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The Role of Hematological Indices in the Diagnosis of Iron deficiency Anemia in patient at Zliten Medical Center

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Abstract:
Anemia represents a significant global health concern, affecting populations across both developing and developed nations. A central debate in the medical field concerns the appropriate hemoglobin threshold that should be used to define anemia, particularly in the elderly population. Among nutritional deficiencies, iron deficiency remains the most prevalent worldwide, impacting more than two billion individuals. Its most serious manifestation, iron deficiency anemia (IDA), is recognized as a major public health problem, disproportionately affecting individuals in low- and middle-income countries.

The present study sought to evaluate the utility of red blood cell (RBC) indices as a screening tool for the Early detection of iron deficiency. A descriptive cross-sectional study was conducted at Zliten Medical Center between October 2022 and April 2023, involving 150 patients diagnosed with IDA. Complete blood count (CBC) parameters were analyzed, including RBC count ($\times 10^3/\mu l$), hemoglobin concentration (Hb, g/dl), mean corpuscular volume (MCV, fL), and mean corpuscular hemoglobin (MCH, pg).

The study cohort consisted of 150 anemic patients, comprising 90 females (60%) and 60 males (40%), with a mean age of 40 years. Results indicated that the mean Hb level was 8 g/dl in females and 9 g/dl in males. The average MCV was 70 fL in females and 75 fL in males, while the mean MCH values were 20 pg and 24 pg, respectively. Additionally, serum ferritin levels were consistently below 100 ng/ml.

The findings suggest that iron deficiency can be reliably predicted at an early stage through the assessment of Hb and RBC indices. This approach represents a cost-effective alternative to more advanced diagnostic methods and could be particularly valuable in resource-limited settings.

Key Words: Hemoglobin, Red cell indices, Iron deficiency Anemia, Red blood cell.

استخدام مؤشرات كريات الدم الحمراء في تشخيص فقر دم عوز الحديد في مركز زليتن الطبي

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الملخص
فقر الدم مشكلة عالمية تؤثر على السكان في كل من البلدان النامية والمتقدمة، وهناك نقاش حول مستوى الهيموغلوبين الذي ينبغي استخدامه لتعريف فقر الدم في السكان عامة وخاصة في كبار السن. نقص الحديد هو المشكلة الغذائية الأكثر شيوعا في العالم، التي تؤثر على أكثر من ملياري شخص. وفقر الدم الناجم عن نقص الحديد هو نتيجته الرئيسية، التي تعتبر مشكلة صحية عامة عالمية، وهي تؤثر في معظمها على البلدان النامية. الغاية من البحث كانت تقدير دور مؤشرات الخلايا الحمراء كأداة للفحص للكشف المبكر عن نقص الحديد. تم عمل دراستنا من أكتوبر 2022 إلى أبريل 2023 باستخدام تصميم مقطعي وصفي على 150 مريضًا من فقر الدم الناجم عن نقص الحديد في مركز زليتن الطبي.

تم قياس البارامترات التالية من نتيجة CBC؛ RBCs count×10^3/µl ,HGB g / dl MCV fL MCH pg وشملت الدراسة الحالية 150 مريضاً بفقر الدم (90 أنثى، 60 %) و (60 ذكرا، 40 ٪)، مع متوسط العمر حوالي 40 عاما. نتائج هذه الدراسة تبين أن، متوسط الهيموجلوبين (HB) في الإناث كان g/dl8، في حين أن متوسط HB في ذكر كان g/dl9. وكان متوسط MCV في الإناث fL70.، حيث كان في الذكور fL75.، وكان متوسط MCH في الإناث pg20.، وفي الذكور كان معدله pg24. ويمكن التنبؤ بنقص الحديد في المراحل المبكرة باستخدام Hb ومؤشرات الخلايا الحمراء، وهو أقل تكلفة بكثير.

الكلمات المفتاحية: الهيموجلوبين، مؤشرات كريات الدم الحمراء، فقر دم عوز الحديد، كريات الدم الحمراء.

Introduction

Red blood cells (RBCs), also termed erythrocytes (from the Greek erythros, meaning red, and kytos, meaning hollow vessel), are the most abundant type of blood cell and the principal vehicle for oxygen transport in vertebrates [1]. They acquire oxygen in the lungs, or in fish the gills, and release it into peripheral tissues via the capillary network [2]. The cytoplasm of erythrocytes is densely packed with hemoglobin (Hb), an iron-containing protein responsible for oxygen binding and for the characteristic red coloration of blood. Each human erythrocyte contains approximately 270 million hemoglobin molecules [3]. The cell membrane, composed of proteins and lipids, provides structural integrity and flexibility, allowing RBCs to deform and pass through narrow capillaries. Mature human erythrocytes are anucleate, biconcave discs that lack organelles, thereby maximizing intracellular space for hemoglobin storage. In adults, nearly 2.4 million new RBCs are produced per second within the bone marrow, with an average lifespan of 100–120 days before degradation and recycling by macrophages. Each complete circulation requires roughly 60 seconds [4,5]. Red cells account for about 84% of the total cellular population in the human body, numbering 20–30 trillion, and contribute to 40–45% of total blood volume [6–9].

Anemia is a hematological disorder characterized by reduced oxygen-carrying capacity of the blood, which may result from a decreased number of circulating erythrocytes, insufficient hemoglobin content, or structural abnormalities that impair hemoglobin function [10,11]. When anemia develops gradually, symptoms are often nonspecific and include fatigue, weakness, shortness of breath, headaches, and diminished exercise tolerance. The causes of anemia are diverse and include blood loss (e.g., gastrointestinal bleeding, trauma, surgical procedures, or donation), impaired RBC production (e.g., deficiencies of iron, folate, or vitamin B12, thalassemia, and bone marrow disorders), and increased RBC destruction due to hemolysis [12].

Recognizing its significant health burden, the World Health Organization (WHO) identified anemia as one of six global nutrition targets for 2025, endorsed by the World Health Assembly in 2012 and 2013. Anemia is classified by severity in adults as mild (≈11 g/dL Hb), moderate (8–11 g/dL Hb), and severe (<8 g/dL Hb), with adjusted diagnostic cut-offs for pregnant women and children [13]. Diagnosis is generally made using a complete blood count (CBC), which measures RBC count, hemoglobin concentration, and red cell indices. Microscopic examination of stained blood smears and automated flow cytometry further support the classification of anemia.

The concept of RBC indices was first introduced by Wintrobe in 1929 [14]. These indices—mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC)—provide critical insights into erythrocyte morphology. MCV reflects the average size of red cells (normal adult range: 80–95 fL), with low values indicating microcytic anemia, normal values normocytic anemia, and elevated values macrocytic anemia [15]. MCH measures the average hemoglobin mass per cell (normal range: 27.5–33.2 pg), where diminished values are associated with microcytic anemia and elevated values with macrocytic anemia [16]. These indices remain essential in distinguishing between different types of anemia and guiding appropriate clinical management.

Methods

Study design and setting

This study was directed from October 2022 to April 2023 by using a descriptive cross-sectional design on 150 patients of Iron deficiency Anemia at Zliten Medical Center.

Data collection procedure

In the beginning, 5 ml venous blood sample was obtained from the subjects and collected into a sterile vacutainer with EDTA anticoagulants and analyzed for hematological parameter such as complete blood count (CBC), Peripheral blood film and serum ferritin.

Hematological analysis:

The CBCs were tested for each individual involved in this study. Sysmex-KX-21N hematology auto analyzer (Sysmex, USA) was used in the diagnostic lab of Misallata central hospital. The CBCs were measured to screen blood status. The following parameters were measured from CBC result; RBCs count×10^3/µl, HGB g/dl, MCV fL. and MCH pg.

However, the 2ml of collected blood samples of each patient were tested by Sysmex-KX-21N to measure CBCs. First; we mixed the sample well to avoid the blood clotting. Secondly, the test tube which contains the blood sample was put under the needle of the Sysmex-KX-21N machine to absorb enough quantity of sample and give sign. The reaction will run automatically and reaction was completed within less than one minute.

Data processing and statistical analysis:

The collected survey data were entered into Microsoft Excel spreadsheets and subsequently exported for further statistical evaluation. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 20. Descriptive statistics, including frequency distributions, percentages, means, and standard deviations, were employed to summarize and present the findings in tabular and graphical formats.

For the purposes of this study, anemia was defined in accordance with the World Health Organization (WHO) criteria. Specifically, anemia was diagnosed when hemoglobin concentrations fell below 12.0 g/dL in men and 11.0 g/dL in non-pregnant women. Severity was further categorized as follows: mild anemia (Hb 10–12 g/dL in men and 10–11 g/dL in women), moderate anemia (Hb 7–9 g/dL in both sexes), and severe anemia (Hb <7 g/dL in both sexes). Absolute iron deficiency was defined as a serum ferritin concentration of less than 100 ng/mL.

Results

The objective of this study was to assess the utility of red cell indices as a screening tool for the early detection of iron deficiency. A total of 150 anemic patients were enrolled, comprising 90 females (60%) and 60 males (40%), with a mean age of 40 years.

The findings revealed that the mean hemoglobin (Hb) concentration was 8 g/dL in females and 9 g/dL in males. The mean corpuscular volume (MCV) averaged 70 fL in females and 75 fL in males, while the mean corpuscular hemoglobin (MCH) was 20 pg in females and 24 pg in males. A combination of reduced Hb levels, decreased MCV, and low MCH, together with serum ferritin concentrations below 100 ng/mL, was indicative of iron deficiency anemia.

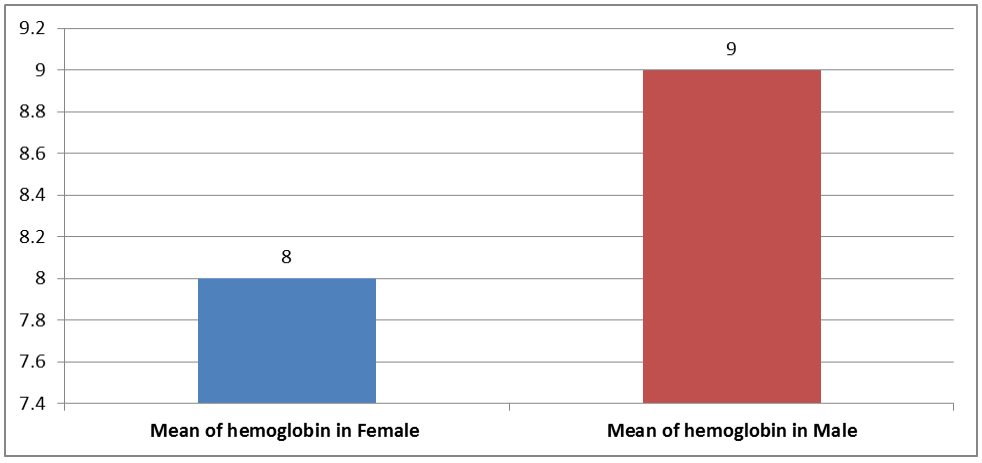

Figure 1. Mean of hemoglobin

Figure 1: shows, the mean of hemoglobin in females, which was in 8 g/dl, while in males was 9 g/dl. Mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) convey similar information and are largely interchangeable in their diagnostic value for identifying nutritional iron deficiency. Among these indices, MCV has been the most widely utilized parameter for the assessment of nutritional iron deficiency.

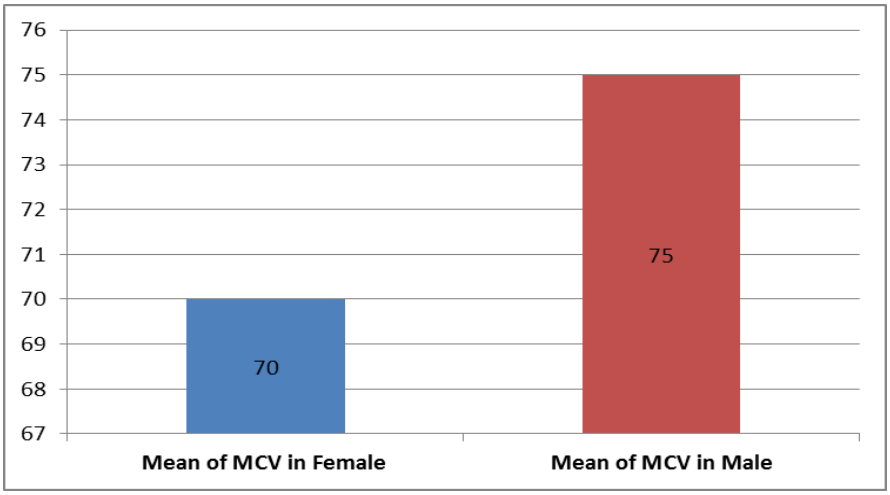

Figure 2. Mean of MCV

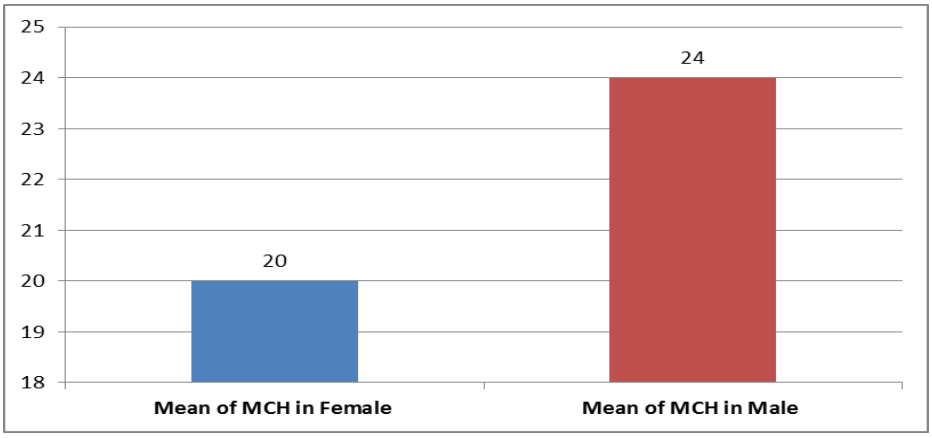

Figure 3. Mean of MCH

As figures 2 and 3 Show, Microcytic hypochromic anemia cases showed the decreased of mean values of MCV and MCH. Among various causes of microcytic hypochromic picture, the common causes are - iron deficiency anemia (IDA).

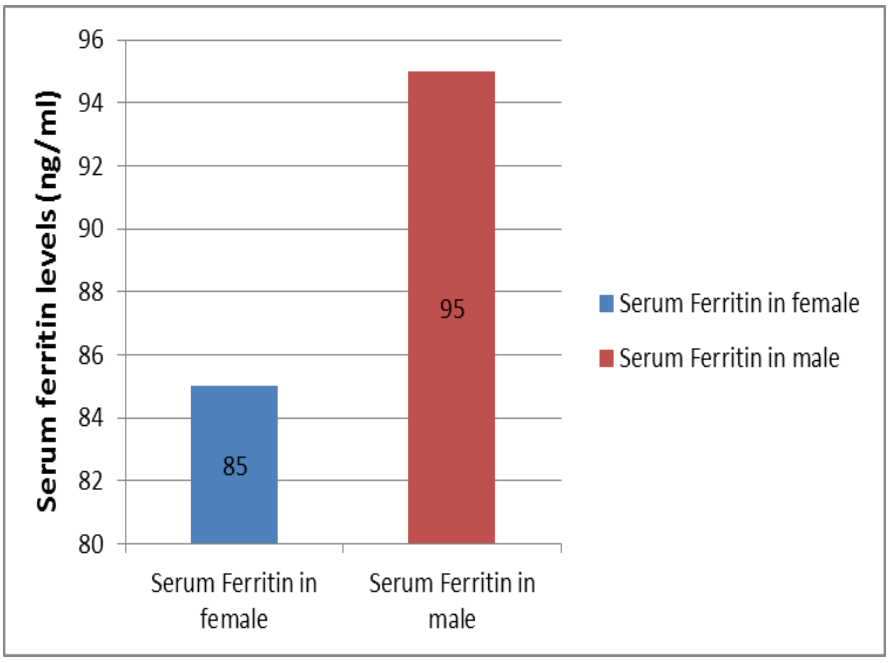

Figure 4. Mean of serum ferritin

As a figure 4 shows the serum ferritin was in low levels in the patient of this study, which confirm the type of anemia is iron deficiency.

Discussion

In iron deficiency anemia (IDA), red blood cell indices typically demonstrate microcytic and hypochromic characteristics. This indicates that the erythrocytes are smaller than normal (microcytic) and contain reduced hemoglobin (hypochromic), leading to decreased values of mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) [17].

The findings of the present study revealed that the mean hemoglobin (Hb) concentration in females was 8 g/dL, whereas in males it was 9 g/dL. The mean MCV was 70 fL in females and 75 fL in males, while the mean MCH was 20 pg in females and 24 pg in males. Low Hb, MCV, and MCH values collectively support the diagnosis of iron deficiency anemia. The prevalence of anemia observed in this study is comparable to that reported in the Sri Lankan National Nutrition Survey of 2009, as well as in other smaller regional studies. Previous investigations in Sri Lanka have demonstrated that 40–50% of women of reproductive age exhibit depleted iron stores, placing them at considerable risk,of developing, anemia during pregnancy [18].

Peripheral blood smear examination further classified the anemic cases predominantly as microcytic hypochromic anemia, with nutritional deficiency identified as the most common underlying etiology. In support of these findings, Sehgal et al. (2015) reported that diagnostic indices such as the Sehgal and Mentzer indices exhibited higher sensitivity and specificity for identifying microcytic hypochromic anemia [19]. Similarly, Ulla et al. (2016), in a study of 50 patients with confirmed iron deficiency, demonstrated that the Shine and Lal index correctly classified approximately 92% of cases of microcytic hypochromic anemia [20].

Conclusion

Iron deficiency anemia (IDA) remains one of the most significant global public health challenges, particularly in developing countries where nutritional deficiencies and limited access to diagnostic resources exacerbate its prevalence. The findings of this study at Zliten Medical Center reinforce the critical role of red blood cell (RBC) indices as effective, accessible, and economical tools for the early detection and assessment of IDA. By analyzing hemoglobin (Hb), mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCH), this research has demonstrated that these indices reliably reflect the microcytic hypochromic changes that are characteristic of iron deficiency.

The results revealed clear gender-based differences, with mean hemoglobin levels of 8 g/dl in females and 9 g/dl in males, mean MCV of 70 fL in females and 75 fL in males, and mean MCH of 20 pg and 24 pg, respectively. These values consistently fell below normal reference ranges, aligning with the diagnosis of IDA. Importantly, the study also confirmed low serum ferritin levels (<100 ng/ml) in the patient population, strengthening the conclusion that reduced Hb, MCV, and MCH are strong indicators of iron deficiency. This highlights that in resource-limited settings, where biochemical tests such as ferritin or transferrin saturation may not always be available, RBC indices can serve as practical alternatives for screening and early diagnosis.

The clinical implications of these findings are far-reaching. First, the study emphasizes that simple, inexpensive hematological markers can be used routinely in primary health care facilities to identify individuals at risk of IDA before the onset of severe complications. This is particularly important in high-risk groups such as women of reproductive age, pregnant women, children, and the elderly. Early detection not only improves patient outcomes through timely treatment with iron supplementation but also reduces the burden of long-term complications associated with untreated anemia, including impaired cognitive development in children, reduced productivity in adults, and increased maternal morbidity.

Second, the study underscores the diagnostic value of RBC indices in differentiating IDA from other causes of microcytic anemia. Although biochemical and genetic tests are required to confirm conditions such as thalassemia trait, indices like MCV and MCH remain the first-line markers that guide clinical suspicion and the need for further evaluation. In addition, the findings resonate with global evidence that combining RBC indices with discriminant formulas (e.g., Mentzer index, Shine and Lal index) can further improve diagnostic accuracy.

From a public health perspective, the reliance on readily available tests such as the complete blood count (CBC) provides a cost-effective approach in low-resource countries like Libya. Given the widespread accessibility of automated hematology analyzers, incorporating RBC indices into standard screening protocols could be a valuable strategy in national health programs aimed at reducing the prevalence of anemia.

Nevertheless, this study is not without limitations. It was restricted to a single medical center with a relatively small sample size of 150 patients. Larger, multicenter studies are needed to generalize the findings to broader populations. Furthermore, while this study focused primarily on Hb, MCV, and MCH, additional indices such as red cell distribution width (RDW) and reticulocyte hemoglobin content (CHr) could enhance diagnostic

sensitivity. Future research should also explore the influence of dietary, socioeconomic, and genetic factors on IDA prevalence in Libya.

In conclusion, this study provides strong evidence that red blood cell indices are invaluable tools for the early detection of iron deficiency anemia. Their simplicity, affordability, and diagnostic accuracy make them particularly well-suited for resource-limited environments. Integrating these parameters into routine practice can significantly improve early diagnosis, treatment, and prevention of IDA, ultimately contributing to better individual health outcomes and reduced public health burden. By reinforcing the importance of basic hematological evaluation, this study advocates for a greater reliance on RBC indices as a frontline approach in the global effort to combat iron deficiency anemia.

Recommend

Based on the findings of this study, the following

1. **Adoption of RBC I**

   Hemoglobin, mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCH) should be utilized as reliable, cost-effective screening tools for the early detection of iron deficiency anemia (IDA), especially in low-resource settings where advanced biochemical testing such as serum ferritin may not be readily available.
2. **Integration into Routine Clinical Practice**

   Complete blood count (CBC) analysis, including red cell indices, should be systematically incorporated into routine clinical evaluations of patients presenting with anemia-related symptoms. This can reduce diagnostic delays and ensure timely initiation of iron supplementation therapy.
3. **Complementary Use of Confirmatory Tests**

   While red cell indices are valuable for screening, confirmatory biochemical tests such as serum ferritin, transferrin saturation, and total iron-binding capacity (TIBC) should be performed where possible to exclude other causes of microcytic anemia, such as thalassemia trait.
4. **Expansion of Diagnostic Criteria**

   Future diagnostic protocols should consider including additional indices, such as red cell distribution width (RDW) and reticulocyte hemoglobin content (CHr), to enhance the diagnostic sensitivity and specificity of IDA detection.
5. **Public Health Strategies**

   Health authorities should promote the use of hematological indices in primary health care centers as a first-line approach to anemia screening. This is particularly critical for high-risk groups such as women of reproductive age, children, and pregnant women, where early detection and intervention can significantly reduce morbidity.
6. **Further Research**

   Larger, multi-center studies are recommended to validate the diagnostic accuracy of red cell indices across diverse populations in Libya and beyond. Future investigations should also assess the correlation between hematological indices and dietary, socioeconomic, and genetic factors influencing the prevalence of IDA.

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