{15,17}. However, the diagnostic utility of Hb varies across different populations. Burke et al. (2016) found high sensitivity (>90%) for Hb among infants, whereas Gebreegziabher et al. (2017) reported sensitivity of 30%, specificity of 79%, and accuracy of 77% in non-pregnant women^{23,24}.

These findings underscore the importance of considering false positives and negatives when relying solely on Hb for diagnosis. Therefore, combining Hb with other diagnostic markers or using alternative approaches may improve diagnostic accuracy.

Our findings suggest that combining MCV with serum ferritin and transferrin saturation improves diagnostic accuracy. The diagnostic performance of MCV and Hb may be influenced by factors such as inflammation, vitamin deficiencies, and chronic diseases. Future studies should investigate the impact of these factors on MCV and Hb diagnostic accuracy. The main strengths of this research include its prospective design, facilitating temporal relationships, and the in-depth examination of MCV and Hb diagnostic performance. Limitations comprise a relatively small sample size, potentially influencing statistical power and may impact the representativeness of the results. Hence, future research should focus on validating these findings in larger, diverse populations.

Conclusion

The present study demonstrates the diagnostic utility of Mean Corpuscular Volume (MCV) in detecting iron deficiency anemia, particularly when combined with serum ferritin and transferrin saturation. The findings highlight the limitations of Hemoglobin (Hb) alone in diagnosing iron deficiency anemia and underscore the importance of considering MCV as a complementary diagnostic tool. These results have significant implications for clinical practice, emphasizing the need for a multifaceted approach to diagnose iron deficiency anemia accurately.

The study's findings suggest that clinicians should use MCV in conjunction with serum ferritin and transferrin saturation to improve diagnostic accuracy and exercise caution when relying solely on Hb for diagnosis. Future research should investigate the impact of inflammation and vitamin deficiencies on MCV and Hb diagnostic accuracy, explore alternative biomarkers for iron deficiency anemia, and validate these findings in larger, diverse populations.

Overall, this study contributes to the existing literature by providing insights into the diagnostic performance of MCV and Hb in iron deficiency

anemia and highlighting the importance of a multifaceted approach to diagnosis.

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