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Cardiac Structural and Functional Changes in Anaemia: A 2D Echocardiographic Study in an Indian Population

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Abstract

Anemia is a widespread global health concern, particularly prevalent in developing countries, like India, where it contributes significantly to cardiovascular morbidity. This study aimed to evaluate cardiac structural and functional changes in anaemic patients using 2D echocardiography and to assess correlations between haemoglobin levels and echocardiographic parameters. A cross-sectional observational study was conducted on 125 anaemic patients (defined as haemoglobin <13 g/dL in males and <12 g/dL in females) at a tertiary care hospital over two years. All patients underwent clinical evaluation, complete blood counts, and detailed 2D echocardiographic assessment. Key parameters assessed included left ventricular end-diastolic volume (LVEDV), ejection fraction (EF), left atrial volume index, E/A ratio, and valvular abnormalities. Results showed that increasing anaemia severity was associated with a rise in LVEDV (from 105 mL to 132 mL), a decline in EF (from 63% to 57%), and worsening diastolic dysfunction (E/A ratio from 1.2 to 0.9). Left atrial enlargement and left ventricular hypertrophy were observed in 39% and 36% of patients, respectively. Notably, haemoglobin levels demonstrated a significant inverse correlation with LVEDV ($r = -0.48$) and a positive correlation with EF ($r = +0.38$, $p < 0.01$). These findings highlight that anaemia exerts a measurable impact on cardiac morphology and function, which can be effectively monitored through 2D echocardiography. Routine echocardiographic evaluation in anaemic patients may aid in early detection of subclinical cardiac dysfunction and guide timely intervention to reduce long-term cardiovascular complications.

Keywords: Anaemia, 2D echocardiography, left ventricular dysfunction, diastolic dysfunction, cardiac remodeling

INTRODUCTION

Anaemia, characterized by a reduction in haemoglobin concentration and red cell mass, affects nearly 1.62 billion people worldwide (24.8%) as per the World Health Organization (WHO), representing one of the most common haematological disorders [1]. The burden is especially high in India due to factors such as malnutrition, chronic infections, and haemoglobinopathies [2, 3]. According to NFHS-5 (2019–21), anaemia affects more than 57% of women, 25% of men, and over 67% of children under five in India (NFHS-5, 2021).

The cardiovascular system is one of the most critically affected organ systems in anaemia. Reduced oxygen delivery to tissues stimulates compensatory mechanisms, including increased cardiac output, decreased systemic vascular resistance, and chronic volume overload [4–6]. While these mechanisms are initially adaptive, prolonged exposure may lead to pathological changes such as left ventricular (LV) dilatation, eccentric hypertrophy, left atrial (LA) enlargement, and eventual systolic and diastolic dysfunction [7–9].

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Two-dimensional (2D) echocardiography offers a sensitive and non-invasive tool to evaluate these structural and functional changes [10, 11]. Studies conducted internationally have shown associations between anaemia and adverse cardiac remodelling [12, 13]. However, despite the magnitude of anaemia in India, there remains limited indigenous data correlating anaemia severity with echocardiographic findings in this population [14, 15].

This study aims to bridge that gap by evaluating structural and functional cardiac changes in anaemic patients and correlating them with haemoglobin levels.

LITERATURE REVIEW

Previous studies have established that anaemia is not merely a hematological issue but a systemic disorder that profoundly affects cardiovascular dynamics. WHO (2005), Chalco et al. (2005), and Dewey & Chaparro (2007) [16–18] observed that even mild anaemia could lead to measurable changes in LV mass and function. Similarly, Jopling et al. (2009) and Lynch (2007) [19, 20] highlighted the increased mortality in anaemic patients with heart failure due to exaggerated compensatory mechanisms.

Anaemia leads to increased preload, reduced afterload and elevated cardiac output to maintain oxygen supply. Chronicity of this hyperdynamic state may lead to eccentric LV hypertrophy and diastolic dysfunction, especially in hypertensive patients [21–24]. Furthermore, left atrial enlargement – a marker of chronic diastolic burden – has been shown to correlate with anaemia severity [25, 26].

Despite this, data on echocardiographic patterns specific to anaemia in South Asian populations remain limited. Our study adds to this growing evidence base by evaluating echocardiographic changes in an Indian cohort [27].

METHODOLOGY

Study Design and Sample

Cross-sectional observational study conducted at a tertiary care hospital over 2 years (2021–2023). Sample Size (Table 1):

Table 1. Anaemia classification (WHO/NFHS-5).

Severity	Males (g/dL)	Females (g/dL)
Mild	12.0–12.9	11.0–11.9
Moderate	9.0–11.9	8.0–10.9
Severe	<9.0	<8.0

125 patients were diagnosed with anaemia.

Inclusion Criteria

- Age >12 years.
- Hb <13 g/dL in males, <12 g/dL in females.

Exclusion Criteria

- Known structural heart disease or pulmonary disease.
- Diabetes mellitus, thyroid disorders, CKD, CLD.
- Pregnancy.
- Patients unwilling to consent.

Assessment

- All patients underwent detailed history-taking and clinical examinations.
- Laboratory investigations included Hb, CBC on ERBA H360.
- 2D echocardiography was performed using GE Vivid E95.
- Simpson’s method for EF, Doppler and color Doppler for diastolic and valvular assessments.

Investigations

- *CBC:* Performed on ERBA H360 (automated 5-part analyzer).
- *2D Echocardiography:* Done with GE Vivid E95, using standard parasternal long/short axis and apical views. Simpson's biplane method is used for LV volumes and EF. Tissue Doppler and color Doppler used for diastolic and valvular assessment.

Statistical Analysis

- SPSS v20.
- ANOVA and Z-tests for quantitative data.
- Pearson's correlation for haemoglobin vs echo parameters.
- p-value <0.05 considered significant.

Hypothesis

- *Null Hypothesis (H_0):* There is no significant correlation between haemoglobin levels and cardiac dysfunction in anaemic patients.
- *Alternative Hypothesis (H_1):* There is a significant correlation between the severity of anaemia and cardiac structural or functional abnormalities as detected by 2D echocardiography.

OBSERVATIONS AND RESULTS (Table 2)

Demographics

- *Mean Age:* 33.6 ± 10.2 years.
- *Gender:* 47.2% males, 52.8% females.

Anaemia Severity

- *Mild:* 32% (n = 40).
- *Moderate:* 46% (n = 58).
- *Severe:* 22% (n = 27).

Table 2. Echocardiographic findings.

Parameter	Mild	Moderate	Severe
LVEDV (mL)	105 ± 15	118 ± 20	132 ± 25
EF (%)	63 ± 6	60 ± 5	57 ± 7
LA Volume Index (mL/m²)	28 ± 4	34 ± 5	41 ± 6
E/A Ratio	1.2 ± 0.3	1.0 ± 0.2	0.9 ± 0.2

Interpretation

The echocardiography data demonstrates a progressive trend of cardiac remodeling with increasing anaemia severity. LVEDV increases notably from 105 mL in mild to 132 mL in severe anaemia, reflecting progressive LV dilatation due to chronic volume overload. EF declines from 63% in mild to 57% in severe anaemia, indicating a reduction in systolic function. LA Volume Index increases from 28 mL/m² to 41 mL/m², suggesting sustained diastolic pressure overload. E/A Ratio decreases from 1.2 to 0.9, indicating worsening diastolic dysfunction (Table 3).

Table 3. Systolic function distribution.

EF category	Mild (n = 40)	Moderate (n = 58)	Severe (n = 27)
EF >60%	40 (100%)	35 (60.5%)	23 (84.4%)
EF 50–59%	0	14 (24.1%)	2 (7.4%)
EF 41–49%	0	7 (12.0%)	2 (7.4%)
EF <40%	0	2 (3.4%)	5 (18.5%)

Interpretation

All patients with mild anaemia maintain EF >60%. In moderate anaemia, 39.5% show systolic dysfunction (EF <60%). In severe anaemia, systolic dysfunction worsens significantly with 18.5% having EF <40%.

Structural Abnormalities (Overall):

- *LV Hypertrophy:* 36%.
- *LA Enlargement:* 39%.
- *Diastolic Dysfunction:* 54%.
- *Mild MR/TR:* 16%.

Correlations

- Haemoglobin vs LVEDV: r = –0.48 (negative correlation).
- Haemoglobin vs EF: r = +0.38 (positive correlation).

DISCUSSION

This study demonstrates a significant relationship between anaemia severity and cardiac structural and functional abnormalities. As anaemia worsens, LV volumes progressively increase, accompanied by declining ejection fraction and worsening diastolic function.

A negative correlation between haemoglobin and LVEDV (r = –0.48) reflects progressive LV dilatation with increasing anaemia severity. A positive correlation between haemoglobin and EF (r = +0.38) indicates that systolic function declines as haemoglobin drops, particularly in severe anaemia after the hyperdynamic state fails.

Diastolic dysfunction was present in 54% of patients, with the E/A ratio declining from 1.2 in mild anaemia to 0.9 in severe cases, reflecting impaired LV relaxation. LA enlargement (39%) was commonly associated with this diastolic burden.

Systolic dysfunction was most prominent in severe anaemia, with 18.5% showing EF <40%, and an additional 14.8% having EF between 41–59%.

Mild functional mitral and tricuspid regurgitation, present in 16%, were likely secondary to annular dilation due to volume overload rather than primary valve disease.

These findings align with reports of progressive left ventricular dilatation, hypertrophy, and worsening systolic and diastolic function with increasing severity of anaemia [28–32].

CONCLUSION

This study clearly establishes that anaemia has a significant impact on cardiac structure and function, with severity correlating with progressive left ventricular dilatation, left atrial enlargement, systolic dysfunction, and diastolic dysfunction.

A significant inverse correlation exists between haemoglobin and LV volumes (r = –0.48), and a positive correlation with EF (r = +0.38), highlighting the chronic cardiovascular strain imposed by anaemia.

These findings strongly reinforce that 2D echocardiography is not merely adjunctive but essential in the comprehensive evaluation of moderate to severe anaemia. It enables early detection of subclinical cardiac dysfunction, allows differentiation from intrinsic cardiomyopathies, and guides timely interventions.

Given the high burden of anaemia in the Indian population, incorporating echocardiographic evaluation into routine clinical assessment can prevent progression to overt heart failure, improve patient outcomes and reduce cardiovascular morbidity.

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