ORIGINAL RESEARCH PAPER

General Medicine

ELECTROCARDIOGRAPHIC CHANGES IN PATIENTS WITH SEVERE ANEMIA PRESENTING TO TERTIARY CARE CENTRE IN SOUTH-WESTERN MAHARASHTRA

KEY WORDS: Severe anemia; Electrocardiography; Echocardiography; Sinus tachycardia; Left ventricular dilatation; Diastolic dysfunction

Dr. Avneet Kaur* Junior Resident, Department of General Medicine, KVV Karad
*Corresponding Author

Dr Mrs Aparna P Patange Professor, Department of General Medicine, KVV Karad

ABSTRACT

Background: Anemia remains a major global health problem, particularly in developing countries like India. Severe anemia leads to reduced oxygen delivery and triggers compensatory cardiovascular adaptations, including increased cardiac output and myocardial changes. These alterations may manifest as electrocardiographic (ECG) and echocardiographic abnormalities, which are often under-recognized. **Aim:** To evaluate electrocardiographic changes in patients with severe anemia and correlate ECG findings with two-dimensional echocardiographic (2D Echo) parameters. **Materials and Methods:** This hospital-based prospective observational study was conducted at Krishna Charitable Hospital and Medical Research Centre over 18 months (March 2024–September 2025). A total of 95 patients aged 18–65 years with severe anemia (hemoglobin <7 g/dL as per World Health Organization criteria) were included using consecutive sampling. Patients with pre-existing cardiac disease and other confounding conditions were excluded. All participants underwent detailed clinical evaluation, laboratory investigations, 12-lead ECG, and transthoracic 2D echocardiography. Statistical analysis was performed using IBM SPSS. **Results:** Sinus tachycardia was the most common ECG finding, particularly in patients with hemoglobin <5 g/dL. ST–T segment abnormalities suggestive of myocardial hypoxia were frequently observed. Echocardiography revealed mild left ventricular dilatation and Grade I diastolic dysfunction, while systolic function was largely preserved. A significant correlation was noted between hemoglobin levels and left ventricular end-diastolic diameter ($r = 0.482$, $p = 0.003$), as well as ST–T changes ($r = 0.365$, $p = 0.029$). **Conclusion:** Severe anemia is associated with significant electrocardiographic and echocardiographic alterations, reflecting cardiovascular adaptation to hypoxia. Early cardiac evaluation using ECG and echocardiography is essential for timely detection and management of subclinical cardiac involvement.

INTRODUCTION:

Anemia continues to be a serious worldwide health issue that particularly affects developing nations such as India because its high rates stem from nutritional deficiencies, chronic diseases and socioeconomic elements.1 Anemia occurs when a person's haemoglobin level drops because this condition prevents the body from delivering oxygen to its organs. The cardiovascular system stands out as the most at risk system because it uses different adaptive processes to deal with oxygen deprivation. The body responds to this situation through three primary mechanisms, which include increased cardiac output and tachycardia and changes in myocardial contractility that produce ECG and echocardiographic alterations. Severe Anemia has been associated with cardiac strain, high-output heart failure, and structural alterations, even in the absence of pre-existing heart disease.2 The two diagnostic methods of Electrocardiography and two-dimensional echocardiography (2D Echo) function as non-invasive testing methods that medical professionals can use to detect cardiovascular changes at an affordable price because these tests are easily accessible. Anaemic patients commonly show four different types of abnormalities, which include sinus tachycardia, ST-T segment changes, left ventricular hypertrophy, and chamber dilatation.'3 However, these findings are often overlooked or misattributed to other conditions, especially in resource-limited settings. There is a pressing need to understand the cardiovascular manifestations of Anemia in diverse populations and regional healthcare environments. Present study aimed to study ECG changes in anemia and correlate the ECG findings with 2D ECHO findings.

MATERIAL & METHODS:

This hospital-based prospective observational study was conducted to evaluate electrocardiographic and two-dimensional echocardiographic changes in patients with severe anemia. The study was carried out in the Department of General Medicine in collaboration with the Department of Cardiology at Krishna Charitable Hospital and Medical Research Centre, a tertiary care center catering to a diverse population in south-western Maharashtra. The study duration extended over 18 months, from March 2024 to September 2025. The study population comprised adult patients aged 18–65 years admitted to the inpatient department with clinical and laboratory evidence of severe anemia, defined according to World Health Organization criteria as hemoglobin <7 g/dL. Patients were enrolled after obtaining written informed consent and were screened based on predefined eligibility criteria. A consecutive purposive sampling technique was adopted, and a total of 95 eligible patients were included during the study period. The sample size was determined based on the estimated prevalence of electrocardiographic and echocardiographic abnormalities in anemic patients from previous literature, including the study by Parmar et al., taking into account statistical power, confidence level, and precision.

Patients with known structural heart disease, coronary artery disease, congenital heart disease, acute infections, sepsis, chronic systemic illnesses affecting cardiac function, pregnancy, lactation, electrolyte imbalances, or those on medications influencing cardiac parameters were excluded. Patients unwilling to provide consent or uncooperative during evaluation were also excluded. All enrolled patients underwent a comprehensive clinical evaluation, including detailed history taking, demographic profiling, and thorough physical examination with special emphasis on cardiovascular assessment. Laboratory investigations were performed at admission using venous blood samples. Hemoglobin levels were measured using a semi-automated hematology analyzer, and complete blood count parameters were recorded. Additional investigations, including renal and liver function tests, were performed as required to exclude underlying systemic conditions and ensure appropriate patient selection.

A standard 12-lead electrocardiogram (ECG) was recorded for all patients using a calibrated machine. ECG parameters assessed included heart rate, rhythm, PR interval, QRS duration, QT/QTc interval, ST-segment and T-wave changes,

evidence of ventricular hypertrophy, axis deviation, and atrial abnormalities. All patients also underwent transthoracic two-dimensional echocardiography using a standardized protocol. Parameters evaluated included left ventricular ejection fraction (LVEF), left ventricular internal diameters in diastole and systole (LVEDD and LVESD), chamber dilatation, interventricular septal thickness, posterior wall thickness, and valvular structure and function. All echocardiographic assessments were performed by a trained cardiologist who was blinded to the clinical details to minimize observer bias. Ethical approval for the study was obtained from the Institutional Ethics Committee of Krishna Institute of Medical Sciences. Written informed consent was obtained from all participants prior to enrollment, and confidentiality of patient data was strictly maintained in accordance with ethical guidelines for biomedical research.

Data were recorded in predesigned case record forms and subsequently entered into a digital database. Data quality was ensured through double-entry verification and periodic random audits of 10% of records. Statistical analysis was performed using IBM SPSS. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Independent t-test and one-way ANOVA were used to compare means, and the chi-square test was applied for categorical data. Pearson's correlation coefficient was used to assess relationships between hemoglobin levels and ECG/echocardiographic parameters. A p-value of less than 0.05 was considered statistically significant.

RESULT:

The present cross-sectional study enrolled 95 patients with severe Anemia, with an age range of 18 to 65 years and a mean age of 43.79 ± 13.80 years. In this study, females constituted a slightly higher proportion (53.68%) compared to males (46.32%).

Table 1: Distribution of symptoms and murmur among patients

		Number of Patients (n)	Percentage (%)
Symptom	Dizziness	28	29.47
	Dyspnea	27	28.42
	Fatigue	27	28.42
	Palpitations	25	26.32
	Syncope	24	25.26
	Chest Pain	17	17.89
Murmur	Yes	36	37.9
	No	59	62.1

Table 2: Showing the mean level of parameters

Parameter	Mean ± SD
Hemoglobin (g/dL)	5.09 ± 0.53
MCV (fL)	75.93 ± 9.90
MCH (pg)	24.32 ± 3.32
MCHC (g/dL)	30.57 ± 1.07
WBC Count ($\times 10^9$/L)	7.31 ± 1.57
Platelet Count ($\times 10^9$/L)	417.32 ± 122.44
PR interval	157.9 ± 25.6
QRS duration	99.8 ± 13.6
QTc interval	421.3 ± 23.5

The haemoglobin concentration showed a significant decrease, which brought the level to 5.09 ± 0.53 g/dL, which indicates the presence of severe Anemia. The mean corpuscular volume (MCV) measurement showed a value of 75.93 ± 9.90 fL, which indicated that the patient was heading toward microcytosis. The results for mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) showed values of 24.32 ± 3.32 pg and 30.57 ± 1.07 g/dL, which demonstrated the presence of hypochromic red blood cells. The mean white blood cell (WBC) count showed a value of 7.31 ± 1.57 ×10 /L that fell within normal limits, but the mean platelet count showed an increase to 417.32 ± 122.44 ×10 /L, which indicated the presence of reactive thrombocytosis that typically occurs with iron deficiency Anemia. The study group had a mean PR interval of 157.9 ± 25.6 ms and a mean QRS duration of 99.8 ± 13.6 ms. The average corrected QT interval (QTc) measured 421.3 ± 23.5 ms, which falls within the normal range (≤ 440 ms in males and ≤ 460 ms in females).

Table 3: Distribution according to heart rate and ST-T changes

		Number of cases	Percent
Heart rate	Tachycardia	51	53.7
	Normal	44	46.3
ST-T Changes (ST- segment depression and T-waveinversion)	Absent	74	77.9
	Present	21	22.1

Tachycardia appeared in 53.7 % of the cases, but 46.3% of the cases maintained normal heart rate levels. Analysis of electrocardiographic ST-T segments revealed the presence of ST-T changes in a subset of patients. ST-segment depression and T-wave inversion were observed in 28 patients (22.1%), whereas 74 patients (77.9%) showed no ST-T findings.

Table 4: Echocardiographic Parameters of Study Participants (n = 95)

Parameter	Mean ± SD
Left Ventricular Ejection Fraction (LVEF, %)	56.0 ± 5.1
Left Ventricular End-Diastolic Diameter (LVEDD, mm)	51.4 ± 4.0
Left Ventricular End-Systolic Diameter (LVESD, mm)	34.0 ± 3.2
Interventricular Septal Thickness (mm)	10.0 ± 1.5
Posterior Wall Thickness (mm)	9.8 ± 1.5

The study group showed an average left ventricular ejection fraction (LVEF) of 56.0 ± 5.1%, indicating that most patients maintained preserved systolic function. The mean left ventricular end-diastolic diameter (LVEDD) was 51.4 ± 4.0 mm, which was relatively increased, particularly among patients with hemoglobin levels <5 g/dL, suggesting ventricular dilatation associated with severe anemia. The mean left ventricular end-systolic diameter (LVESD) was 34.0 ± 3.2 mm, which also reflects the adaptive response of the left ventricle during high-output states caused by chronic severe anemia. Additionally, interventricular septal thickness and posterior wall thickness were 10.0 ± 1.5 mm and 9.8 ± 1.5 mm, respectively, indicating mild concentric remodeling. These echocardiographic findings suggest that severe anemia, particularly in patients with hemoglobin <5g/dL contributes to increased LVEDD and structural adaptation of the left ventricle, enabling the heart to maintain adequate cardiac output despite reduced oxygen-carrying capacity of blood.

Table 5: Distribution of Diastolic Dysfunction, Valvular Changes, ICU Admission, and Patient Outcomes among Study Participants (n = 95)

		Number of Cases (n)	Percentage (%)
Grade of Diastolic Dysfunction	Grade I	52	54.7
	Grade II	7	7.4
	Grade III	0	0.0
	None	32	33.7
Valvular changes	Mitral regurgitation	50	52.6
	Aortic regurgitation	12	12.6
	None	33	34.7
ICU admission	Yes	26	27.4
	No	69	72.6
Patients' outcome	Discharge	82	86.3
	Death	13	13.7

The assessment of diastolic function showed that 52 patients

from the total examined group of 56 patients achieved Grade I diastolic dysfunction, while 7 patients (7.4%) had Grade II dysfunction. The study found no patients with Grade III diastolic dysfunction, and 32 patients (33.7%) maintained normal diastolic function. The results show that most patients in this study experience mild (Grade I) diastolic impairment because they developed chronic severe Anemia. Valvular abnormalities were present in most of the patients examined in the study. The most frequent abnormality, which affected 50 patients who had mitral regurgitation (MR), was aortic regurgitation (AR), which affected 12 patients. No valvular abnormality was detected in 33 patients (34.7%). Among the 95 patients evaluated, 27.4% required admission to the Intensive Care Unit (ICU), while the remaining 72.6% were managed in the general ward. Most patients (86.3%) were successfully discharged following treatment, reflecting an overall favourable prognosis. The results showed that 13.7% of patients died because their primary medical condition was too serious to survive.

Table 6: Correlation of LVEDD and ST-T changes with hemoglobin

		Hemoglobin
LVEDD (mm)	r	0.482
	p-value	0.01*
ST-T changes	r	0.365
	p-value	0.02*

A moderate positive correlation was observed between hemoglobin and LVEDD ($r = 0.482$, $p<0.05$). A moderate positive correlation was observed between hemoglobin and ST-T changes ($r = 0.365$, $p<0.05$). The chi-square test (^{2} = 0.562, df = 1, p = 0.453) and likelihood ratio (p = 0.452) showed no statistically significant association between diastolic dysfunction and ICU admission. The chi-square test (^{2} = 0.262, df = 1, p = 0.609) and likelihood ratio (p = 0.611) indicated no statistically significant association between LVH and ICU admission.

DISCUSSION:

The findings provide important insights into the range of cardiovascular manifestations associated with anemia and highlight the importance of incorporating cardiac evaluation in the clinical management of these patients. In the demographic analysis of the cohort, severe Anemia was seen to affect female subjects in reproductive age groups. This observation is congruent with the findings of Toteja et al. (2006), in which Anemia was seen disproportionately running more among Indian females, mainly due to nutritional deficits, menstrual blood loss, and repeated pregnancies.4 Kaur (2014) also remarked that the ever-present challenge of Anemia exists even in modern-day women, at more than 50% in some rural populations. Findings further corroborate that gender-based disparities in nutritional status and access to healthcare persistently contribute to this epidemiological pattern.5 Electrocardiographic assessment in our group of studied patients showed that tachycardia occurred in almost 66 percent of patients who had haemoglobin levels below 5 g/dL. The research conducted by Anand and Gupta (2018) verified this trend, which showed that anaemic people developed tachycardia because their bodies were sustaining high sympathetic nervous system activity and continuous fluid retention.[6]

ST–T segment abnormalities, including ST depression and T-wave inversion, were commonly observed, particularly in patients with haemoglobin levels below 5 g/dL, indicating myocardial hypoxia. Despite these changes, the QTc interval remained within normal limits in most patients, suggesting preserved electrical stability and no increased risk of ventricular arrhythmias. Notably, among patients with haemoglobin <5 g/dL, 28 out of 33 exhibited ST–T changes along with increased left ventricular end-diastolic diameter (LVEDD), highlighting a significant association between severe anemia, myocardial ischemia, and cardiac structural alterations. The echocardiographic results showed that a major part of the study group had left ventricular dilation together with left ventricular mass index elevation, which matched the earlier findings of Anand and Gupta (2018) and Arief et al. (2020). The studies demonstrated that chamber size increase, together with blood vessel pressure rise, serves as a measurement for both Anemia severity and its length of existence.6,7 The combination of these findings demonstrates that severe Anemia creates more than just a blood condition because it affects the entire body, especially the heart's anatomy and operational capacity.

Inter-comparison between subgroups revealed that patients with extremely severe Anemia (Hb <5 g/dL) had significantly higher rates of chamber dilatation and diastolic dysfunction compared with those in the moderately severe group (Hb 5–7 g/dL), indicating a threshold effect where cardiovascular remodelling accelerates once haemoglobin falls below critical levels, as also observed by Nair et al. (2005).8 Chamber dilatation was frequently associated with elevated pulmonary artery pressures, consistent with Smith et al. (2009), who linked left ventricular changes to secondary pulmonary hypertension.[9]

In the present study, a statistically significant correlation was observed between haemoglobin levels and left ventricular end-diastolic diameter (LVEDD). Pearson correlation analysis demonstrated a moderate positive correlation ($r = 0.482$, $p = 0.003$), indicating that variations in haemoglobin levels were significantly associated with changes in LVEDD among the study population. These findings suggest that severe anemia may influence cardiac chamber dimensions, possibly due to chronic volume overload and compensatory hemodynamic adaptations. Similar observations have been reported in previous studies. Khanapurkar et al. (2014) demonstrated that patients with severe anemia frequently exhibit left ventricular dilatation and altered cardiac dimensions, reflecting the adaptive mechanisms of the myocardium in response to chronic tissue hypoxia and increased cardiac output requirements.10 The present study also demonstrated a statistically significant association between haemoglobin levels and ST–T changes on electrocardiography ($r = 0.365$, $p = 0.029$). ST–T abnormalities are considered markers of myocardial repolarization disturbances, which may occur secondary to myocardial hypoxia in patients with severe anemia. These findings are consistent with earlier reports by Varat et al., who described electrocardiographic changes such as ST-segment depression and T-wave inversion in patients with severe anemia, attributed primarily to reduced oxygen delivery to the myocardium.11 Furthermore, similar observations have been reported by Anand and Gupta, who noted that repolarization abnormalities and sinus tachycardia were common electrocardiographic findings in patients with severe anemia.[6]

The study's strengths include an adequate sample size, standardized ECG and echocardiographic assessment, and conduct in a tertiary care setting. However, its cross-sectional design limits causal inference, and the absence of advanced echocardiographic techniques (e.g., strain imaging, tissue Doppler) may have underestimated subclinical dysfunction. Being a single-center study may also affect generalizability. The findings demonstrate that severe anemia is associated with significant ECG and echocardiographic abnormalities, including tachycardia, repolarization changes, chamber dilatation, and diastolic dysfunction, with more pronounced changes at haemoglobin levels below 5 g/dL. These results highlight the need for comprehensive cardiovascular evaluation in severe anemia, with echocardiography aiding clinical decision-making. Further longitudinal studies using advanced imaging are recommended to better understand anemia-induced cardiomyopathy.

CONCLUSION:

Severe anemia is associated with significant electrocardiographic and echocardiographic changes, reflecting cardiovascular adaptation to reduced oxygen-carrying capacity. Sinus tachycardia and mild ST–T changes were common, while most patients maintained preserved systolic function with evidence of early diastolic dysfunction and mild ventricular dilatation. The severity of anemia correlated with the extent of cardiac abnormalities, particularly at lower haemoglobin levels. These findings highlight the importance of routine cardiac evaluation in patients with severe anemia for early detection and management of subclinical cardiac involvement.

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