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Original research article

Analysis of haemoglobin to red cell count ratio in individuals with sickle cell anaemia and healthy controls

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Abstract

Background: Sickle cell anaemia (SCA) is a genetic condition characterized by altered hemoglobin structure and function. This study aims to analyze various hematological parameters, emphasizing the haemoglobin to red cell count ratio, among patients with SCA in comparison to healthy controls.

Methods: Hematological parameters including hemoglobin concentration, red cell count, and related ratios were measured for both SCA patients and healthy controls. Parameters were further analyzed based on gender and age demographics.

Results: SCA patients consistently exhibited lower hemoglobin concentration and red cell counts compared to healthy controls. Despite the reduced counts, the hemoglobin to red cell count ratio remained comparable between the two groups. Gender-wise analysis revealed minimal variation in the Hb: RCC ratio. Age-wise breakdown showed a pronounced decline in hemoglobin levels for SCA patients across all age groups. Additionally, a slightly elevated Mean Corpuscular Hemoglobin (MCH) was observed in the SCA group, indicating higher hemoglobin content per red cell.

Conclusions: The findings underline the adaptive erythrocytic alterations in SCA patients, which might be compensatory mechanisms to counterbalance the inherent reduced oxygen-carrying capacity. Understanding these alterations is crucial for developing targeted therapeutic strategies for SCA.

Keywords: Sickle cell anemia, hemoglobin concentration, red cell count, hemoglobin to red cell count ratio, mean corpuscular hemoglobin

Introduction

Sickle cell anemia (SCA) is a hereditary hematological disorder resulting from a single amino acid mutation in the β-globin chain of hemoglobin, leading to the formation of abnormal hemoglobin known as Hemoglobin S (HbS). This anomalous hemoglobin causes erythrocytes to assume a distinctive 'sickle' shape under deoxygenating conditions, resulting in various clinical complications ranging from pain crises to organ damage [1].

The criticality of understanding the hemoglobin content in relation to the red cell count in patients with SCA cannot be overstated. Hemoglobin (Hb), a tetramer protein, is pivotal in transporting oxygen throughout the body, while the red cell count provides an index of the number of erythrocytes available for this transport. The ratio of Hb to red cell count potentially offers a nuanced insight into the functional capacity of erythrocytes, reflecting the oxygen-carrying capacity per cell [2].

Prior studies have postulated that the hemoglobin to red cell count ratio may be notably altered in SCA patients. In their landmark study, Steinberg and colleagues [3] elucidated that in SCA, despite reduced red cell lifespan due to sickling and subsequent hemolysis, there's a compensatory elevation in hemoglobin content in the remaining erythrocytes. This compensatory mechanism aims to augment the oxygen-carrying capacity of the residual non-sickled erythrocytes, which is critical for SCA patients.

Additionally, Platt *et al.* [4] reported that in SCA, the red cell indices, particularly mean corpuscular hemoglobin (MCH) and mean corpuscular volume (MCV), tend to vary considerably when contrasted with healthy controls. These indices, which inherently reflect the hemoglobin content per cell and the size of the red cells respectively, underscore the perturbations in erythropoiesis and hemoglobinization in SCA.

Comparing this ratio with healthy individuals provides a contrastive analysis, offering a clearer depiction of the erythrocytic alterations in SCA. It's well-established that healthy individuals maintain an equilibrium between erythropoiesis and hemoglobin synthesis, ensuring optimal oxygen delivery to tissues. As highlighted by Noguchi & Schechter [5], deviations from the normative Hb to red cell count ratio may indicate aberrant erythropoietic activity or hemoglobin synthesis.

The aim of the study is to analyze and compare the hemoglobin to red cell count ratio between individuals with sickle cell anemia and healthy controls to better understand erythrocytic alterations in the disease, this study of the Hb to red cell count ratio offers a unique vantage point into the

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pathophysiological adaptations in SCA. Comparing this ratio between SCA patients and healthy controls not only enhances our comprehension of the disease but may also illuminate potential therapeutic targets for enhancing the quality of life of SCA patients.

Material and Methods

The cross-sectional, observational study was conducted at Department of Physiology, Mamata Medical College, Khammam, this study includes a total of 200 participants in which 100 individuals in the sickle cell anemia group and 100 in the control group.

Inclusion criteria

1. **Sickle cell anemia group:** Confirmed diagnosis of sickle cell anemia using hemoglobin electrophoresis.
2. **Control group:** Individuals without any known hemoglobinopathies or chronic illnesses.

Exclusion criteria

1. Individuals with other types of hemoglobinopathies or blood disorders.
2. Patients on chronic transfusion therapy.
3. Individuals with any acute illness or infection at the time of study.

Materials

1. Automated Hematology Analyzer for complete blood count (CBC) measurements.
2. Hemoglobin electrophoresis machine to confirm SCA diagnosis.

Methods

Blood collection: 5 ml of venous blood was drawn from each participant using a sterile syringe and dispensed into ethylene diamine tetra acetic acid (EDTA) tubes.

Hemoglobin and Red cell count analysis

- The samples were analyzed within 2 hours of collection using the Automated Hematology Analyzer.
- Hemoglobin concentration and red cell count were recorded for each participant.

Calculation of hemoglobin to red cell count ratio: For each participant, the hemoglobin to red cell count ratio was calculated by dividing the hemoglobin concentration (g/dL) by the red cell count (in millions per μL).

Statistical analysis: Data was analyzed using SPSS software. Descriptive statistics (mean, standard deviation) were used for demographics and baseline characteristics. A p-value of <0.05 was considered statistically significant.

Results

Table 1: Gender-wise Distribution of Hemoglobin to Red Cell Count Ratio in Both Groups

Gender	Group	Hb: RCC Ratio (Mean ± SD)	Number of Participants
Male	Sickle Cell Anemia	2.8 ± 0.5	50
Male	Healthy Control	2.7 ± 0.4	50
Female	Sickle Cell Anemia	3.0 ± 0.6	50
Female	Healthy Control	2.9 ± 0.5	50

Table 1 presents the gender-specific distribution of the Hemoglobin to Red Cell Count Ratio (Hb: RCC) for both sickle cell anemia patients and healthy controls. Both male and female sickle cell anemia patients have slightly higher Hb: RCC ratios than their healthy counterparts, but the differences are minimal, highlighting a consistency in this ratio across genders and groups.

Table 2: Age-wise Distribution of Hemoglobin Concentration in Both Groups

Age Group	Group	Hemoglobin Concentration (g/dL, Mean ± SD)
20-30	Sickle Cell Anemia	9.5 ± 1.4
20-30	Healthy Control	14.7 ± 1.2
31-40	Sickle Cell Anemia	9.0 ± 1.6
31-40	Healthy Control	14.4 ± 1.0
41-50	Sickle Cell Anemia	8.8 ± 1.5
41-50	Healthy Control	14.2 ± 0.9

Table 2 delineates the age-wise distribution of hemoglobin concentrations for sickle cell anemia patients

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and healthy controls. Across all age groups, sickle cell anemia patients consistently exhibit lower hemoglobin levels compared to the healthy controls, emphasizing the anemic nature of the disease across different age brackets.

Table 3: Distribution of Mean Corpuscular Hemoglobin (MCH) in Both Groups

Parameter	Sickle Cell Anemia Group (Mean ± SD, pg/cell)	Healthy Control Group (Mean ± SD, pg/cell)
MCH	28.8 ± 2.5	28.5 ± 1.8

Table 3 compares the Mean Corpuscular Hemoglobin (MCH) values between sickle cell anemia patients and healthy controls. The data reveals a slight increase in MCH for the sickle cell group, suggesting that, on average, individual sickled red cells carry slightly more hemoglobin than the cells of healthy controls.

Table 4: Hematocrit Levels in Both Groups

Group	Hematocrit (%, Mean ± SD)
Sickle Cell Anemia	27.5 ± 4.2
Healthy Control	42.0 ± 3.5

Table 4 contrasts the hematocrit levels between sickle cell anemia patients and healthy controls. Sickle cell patients exhibit a notably reduced hematocrit (27.5%) compared to healthy individuals (42.0%), indicating a decreased proportion of blood volume occupied by red cells in the sickle cell group.

Table 5: Comparison of Hemoglobin (Hb) Concentration, Red Cell Count (RCC) and Hemoglobin to Red Cell Count Ratio (Hb: RCC) between SCA Patients and Healthy Controls

Parameter	Sickle Cell Anemia Group (Mean ± SD)	Healthy Control Group (Mean ± SD)	p-value*
Number of Participants	100	100	-
Hemoglobin Concentration (g/dL)	9.2 ± 1.5	14.5 ± 1.0	<0.001
Red Cell Count (millions/μL)	3.2 ± 0.8	5.1 ± 0.6	<0.001
Hb:RCC Ratio	2.9 ± 0.6	2.8 ± 0.5	0.45

p-value derived from the Student's t-test. A p-value of less than 0.05 was considered statistically significant.

Above table shows, Sickle Cell Anemia Group exhibits a lower mean hemoglobin concentration (9.2 g/dL) compared to the Healthy Control Group (14.5 g/dL), indicative of the anemic condition associated with the disease. Similarly, the red cell count is reduced in the Sickle Cell Anemia Group (3.2 million/μL) relative to the Healthy Control Group (5.1 million/μL), reflecting the increased destruction of malformed sickle cells. The Hemoglobin to Red Cell Count Ratio (Hb:RCC), which represents the average hemoglobin content per red cell, is nearly comparable between the two groups: 2.9 for the Sickle Cell Anemia Group and 2.8 for the Healthy Control Group.

Discussion

The comparison of various hematological parameters between sickle cell anemia patients and healthy controls provides a comprehensive understanding of the erythrocytic alterations in sickle cell disease. Present observations established the baseline differences in hemoglobin concentration and red cell count between the two groups. As expected, the sickle cell group exhibited lower values for both parameters, in line with previously documented anemic conditions associated with the disease (Rees, Williams, & Gladwin, 2010). However, a striking observation was the similarity in the hemoglobin to red cell count ratio between the groups. This might suggest that the remaining erythrocytes in sickle cell patients might have a compensatory increase in hemoglobin content. This phenomenon was also noted by Kato and group [5], who hypothesized that such adaptations might help maintain oxygen-carrying capacity.

Our results provided a gender-specific breakdown of the Hb:RCC ratio. Interestingly, the difference in the ratio between the sickle cell anemia patients and healthy controls was minimal, regardless of gender. This uniformity across genders could indicate a universal compensatory mechanism that isn't gender-dependent. Earlier studies by Stuart & Nagel [6] support this observation, highlighting minimal gender-based variations in hematological parameters among sickle cell patients.

The age-wise breakdown of hemoglobin concentrations reaffirms the chronic anemic state of sickle cell patients across different age brackets. Previous studies [8] have consistently shown declining hemoglobin levels with age in sickle cell patients, but the exact mechanism remains under study. It is worth noting that while there's a decline in hemoglobin concentration with age in both groups, the decline is more pronounced in sickle cell patients.

The slightly elevated Mean Corpuscular Hemoglobin (MCH) in the sickle cell group suggests higher hemoglobin content per red cell. This might be linked to the bone marrow's response to chronic hemolysis, producing red cells that are denser in hemoglobin to compensate for the reduced number of

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cells. This observation aligns with findings from Pauling & Itano [9], where erythrocyte adaptations in sickle cell patients were reported.

There was a marked difference in hematocrit levels. The decreased hematocrit in sickle cell patients aligns with their known reduced red cell lifespan and increased hemolysis [10]. Furthermore, this difference emphasizes the reduced oxygen-carrying capacity in sickle cell patients, correlating with clinical manifestations like fatigue and dyspnea.

In conclusion, the hematological differences highlighted in this study provide a deeper understanding of the erythrocytic alterations in sickle cell anemia. The findings resonate with previous research, emphasizing the adaptive and maladaptive changes that occur in sickle cell anemia. These insights not only enhance our knowledge about the disease but also pave the way for targeted therapeutic strategies.

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