Original Article

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Internal Medicine Section

Diastolic Dysfunction in Patients with Hypertension Assessed by 2D Echo and Doppler Imaging and its Association with Clinical Profile and ECG Findings: A Cross-sectional Study

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ABSTRACT

Introduction: Hypertension is a major risk factor for cardiovascular diseases and is strongly associated with Diastolic Dysfunction (DD), which can lead to Heart Failure with preserved Ejection Fraction (HFpEF). Despite its clinical significance, DD often remains underdiagnosed, necessitating routine echocardiographic screening for early detection.

Aim: To evaluate the prevalence of DD in hypertensive patients using 2 Dimensional (2D) echocardiography and doppler imaging, along with its association with clinical characteristics and Electrocardiogram (ECG) findings.

Materials and Methods: The present cross-sectional analytical study was conducted at Dr. D. Y. Patil Medical College and Research Centre, Pune, Maharashtra, India from February 2023 to September 2025. A total of 100 hypertensive patients were recruited using a purposive sampling method. Each participant underwent clinical assessment, Blood Pressure (BP) measurement, ECG, and (2D echo and doppler imaging). The prevalence and severity of DD were analysed, and its associations with age, duration of hypertension, severity of hypertension, and ECG findings were evaluated. Statistical analyses were performed using Statistical Package for Social Sciences (SPSS) version 20, with a p-value <0.05 considered significant.

Results: DD was detected in 46% of hypertensive patients, with 19% having grade 1 DD, 11% grade 2, and 16% grade 3. The prevalence of DD increased with age, from 25% in patients below 40 years to 62.5% in those aged 71-80 years. A significant association was found between hypertension duration and DD (p=0.023*), with 26.1% of patients with 1-5 years of hypertension exhibiting DD, increasing to 66.7% in those with more than 15 years. Among patients with grade 3 hypertension, 75% had DD confirming that worsening hypertension increases DD risk. On ECG analysis, 17% of patients had Left Ventricular Hypertrophy (LVH), and 70.6% of them had DD (p=0.026*), indicating a strong association between LVH and DD. Echocardiographic findings showed 46% had impaired LV relaxation, and 27% had elevated Left Atrial Pressure (LAP). Comparative analysis revealed that patients with DD had significantly higher mean age, longer hypertension duration, and higher Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) (p<0.05), whereas Body Mass Index (BMI), Blood Sugar Levels (BSL), and lipid profiles did not show significant differences.

Conclusion: The study found that DD is prevalent in nearly half of hypertensive patients, with its prevalence increasing with age, hypertension severity, and duration. Significant associations were observed between LVH on ECG and echocardiographic evidence of DD, reinforcing the need for early screening and stringent BP control to prevent progression to heart failure. Routine echocardiographic assessment of hypertensive patients should be emphasised to detect and manage DD at an early stage.

Keywords: Echocardiography, Heart failure with preserved ejection fraction, Hypertension duration, Left atrial pressure, Left ventricular hypertrophy

INTRODUCTION

Hypertension, or elevated BP, is a major global public health concern, contributing significantly to cardiovascular morbidity and mortality. It is often asymptomatic, easily identifiable, and treatable, yet, if left uncontrolled, it can lead to severe complications, including DD and heart failure. The role of hypertension in the progression of Left Ventricular Diastolic Dysfunction (LVDD) has been well-documented, emphasising the need for early diagnosis and intervention [1].

The DD is characterised by an increase in diastolic filling pressure due to impaired left ventricular relaxation and increased chamber stiffness. This condition frequently progresses to HFpEF, leading to substantial morbidity [2]. Hypertension-induced LVDD is often underdiagnosed due to the absence of specific clinical symptoms in its early stages. However, echocardiographic assessments, particularly using doppler imaging, have emerged as a valuable tool in the early detection of LVDD in hypertensive patients [3].

Previous literature has identified risk factors contributing to LVDD, including age, obesity, diabetes mellitus, aortic stenosis, myocardial ischemia, and other cardiovascular comorbidities [4]. Prolonged hypertension results in increased afterload, triggering cardiac remodeling and subsequent alterations in diastolic and systolic function. Impaired left ventricular relaxation, associated with poorly controlled hypertension, contributes to the pathophysiology of LVDD and significantly raises the risk of Major Adverse Cardiac Events (MACE) [5]. It is estimated that up to 33% of hypertensive individuals without LVH exhibit asymptomatic DD, further underscoring the need for effective screening strategies [6].

Despite advancements in imaging techniques, diagnosing LVDD remains challenging. Echocardiography, particularly two-Dimensional (2D) doppler imaging, provides a non-invasive and reliable method for assessing diastolic function. It is more sensitive than ECG in detecting early-stage LVDD [7]. However, a significant proportion of hypertensive individuals remain undiagnosed due to the lack of routine echocardiographic screening in clinical settings [8]. The relationship between hypertension and LVDD has previously been explored establishing that elevated BP contributes significantly to impaired ventricular relaxation and increased pressures.

A study reported a high prevalence of LVDD in patients [9] with longstanding hypertension [10], while others highlighted the correlation between the severity of hypertension and worsening diastolic function [11-13]. Despite these findings, there remains a gap in literature from the Indian subcontinent addressing the clinical and electrocardiographic correlates of DD in hypertensive patients using comprehensive echocardiographic evaluation. The current study seeks to bridge this gap by assessing DD in a well-characterised cohort of hypertensive individuals and correlating it with ECG findings, hypertension duration, and severity, thereby offering novel insights into early detection and risk stratification strategies in routine clinical practice.

The present study aimed to assess the prevalence of DD in hypertensive patients using 2D Echo and doppler imaging and its association with clinical profiles and ECG findings. Understanding the relationship between hypertension and LVDD can aid in the early detection and management of DD, potentially improving cardiovascular outcomes in hypertensive patients.

MATERIALS AND METHODS

The present observational cross-sectional analytical study was conducted at in the Medicine Outpatient Department (OPD) and inpatient wards at Dr. D. Y. Patil Medical College and Research Centre, Pune, Maharashtra, India between February 2023 and September 2025.

Sample size calculation: The sample size was determined based on a study by Ahmed AM et al., which reported that 50.3% of hypertensive patients undergoing echocardiography had LVDD [14]. The sample size was calculated using the formula:

$$n=4pq/l^2,$$

where, p=50.3 (prevalence), q=100-p=49.7, and l=10 (margin of error).

Substituting the values:

$$n=(4\times50.3\times49.7)/(10)^2=(4\times2500.91)/100=10003.64/100=100.04$$

Thus, a minimum of 100 participants was deemed adequate to achieve the desired statistical power, and accordingly, 100 hypertensive patients were enrolled in the study.

A purposive sampling technique was employed, and consecutive hypertensive patients meeting the inclusion criteria were recruited until the required sample size was reached. Informed written consent was obtained from all participants after explaining the study's purpose and potential benefits in a language they understood. Ethical clearance (IESC/PGS/2023/24) was obtained from the Institutional Ethics Committee (IEC) before commencing the study.

Inclusion and Exclusion criteria: Patients diagnosed with hypertension (essential or secondary), aged 18 years or older, were included in the study. Both newly diagnosed hypertensive patients and those already on antihypertensive medication were eligible for inclusion. Patients with heart failure with reduced ejection fraction, ischemic heart disease, valvular heart disease, cardiomyopathies, or diabetes mellitus (Type 1 or Type 2) were excluded. Patients who were unwilling to participate were also excluded.

Study Procedure

Clinical assessment: A detailed clinical evaluation was conducted for each participant, which included history-taking and a comprehensive physical examination. Data were recorded using a structured case proforma, which included demographic details such as age and gender. The history of hypertension, including duration, and associated symptoms (such as dysnoea, palpitations, pedal oedema, and fatigue), was documented. Information regarding risk factors (such as smoking, alcohol consumption, diet and tobacco) and family history of hypertension) was also collected.

Body weight and height were measured to calculate the BMI, which was categorised as per the World Health Organisation (WHO) classification for the Asian population: underweight (<18.5 kg/m^2), normal (18.5-22.9 kg/m^2), overweight (23-24.9 kg/m^2), and obese (≥25 kg/m^2) [14]. This categorisation was used to assess the association between BMI and DD in the study population.

Diagnostic investigations: All participants underwent ECG and echocardiographic (2D Echo and doppler) assessment. Twelve-lead ECG was performed to evaluate left axis deviation, left atrial enlargement, and LVH. Two-dimensional echocardiography and doppler imaging were conducted using a Siemens G60S Sonolines Echocardiograph with a 2-4 MHz cardiac probe. The American Society of Echocardiography guidelines were followed for M-mode measurements. DD were graded as 1, 2 and 3 [15].

Biochemical parameters: In addition to ECG and echocardiography, fasting blood sugar and post prandial BSL-R, and lipid profiles were performed. The findings were recorded in the clinical proforma for further analysis.

The BP was measured using an automated sphygmomanometer after a 5-minute rest, with the patient seated and using an appropriately sized cuff. Hypertension was categorised according to the American College of Cardiology (ACC) and American Heart Association (AHA) 2017 guidelines [1].

STATISTICAL ANALYSIS

Categorical variables were expressed as frequency and percentages, while continuous variables were summarised using mean and Standard Deviation (SD). The Chi-square (χ^2) test was used to compare categorical variables, while the t-test was applied to compare continuous variables with a normal distribution. A p-value <0.05 was considered statistically significant. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 27.0.

RESULTS

A total of 100 hypertensive patients were included in the study. The mean age of the participants was 56.9 years (range: 30-84 years), with the highest proportion belonging to the 41-50 years (25%) and 61-70 years (24%) age groups. The study had 62 males (62%) and 38 females (38%), with a male-to-female ratio of 1.6:1. The majority of patients (40%) had hypertension for 6-10 years, while 31% had hypertension for 11-15 years. A family history of hypertension was present in 34% of participants.

The most commonly reported symptom was breathlessness in (39%) patients, followed by cough in 23 (23%) patients, chest pain in 21 (21%) patients, and pedal oedema in 15 (15%) patients. A small proportion, 8 (8%) patients was asymptomatic and had presented for routine follow-up.

Hypertension grading and risk factors: At the time of examination, 53 (53%) patients had normal BP due to ongoing antihypertensive treatment, while 30 (30%) patients had grade 1 hypertension, 13 (13%) patients had grade 2, and 4 (4%) patients had grade 3 hypertension [Table/Fig-1].

Regarding lifestyle factors, 29 (29%) patients were smokers, 22 (22%) patients consumed alcohol, and 16 (16%) patients chewed tobacco. The majority, 65 (65%) patients, followed a mixed diet, while 24 (24%) patients were vegetarians.

Variables	Frequency (n=100)	Percentage (%)
Age group (years)		
≤40	12	12
41-50	25	25
51-60	21	21
61-70	24	24
71-80	16	16
>80	2	2
Gender		
Male	62	62
Female	38	38
Family history of hypertension		
No	66	66
Yes	34	34
Hypertension duration		
1-5 years	23	23
6-10 years	40	40
11-15 years	31	31
>15 years	6	6
Hypertension grade [16]		
Normal BP (120-129/80-84 mm Hg)	53	53
Grade 1 (130-139/90-99 mm Hg)	30	30
Grade 2 (140-159/100-109 mm Hg)	13	13
Grade 3 (>160/110 mm Hg)	4	4
BMI category		
18.5-22.9 kg/m^2	21	21
23-27.9 kg/m^2	40	40
28-29.9 kg/m^2	18	18
>30 kg/m^2	21	21
Habits		
Smoking	29	29
Alcoholism	22	22
Tobacco chewing	16	16
Diet history		
Mixed	65	65
Non-vegetarian	11	11
Vegetarian	24	24
Complaints		
Breathlessness	39	39
Cough	23	23
Chest pain	21	21
Pedal oedema	15	15
Palpitation	5	5
Abdominal pain	2	2
Fever	1	1
Headache	1	1
None	8	8

[Table/Fig-1]: Demographic and clinical characteristics of study participants.

BMI analysis showed that 21 (21%) patients were obese (BMI >30 kg/m^2), while 40 (40%) patients were overweight (BMI 23-27.9 kg/m^2).

Prevalence of Diastolic Dysfunction (DD) and associated factors: The DD was detected in 46% of hypertensive patients, with 19% having grade 1 DD, 11% having grade 2, and 16% having grade 3 DD. The prevalence of DD increased with age, from 25% in patients under 40 years to 62.5% in those aged 71-80 years. Similarly, the prevalence of DD increased with the duration of hypertension, from 26.1% in those with hypertension for 1-5 years to 66.7% in those with hypertension for more than 15 years (p=0.023). Among patients with normal BP, 37.7% had DD, while 75% of those with grade 3 hypertension had DD although the association was not significant p>0.05 [Table/Fig-2].

Variables	Diastolic Dysfunction (DD) (%)	No Diastolic Dysfunction (DD) (%)	p-value
Age (years)			
≤40	3 (25.0)	9 (75.0)	0.152
41-50	9 (36.0)	16 (64.0)	
51-60	10 (47.6)	11 (52.4)	
61-70	14 (58.3)	10 (41.7)	
71-80	10 (62.5)	6 (37.5)	
Gender			
Female	17 (44.7)	21 (55.3)	0.834
Male	29 (46.8)	33 (53.2)	
Hypertension duration (years)			
1-5	6 (26.1)	17 (73.9)	0.023*
6-10	16 (40.0)	24 (60.0)	
11-15	20 (64.5)	11 (35.5)	
>15	4 (66.7)	2 (33.3)	
Hypertension grade			
Normal BP	20 (37.7)	33 (62.3)	0.2239
Grade 1	15 (50.0)	15 (50.0)	
Grade 2	8 (61.5)	5 (38.5)	
Grade 3	3 (75.0)	1 (25.0)	

[Table/Fig-2]: Prevalence of Diastolic Dysfunction (DD) based on key factors. Chi-square test was used to calculate the p-value. p-value of <0.05 is considered as significant

Electrocardiographic and echocardiographic findings: On ECG analysis, 17% of patients had LVH, 31% had ST wave changes, 22% had T wave inversion, and 22% had tachycardia. A significant association was found between LVH on ECG and DD, with 70.6% of patients with LVH also having DD (p=0.026*).

Echocardiographic findings showed that 18% of patients had Regional Wall Motion Abnormalities (RMWA), while 27% had elevated LAP. Left ventricular relaxation impairment was observed in 46% of patients. Among patients with LVH on echocardiography, 17% had mild concentric LVH, 10% had moderate concentric LVH, and 11% had severe concentric LVH [Table/Fig-3].

Findings	n (%)	Associated with DD (n, % or p-value)
LVH on ECG	17 (17%)	12/17 (70.6%), p=0.026*

[Table/Fig-3]: ECG findings and association with Diastolic Dysfunction (DD). Chi-square test was used to calculate the p-value. p-value of <0.05 is considered as significant

On comparing clinical and biochemical parameters between patients with and without DD, those with DD had significantly higher mean age (59.93±12.7 years vs. 54.39±13.7 years, p=0.04*), longer duration of hypertension (2.48±0.83 years vs. 1.96±0.82 years, p=0.003*), and higher systolic (139.35±21.7 mmHg vs. 128.44±21.51 mmHg, p=0.014*) and DBP (84.78±11.5 mmHg vs. 79.33±11.8 mmHg, p=0.022*). BMI, BSL, and lipid profile variables did not show statistically significant differences between groups [Table/Fig-4].

Parameters	DD present (Mean±SD) (n=46)	DD absent (Mean±SD) (n=54)	p-value
Age (years)	59.93±12.7	54.39±13.7	0.040*
Duration of hypertension (years)	2.48±0.83	1.96±0.82	0.003*
Systolic BP (mmHg)	139.35±21.7	128.44±21.51	0.014*
Diastolic BP (mmHg)	84.78±11.5	79.33±11.8	0.022*
BMI (kg/m^2)	25.8±3.9	25.3±4.1	0.512
Fasting blood sugar (mg/dL)	106.3±12.4	104.7±13.2	0.631

Postprandial blood sugar (mg/dL)	159.2±21.3	155.6±24.1	0.482
Total cholesterol (mg/dL)	185.6±28.1	181.3±30.2	0.398
LDL (mg/dL)	109.4±18.6	106.7±19.4	0.507
HDL (mg/dL)	43.5±8.2	44.1±7.6	0.671
Triglycerides (mg/dL)	151.7±33.2	148.9±35.7	0.583

[Table/Fig-4]: Comparison of clinical and biochemical parameters in patients with and without Diastolic Dysfunction (DD).
Independent t-test was used to calculate the p-value. p-value of <0.05 is considered as significant

DISCUSSION

The present study investigated the prevalence of DD in hypertensive patients using 2D echocardiography and doppler imaging, along with its association with clinical characteristics and ECG findings. The results highlighted that 46% of hypertensive patients exhibited DD, with its prevalence increasing with age, duration, and severity of hypertension. These findings align with previous studies, which emphasise the role of hypertension as a major contributor to LVDD and heart failure [9,10].

The 46% prevalence of DD observed in this study is consistent with earlier research. Swierblewska E et al., reported a 49.7% prevalence of LVDD in hypertensive patients, with grade 1 DD in 24.4% and grade2 in 19.3% [10]. Similarly, Al-Ghamdi S et al., found that 44.2% of hypertensive patients had LVDD, and the prevalence increased with worsening hypertension [11]. Another study by Ike SO et al., reported LVDD in 82.86% of hypertensive patients, with a higher prevalence among those with severe hypertension [12]. These studies confirm that DD is an early and frequent complication of hypertension, often detected before the onset of clinical heart failure [16].

A significant association between mean age and DD was observed in the present study. The prevalence of DD increased from 25% in patients below 40 years to 62.5% in those aged 71-80 years, reinforcing findings from previous research [10,16-17]. Li SY et al., also reported that aging leads to increased passive ventricular stiffness, a key factor in DD, due to increased interstitial collagen deposition and a decline in functional myocytes [17,18]. These age related structural changes impair left ventricular compliance and relaxation, making older individuals more susceptible to DD.

This study found that longer duration of hypertension was associated with a higher prevalence of DD (p=0.023). The prevalence of DD increased from 26.1% in patients with 1-5 years of hypertension to 66.7% in those with more than 15 years. Similar observations were made in studies by Ingle VV et al., and Mohmad AL et al., where longstanding hypertension was a strong predictor of DD [18,19]. Chronic hypertension leads to myocardial fibrosis, increased left ventricular mass, and stiffness, all of which contribute to DD [17].

A 37.7% of patients with normal BP having DD, compared to 75% of those with grade 3 hypertension. This trend aligns with the findings of Mohmad AL et al., who reported that 73% of patients with Stage II-III hypertension had DD [19]. Ike SO et al., and Al-Ghamdi S et al., also demonstrated a higher prevalence of DD in patients with severe hypertension [11,12]. These results emphasise that inadequate BP control accelerates DD, underscoring the need for early diagnosis and aggressive hypertension management.

This study found a significant association between LVH on ECG and DD, with 70.6% of patients with LVH also having DD (p=0.026*). Borhani NO et al., highlighted that LVH is a major complication of hypertension, often preceding DD and heart failure [20]. Swierblewska E et al., also found that LVH on ECG was a strong predictor of DD, with a significant correlation between ECG-diagnosed LVH and echocardiographic LVDD [10]. The Hypertension Detection and Follow-up Program (HDFP) similarly reported that ECG-diagnosed LVH had a prevalence of 5-11% in hypertensive patients, emphasising its importance as a screening tool for DD [21].

Echocardiographic analysis in the present study revealed 46% of patients had impaired LV relaxation, and 27% had elevated LAP. Similar findings were reported by Nagaonkar VS who found that all patients with ECG-diagnosed LVH exhibited DD on echocardiography [21]. This supports the use of 2D echocardiography and doppler imaging as crucial tools for detecting subclinical DD, even in asymptomatic patients [16].

Comparative analysis revealed that patients with DD had significantly higher mean age (p=0.04*), longer hypertension duration (p=0.003*), and higher SBP (p=0.014*) and DBP (p=0.022*) than those without DD. These findings align with those of Swierblewska E et al., who found that age, hypertension duration, and SBP were independent risk factors for DD [10]. In contrast, BMI, BSLs, and lipid profiles did not show significant differences, indicating that hypertension itself, rather than metabolic factors, plays a dominant role in DD progression [10,17].

The findings of this study highlight the need for routine echocardiographic screening in hypertensive patients, particularly those with longstanding or severe hypertension. Early detection of LVDD can help in preventing HFpEF, which is often underdiagnosed. Aggressive BP control, lifestyle modifications, and antihypertensive therapy may help reverse early-stage DD, as suggested in previous studies [10,17].

Limitation(s)

The present study had certain limitations. The sample size was relatively small (n=100), and the study was conducted at a single tertiary care hospital, which may limit generalisability. Additionally, longitudinal follow-up was not performed to assess the progression of DD over time. Future studies should include larger, multi-center populations with long-term follow-up to evaluate the impact of hypertension treatment on diastolic function.

CONCLUSION(S)

The present study found that DD was present in 46% of hypertensive patients. Comparative analysis revealed that patients with DD had significantly higher mean age, longer hypertension duration, and higher SBP and DBP than those without DD. Significant associations were observed between LVH on ECG and echocardiographic evidence of DD, reinforcing the importance of early screening using non-invasive tools. The findings underscore the need for stringent hypertension control and routine echocardiographic assessments to prevent heart failure and adverse cardiovascular outcomes in hypertensive patients.

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