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Efficacy of Mentzer Index and Red Cell Distribution Width as Discriminatory Indices Between Beta-Thalassemia Carrier State and Iron Deficiency Anemia: A Study of 150 Cases

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Abstract

Background: Microcytic hypochromic anemia is a common hematological finding, particularly in developing countries. The two most frequent causes are iron deficiency anemia (IDA) and beta-thalassemia carrier state (β-thalassemia trait, BTT). Differentiation between these two conditions is essential, as their management, prognosis, and genetic counseling implications differ significantly. Simple red cell indices derived from complete blood count (CBC), such as the Mentzer Index and Red Cell Distribution Width (RDW), are widely used as screening tools in resource-limited settings. **Objective:** To evaluate the diagnostic efficacy of the Mentzer Index and RDW in distinguishing beta-thalassemia carrier state from iron deficiency anemia. **Methods:** This cross-sectional analytical study was conducted on 150 patients presenting with microcytic hypochromic anemia. Complete blood count parameters were obtained using an automated hematology analyzer. Mentzer Index was calculated as mean corpuscular volume divided by red blood cell count. RDW values were recorded directly from analyzer reports. Iron deficiency anemia was confirmed by low serum ferritin levels, while beta-thalassemia carrier state was diagnosed based on elevated HbA levels on hemoglobin electrophoresis or high-performance liquid chromatography. The diagnostic performance of the Mentzer Index and RDW was assessed by calculating sensitivity and specificity. **Results:** Out of 150 cases, 90 (60%) were diagnosed with iron deficiency anemia and 60 (40%) with beta-thalassemia carrier state. Mean Mentzer Index values were significantly higher in iron deficiency anemia, while beta-thalassemia carriers showed lower values. A Mentzer Index cutoff less than 13 demonstrated high sensitivity and specificity for identifying the beta-thalassemia carrier state. RDW values were significantly elevated in iron deficiency anemia compared to beta-thalassemia carriers, showing high sensitivity for detecting iron deficiency anemia. Combined use of both indices improved diagnostic accuracy. **Conclusion:** Mentzer Index and RDW are simple, cost-effective, and reliable screening tools for differentiating IDA from β-thalassemia carrier state, particularly in low-resource settings.

Keywords: Iron deficiency anemia, Beta-thalassemia carrier state, Mentzer Index, Red cell distribution width, Microcytic hypochromic anemia, Red blood cell indices, Screening indices, Complete blood count.

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Introduction

Anemia remains one of the most prevalent public health problems worldwide, disproportionately affecting populations in low- and middle-income countries. Among the various types of anemia, microcytic hypochromic anemia is most commonly encountered in clinical practice. The principal causes of microcytic anemia include iron deficiency anemia (IDA), beta-thalassemia, anemia of chronic disease, and sideroblastic anemia, with IDA and beta-thalassemia trait being the most frequent etiologies.[1]

Iron deficiency anemia is primarily caused by inadequate dietary intake, malabsorption, increased physiological demand, or chronic blood loss. In infants and children, diminished iron stores at birth are an important cause of iron deficiency anemia. It is associated with significant morbidity, including impaired cognitive development, reduced physical capacity, and adverse pregnancy outcomes.[2] In contrast, the beta-thalassemia carrier state is a hereditary hemoglobinopathy characterized by reduced or absent synthesis of beta globin chains, leading to microcytosis with relatively preserved hemoglobin levels.[3]

Distinguishing IDA from the beta-thalassemia carrier state is clinically important. Iron supplementation, which is the cornerstone of treatment for IDA, is unnecessary and potentially harmful in individuals with beta-thalassemia trait. Furthermore, identification of carriers is essential for genetic counseling and prevention of thalassemia major through premarital and antenatal screening programs.[4]

Definitive diagnosis of iron deficiency anemia requires biochemical tests such as serum ferritin, serum iron, total iron-binding capacity, and transferrin saturation. Similarly, diagnosis of the beta-thalassemia carrier state relies on hemoglobin electrophoresis or high-performance liquid chromatography (HPLC) to detect elevated HbA_2 levels. However, these investigations are costly, time-consuming, and not always available in peripheral healthcare facilities.[5]

Complete blood count (CBC) parameters obtained from automated analyzers are widely accessible and inexpensive. Over the years, several mathematical indices derived from red blood cell parameters have been proposed to differentiate IDA from beta-thalassemia trait. Among these, the Mentzer Index, calculated as mean corpuscular volume (MCV) divided by red blood cell (RBC) count, is one of the most commonly used. A value less than 13 suggests beta-thalassemia trait, while a value greater than 13 favors iron deficiency anemia.[6]

Red Cell Distribution Width (RDW) reflects the degree of anisocytosis and is typically elevated in iron deficiency anemia due to heterogeneous red cell populations. In contrast, RDW is usually normal or mildly increased in the beta-thalassemia carrier state. An RDW value typically above 15% may indicate underlying nutritional deficiencies (such as iron, vitamin B12, or folate deficiency), chronic inflammation, or recent blood loss as well.[7]

This study aims to evaluate the efficacy of the Mentzer Index and RDW as discriminatory indices between iron deficiency anemia and beta-thalassemia carrier state in a cohort of 150 patients presenting with microcytic hypochromic anemia.

Materials and methods

This cross-sectional analytical study was conducted in the Department of Hematology of a tertiary care hospital over a period of one year. A total of 150 patients presenting with microcytic hypochromic anemia were included in the study.

Inclusion criteria:

- Patients of both sexes aged ≥15 years
- Hemoglobin level below the normal reference range
- Mean corpuscular volume (MCV) <80 fL

Exclusion criteria:

- Patients with anemia of chronic disease
- Known hemoglobinopathies other than beta-thalassemia trait
- A recent blood transfusion within the last three months
- Pregnancy

After obtaining informed consent, venous blood samples were collected in EDTA tubes for complete blood count analysis. Hematological parameters, including hemoglobin (Hb), RBC count, MCV, mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and RDW, were measured using an automated hematology analyzer.

Mentzer Index = MCV (fL) / RBC count ($\times 10^{12}$/L)

Based on standard diagnostic criteria, patients were classified into two groups:

- Iron Deficiency Anemia (IDA): Confirmed by low serum ferritin levels
- Beta-thalassemia Carrier State (BTT): Confirmed by HbA_2 level ≥3.5% on hemoglobin electrophoresis or HPLC

RDW values were categorized as normal or increased according to laboratory reference ranges.

Statistical analysis was performed using standard statistical software. Sensitivity, specificity, positive predictive value, and negative predictive value of the Mentzer Index and RDW were calculated. A p-value <0.05 was considered statistically significant.

Results

A total of 150 patients with microcytic hypochromic anemia were included in the study. Based on definitive diagnostic criteria, 90 patients (60%) were diagnosed with iron deficiency anemia, while 60 patients (40%) were identified as having beta-thalassemia carrier state.

The mean hemoglobin concentration was lower in patients with iron deficiency anemia compared to beta-thalassemia carriers. Patients with iron deficiency anemia had a mean hemoglobin level of 8.9 ± 1.4 g/dL, whereas beta-thalassemia carriers had a relatively higher mean hemoglobin level of 10.5 ± 1.2 g/dL. This difference reflects the milder anemia typically observed in beta-thalassemia trait.

A marked difference in red blood cell count was observed between the two groups. The mean RBC count in iron deficiency anemia was 3.6 ± 0.5 $\times 10^{12}$/L, while beta-thalassemia carriers demonstrated a significantly higher mean RBC count of 5.4 ± 0.6 $\times 10^{12}$/L. This finding is consistent with compensatory erythropoiesis seen in beta-thalassemia trait.

The mean corpuscular volume was reduced in both groups, confirming microcytosis. However, beta-thalassemia carriers showed a slightly lower mean MCV (64.1 ± 5.4 fL) compared to patients with iron deficiency anemia (68.2 ± 6.1 fL). Despite overlap, the difference was statistically significant.

Red cell distribution width showed a clear discriminatory pattern. Patients with iron deficiency anemia had a significantly elevated mean RDW value of 17.8 ± 2.3%, indicating marked anisocytosis. In contrast, beta-thalassemia carriers had a near-normal mean RDW value of 13.4 ± 1.8%, reflecting uniform microcytosis.

Mentzer Index values differed substantially between the two groups. The mean Mentzer Index in iron deficiency anemia was 18.9 ± 3.2, whereas beta-thalassemia carriers had a significantly lower mean value of 11.8 ± 2.1. A Mentzer Index value below 13 correctly identified the majority of beta-thalassemia carriers, while values equal to or greater than 13 were predominantly associated with iron deficiency anemia.

Using a cutoff value of less than 13, the Mentzer Index demonstrated a sensitivity of 90% and a specificity of 86.7% for detecting the beta-thalassemia carrier state. Red cell distribution width showed a sensitivity of 91.1% for identifying iron deficiency anemia, although specificity was lower due to occasional elevation of RDW in beta-thalassemia carriers with associated nutritional deficiencies.

Overall, the combined use of the Mentzer Index and RDW improved diagnostic discrimination between iron deficiency anemia and beta-thalassemia carrier state.

Table 01: Distribution of Study Subjects According to Diagnosis (n = 150)

Diagnosis	Number of Cases	Percentage (%)
Iron Deficiency Anemia (IDA)	90	60.0
Beta-Thalassemia Carrier State (BTT)	60	40.0
Total	**150**	**100.0**

Table 02: Comparison of Mean Hematological Parameters Between IDA and BTT

Parameter	IDA (Mean ± SD)	BTT (Mean ± SD)
Hemoglobin (g/dL)	8.9 ± 1.4	10.5 ± 1.2
Red Blood Cell Count ($\times 10^{12}$/L)	3.6 ± 0.5	5.4 ± 0.6
Mean Corpuscular Volume (fL)	68.2 ± 6.1	64.1 ± 5.4
Mean Corpuscular Hemoglobin (pg)	22.1 ± 2.8	20.3 ± 2.4
Mean Corpuscular Hemoglobin Concentration (g/dL)	31.2 ± 1.6	31.6 ± 1.4
Red Cell Distribution Width (%)	17.8 ± 2.3	13.4 ± 1.8
Mentzer Index	18.9 ± 3.2	11.8 ± 2.1

Table 03: Distribution of Cases According to Mentzer Index Cutoff Value

Mentzer Index Value	Iron Deficiency Anemia	Beta-Thalassemia Carrier State	Total
< 13	12	54	66
≥ 13	78	6	84
Total	**90**	**60**	**150**

Table 04: Diagnostic Performance of Mentzer Index for Beta-Thalassemia Carrier State

Diagnostic Parameter	Value (%)
Sensitivity	90.0
Specificity	86.7
Positive Predictive Value (PPV)	81.8
Negative Predictive Value (NPV)	92.9
Overall Accuracy	88.0

Table 05: Distribution of RDW Values in IDA and BTT

RDW Status	Iron Deficiency Anemia	Beta-Thalassemia Carrier State	Total
Increased RDW	82	18	100
Normal RDW	8	42	50
Total	**90**	**60**	**150**

Table 06: Diagnostic Performance of RDW for Iron Deficiency Anemia

Diagnostic Parameter	Value (%)
Sensitivity	91.1
Specificity	70.0
Positive Predictive Value (PPV)	82.0
Negative Predictive Value (NPV)	84.0
Overall Accuracy	82.7

Table 07: Combined Use of Mentzer Index and RDW

Mentzer Index	RDW	Probable Diagnosis
<13	Normal	Beta-Thalassemia Carrier State
<13	Increased	BTT with possible iron deficiency
≥ 13	Increased	Iron Deficiency Anemia
≥ 13	Normal	Mild/early Iron Deficiency or mixed etiology

Discussion

Differentiation between iron deficiency anemia and beta-thalassemia carrier state remains a diagnostic challenge, especially in resource-limited settings where advanced investigations may not be readily available. This study evaluated the utility of two simple hematological indices—the Mentzer Index and RDW—in distinguishing these conditions.

In the present study, iron deficiency anemia accounted for 60% of cases, while beta-thalassemia carrier state constituted 40%. This distribution is consistent with previous studies conducted in South Asian populations, where both conditions are highly prevalent.[8]

The mean RBC count was significantly higher in beta-thalassemia carriers compared to iron deficiency anemia patients. This finding aligns with the pathophysiology of beta-thalassemia trait, where ineffective erythropoiesis leads to a compensatory increase in RBC production.[9] Conversely, iron deficiency anemia is characterized by reduced RBC production due to insufficient iron availability.

The Mentzer Index demonstrated high sensitivity (90%) and specificity (86.7%) for identifying the beta-thalassemia carrier state. Similar results have been reported by Mentzer himself and subsequent investigators, reinforcing its usefulness as a screening tool.[6,10] A Mentzer Index value below 13 reliably indicated beta-thalassemia trait in the majority of cases. RDW was markedly elevated in patients with iron deficiency anemia, reflecting increased variability in red cell size due to asynchronous erythropoiesis. In contrast, RDW values were relatively normal in beta-thalassemia carriers, where microcytosis is uniform.[7] The sensitivity of RDW for detecting IDA in this study was 91.1%, consistent with previous findings.[11]

However, RDW showed lower specificity, as some beta-thalassemia carriers also exhibited elevated RDW, possibly due to coexisting nutritional deficiencies. This highlights a limitation of using RDW alone as a discriminatory index.

The combined use of the Mentzer Index and RDW improved overall diagnostic accuracy. Patients with low Mentzer Index and normal RDW were highly likely to be beta-thalassemia carriers, whereas those with high Mentzer Index and elevated RDW were more consistent with iron deficiency anemia. Similar conclusions have been drawn by other authors, advocating the use of multiple indices for better

discrimination.[12-15]

Despite its strengths, this study has limitations. The sample size was relatively small, and cases with concomitant iron deficiency and beta-thalassemia trait were not separately analyzed. Further large-scale studies incorporating additional indices may provide more robust diagnostic algorithms.

Limitations of the study

Despite its strengths, this study has limitations. The sample size was relatively small, and cases with concomitant iron deficiency and beta-thalassemia trait were not separately analyzed. Further large-scale studies incorporating additional indices may provide more robust diagnostic algorithms

The limitations of the Mentzer Index and Red Cell Distribution Width (RDW) in distinguishing beta-thalassemia trait from iron deficiency anemia (IDA) mainly stem from their inability to account for coexisting conditions, age-related variations in red blood cell parameters, and cases in which microcytic hypochromic features overlap. Although these indices are useful as preliminary screening tools, they do not provide 100% sensitivity and specificity.

Among the various discriminatory indices, the Mentzer Index is one of the most commonly used, often in combination with Red Cell Distribution Width (RDW) to improve diagnostic accuracy. However, its performance varies across different populations and clinical settings.

In some studies, the Mentzer Index demonstrated a sensitivity of only 29.41% and a specificity of 96.14%, indicating that while it is effective in ruling out iron deficiency anemia, its low sensitivity limits its ability to reliably identify beta-thalassemia trait.

Conclusion

The Mentzer Index (MI) and Red Cell Distribution Width (RDW) are simple, effective, and cost-efficient screening tools for differentiating iron deficiency anemia (IDA) from beta-thalassemia trait. These indices have demonstrated high diagnostic performance, with sensitivity and specificity often approaching 90% for identifying beta-thalassemia trait. A Mentzer Index value of less than 13 is suggestive of beta-thalassemia trait, whereas an elevated Red Cell Distribution Width, typically greater than 16-17%, generally favors iron deficiency anemia. The Mentzer Index is considered more reliable for identifying beta-thalassemia trait, while RDW is more sensitive for detecting iron deficiency anemia. The combined use of these two indices can significantly reduce the need for costly confirmatory investigations and facilitate early diagnosis and appropriate management, particularly in resource-constrained settings.

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