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Original Article

Echocardiographic Assessment of Structural and Functional Cardiac Changes Among Patients With Essential Hypertension: A Cross-Sectional Observational Study

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ABSTRACT

Background: Hypertension is a major risk factor for cardiovascular morbidity and mortality and leads to structural and functional cardiac alterations, particularly left ventricular hypertrophy (LVH) and diastolic dysfunction. Echocardiography enables early detection of these abnormalities.

Methods: A prospective cross-sectional observational study was conducted among 38 hypertensive patients aged 30–80 years at Aarupadai Veedu Medical College and Hospital, Puducherry. Echocardiographic evaluation was performed according to American Society of Echocardiography guidelines. Left ventricular structure, systolic function, and diastolic function were assessed. Statistical analysis was performed using SPSS version 21, and associations were evaluated using the Chi-square test.

Results: The mean age of participants was 55 ± 11 years, with 55% males. Grade I diastolic dysfunction was observed in 71% of patients, LVH in 68%, and mild systolic dysfunction in 63%. LVH showed a significant association with diastolic dysfunction ($p < 0.001$).

Conclusion: Echocardiography detects early cardiac remodeling in hypertensive patients and supports routine screening for timely risk stratification and prevention of cardiovascular complications.

Keywords: Hypertension, Echocardiography, Left ventricular hypertrophy, Diastolic dysfunction, Left ventricular ejection fraction, Cardiac remodeling

Introduction:

Hypertension is one of the most prevalent chronic medical conditions worldwide and represents a major contributor to cardiovascular morbidity and mortality. It is strongly associated with ischemic heart disease, stroke, heart failure, and chronic kidney disease. According to the World Health Organization, more than one billion individuals globally are affected by hypertension, making it a major public health concern [1]. Persistent elevation of arterial blood pressure increases myocardial workload and results in progressive structural and functional alterations in the heart. Long-standing hypertension leads to adaptive changes such as left ventricular hypertrophy (LVH), which initially serves as a compensatory mechanism to maintain cardiac output against increased systemic vascular resistance. However, prolonged hypertrophy results in increased myocardial stiffness, impaired ventricular relaxation, and eventually diastolic dysfunction [2]. Echocardiography plays a central role in evaluating hypertensive heart disease because it provides accurate assessment of ventricular geometry, myocardial thickness, chamber dimensions, and systolic and diastolic function. Importantly, echocardiography enables detection of subclinical cardiac abnormalities even in asymptomatic hypertensive patients [3,4,5].

The American Society of Echocardiography recommends echocardiographic evaluation in hypertensive individuals for assessment of left ventricular mass, ventricular geometry, and diastolic function, which are strong predictors of cardiovascular morbidity and mortality [6,7]. Therefore, the present study aimed to evaluate echocardiographic structural and functional changes among patients with essential hypertension and to determine their association with selected clinical variables.

Materials and Methods

Study Design and Setting

This prospective cross-sectional observational study was conducted in the Department of Cardiology at Aarupadai Veedu Medical College and Hospital, Puducherry, a tertiary care teaching institution. The study was carried out over a period of one month. The objective of the study was to evaluate structural and functional cardiac changes detected by echocardiography among patients with essential hypertension.

Study Population

The study population consisted of patients attending the cardiology outpatient and inpatient departments who had been previously diagnosed with essential hypertension. Eligible participants were recruited consecutively during the study period after screening for inclusion and exclusion criteria.

Sample Size and Sampling Technique

A total of 38 hypertensive patients were included in the study. Participants were recruited using a consecutive sampling technique, whereby all eligible patients presenting during the study period were enrolled until the required sample size was achieved.

Inclusion Criteria

Adults aged 30–80 years

Patients with confirmed diagnosis of essential hypertension

Patients willing to participate and provide written informed consent

Exclusion Criteria

Known valvular heart disease

Congenital heart disease

Previously diagnosed structural cardiac abnormalities

Pregnant or lactating women

Patients with severe systemic illness

Patients unwilling to participate

Ethical Approval

The study protocol was reviewed and approved by the Institutional Human Ethics Committee (IHEC) of Aarupadai Veedu Medical College and Hospital prior to study initiation. Written informed consent was obtained from all participants after explaining the study objectives and procedures. Confidentiality of patient information was strictly maintained throughout the study.

Clinical Evaluation and Echocardiographic Assessment

All participants underwent detailed clinical evaluation, including demographic profiling, medical history, duration of hypertension, medication history, and assessment of associated risk factors and comorbid conditions. Anthropometric measurements such as height and weight were recorded, and body mass index (BMI) was calculated using the standard formula (kg/m²). Blood pressure was measured using a calibrated sphygmomanometer after the participant had rested for at least 5 minutes in the seated position, and the average of two readings taken 5 minutes apart was considered for analysis.

Hypertension classification was performed according to Joint National Committee (JNC-7) guidelines [3]. Subsequently, all participants underwent comprehensive transthoracic echocardiographic examination using a Mindray ultrasound system with a phased-array transducer (2–4 MHz), following the recommendations of the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI). Standard two-dimensional, M-mode, pulsed-wave Doppler, and tissue Doppler imaging were performed in parasternal long-axis, parasternal short-axis, and apical four-chamber views. Left ventricular systolic function was assessed by calculating left ventricular ejection fraction using the Teichholz method. Left ventricular hypertrophy was evaluated using interventricular septal thickness, posterior wall thickness, and left ventricular mass indexed to body surface area. Diastolic function was assessed using transmitral inflow velocities (E wave, A wave, E/A ratio), deceleration time, isovolumetric relaxation time, and mitral annular tissue Doppler velocity (e′), and graded according to ASE recommendations [6,7]. Measurements were obtained in the left lateral decubitus position and averaged over three cardiac cycles to improve accuracy and reproducibility .

Results

A total of 38 patients with essential hypertension were included in the present study. Echocardiographic evaluation was performed to assess structural and functional cardiac changes associated with hypertension.

Baseline Characteristics of the Study Population

The mean age of the study population was 55 ± 11 years, indicating that the majority of participants belonged to the middle-aged group. Among the participants, 21 (55%) were males and 17 (45%) were females, showing a slight male predominance. The mean body mass index (BMI) of the participants was 29 ± 5 kg/m², suggesting that a large proportion of the study population was either overweight or obese. The mean left ventricular ejection fraction (LVEF) was 46 ± 7%, indicating the presence of mild systolic dysfunction in several participants. These findings suggest that hypertension in this study population was commonly associated with increased cardiovascular risk factors such as elevated BMI and reduced systolic performance **(Table-1)**.

Variable	**Value**
Age (years)	55 ± 11
BMI (kg/m²)	29 ± 5
Ejection Fraction (%)	46 ± 7
Male	21 (55%)
Female	17 (45%)

Table 1: Baseline Characteristics of the Study Population (n = 38)

Age Distribution of Participants

The age of the participants ranged between 30 and 80 years. The distribution of participants across age groups demonstrated that the highest proportion belonged to the 50–59 years age group (29%), followed by the 60–69 years age group (24%). Participants aged 40–49 years accounted for 21%, while those aged 30–39 years and 70–80 years each accounted for 13% of the study population. This distribution indicates that echocardiographic abnormalities associated with hypertension were more frequently observed among middle-aged and elderly individuals, highlighting the progressive nature of hypertensive cardiac remodeling with advancing age **(Table-2)**.

Age Group (years)	Frequency	Percentage
30–39	5	13%
40–49	8	21%
50–59	11	29%
60–69	9	24%
70–80	5	13%
Total	38	100%

Table 2: Age Distribution of Participants

Echocardiographic Findings in Hypertensive Patients

Echocardiographic evaluation revealed a high prevalence of both structural and functional cardiac abnormalities among hypertensive patients. Left ventricular systolic function assessment showed that 24 participants (63%) had mild systolic dysfunction, while 14 participants (37%) had normal systolic function. The mean LVEF of 46 ± 7% further supports the presence of early systolic impairment in a substantial proportion of the study population.

Assessment of left ventricular diastolic function demonstrated that Grade I diastolic dysfunction was the most frequently observed abnormality and was present in 27 participants (71%), whereas 11 participants (29%) had normal diastolic function. These findings indicate that impaired myocardial relaxation represents one of the earliest manifestations of hypertensive heart disease.

Evaluation of left ventricular geometry revealed that left ventricular hypertrophy (LVH) was present in 26 participants (68%), suggesting a high prevalence of structural cardiac remodeling among hypertensive individuals. Overall, these findings demonstrate that both systolic and diastolic dysfunction, along with left ventricular hypertrophy, were commonly observed echocardiographic abnormalities in the study population **(Table-3).**

Parameter	Frequency	Percentage
Mild LV systolic dysfunction	24	63%
Normal systolic function	14	37%
Grade I diastolic dysfunction	27	71%
Normal diastolic function	11	29%
Left ventricular hypertrophy (LVH)	26	68%

Table 3: Echocardiographic Findings in Hypertensive Patients

Association Between Left Ventricular Diastolic Dysfunction and Clinical Variables

The association between left ventricular diastolic dysfunction and selected demographic and echocardiographic variables was analyzed using the Chi-square test. A statistically significant association was observed between left ventricular hypertrophy and diastolic dysfunction ($p < 0.001$), indicating that structural remodeling of the left ventricle plays an important role in the development of impaired ventricular relaxation.

Similarly, reduced left ventricular ejection fraction showed a significant association with diastolic dysfunction ($p < 0.001$), suggesting that early systolic impairment may coexist with abnormalities in ventricular filling among hypertensive patients. However, age ($p = 0.333$), sex ($p = 0.151$), and body mass index ($p = 0.516$) did not demonstrate statistically significant associations with diastolic dysfunction in the present study population. These results suggest that echocardiographic structural parameters, particularly left ventricular hypertrophy, are stronger predictors of diastolic dysfunction than demographic variables in hypertensive individuals.

Discussion

Hypertension remains a major global public health concern and is a leading contributor to cardiovascular morbidity and mortality worldwide. Persistent elevation of arterial blood pressure results in progressive structural and functional alterations in the myocardium, including left ventricular hypertrophy (LVH), systolic dysfunction, and diastolic dysfunction. Echocardiography plays an essential role in detecting these abnormalities at an early stage and provides valuable insight into the development and progression of hypertensive heart disease. The present study evaluated echocardiographic changes among patients with essential hypertension and examined their association with selected demographic and clinical variables. Similar observations have been reported in echocardiographic evaluation studies of hypertensive populations demonstrating early subclinical myocardial involvement detectable by imaging modalities before overt clinical disease becomes evident [7].

In the present study, a slightly higher proportion of males (55%) compared with females (45%) was observed. This finding is consistent with earlier epidemiological studies reporting increased prevalence of hypertension-related cardiovascular complications among males compared with females, particularly in middle-aged populations. Differences in lifestyle-related risk factors such as smoking, alcohol intake, occupational stress, and physical inactivity may contribute to this gender variation. Additionally, estrogen-mediated cardioprotective mechanisms in premenopausal women are known to delay myocardial remodeling associated with hypertension [8].

The age distribution of participants demonstrated that the majority belonged to the 50–59 years age group, followed by the 60–69 years age group, suggesting that hypertensive cardiac involvement increases with advancing age. Age-related arterial stiffness, endothelial dysfunction, and reduced myocardial compliance are important contributors to the development of hypertensive heart disease. Previous echocardiographic studies have similarly demonstrated that increasing age is associated with progressive increase in left ventricular mass and deterioration of diastolic function [6].

Body mass index analysis revealed that nearly 79% of participants were either overweight or obese. Obesity is a well-recognized independent risk factor for hypertension and cardiovascular disease. Increased adiposity contributes to elevated cardiac output, activation of the renin–angiotensin–aldosterone system, sympathetic nervous system stimulation, and vascular remodeling, all of which promote left ventricular hypertrophy and impaired ventricular relaxation. Earlier studies have demonstrated a strong association between obesity and increased left ventricular mass index among hypertensive individuals [9-12].

Another important observation in the present study was that a substantial proportion of participants had inadequately controlled hypertension. Poor blood pressure control is a major determinant of hypertensive heart disease progression. Chronic pressure overload initially produces adaptive concentric hypertrophy that helps maintain cardiac output; however, prolonged exposure results in myocardial fibrosis, increased ventricular stiffness, and impaired diastolic relaxation. Similar findings have been described in previous investigations evaluating structural cardiac adaptation in uncontrolled hypertensive populations[4].

Echocardiographic evaluation in the present study demonstrated that mild left ventricular systolic dysfunction was present in 63% of participants, with a mean left ventricular ejection fraction of 46 ± 7%. Although hypertension predominantly affects diastolic function during early disease stages, long-standing uncontrolled hypertension may eventually lead to systolic dysfunction due to progressive myocardial fibrosis and adverse ventricular remodeling. Previous studies have reported that reduced left ventricular ejection fraction among hypertensive individuals is associated with increased risk of heart failure and adverse cardiovascular outcomes [5]. One of the most important findings of the present study was the high prevalence of left ventricular diastolic dysfunction, which was observed in 71% of participants, predominantly as Grade I diastolic dysfunction. Diastolic dysfunction represents one of the earliest manifestations of hypertensive heart disease and reflects impaired myocardial relaxation secondary to increased myocardial stiffness and interstitial fibrosis. Similar findings have been reported in earlier studies where diastolic dysfunction was identified as a common subclinical abnormality among hypertensive patients even before the development of overt systolic impairment [6].

Left ventricular hypertrophy was observed in 68% of the study population, indicating a high prevalence of structural cardiac remodeling among hypertensive patients. LVH represents an adaptive response to chronic pressure overload characterized by increased myocardial wall thickness and collagen deposition. However, persistent hypertrophy contributes to reduced ventricular compliance and impaired ventricular filling. LVH has been recognized as an independent predictor of cardiovascular morbidity and mortality and is strongly associated with adverse clinical outcomes in hypertensive patients [8].

The present study demonstrated a statistically significant association between left ventricular hypertrophy and diastolic dysfunction ($p < 0.001$), suggesting that structural remodeling plays a key role in the development of impaired ventricular relaxation. Increased myocardial thickness reduces ventricular compliance and elevates left ventricular filling pressures, thereby contributing to diastolic dysfunction. Similar associations have been reported in previous studies demonstrating that hypertensive patients with LVH are at significantly increased risk of developing diastolic dysfunction and heart failure [7]. Overall, the findings of the present study highlight the high prevalence of both structural and functional cardiac abnormalities among patients with essential hypertension and emphasize the importance of routine echocardiographic evaluation for early identification of hypertensive heart disease and prevention of long-term cardiovascular complications

Conclusion

The present study demonstrated that essential hypertension is associated with significant structural and functional cardiac alterations detectable by echocardiography. A high prevalence of left ventricular hypertrophy, Grade I diastolic dysfunction, and mild systolic dysfunction was observed among hypertensive patients, indicating early myocardial involvement even in the absence of overt clinical symptoms. The study also identified a significant association between left ventricular hypertrophy and diastolic dysfunction, highlighting the impact of chronic pressure overload on ventricular remodeling and impaired myocardial relaxation.

These findings emphasize the importance of routine echocardiographic evaluation in patients with hypertension for early detection of subclinical cardiac abnormalities. Early identification of hypertensive cardiac changes may facilitate timely therapeutic intervention, improve risk stratification, and reduce the likelihood of progression to heart failure and other adverse cardiovascular outcomes. Further large-scale longitudinal studies are recommended to better understand the progression of hypertensive heart disease and to strengthen strategies for early cardiovascular risk prevention.

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