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A CLINICAL STUDY OF ELECTROCARDIOGRAPHIC CHANGES IN ANEMIC PATIENTS BEFORE AND AFTER BLOOD TRANSFUSION

General Medicine

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ABSTRACT

Background: Anaemia is a prevalent clinical condition that significantly impacts cardiovascular physiology due to reduced oxygen-carrying capacity and compensatory hemodynamic changes. These alterations may manifest as electrocardiographic (ECG) abnormalities, often mimicking primary cardiac disease. The severity of anaemia has been shown to correlate with the extent of ECG changes, many of which are reversible following appropriate correction, particularly with blood transfusion.

Aim: To evaluate electrocardiographic changes in patients with anemia and assess their reversibility following blood transfusion.

Objectives:

1. To identify common ECG abnormalities in patients with anemia.
2. To correlate ECG findings with hemoglobin levels.
3. To assess changes in ECG parameters before and after blood transfusion.

Materials and Methods: This prospective observational study was conducted on 50 patients diagnosed with moderate to severe anemia (hemoglobin <8 g/dL). Patients above 18 years of age were included after applying appropriate exclusion criteria to eliminate confounding cardiac and systemic conditions. Baseline clinical evaluation, hematological investigations, and 12-lead ECG recordings were performed on Day 1. Patients underwent appropriate management including blood transfusion and supportive therapy. Repeat ECG and hemoglobin estimation were performed on Day 4 following correction of anemia. Data were analyzed using SPSS software. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Statistical significance was determined using appropriate tests including paired comparisons and ANOVA, with $p<0.05$ considered significant. **Results:** The mean age of study participants was 50.7 ± 16.8 years, with a male predominance (64%). The mean hemoglobin level improved significantly from 5.8 ± 0.9 g/dL on Day 1 to 8.7 ± 0.8 g/dL on Day 4. ECG abnormalities were observed in the majority of patients at baseline, with sinus tachycardia being the most common finding (64%), followed by sinus tachycardia with T wave changes (32%) and ST segment depression (2%). A significant association was observed between lower hemoglobin levels and the presence of ECG abnormalities ($p<0.001$). Following blood transfusion, there was a marked reversal of ECG changes, with most patients demonstrating normalization of ECG parameters. **Conclusion:** Electrocardiographic abnormalities are frequently observed in patients with moderate to severe anemia and are strongly associated with the degree of hemoglobin reduction. These changes are largely reversible following correction of anemia with blood transfusion, underscoring the importance of early recognition and timely management to prevent misdiagnosis of primary cardiac pathology.

KEYWORDS

Anaemia, Electrocardiographic Changes, Hemoglobin, Blood Transfusion, Sinus Tachycardia, T Wave Changes, ST Segment Depression

INTRODUCTION

Anaemia remains one of the most prevalent hematological disorders worldwide and continues to pose a significant public health burden, particularly in developing countries. It is defined by a reduction in hemoglobin concentration, resulting in decreased oxygen-carrying capacity of blood and subsequent tissue hypoxia [1]. The clinical manifestations of anaemia depend on its severity, duration, and the compensatory capacity of the cardiovascular system. While mild anaemia may be asymptomatic, moderate to severe anaemia can lead to significant systemic and cardiovascular alterations [2].

The cardiovascular system plays a central role in compensating for the reduced oxygen delivery in anaemia. Physiological adaptations include increased cardiac output, tachycardia, reduced peripheral vascular resistance, and increased plasma volume. These changes are primarily aimed at maintaining adequate tissue oxygenation [3]. However, persistent or severe anaemia leads to a hyperdynamic circulatory state, which increases myocardial workload and oxygen demand. When the compensatory mechanisms are overwhelmed, a mismatch between myocardial oxygen supply and demand may occur, potentially resulting in myocardial ischemia or functional cardiac disturbances [4].

Electrocardiography (ECG) serves as a simple, non-invasive, and widely available tool to assess cardiac function. In patients with anaemia, a variety of ECG changes have been reported, reflecting the underlying hemodynamic and metabolic stress on the myocardium [5]. Commonly observed abnormalities include sinus tachycardia, ST segment depression, T wave inversion or flattening, and occasionally prolongation of QT interval or features suggestive of left ventricular hypertrophy in chronic cases. These changes may resemble those seen in ischemic heart disease, thereby creating diagnostic confusion, especially in the absence of prior cardiac history [6].

Several studies have demonstrated a significant correlation between the severity of anaemia and the presence as well as extent of ECG abnormalities. Patients with lower hemoglobin levels, particularly below 5 g/dL, are more likely to exhibit pronounced electrocardiographic changes [7]. The pathophysiological basis of these changes includes reduced oxygen delivery to the myocardium, increased cardiac workload, and alterations in myocardial repolarization due to hypoxia. Additionally, changes in blood viscosity and hemodynamic parameters further contribute to electrical instability of the myocardium [8].

An important and clinically relevant aspect of anaemia-induced ECG changes is their reversibility. With appropriate treatment, particularly blood transfusion and correction of hemoglobin levels, most of these electrocardiographic abnormalities tend to resolve. This reversibility indicates that these changes are largely functional rather than structural, distinguishing them from primary cardiac diseases. Recognition of this phenomenon is essential to avoid misdiagnosis and unnecessary cardiac interventions [9,10].

Despite the known association between anaemia and ECG changes, there is limited data evaluating the pattern of electrocardiographic abnormalities and their reversibility following blood transfusion in the Indian population. Moreover, the extent to which hemoglobin

improvement translates into normalization of ECG findings requires further systematic evaluation.

In this context, the present study was undertaken to assess the electrocardiographic changes in patients with moderate to severe anaemia, to correlate these changes with hemoglobin levels, and to evaluate the reversibility of these abnormalities following blood transfusion.

Aims and Objectives

Aim:

To study electrocardiographic changes in patients with anemia and to evaluate their reversibility following blood transfusion.

Objectives:

1. To identify the common electrocardiographic abnormalities in patients with moderate to severe anemia.
2. To correlate electrocardiographic changes with hemoglobin levels.
3. To assess the changes in electrocardiographic parameters before and after blood transfusion.
4. To evaluate the reversibility of electrocardiographic abnormalities following correction of anemia.

MATERIALS AND METHODS

Study Design: This study was a prospective observational study.

Study Setting: The study was conducted in the Department of General Medicine at Meenakshi Medical College Hospital and Research Institute, Kanchipuram, Tamil Nadu.

Study Duration: The study was carried out over a period of one year from May 2025 to May 2026.

Sample Size: A total of 50 patients were included in the study.

Study Population: Patients admitted to the medicine wards and those attending outpatient services with moderate to severe anemia were included in the study.

Inclusion Criteria:

1. Patients aged ≥18 years.
2. Male and female patients with hemoglobin less than 8 g/dL.
3. Patients willing to participate and providing informed consent.

Exclusion Criteria:

1. Patients with a recent history of major blood loss.
2. Patients with pre-existing heart diseases such as valvular heart disease, congenital heart disease, hypertensive heart disease, or thyrotoxicosis.
3. Patients with systemic conditions affecting cardiorespiratory dynamics such as renal failure, cor pulmonale, tuberculosis, and other respiratory diseases.
4. Pregnant women.
5. Patients with leukemia.

Study Procedure

All patients underwent detailed clinical evaluation including history taking and physical examination. Baseline laboratory investigations were performed, including complete hemogram with red cell indices (hemoglobin, RBC count, hematocrit, MCV, MCH, MCHC, RDW), platelet count, and peripheral smear examination.

A standard 12-lead electrocardiogram (ECG) was recorded for all patients on Day 1 (before treatment). ECGs were analyzed for the presence of abnormalities such as:

- Sinus tachycardia
- ST segment depression
- T wave inversion or flattening
- Other relevant changes if present

Patients were treated appropriately with blood transfusion and supportive therapy as indicated. Following correction of anemia, repeat hemoglobin estimation and ECG were performed on Day 4.

Outcome Measures:

1. Presence and type of ECG abnormalities before treatment.
2. Change in hemoglobin levels after treatment.
3. Reversal or persistence of ECG changes following blood transfusion.

Statistical Analysis:

Data were entered into Microsoft Excel and analyzed using SPSS software (version 25.0). Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Statistical tests such as paired t-test and ANOVA were used to assess differences between pre- and post-treatment values. Chi-square test was applied for categorical data. A p-value of less than 0.05 was considered statistically significant.

Results Summary:

A total of 50 patients with moderate to severe anemia were included in the study. The mean age was 50.7 ± 16.8 years, with the majority belonging to the 41–50 years age group. There was a male predominance (64%). The mean hemoglobin increased significantly from 5.8 ± 0.9 g/dL on Day 1 to 8.7 ± 0.8 g/dL on Day 4 following blood transfusion. The most common presenting complaints were generalized weakness, breathlessness, and loss of appetite. Sinus tachycardia was the most common ECG abnormality observed, followed by T wave changes and ST segment depression. A significant association was observed between lower hemoglobin levels and ECG abnormalities ($p<0.001$). Most ECG changes showed reversal after correction of anemia.

Table 1: Age-wise Distribution of Study Participants

Age group (years)	Number of patients	Percentage (%)
≤20	4	8
21–30	2	4
31–40	7	14
41–50	16	32
51–60	5	10
61–70	12	24
>70	4	8
Total	50	100

Table 1 shows that the majority of patients belonged to the 41–50 years age group, followed by the 61–70 years age group.

Table 2: Gender Distribution of Study Participants

Gender	Number of patients	Percentage (%)
Male	32	64
Female	18	36
Total	50	100

Table 2 shows that males constituted the majority of the study population.

Table 3: Age Distribution According to Gender

Age group (years)	Male (n, %)	Female (n, %)
≤20	0 (0.0)	4 (22.2)
21–30	1 (3.1)	1 (5.6)
31–40	4 (12.5)	3 (16.7)
41–50	13 (40.6)	3 (16.7)
51–60	4 (12.5)	1 (5.6)
61–70	7 (21.9)	5 (27.8)
>70	3 (9.4)	1 (5.6)
Total	32 (100)	18 (100)

Table 3 shows that the highest number of male patients were in the 41–50 years group, while females were more evenly distributed.

Table 4: Hemoglobin Levels before and After Treatment

Parameter	Range	Mean	SD	Median
Day 1 Hb (g/dL)	3.2–7	5.8	0.9	6
Day 4 Hb (g/dL)	6.8–10	8.7	0.8	8.9

Table 4 shows a significant increase in hemoglobin levels following blood transfusion.

Table 5: Presenting Complaints of Patients

Presenting complaints	Number of patients	Percentage (%)
Generalized weakness, breathlessness and loss of appetite	30	60
Easy fatigability, loss of appetite	10	20
Breathlessness, loss of appetite and easy fatigability	4	8
Generalized weakness and breathlessness	2	4
Others	4	8
Total	50	100

Table 5 shows that generalized weakness with breathlessness and loss of appetite was the most common presentation.

Table 6: ECG Changes on Day 1

ECG findings	Number of patients	Percentage (%)
Normal	1	2
Sinus tachycardia	32	64
Sinus tachycardia with T wave changes	16	32
ST segment depression	1	2
Total	50	100

Table 6 shows that sinus tachycardia was the most common ECG abnormality.

Table 7: Type of Anemia Among Study Participants

Type of anemia	Number of patients	Percentage (%)
Microcytic hypochromic	22	44
Dimorphic	16	32
Macrocytic	12	24
Total	50	100

Table 7 shows that microcytic hypochromic anemia was the most common type.

Table 8: ECG Changes in Relation to Hemoglobin Levels (Day 1 vs Day 4)

ECG change	Day 1 Hb Mean ± SD	Day 4 Hb Mean ± SD	p value
Normal	6.2 ± 0.0	8.0 ± 0.0	-
Sinus tachycardia	6.1 ± 0.7	9.0 ± 0.7	<0.001*
Sinus tachycardia with T wave changes	5.4 ± 0.8	8.3 ± 0.8	<0.001*
ST segment depression	3.2 ± 0.0	7.2 ± 0.0	-

Table 8 shows significant improvement in hemoglobin levels across all ECG categories.

Table 9: Overall ECG Abnormality Prevalence

ECG status	Number of patients	Percentage (%)
Abnormal ECG	49	98
Normal ECG	1	2
Total	50	100

Table 9 shows that ECG abnormalities were present in 98% of patients.

Table 10: Severity of Anemia and ECG Changes Correlation

Hb range (g/dL)	ECG abnormality present (n)	Percentage (%)
3–5	High	Majority
5–7	Moderate	Moderate

Table 10 shows that more severe anemia was associated with more significant ECG abnormalities.

Table 11: Reversibility of ECG Changes After Treatment

ECG outcome after treatment	Number of patients	Percentage (%)
Complete reversal	49	98
Partial/no reversal	1	2
Total	50	100

Table 11 shows that most ECG abnormalities resolved after correction of anemia.

Table 12: Statistical Significance of ECG Changes with Hemoglobin Improvement

Parameter	p value	Significance
Hb vs ECG changes	<0.001	Significant

Table 12 shows a significant association between hemoglobin improvement and ECG normalization.

Table 1 shows that the highest number of patients belonged to the 41–50 years age group with 16 patients (32%), followed by the 61–70 years group with 12 patients (24%), indicating that middle-aged and elderly individuals constituted the majority of the study population.

Table 2 shows that out of 50 patients, 32 were males (64%) and 18 were females (36%), demonstrating a clear male predominance in the study population.

Table 3 shows that among males, the majority were in the 41–50 years age group with 13 patients (40.6%), followed by 61–70 years with 7 patients (21.9%), whereas females were relatively more distributed, with the highest proportion in 61–70 years (5 patients, 27.8%) and ≤20 years (4 patients, 22.2%).

Table 4 shows that the mean hemoglobin level increased from 5.8 ± 0.9 g/dL on Day 1 to 8.7 ± 0.8 g/dL on Day 4, indicating a significant improvement of approximately 2.9 g/dL following blood transfusion and treatment.

Table 5 shows that the most common presenting complaint was generalized weakness associated with breathlessness and loss of appetite seen in 30 patients (60%), followed by easy fatigability with loss of appetite in 10 patients (20%), indicating that fatigue-related symptoms predominated in anemic patients.

Table 6 shows that sinus tachycardia was the most common ECG abnormality observed in 32 patients (64%), followed by sinus tachycardia with T wave changes in 16 patients (32%), while only 1 patient (2%) had ST segment depression and 1 patient (2%) had a normal ECG, indicating a high prevalence of ECG abnormalities (98%).

Table 7 shows that microcytic hypochromic anemia was the most common type seen in 22 patients (44%), followed by dimorphic anemia in 16 patients (32%) and macrocytic anemia in 12 patients (24%), suggesting iron deficiency as the predominant etiology.

Table 8 shows that patients with sinus tachycardia had a mean hemoglobin of 6.1 ± 0.7 g/dL on Day 1 which increased to 9.0 ± 0.7 g/dL on Day 4, while those with sinus tachycardia with T wave changes improved from 5.4 ± 0.8 g/dL to 8.3 ± 0.8 g/dL, both showing statistically significant improvement ($p<0.001$), indicating a strong association between hemoglobin correction and ECG normalization.

Table 9 shows that ECG abnormalities were present in 49 out of 50 patients (98%), while only 1 patient (2%) had a normal ECG, highlighting the strong association between anemia and electrocardiographic changes.

Table 10 shows that patients with lower hemoglobin levels (3–5 g/dL) exhibited more severe ECG abnormalities compared to those with relatively higher hemoglobin levels (5–7 g/dL), indicating that severity of anemia directly influences the extent of ECG changes.

Table 11 shows that complete reversal of ECG abnormalities was observed in 49 patients (98%) after treatment, while only 1 patient (2%) showed partial or no reversal, confirming that most ECG changes in anemia are reversible.

Table 12 shows that there was a statistically significant association between hemoglobin improvement and ECG normalization with a p value of <0.001, confirming that correction of anemia leads to significant improvement in cardiac electrical activity.

Discussion

The present study was conducted to evaluate electrocardiographic changes in patients with moderate to severe anemia and to assess their reversibility following correction with blood transfusion. The findings of this study demonstrate a clear association between the severity of anemia and the presence of ECG abnormalities, along with significant reversibility after treatment.

In the present study, the majority of patients belonged to the 41–50 years age group (32%), with a mean age of 50.7 ± 16.8 years. There was a male predominance (64%). This demographic pattern is comparable to similar observational studies, where middle-aged individuals constituted the majority of cases. The higher proportion of males in this study may be attributed to healthcare-seeking behavior and referral patterns rather than true disease prevalence [11,12].

The mean hemoglobin level at baseline was 5.8 ± 0.9 g/dL, which improved significantly to 8.7 ± 0.8 g/dL following blood transfusion. This rise of approximately 3 g/dL is consistent with standard transfusion outcomes and indicates effective correction of anemia. Similar improvements in hemoglobin levels have been reported in comparable studies evaluating severe anemia and its cardiovascular impact [13].

Electrocardiographic abnormalities were highly prevalent in the present study, observed in 98% of patients. Sinus tachycardia was the

most common finding (64%), followed by sinus tachycardia with T wave changes (32%) and ST segment depression (2%). These findings are consistent with previously reported studies, where sinus tachycardia and repolarization abnormalities were the most frequent ECG changes in anemia . The presence of tachycardia reflects the compensatory mechanism of increased cardiac output in response to reduced oxygen-carrying capacity [14,15].

T wave changes and ST segment depression observed in this study suggest myocardial repolarization abnormalities secondary to tissue hypoxia. These findings can mimic ischemic heart disease and may lead to diagnostic confusion if anemia is not considered as an underlying cause. The pathophysiological basis of these changes lies in reduced oxygen delivery to the myocardium and increased cardiac workload, resulting in supply-demand mismatch [16].

A significant correlation was observed between hemoglobin levels and ECG changes. Patients with lower hemoglobin levels (particularly in the range of 3–5 g/dL) exhibited more pronounced ECG abnormalities compared to those with relatively higher levels. This finding is in agreement with earlier studies, which have demonstrated that the severity of anemia directly influences the extent of electrocardiographic changes . The statistical significance observed in this study ($p<0.001$) further strengthens this association [17].

One of the most important observations in the present study was the reversibility of ECG changes following correction of anemia. After treatment, 98% of patients showed complete normalization of ECG findings, while only one patient showed partial persistence of abnormalities. This is consistent with previous studies, where most ECG changes were found to be reversible after appropriate management of anemia . This reversibility suggests that these changes are functional rather than structural in nature [18,19].

The most common type of anemia observed in this study was microcytic hypochromic anemia (44%), followed by dimorphic anemia (32%) and macrocytic anemia (24%). This distribution indicates that iron deficiency anemia remains the predominant cause, which aligns with the epidemiological profile in developing countries. Although the type of anemia was not directly correlated with ECG changes in this study, it provides insight into the underlying etiology [20].

The clinical implications of this study are significant. ECG abnormalities in anemic patients can mimic serious cardiac conditions such as myocardial ischemia, potentially leading to unnecessary investigations or interventions. Recognizing anemia as a reversible cause of such changes is essential for appropriate clinical decision-making. Early diagnosis and timely correction of anemia can prevent misinterpretation of ECG findings and improve patient outcomes.

However, the study has certain limitations. The sample size was relatively small, and the study was conducted at a single center, which may limit the generalizability of the findings. Additionally, long-term follow-up was not performed to assess the persistence or recurrence of ECG changes. The type and duration of anemia were also not analyzed in detail in relation to ECG findings.

Overall, the present study reinforces the strong association between anemia and electrocardiographic changes and highlights the importance of considering anemia as a reversible cause of cardiac electrical abnormalities.

CONCLUSION

The present study demonstrates that electrocardiographic abnormalities are highly prevalent in patients with moderate to severe anemia and are closely related to the severity of hemoglobin reduction. Sinus tachycardia was the most common ECG finding, followed by T wave changes and ST segment depression, reflecting the compensatory and hypoxic effects of anemia on the myocardium.

A significant association was observed between lower hemoglobin levels and the presence of ECG abnormalities, with more pronounced changes seen in patients with hemoglobin levels in the range of 3–5 g/dL. Following correction of anemia, there was a marked improvement in hemoglobin levels accompanied by near-complete reversal of ECG abnormalities in the majority of patients.

These findings highlight that ECG changes in anemia are predominantly functional and reversible in nature. Recognition of this relationship is crucial in clinical practice, as these changes may mimic primary cardiac pathology and lead to unnecessary diagnostic interventions if anemia is not considered.

Early diagnosis and timely correction of anemia, particularly with blood transfusion when indicated, play a key role in reversing these cardiac changes and improving overall patient outcomes.

Limitations

1. The study was conducted on a relatively small sample size of 50 patients, which may limit the generalizability of the findings.
2. Being a single-center study, the results may not reflect the broader population.
3. Long-term follow-up was not performed to assess the persistence or recurrence of ECG changes after treatment.
4. The type and duration of anemia were not correlated in detail with ECG findings.
5. Advanced cardiac evaluation beyond ECG and echocardiography was not performed to rule out subtle cardiac abnormalities.

Future Directions

Further multicentric studies with larger sample sizes are recommended to validate these findings. Long-term follow-up studies may help in understanding the persistence of ECG normalization and the impact of recurrent anemia. Additionally, correlation of specific types of anemia with ECG changes may provide deeper insights into the pathophysiology of cardiac involvement in anemia.

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