RJNMSR
Review Journal of Neurological & Medical Sciences Review
Volume 4, Issue 6, 2026

COMPARATIVE ECHOCARDIOGRAPHIC EVALUATION OF LEFT VENTRICULAR FUNCTION IN CONTROLLED AND UNCONTROLLED HYPERTENSION

Zaib Un Nisa Wagma[1], Nayab Ali[2], Minhal Hussain[3], Aisha Sahib[4], Syed Baqir Ali Shah[5], Zunaira Rizwan[6], Ajmal Khan[*7]

[1,2]*Department of Cardiology, Khyber Medical University, Peshawar, Pakistan*
[3]*Department of Cardiology, City University of Information Science and Technology Peshawar, Pakistan*
[4]*Department of Cardiology, Gomal University, Dera Ismail Khan, Pakistan*
[5,6]*Department of Cardiology, Rehman Medical Institute, Peshawar, Pakistan*
[*7]*Rehman College of Allied Health Sciences, Rehman Medical Institute, Peshawar, Pakistan*

[*7]ajmal.mashwani1@gmail.com

Corresponding Author: *
Ajmal Khan
DOI: https://doi.org/10.5281/zenodo.20909012

Received	Accepted	Published
24 April 2026	06 June 2026	21 June 2026

ABSTRACT

Background: *Hypertension is associated with progressive structural and functional remodelling of the left ventricle, including hypertrophy, diastolic impairment, and a gradual decline in systolic performance. Echocardiography remains the principal non-invasive modality for detecting these cardiac changes at an early, reversible stage.*

Objective: *To compare left ventricular structural and functional echocardiographic parameters between patients with controlled and uncontrolled hypertension.*

Methods: *This comparative cross-sectional study was conducted at the Department of Cardiology, Ch. Pervaiz Elahi Institute of Cardiology, Multan. A total of 200 hypertensive patients were enrolled through consecutive convenience sampling and divided into two equal groups of 100 each: controlled hypertension (mean SBP <140 mmHg and DBP <90 mmHg) and uncontrolled hypertension (mean SBP ≥140 mmHg and/or DBP ≥90 mmHg). All participants underwent standardized transthoracic echocardiography to assess left ventricular mass index (LVMI), ejection fraction (LVEF), and diastolic indices (E/A and E/e′ ratios). Data were analysed using SPSS v25.0; continuous variables were compared with the independent-samples t-test and the Mann-Whitney U test, and categorical variables with the chi-square test. A p-value <0.05 was considered significant.*

Results: *Left ventricular hypertrophy was more prevalent in the uncontrolled group than the controlled group (70% vs 40%), with a correspondingly higher mean LVMI (125 ± 15 g/m² vs 95 ± 12 g/m²). Diastolic dysfunction was also more frequent in the uncontrolled group (63% vs 37%), reflected in a lower E/A ratio (0.9 ± 0.4 vs 1.2 ± 0.3) and a higher E/e′ ratio (18 ± 3 vs 12 ± 2). Mean LVEF was lower in the uncontrolled group (55 ± 7% vs 60 ± 5%), and systolic dysfunction was more prevalent (30% vs 10%). The Mann-Whitney U test confirmed a highly significant difference in median LVMI between groups (129.0 vs 91.0 g/m², p<0.0001).*

Conclusion: *Uncontrolled hypertension is associated with significantly greater left ventricular hypertrophy, diastolic dysfunction, and early systolic impairment compared with controlled hypertension.*

These findings reinforce the value of sustained blood pressure control and routine echocardiographic surveillance in hypertensive patients.

Keywords: *Hypertension; Echocardiography; Left ventricular hypertrophy; Diastolic dysfunction; Ejection fraction; Left ventricular mass index*

INTRODUCTION

Hypertension remains one of the most prevalent modifiable risk factors for cardiovascular disease worldwide, affecting more than a billion people and contributing substantially to the global burden of stroke, heart failure, and chronic kidney disease [1]. Although the proportion of patients aware of their diagnosis has improved in many regions, the proportion achieving adequate blood pressure control continues to lag behind, owing to inconsistent treatment adherence, limited access to care, and clinical inertia in regimen intensification [2,3].

Chronically elevated blood pressure imposes a sustained haemodynamic load on the left ventricle, driving compensatory hypertrophy of the myocardium, impaired ventricular relaxation, and, over time, a measurable decline in systolic function. These changes are frequently subclinical in their early stages and are best detected using transthoracic echocardiography, which offers a reproducible, radiation-free means of quantifying left ventricular mass, geometry, and both diastolic and systolic performance [11,12].

While the pathophysiological relationship between poorly controlled hypertension and adverse cardiac remodelling is well established, direct comparative data from local cardiology populations remain limited. Characterising these differences in a defined clinical cohort can help clinicians identify patients at greatest risk of progression and reinforce the rationale for sustained blood pressure control. The present study was therefore designed to compare echocardiographic indices of left ventricular structure and function between patients with controlled and uncontrolled hypertension attending a tertiary cardiology centre.

The specific objectives of this study were: (1) to determine the prevalence and severity of left ventricular hypertrophy and diastolic dysfunction in controlled versus uncontrolled hypertensive patients; and (2) to compare left ventricular ejection fraction between the two groups in order to evaluate the impact of blood pressure control on systolic function.

MATERIALS AND METHODS

Study Design and Setting

This was a comparative, cross-sectional study conducted in the Department of Cardiology at the Ch. Pervaiz Elahi Institute of Cardiology, Multan, Pakistan, over a defined study period. The design allowed direct comparison of left ventricular structural and functional echocardiographic parameters between patients with controlled and uncontrolled hypertension at a single time point.

Sample Size and Sampling Technique

A total of 200 hypertensive patients were enrolled and stratified into two equal groups of 100 patients each controlled hypertension and uncontrolled hypertension based on documented blood pressure control status. Participants were recruited from the outpatient and inpatient services of the cardiology department using a consecutive convenience sampling technique.

Inclusion Criteria

Patients aged 18 years or older with a documented diagnosis of hypertension for at least one year, classified as having controlled or uncontrolled hypertension on the basis of recent clinical records, and willing to provide written informed consent, were eligible for enrolment.

Exclusion Criteria

Patients with valvular heart disease, congenital heart disease, or cardiomyopathy; those with a myocardial infarction or stroke within the preceding six months; pregnant women; patients with technically inadequate echocardiographic windows; and those with chronic illnesses known to independently affect cardiac function (such as chronic kidney disease or chronic obstructive pulmonary disease) were excluded.

Blood Pressure Classification

Blood pressure was measured using a calibrated digital sphygmomanometer after at least five minutes of seated rest. Three readings were obtained at five-minute intervals and averaged. Patients with a mean systolic blood pressure below 140 mmHg and diastolic blood pressure below 90 mmHg were classified as controlled hypertensives; those with a mean systolic blood pressure of 140 mmHg or higher and/or a diastolic blood pressure of 90 mmHg or higher were classified as uncontrolled hypertensives.

Echocardiographic Assessment

All patients underwent a comprehensive transthoracic echocardiographic examination performed by trained cardiologists using standardised protocols. Left ventricular end-diastolic and end-systolic dimensions were recorded to assess chamber size, and interventricular septal and posterior wall thickness were measured to evaluate left ventricular hypertrophy. Left ventricular ejection fraction was calculated using Simpson's biplane method. Diastolic function was assessed using the mitral inflow E/A ratio and the tissue Doppler-derived E/e′ ratio, in line with standard echocardiographic recommendations [11,12].

Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board of the Ch. Pervaiz Elahi Institute of Cardiology, Multan. Written informed consent was obtained from all participants after a full explanation of the study's purpose, procedures, and potential risks and benefits. Participants were assured of confidentiality and informed of their right to withdraw at any stage without affecting their ongoing clinical care.

Statistical Analysis

Data was analysed using SPSS version 25.0 and GraphPad Prism. Continuous variables were expressed as mean ± standard deviation and compared between groups using the independent-samples t-test, with the Mann-Whitney U test applied for non-normally distributed variables such as left ventricular mass index. Categorical variables were expressed as frequencies and percentages and compared using the chi-square test. A two-tailed p-value of less than 0.05 was considered statistically significant.

RESULTS

Demographic and Clinical Characteristics

Of the 200 enrolled patients, the uncontrolled hypertension group had a slightly higher proportion of male participants (60% vs 55%) and a marginally older mean age (52.1 ± 8.5 years vs 50.3 ± 7.8 years) compared with the controlled group. The uncontrolled group also had a longer mean duration of hypertension (10.1 ± 4.5 years vs 8.5 ± 3.2 years), higher mean systolic and diastolic blood pressures, and a lower rate of antihypertensive medication adherence (90% vs 100%), as summarised in Table 1.

Table 1. Comparison of clinical characteristics between controlled and uncontrolled hypertension groups.

Clinical Characteristic	Controlled Hypertension (n=100)	Uncontrolled Hypertension (n=100)
Duration of hypertension (years)	8.5 ± 3.2	10.1 ± 4.5
Mean systolic blood pressure (mmHg)	132 ± 6	148 ± 10
Mean diastolic blood pressure (mmHg)	85 ± 5	96 ± 8
Medication adherence	100%	90%

Left Ventricular Hypertrophy and Mass Index

Left ventricular hypertrophy was present in 70% of the uncontrolled hypertension group compared with 40% of the controlled group (Table 2, Figure 1). The mean left ventricular mass index (LVMI) was correspondingly higher in the uncontrolled group (125 ± 15 g/m²) than in the controlled group (95 ± 12 g/m²), as illustrated in Figure 2.

Table 2. Prevalence of left ventricular hypertrophy and mean LVMI in controlled and uncontrolled hypertension groups.

Parameter	Controlled Hypertension	Uncontrolled Hypertension
Prevalence of LVH	40%	70%
Mean LVMI (g/m²)	95 ± 12	125 ± 15

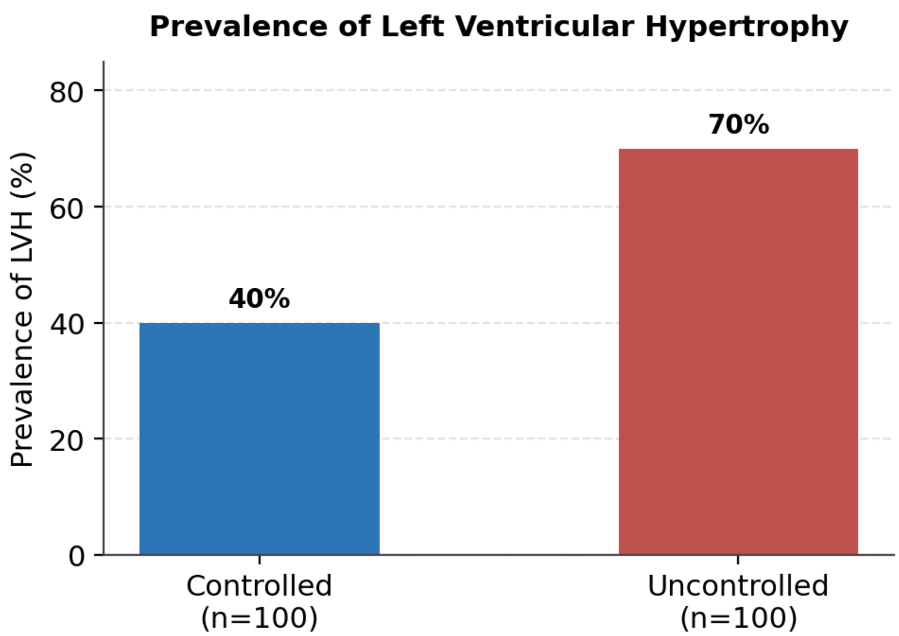

Figure 1. Prevalence of left ventricular hypertrophy (LVH) in controlled vs uncontrolled hypertension groups.

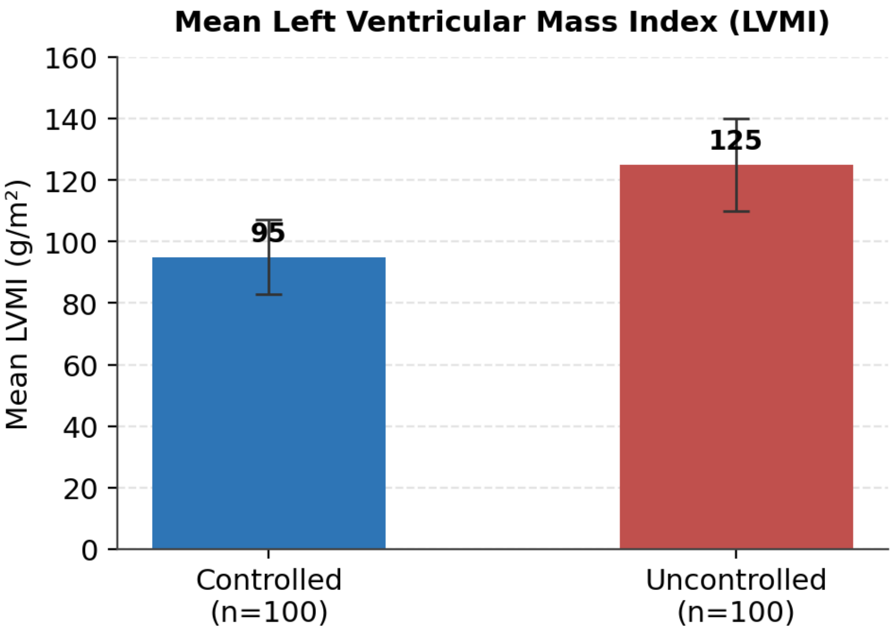

Figure 2. Mean left ventricular mass index (LVMI, g/m² ± SD) in controlled vs uncontrolled hypertension groups

Diastolic Function

Diastolic dysfunction was identified in 63% of the uncontrolled group compared with 37% of the controlled group, as shown in Figure 3. The mean E/A ratio was lower in the uncontrolled group (0.9 ± 0.4) than in the controlled group (1.2 ± 0.3), while the mean E/e′ ratio, reflecting left ventricular filling pressure, was markedly higher in the uncontrolled group (18 ± 3) than in the controlled group (12 ± 2). These diastolic indices are summarised in Table 3 and depicted graphically in Figure 4.

Table 3. Comparison of diastolic function parameters between controlled and uncontrolled hypertension groups.

Parameter	Controlled Hypertension	Uncontrolled Hypertension
E/A ratio (mean ± SD)	1.2 ± 0.3	0.9 ± 0.4
E/e′ ratio (mean ± SD)	12 ± 2	18 ± 3

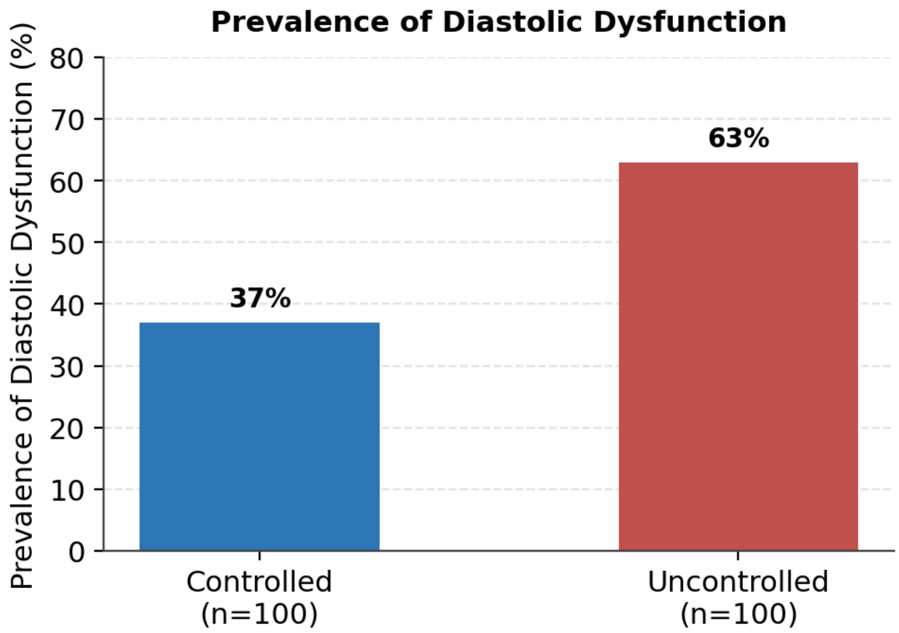

Figure 3. Prevalence of diastolic dysfunction in controlled vs uncontrolled hypertension groups.

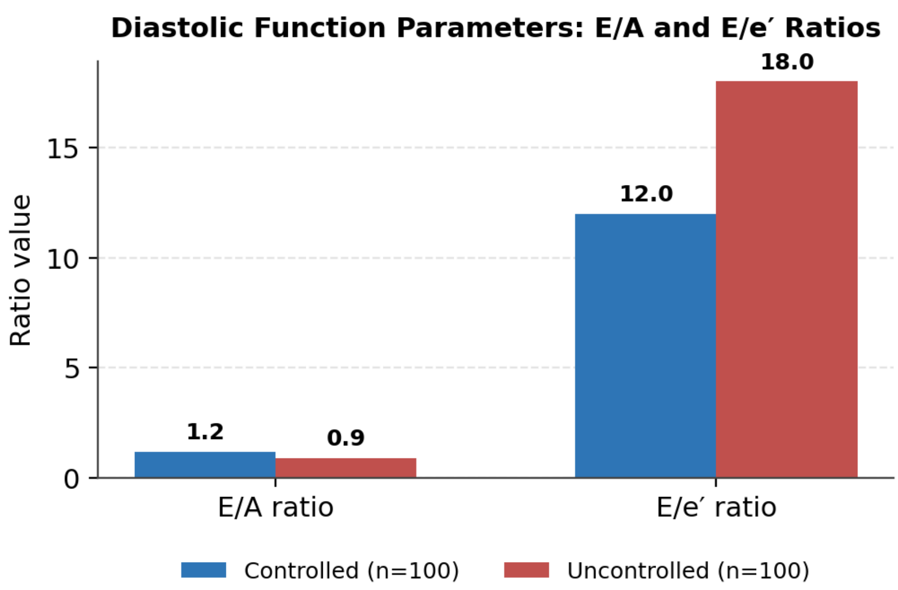

Figure 4. Comparison of E/A and E/e' ratios between controlled and uncontrolled hypertension groups.

Left Ventricular Ejection Fraction and Systolic Function

Mean left ventricular ejection fraction (LVEF) was significantly lower in the uncontrolled group (55 ± 7%) compared with the controlled group (60 ± 5%), as presented in Table 4 and Figure 5. Although both group means remained within the broadly normal range, systolic dysfunction was identified in 30% of the uncontrolled group compared with only 10% of the controlled group (Table 5, Figure 6).

Table 4. Comparison of left ventricular ejection fraction between controlled and uncontrolled hypertension groups

Group	Mean LVEF (% ± SD)
Controlled	60 ± 5
Uncontrolled	55 ± 7

.

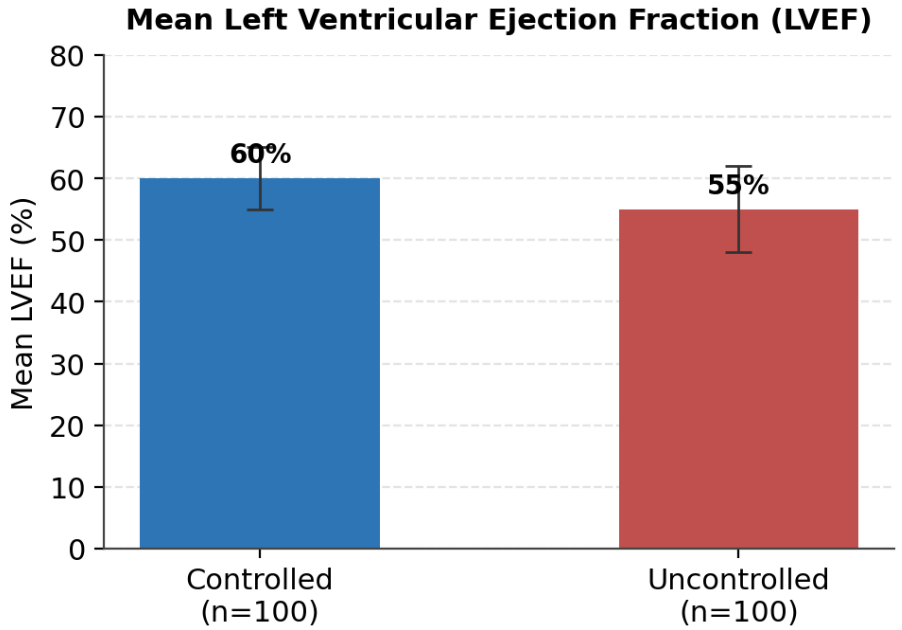

Figure 5. Mean left ventricular ejection fraction (LVEF, % ± SD) in controlled vs uncontrolled hypertension groups.

Table 5. Prevalence of systolic dysfunction in controlled and uncontrolled hypertension groups.

Group	Prevalence of Systolic Dysfunction
Controlled	10%
Uncontrolled	30%

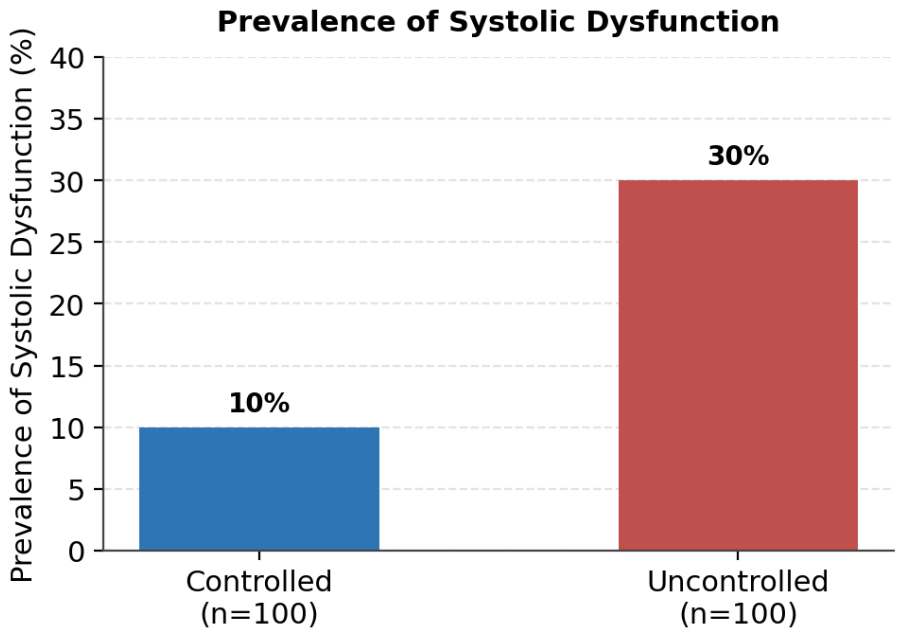

Figure 6. Prevalence of systolic dysfunction in controlled vs uncontrolled hypertension groups.

Statistical Comparison of LVMI

A Mann-Whitney U test was performed to compare median LVMI between groups, given the non-normal distribution of this variable. The median LVMI was significantly higher in the uncontrolled group than in the controlled group (129.0 g/m² vs 91.0 g/m²; U = 0; p<0.0001), with a Hodges-Lehmann median difference of 38.0 g/m², as detailed in Table 6. This confirms a strong and statistically robust association between poor blood pressure control and left ventricular structural remodelling.

Table 6. Mann-Whitney U test results for LVMI comparison between controlled and uncontrolled groups.

Statistic	Value
Median LVMI – Controlled (n=100)	91.0 g/m²
Median LVMI – Uncontrolled (n=100)	129.0 g/m²
Mann-Whitney U	0
Median difference (Hodges-Lehmann)	38.0 g/m²
p-value (two-tailed)	<0.0001

DISCUSSION

The present study demonstrates that uncontrolled hypertension is associated with substantially greater left ventricular structural remodelling and functional impairment than well-controlled hypertension. The markedly higher LVMI observed in the uncontrolled group (Table 2, Figure 2) is consistent with the work of Verdecchia et al., who described a strong association between inadequately controlled blood pressure and the development of left ventricular hypertrophy [4], and with Okin et al., who showed that effective blood pressure control is associated with regression of hypertrophic changes and improved outcomes [5]. The 70% prevalence of LVH in the uncontrolled group, nearly double that of the controlled group (Figure 1), underscores how sustained pressure overload rather than hypertension per se drives the structural transition from a compensated to a hypertrophied ventricle.

Mechanistically, the higher LVMI and hypertrophy prevalence observed here likely reflect the cumulative haemodynamic burden imposed by chronically elevated afterload. Persistent elevation in systolic and diastolic pressures, evident in this cohort's clinical profile (Table 1), increases wall stress on the myocardium, triggering compensatory concentric hypertrophy through both myocyte enlargement and interstitial fibrosis. Over time, this adaptive response becomes maladaptive, impairing relaxation and, eventually, contractile reserve a sequence broadly mirrored in the progression from elevated LVMI, to diastolic dysfunction, to early systolic impairment observed across this cohort.

The diastolic indices observed in this study are a reduced E/A ratio and an elevated E/e′ ratio in the uncontrolled group (Table 3, Figure 4) mirror the findings of Devereux et al., who linked poorly controlled blood pressure with impaired ventricular relaxation and elevated filling pressures [6]. The higher prevalence of diastolic dysfunction in the uncontrolled group (63% vs 37%, Figure 3) is of clinical concern, since diastolic dysfunction frequently precedes overt heart failure with preserved ejection fraction and may remain clinically silent for years before symptoms emerge. The broader pattern of reversibility with intensive treatment described in a meta-analysis by Thomopoulos et al. lends further support to the idea that diastolic abnormalities associated with uncontrolled hypertension are, at least partially, modifiable through sustained blood pressure control [7].

The modest but statistically meaningful reduction in LVEF among uncontrolled patients in this cohort (55 ± 7% vs 60 ± 5%, Table 4, Figure 5) is consistent with evidence from the SPRINT trial, which demonstrated that intensive blood pressure management helps preserve systolic function and reduces the risk of progression to heart failure [8]. Earlier work by Koren et al. similarly showed that sustained, poorly controlled hypertension accelerates the onset of systolic impairment [9]. The threefold higher prevalence of overt systolic dysfunction in the uncontrolled group (30% vs 10%, Table 5, Figure 6) suggests that, while mean LVEF differences between groups appear numerically modest, a clinically meaningful subset of uncontrolled patients had already progressed to measurable systolic compromise a finding that average values alone can understate.

The Mann-Whitney U analysis (Table 6) provided additional statistical confirmation of the magnitude of structural remodelling, with a median LVMI difference of 38.0 g/m² between groups ($p<0.0001$). The use of a non-parametric test for this comparison was appropriate given the skewed distribution typically seen with LVMI in hypertensive populations, and the very low U statistic together with the narrow, highly significant p-value reflects a separation between groups that is unlikely to be attributable to chance or sampling variation alone.

Taken together, these findings reinforce the clinical importance of integrating routine echocardiographic surveillance into the long-term management of hypertensive patients, particularly those with suboptimal blood pressure control. The slightly lower medication adherence observed in the uncontrolled group (90% vs 100%, Table 1) is consistent with observations by Chobanian et al. that even modest reductions in adherence can have a cumulative detrimental effect on cardiac structure and function over time [10]. This suggests that interventions aimed at improving adherence including patient education, simplified treatment regimens, and structured follow-up may meaningfully reduce the burden of hypertensive cardiac remodelling.

From a public health perspective, these findings carry particular relevance for resource-limited settings, where access to advanced cardiac imaging and specialist follow-up is often constrained. In such contexts, echocardiography performed at the time of diagnosis or during routine review may serve as an efficient triage tool, helping clinicians identify patients with early hypertrophic or diastolic changes who would benefit most from intensified antihypertensive therapy, closer monitoring, and targeted adherence support. Embedding even periodic echocardiographic assessment into primary and secondary care pathways for hypertension could therefore yield disproportionate benefit relative to its cost, particularly in populations where uncontrolled hypertension remains common.

The findings of this study should also be considered alongside its methodological strengths. The use of a clearly defined blood pressure classification protocol, standardised echocardiographic technique, and a reasonably large, balanced sample of 200 patients (100 per group) allowed for meaningful between-group comparisons across multiple structural and functional parameters simultaneously, rather than relying on a single isolated metric. This multiparametric approach spanning LVMI, E/A and E/e′ ratios, and LVEF provides a more complete picture of the spectrum of hypertensive cardiac remodelling than any single measure in isolation.

Limitations

This study has several limitations. The use of consecutive convenience sampling may introduce selection bias and limit the generalisability of the findings to the broader hypertensive population, particularly patients managed outside tertiary cardiology centres. Single-centre recruitment further restricts external validity, since referral patterns and case mix at a specialised cardiology institute may differ from those seen in primary care or community settings. Inter-observer variability in echocardiographic measurement, despite the use of a standardised protocol, may have introduced minor measurement variation; future studies could mitigate this through blinded or automated image analysis. Additionally, the cross-sectional design precludes any causal inference regarding the temporal relationship between blood pressure control and cardiac remodelling; it remains possible that some baseline structural differences predated the divergence in blood pressure control rather than resulting solely from it. Finally, this study did not adjust for potential confounders such as body mass index, diabetes status, or duration of specific antihypertensive drug classes, all of which may independently influence left ventricular structure and function.

Future Research Directions

Longitudinal studies tracking the same patients over time would help clarify the temporal sequence and reversibility of the structural and functional changes identified here, and could establish whether sustained blood pressure normalisation leads to measurable regression of LVMI and diastolic indices. Future work would also benefit from multivariable analysis adjusting for comorbidities such as diabetes and obesity, as well as exploration of advanced imaging modalities, including strain echocardiography and cardiac magnetic resonance imaging, which may detect subclinical myocardial dysfunction earlier than conventional parameters. Multicentre studies incorporating patients from primary care and community settings would further strengthen the generalisability of these findings beyond a single tertiary cardiology institute.

CONCLUSION

Uncontrolled hypertension is associated with a significantly higher prevalence of left ventricular hypertrophy, more pronounced diastolic dysfunction, and early evidence of systolic impairment compared with controlled hypertension. These findings support the integration of routine echocardiographic monitoring into the long-term care of hypertensive patients and underscore the clinical value of sustained blood pressure control, medication adherence, and timely treatment intensification in limiting progressive cardiac remodelling.

REFERENCES

1. Mills KT, Stefanescu A, He J. The global epidemiology of hypertension. Nat Rev Nephrol. 2020;16(4):223-237.
2. Centers for Disease Control and Prevention. Hypertension control among US adults. CDC Reports. 2023.
3. Mensah GA, Roth GA, Fuster V. The global burden of cardiovascular diseases and risk factors. J Am Coll Cardiol. 2019;74(20):2529-2532.
4. Verdecchia P, Schillaci G, Borgioni C, et al. Adverse prognostic significance of left ventricular hypertrophy in hypertension. Am J Hypertens. 2001;14(9 Pt 1):867-873.

5. Okin PM, Devereux RB, Jern S, et al. Regression of electrocardiographic left ventricular hypertrophy during antihypertensive treatment and prediction of major cardiovascular events. JAMA. 2012;292(19):2343-2349.
6. Devereux RB, Roman MJ, Liu JE, et al. Congestive heart failure despite normal left ventricular systolic function in a population-based sample: the Strong Heart Study. Am J Cardiol. 2004;86(10):1090-1096.
7. Thomopoulos C, Parati G, Zanchetti A. Effects of blood pressure lowering on outcome incidence in hypertension: assessment of diastolic dysfunction. J Hypertens. 2020;38(8):1404-1415.
8. SPRINT Research Group. A randomized trial of intensive versus standard blood-pressure control. N Engl J Med. 2015;373(22):2103-2116.
9. Koren MJ, Devereux RB, Casale PN, Savage DD, Laragh JH. Relation of left ventricular mass and geometry to morbidity and mortality in uncomplicated essential hypertension. Ann Intern Med. 1991;114(5):345-352.
10. Chobanian AV, Bakris GL, Black HR, et al. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. Hypertension. 2003;42(6):1206-1252.
11. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults. J Am Soc Echocardiogr. 2015;28(1):1-39.
12. Nagueh SF, Smiseth OA, Appleton CP, et al. Recommendations for the evaluation of left ventricular diastolic function by echocardiography. Eur Heart J Cardiovasc Imaging. 2016;17(12):1321-1360.