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Original Research Article

Correlation of Hemoglobin Levels with Oxygen Saturation and Resting Heart Rate in Patients with Chronic Anemia: A Cross-Sectional Study from a Tertiary Care Center

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Abstract:

Background: Chronic anemia leads to reduced oxygen-carrying capacity of blood and triggers physiological compensatory mechanisms, particularly involving the cardiovascular and respiratory systems. Assessment of these adaptations using simple, non-invasive physiological parameters may provide valuable insights into the severity and functional impact of anemia, especially in resource-limited settings.

Objectives: (1) To assess resting oxygen saturation and heart rate in patients with chronic anemia. (2) To correlate hemoglobin levels with oxygen saturation and resting heart rate. (3) To evaluate the physiological compensatory response to chronic anemia using routinely available clinical parameters.

Materials and Methods: This hospital-based cross-sectional study was conducted at a tertiary care center over a defined study period. Patients diagnosed with chronic anemia were enrolled after obtaining informed consent. Hemoglobin levels were estimated using automated hematology analyzers. Resting oxygen saturation was measured using a finger pulse oximeter, and heart rate was recorded after adequate rest. Statistical analysis was performed to assess correlations between hemoglobin concentration and physiological parameters.

Results: A significant negative correlation was observed between hemoglobin levels and resting heart rate, indicating increasing tachycardia with declining hemoglobin concentration. Hemoglobin levels showed a mild but statistically significant positive correlation with oxygen saturation. These findings reflect physiological cardiovascular compensation in chronic anemia.

Conclusion: Hemoglobin levels in chronic anemia correlate significantly with resting heart rate and, to a lesser extent, with oxygen saturation. Simple physiological measurements such as pulse rate and oxygen saturation can serve as useful adjuncts in assessing the functional severity of chronic anemia, particularly in resource-constrained healthcare settings.

Keywords: Chronic Anemia, Hemoglobin, Oxygen Saturation, Heart Rate, Physiological Compensation.
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Introduction

Anemia continues to be a major public health problem in India, affecting a substantial proportion of children, women of reproductive age, and elderly individuals. According to the World Health Organization, anemia remains highly prevalent in developing countries and contributes significantly to morbidity and reduced quality of life. [1] While nutritional deficiencies are the most common cause, chronic anemia resulting from hemoglobinopathies, chronic infections, renal disorders, and autoimmune diseases is frequently encountered in tertiary care hospitals. [2] Chronic anemia is associated not only with reduced hemoglobin levels but also with sustained physiological adaptations aimed at maintaining adequate tissue oxygen delivery. [3]

Hemoglobin plays a central role in oxygen transport, and a persistent reduction in hemoglobin concentration leads to decreased arterial oxygen content. To compensate, the body activates multiple adaptive mechanisms including increased cardiac output, redistribution of blood flow, and alterations in respiratory physiology. [3] Among these, an increase in resting heart rate represents a key cardiovascular response that helps preserve oxygen delivery to vital organs. Oxygen saturation, although often maintained within the normal range at rest in chronic anemia, may demonstrate subtle reductions reflecting the limits of physiological compensation. [4]

The assessment of anemia traditionally relies on hematological parameters such as hemoglobin concentration and red cell indices. However, these laboratory parameters alone do not adequately reflect the functional impact of anemia on tissue oxygenation and cardiovascular workload. Physiological measurements such as heart rate and oxygen saturation provide real-time insight into the body's response to reduced oxygen-carrying capacity and may serve as useful adjuncts to routine hematological evaluation. [5]

In resource-limited healthcare settings, particularly in smaller cities and district-level medical colleges in India, access to advanced investigations for evaluating tissue hypoxia or cardiovascular function is often limited. Simple, non-invasive tools such as pulse oximetry and resting heart rate measurement are widely available, cost-effective, and easy to incorporate into routine clinical practice. [6] Despite this practical advantage, limited data are available correlating hemoglobin levels with basic physiological parameters in patients with chronic anemia in the Indian population. [7]

The present study was therefore undertaken to evaluate the relationship between hemoglobin concentration, oxygen saturation, and resting heart rate in patients with chronic anemia attending a tertiary care center. By correlating hematological and physiological parameters, this study aims to highlight the clinical utility of simple physiological measurements in assessing the severity and functional consequences of chronic anemia in resource-constrained settings. [7]

Materials asnd Methods

Study Design: A hospital-based observational cross-sectional study.

Study Setting: The study was conducted in the Departments of Pathology and Physiology at a tertiary care teaching hospital.

Study Duration: The study was carried out over a period of one year.

Study Population: Patients diagnosed with chronic anemia attending outpatient departments or admitted to wards during the study period were included.

Definition of Chronic Anemia: Chronic anemia was defined as hemoglobin levels below World Health Organization cut-off values persisting for more than three months, based on clinical history and available laboratory records.

Sample Size: A total of 60 patients with chronic anemia were enrolled in the study.

Inclusion Criteria

- Patients aged ≥18 years
- Both sexes
- Laboratory-confirmed anemia of chronic duration
- Willingness to participate and provide informed consent

Exclusion Criteria

- Acute blood loss anemia
- Recent blood transfusion (within the past 4 weeks)
- Known chronic lung disease (e.g., COPD, interstitial lung disease)
- Congenital or acquired heart disease
- Acute febrile illness or sepsis
- Peripheral vascular disease affecting pulse oximetry readings

Hematological Assessment: Venous blood samples were collected under aseptic precautions. Hemoglobin concentration was estimated using an automated hematology analyzer calibrated according to standard laboratory protocols.

Physiological Assessment

Measurement of Oxygen Saturation: Oxygen saturation (SpO_2) was measured using a portable finger pulse oximeter. Patients were allowed to rest in a seated position for at least five minutes before recording. Measurements were taken on the index finger of the non-dominant hand. Nail polish, artificial nails, or cold extremities were avoided to prevent erroneous readings. The highest stable SpO_2 value recorded over a 30-second period was documented.

Measurement of Resting Heart Rate: Resting heart rate was recorded simultaneously using the pulse oximeter and cross-verified manually by palpating the radial pulse for one full minute.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS software (version 26.0). Quantitative variables were expressed as mean ± standard deviation. Pearson's correlation coefficient was used to assess the relationship between hemoglobin levels and physiological parameters. A p-value <0.05 was considered statistically significant.

Results

A total of 60 patients with chronic anemia were included in the study. The study population comprised both male and female patients across a wide adult age range. The mean hemoglobin concentration indicated moderate to severe anemia in the majority of participants.

Table 1: Demographic and Hemoglobin Profile of Study Participants (N = 60)

Parameter	Mean ± SD	Range
Age (years)	41.6 ± 13.2	19 – 68
Hemoglobin (g/dL)	7.9 ± 1.6	4.8 – 10.9
Male: Female ratio	1.1: 1	NA

Resting physiological parameters demonstrated evidence of cardiovascular compensation. As hemoglobin levels decreased, an increase in resting heart rate was observed. Oxygen saturation values were largely maintained within the normal range; however, a mild decline was noted in patients with lower hemoglobin levels.

Table 2: Resting Physiological Parameters in Patients with Chronic Anemia

Parameter	Mean ± SD	Range	Reference Range
Oxygen Saturation (SpO_2, %)	95.2 ± 2.1	90 – 99	95 – 100
Resting Heart Rate (beats/min)	92 ± 14	68 – 112	60 – 100

Correlation analysis revealed a statistically significant negative correlation between hemoglobin concentration and resting heart rate. Hemoglobin levels also showed a mild but statistically significant positive correlation with oxygen saturation.

Table 3: Correlation Between Hemoglobin Levels and Physiological Parameters

Comparison	r-value	p-value
Hemoglobin vs Oxygen Saturation (SpO_2)	+0.42	0.002*
Hemoglobin vs Resting Heart Rate	–0.68	<0.001*

$p < 0.05$ considered statistically significant

Discussion

The present study evaluated the relationship between hemoglobin concentration and simple physiological parameters, namely oxygen saturation and resting heart rate, in patients with chronic anemia. Chronic anemia is characterized by a sustained reduction in the oxygen-carrying capacity of blood, leading to long-term physiological adaptations aimed at preserving tissue oxygen delivery. Understanding these compensatory mechanisms is clinically important, particularly in resource-limited settings where advanced cardiopulmonary investigations are often unavailable. [3]

In the current study, a significant negative correlation was observed between hemoglobin levels and resting heart rate. Patients with lower hemoglobin concentrations demonstrated higher resting heart rates, reflecting increased cardiac output as a compensatory response to reduced arterial oxygen content. This finding is consistent with established physiological principles, wherein tachycardia represents a primary cardiovascular adaptation to chronic hypoxia in order to maintain adequate oxygen delivery to vital organs. [3] The strength of the correlation observed in this study suggests that resting heart rate may serve as a simple and reliable functional indicator of anemia severity.

Similar observations were reported by Weiskopf et al., who demonstrated that progressive reductions in hemoglobin concentration are associated with compensatory increases in heart rate and cardiac output, even in the absence of overt cardiopulmonary disease. [1] Their findings highlighted the dominant role of cardiovascular adaptations in maintaining oxygen delivery during anemia, which is in agreement with the results of the present study.

Oxygen saturation values in this study were largely preserved within the normal range at rest, although a mild but statistically significant positive correlation with hemoglobin concentration was observed. This indicates that while pulmonary gas exchange remains intact in most cases of chronic anemia, lower hemoglobin levels may still be associated with subtle reductions in measured SpO_2. This observation underscores the important physiological distinction between oxygen saturation and oxygen content, as oxygen saturation alone does not reflect the reduced oxygen-carrying capacity of blood in anemia. [4]

These findings are consistent with the observations of Cohen and Haas, who reported that patients with chronic anemia often maintain near-normal oxygen saturation at rest despite significant reductions in hemoglobin concentration, owing to effective compensatory mechanisms. [2] However, they also emphasized that such compensation has physiological limits, particularly in cases of severe anemia or during periods of increased metabolic demand. The mild correlation observed in the present study likely reflects this balance between

preserved pulmonary function and reduced hemoglobin-mediated oxygen transport.

The inverse relationship between hemoglobin concentration and resting heart rate observed in this study further supports the concept that heart rate may be a more sensitive physiological marker of anemia severity than resting oxygen saturation alone. From a clinical perspective, this has important implications, as pulse rate measurement is universally available, non-invasive, inexpensive, and easy to perform. When interpreted alongside hemoglobin values, resting heart rate can provide valuable insight into the functional impact of chronic anemia beyond laboratory measurements alone. [5]

From an Indian healthcare perspective, these findings assume particular relevance. In many district-level hospitals and medical colleges, access to advanced diagnostic modalities such as echocardiography, arterial blood gas analysis, or cardiopulmonary exercise testing is limited. Simple tools such as pulse oximetry and resting heart rate assessment offer a pragmatic and cost-effective approach to evaluating physiological adaptation in patients with chronic anemia. [6] The results of the present study suggest that integrating basic physiological measurements into routine anemia assessment may enhance clinical evaluation without increasing diagnostic burden.

A study by Singh et al., conducted in an Indian population, similarly reported increased resting heart rate and reduced functional capacity in patients with moderate to severe anemia, reinforcing the relevance of cardiovascular compensation in chronic anemia within the Indian context. [7] Their findings, together with those of the present study, support the utility of simple physiological parameters as adjuncts to hematological assessment in routine clinical practice.

Nevertheless, it is important to recognize that oxygen saturation and heart rate can be influenced by factors other than anemia, including anxiety, dehydration, autonomic variability, and subclinical infections. Therefore, these parameters should be interpreted in conjunction with hematological findings and overall clinical assessment rather than in isolation.

Overall, the present study demonstrates that chronic anemia is associated with predictable physiological adaptations, most notably tachycardia, with relatively preserved oxygen saturation at rest. The observed correlations reinforce the role of simple physiological measurements as useful adjuncts in assessing the functional severity of chronic anemia, particularly in settings with limited diagnostic resources.

Conclusion

Hemoglobin levels in patients with chronic anemia show a significant negative correlation with resting heart rate and a mild but significant positive correlation with oxygen saturation. These findings reflect physiological cardiovascular compensation to reduced oxygen-carrying capacity in chronic anemia. Simple, non-invasive physiological measurements such as heart rate and oxygen saturation can serve as useful adjuncts to hematological parameters in assessing the functional severity of chronic anemia, particularly in resource-limited healthcare settings.

Limitations: The study was limited by a relatively small sample size and a single-center design. Etiological classification of anemia and assessment of dynamic changes during exertion were not performed. The cross-sectional nature of the study precluded evaluation of longitudinal physiological changes with treatment.

Recommendations: Larger multicentric studies are recommended to further validate these findings and to explore the role of physiological parameters in monitoring treatment response. Incorporation of simple physiological assessment alongside routine hematological evaluation may improve clinical assessment of chronic anemia in routine practice.

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