RESEARCH ARTICLE

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Effect of Blood Pressure Control on Left Atrial Function Assessed by 2D Echocardiography in Newly Diagnosed Patients with Systemic Hypertension

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Abstract

Background and Aim: The objective of this study was to investigate the impact of appropriate blood pressure (BP) control on left atrial (LA) function in recently diagnosed individuals with systemic hypertension (HTN), as assessed by two-dimensional (2D) speckle echocardiography and electrocardiography.

Materials and Methods: The study included 50 patients who were recently diagnosed with systemic arterial HTN and sought medical attention at Ain Shams University Hospital. The patients' demographic information, risk factors, general and local examinations, 12-lead electrocardiograms (ECG), 2D speckle tracking ECGs, and laboratory measurements were evaluated. Following six months of appropriate BP control in accordance with Joint National Committee 10, the patients were followed up.

Results: Peak atrial longitudinal strain (PALS) increased in the current study, with a mean change of 35.04±4.33 to 38.92±5.52 and a *P*-value <0.001. The mean peak atrial contraction, picture archiving and communication system (PACS) strain, increased from 17.38±4.67 to 20.46±4.39, with a *P*-value of less than 0.001. The mitral peak early (E) and septal mitral annular velocities (e') and their average E/e' decreased with a change in the mean from 8.8±0.93 to 7.8±1.16, with a *P*-value of less than 0.001. The mean LA stiffness index (LASI) decreased from 0.24±0.04 to 0.2±0.03, with a *P*-value less than 0.001. The ECG follow-up showed no discernible change in the *P-wave's* duration or amplitude with *P*-values of 0.135 and 0.785, respectively.

Conclusion: The results of this study showed that patients with HTN may benefit from speckle tracking imaging to identify mild impairment of LA function. PALS, PACS, E/e', and LASI improve in hypertensive patients when BP is well controlled. Additional studies are necessary to enhance the comprehension of LA function assessed via speckle tracking echocardiography, particularly in predicting atrial fibrillation and evaluating the risk of heart failure.

Keywords: Hypertension, left atrium strain, left atrium stiffness index, intra-atrial conduction delay

INTRODUCTION

Hypertension (HTN) can insidiously affect the body for an extended period before the onset of any clinical manifestations. If left uncontrolled, it can cause severe complications, including disability, diminished quality of life, and even fatal events, such as myocardial infarction and stroke.[1] Transthoracic echocardiography (TTE) remains the primary imaging technique for assessing left atrial (LA) volume index (LAVI) and functional capacity. Nevertheless, TTE has introduced innovative methods for the anatomical and functional evaluation of the LA, including the calculation of the LA strain index (LASI) derived from global longitudinal strain (GLS) measurements.[2] The

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LA can be conceptualized as a dynamic extension of the left ventricle (LV), playing a pivotal role in optimizing LV filling and overall cardiac function through its reservoir, conduit, and booster pump phases. This tri-phasic mechanism relies not only on LV diastolic and systolic performance but also on the inherent characteristics of the LA. Consequently, any disruption in ventricular function or changes in loading conditions can influence the interplay between the LA and ventricle.[3] Enlargement of the LA has been definitively linked to an increased risk of ischemic stroke and cardiovascular disorders.[4] Speckle tracking echocardiography (STE) facilitates a direct, angle-independent assessment of myocardial deformation, yielding sensitive and highly reproducible indices of myocardial fiber dysfunction. This technique addresses many of the limitations associated with strain measurements derived from Doppler imaging.[5]

MATERIALS AND METHODS

This prospective observational study aimed to assess the effect of adequate blood pressure (BP) control on LA function, as measured by two-dimensional (2D) echocardiography, in newly diagnosed patients with systemic HTN.

The current study included 50 patients with established systemic arterial HTN. All patients were adequately controlled on medications during follow-up. Proper history of demographic data, risk factors, current treatment, and general and local examination with emphasis on heart rate (HR), BP and heart sounds.

Approval was obtained from the ethical committee at Ain Shams University Faculty of Medicine Research Ethics Committee before starting the research (approval number: MS 87/2023, date: 15.02.2023).

Informed written consent was obtained from all participants, ensuring their full adherence to appropriate privacy and confidentiality standards.

The inclusion criteria were as follows: both sexes, age >18 years, and recently diagnosed systemic arterial HTN within 6 to 12 months, on antihypertensive medications uncontrolled according to Joint National Committee (JNC) 8 guidelines.[6] The exclusion criteria encompassed the following: patients younger than 18 years, those diagnosed with chronic coronary syndrome or acute coronary syndrome, patients with valvular disease, patients with atrial arrhythmias, patients exhibiting a LV ejection fraction (EF) below 50%, and those with comorbidities such as thyroid dysfunction.

A comprehensive checklist was used to assess all relevant clinical data pertaining to the patients. This documentation was compiled, and the data were systematically entered into a computerized system to establish a structured database for all individuals. Measures were subsequently implemented to ensure the strict confidentiality of the collected data.

All patients who provided written informed consent were subjected to the following at baseline: A thorough history was obtained, encompassing clinical and demographic information, such as sex and age, as well as risk factors and comorbidities, including diabetes, dyslipidemia, smoking, obesity, and the presence of a family history of relevant conditions.

Duration of the study: Study started from October 2022 to July 2023, collection of the patients at baseline from October 2022 to November 2022, follow-up electrocardiogram (ECG) and echocardiography were done after 6 months from proper control of BP to be below 140 systolic BP and below 90 diastolic BP according to JNC 8 guidelines.[6]

Comprehensive physical examination including vital signs including BP, HR and auscultation of the heart and lungs.

Investigations: Twelve lead surface ECG: with special emphasis on *P*-wave amplitude and *P*-wave duration, complete blood count, creatinine, sodium, and potassium, trans-thoracic echocardiography.

2D STE: A Vivid e95 GE Healthcare cardiac ultrasound system with a multifrequency transducer (3-8 MHz) was used to perform echocardiography. All patients underwent a standard TTE study in the four windows (parasternal, apical, subcostal, and suprasternal). All the studies were conducted by a single cardiologist.

Conventional 2D echocardiography was used to capture apical four- and two-chamber views of the LA at relatively high frame rates (60-80 frames per second). After tracing the LA endocardium in both views, the region of interest (ROI) was adjusted to the LA. The ROI was determined by extending the LA endocardial and epicardial surfaces at their junctions, particularly in areas of discontinuity in the LA wall, such as the regions corresponding to the pulmonary veins and the LA appendage.

The ROI was segmented into six parts, resulting in 12 segments that were analyzed. The software generated individual longitudinal strain curves for each segment along with the global strain for each view. Additionally, it was utilized to assess the peak atrial longitudinal strain (PALS), representing LA systolic strain, and peak atrial contraction strain (PACS), corresponding to late diastolic strain.

Mitral peak early (E) and atrial contraction (A) flow velocities, as well as septal mitral annular velocities (e'), were used as indicators for assessing diastolic function. Mitral inflow patterns were recorded using pulsed-wave Doppler echocardiography to

capture early diastolic inflow velocity (E), velocity during A, and the ratio of E to A waves (E/A).

The LAVI was determined using the biplane area-length technique and was derived from the apical 4- and 2-chamber views. Volumetric measurements were performed during end systole from the frame immediately before mitral valve opening, after which the volume was adjusted for body surface area.

LV systolic function was assessed via 2D imaging in both apical 4-chamber and 2-chamber views using the biplane method of discs, following the modified Simpson rule.

The LA emptying fraction (LAEF) was calculated using biplane Simpson's method with the following formula: (LA maximum volume-LA minimum volume)/LA maximum volume × 100.

LA maximum volume: LA volume at end-systole immediately before mitral valve opening.

LA minimum volume: LA volume at end-diastole immediately before mitral valve closure.

The LA stiffness index (LASI) was calculated based on GLS. The LASI was calculated as the ratio of E/e' to LA-GLS (Figures 1-5).

Follow-up data: All enrolled patients should have their BP properly controlled according to the JNC 8 guidelines and follow-up BP after one week of increasing the medication dose and then monthly at our outpatient clinics.

ECG and echocardiography assessments were performed for all patients with the above-mentioned baseline parameters reassessed after 6 months of properly controlled BP, and then both data were compared for each patient (Figure 6).

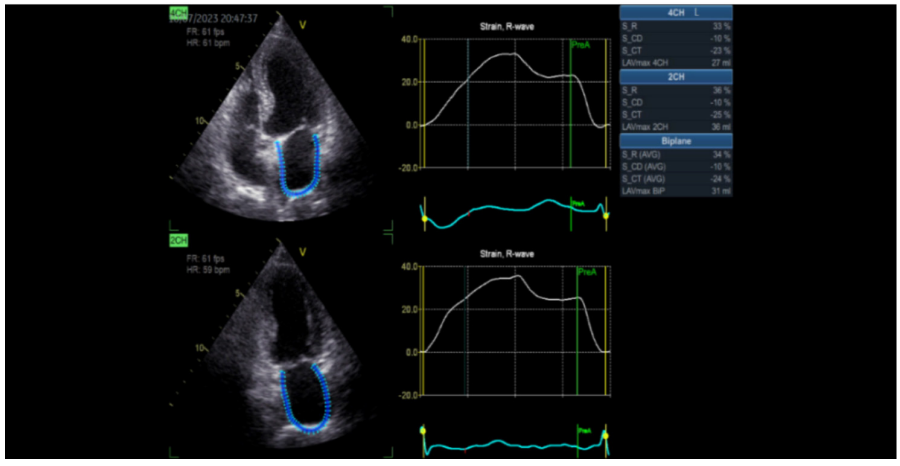

Figure 1: LA strain in apical 4 and apical 2 chamber views
LA: Left atrial

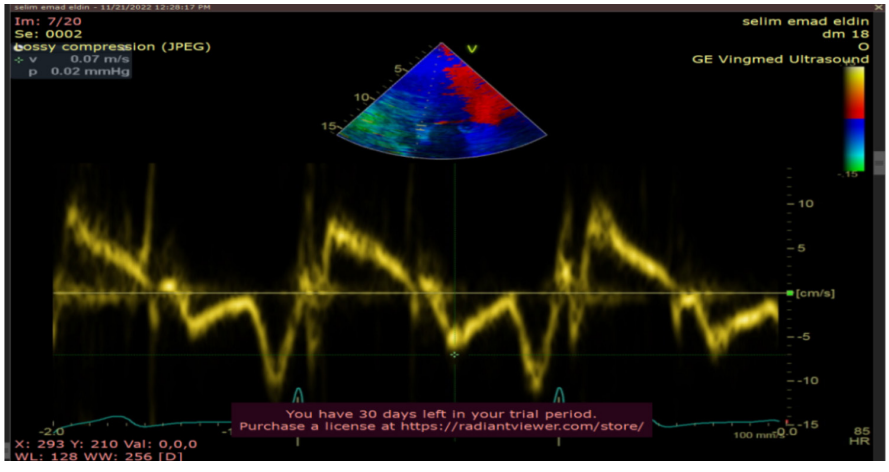

Figure 2: Tissue Doppler analysis of the septal mitral annulus to calculate septal e' in apical 4 chamber (follow-up study of patient number 8)
e': Mitral annular velocities

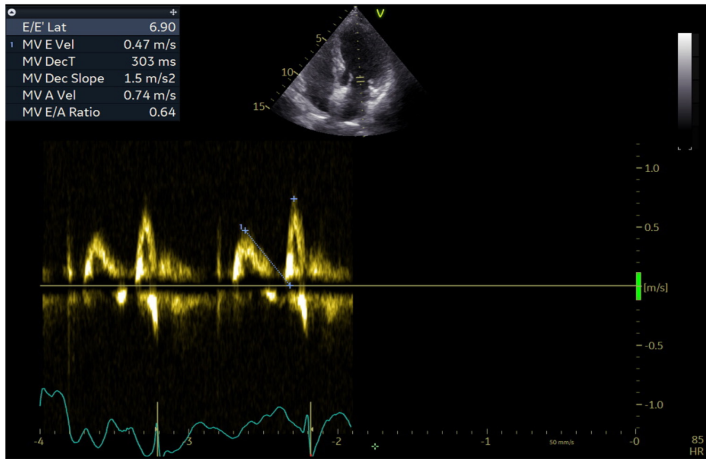

Figure 3: Pulsed-wave Doppler spectra on the tips of the mitral valve in apical 4 chambers view to calculate the A and E waves

E: Mitral peak early, e': Mitral annular velocities, A: Atrial contraction

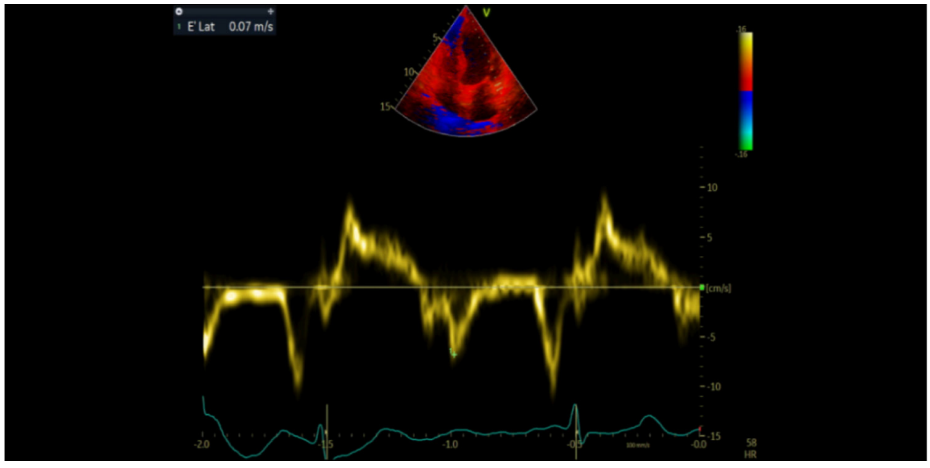

Figure 4: Tissue Doppler analysis of the lateral mitral annulus to calculate lateral e' in apical 4 chambers view

e': Mitral annular velocities

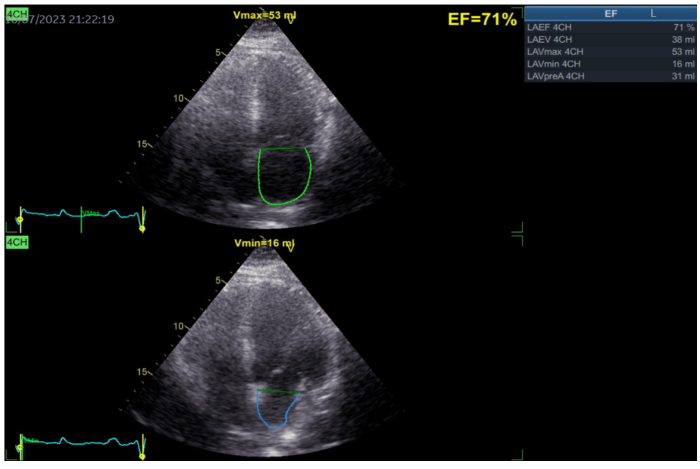

Figure 5: Apical 4 chamber view calculating left atrium maximum and minimum volumes and emptying fraction

EF: Ejection function, LAEV: Left atrial ellipsoid volume, LAEF: Left atrial emptying fraction, LAV: Left atrial volume

Statistical Analysis

The data were obtained, revised, coded, and entered using the Statistical Package for Social Science (IBM SPSS) version 20. For parametric data, qualitative variables were expressed as numbers and percentages, whereas quantitative variables were summarized as means, standard deviations, and ranges. For non-parametric data, medians with interquartile ranges (IQR) were reported. To compare two groups with qualitative data, the chi-square test was used, and the Fisher exact test was used when the expected frequency in any cell was below 5. For quantitative data with a parametric distribution, an independent t-test was applied to compare the two groups, and the Mann-Whitney test was used for non-parametric data comparisons. For comparisons of quantitative data with parametric distributions across more than two groups, one-way ANOVA was used, while the Kruskal-Wallis test was employed for nonparametric data. The confidence interval was set at 95%, with a 5% margin of error. Therefore, statistical significance was interpreted as follows: $P > 0.05$: non-significant, $P < 0.05$: significant (S); and $P < 0.01$: highly significant.

RESULTS

The study was conducted on 50 patients newly diagnosed with uncontrolled systemic HTN. Presented to the outpatient clinic to properly control BP according to the JNC 8 guidelines, history and examination were performed according to the protocol shown in (Figure 7).

Description of baseline and follow-up BP after 6 months for the patients: The baseline mean systolic BP was 149.5±24.9/ mean diastolic BP mean was 90.1±11.0, at the end of follow-up, the mean systolic BP was 134.4±15.7/mean diastolic BP was 79±9 mm Hg ($P = 0.005$ Systolic BP and $P = 0.01$ diastolic BP) (Figure 8).

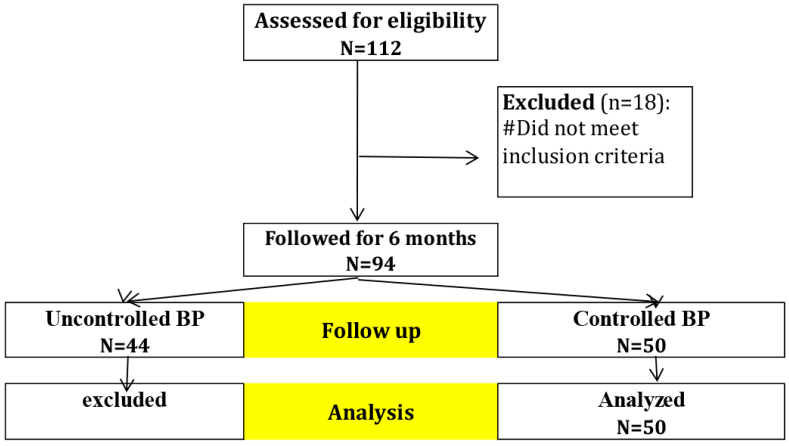

Figure 6: Study design
BP: Blood pressure

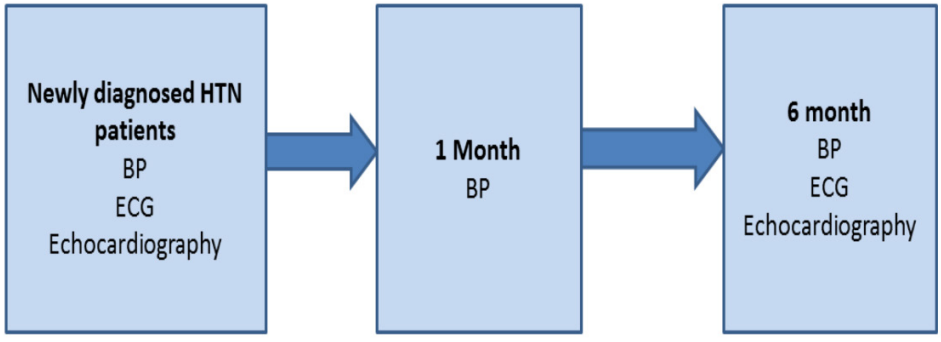

Figure 7: Flow chart and duration of the current study
BP: Blood pressure, ECG: Electrocardiogram, HTN: Hypertension

Description of demographic data and risk factors among all studied populations: The mean age of the study population was 51.26 years ±6.39 ranging from 40 to 62, with 28% males and 72% females. Eleven patients (22%) were smokers.

All the patients included in our study had uncontrolled BP above 140/90 mmHg at the time of examination and then proper BP control below 140/90 mmHg with lifestyle modification and medications. BP measurements at follow-up were performed monthly at our outpatient clinic (Table 1).

Description of the baseline ECG and Echocardiography parameters for the patients: Baseline ECG parameters included the amplitude of the *P*-wave, which ranged from 0.16 mV to 0.21 mV, the mean was 0.19±0.01 (all with in normal range below 0.25 mV), and the *P*-wave duration, which ranged from 80 ms to 100 ms with a mean 89.22±5.96 (all with in normal range).

Baseline echocardiography parameters included the following: EF ranged from 55% to 66% with a mean 60.92±3.47, PALS (reservoir strain) ranged from 22 to 43 with a mean 35.04±4.33, PACS ranged from 7 to 25 with a mean 17.38±4.67, E wave ranged from 0.4 m/s to 1.02 m/s with a mean 0.68±0.17, A wave ranged from 0.59 m/s to 1.08 m/s with a mean 0.82±0.12, E/A wave ranged from 0.57 to 1.19 with a mean 0.83±0.16, E/e' ranged from 6.21 to 10 with a mean 8.8±0.93, empty fraction ranged from 53% to 70% with a mean 64.68±5.02, LAVI ranged from 20 mL/m^2 to 33 mL/m^2 with a mean 27.12± 2.97 and LASI ranged from 0.18 to 0.33 with a mean 0.24±0.04 (Table 2).

Description of ECG parameters at baseline and after 6 months of properly controlled BP: There was no statistically significant difference between the *P*-wave duration and amplitude at baseline and six month follow-up after proper control of BP. The *P*-wave duration and amplitude were within the normal range (Table 3).

Description of echocardiography parameters at baseline and after 6 months of properly controlled BP: There was a strong relationship between control of BP and changes in PALS, PACS, E/e', and LASI, as shown: PALS showed an increase with change of the mean from 35.04±4.33 to 38.92±5.52 with *P*-value below 0.001. PACS showed an increase with change of the mean from 17.38±4.67 to 20.46±4.39 with *P*-value below 0.001 (Figure 9). E/e' showed a decrease with change of the mean from 8.8±0.93 to 7.8±1.16 with *P*-value below 0.001 (Figure 10). LASI showed a decrease with change of the mean from 0.24±0.04 to 0.2±0.03 with *P*-value below 0.001 (Figure 11). There was no statistically significant difference between baseline executive function and 6 months after implantation of the modified biplane Simpson method (Table 4).

Table 1: Demographic data and characteristics of the study population

		Total no. =50
Age	Mean ± SD	51.26±6.39
	Range	40-62
Sex	Female	36 (72.0%)
	Male	14 (28.0%)
BMI	Mean ± SD	30.74±4.68
	Range	24-41
Duration since diagnosis	6 month	30 (60.0%)
	1 year	20 (40.0%)
Drugs	BB (bisoprolol)	26 (52.0%)
	ACEI and ARBs	18 (36.0%)
	CCB	6 (12.0%)
Smoker	Non-smoker	88 (78.0%)
	Smoker	11 (22.0%)

ACEI: Angiotensin-converting enzyme inhibitors, ARBs: Angiotensin II receptor blockers, CCB: Calcium channel blocker, BMI: Body mass index, SD: Standard deviation, BB: Beta-blockers

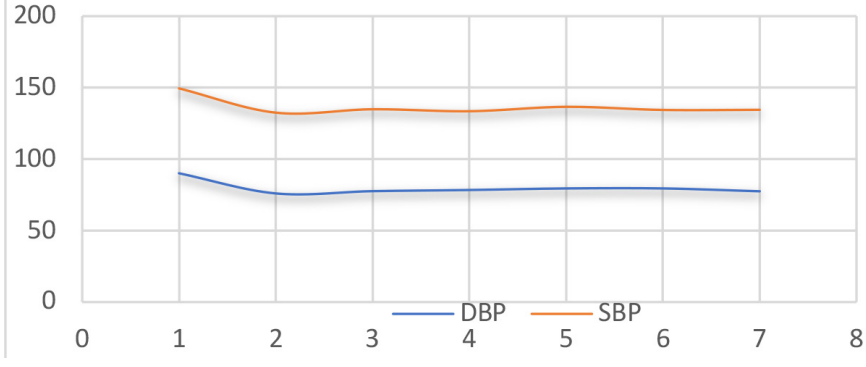

Figure 8: Showing blood pressure at baseline and during follow-up monthly

DBP: Diastolic blood pressure, SBP: Systolic blood pressure

Table 2: Baseline ECG and ECHO parameters among the study patients

Baseline		Total no =50
ECG		
Wave amplitude (mV)	Mean ± SD	0.19±0.01
	Range	0.16-0.21
P-wave duration (ms)	Mean ± SD	89.22±5.96
	Range	80-100
ECHO		
EF %	Mean ± SD	60.92±3.47
	Range	55-66
PALS	Mean ± SD	35.04±4.33
	Range	22-43
PACS	Mean ± SD	17.38±4.67
	Range	7-25
E wave	Mean ± SD	0.68±0.17
	Range	0.4-1.02
A wave	Mean ± SD	0.82±0.12
	Range	0.59-1.08
e'	Mean ± SD	0.08±0.02
	Range	0.06-0.11
E/e'	Mean ± SD	8.8±0.93
	Range	6.21-10
E/A	Mean ± SD	0.83±0.16
	Range	0.57-1.19
Diastolic Dysfunction	No	8 (16.0%)
	Yes	42 (84.0%)
LAVI	Mean ± SD	27.12±2.97
	Range	20-33
Emptying fraction	Mean ± SD	64.68±5.02
	Range	53-70
Maximum Volume	Median (IQR)	34 (29-44)
	Range	14-55
Minimum Volume	Median (IQR)	12 (8-14)
	Range	3-23
LASI	Mean ± SD	0.24±0.04
	Range	0.18-0.33

ECG: Electrocardiogram, ECHO: Echocardiography, EF: Executive function, PALS: Peak atrial longitudinal strain, PACS: Peak atrial contraction strain, e': Mitral annular velocities, E: Mitral peak early, A: Atrial contraction, LAVI: Left atrial volume index, LASI: Left atrial strain index, SD: Standard deviation, IQR: Inter quantile range, no.: Number

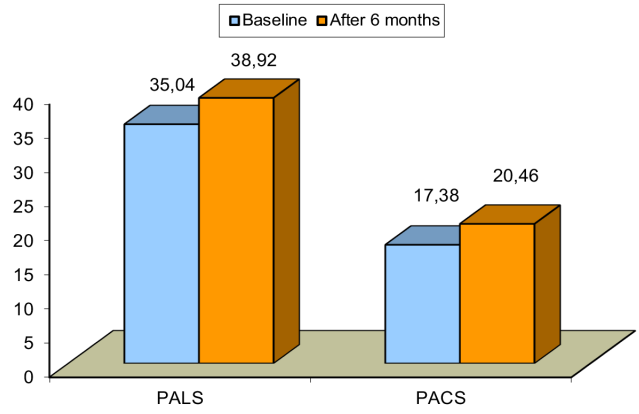

Figure 9: PALS and PACS at baseline and follow-up after 6 months

PALS: Peak atrial longitudinal strain, PACS: Peak atrial contraction strain

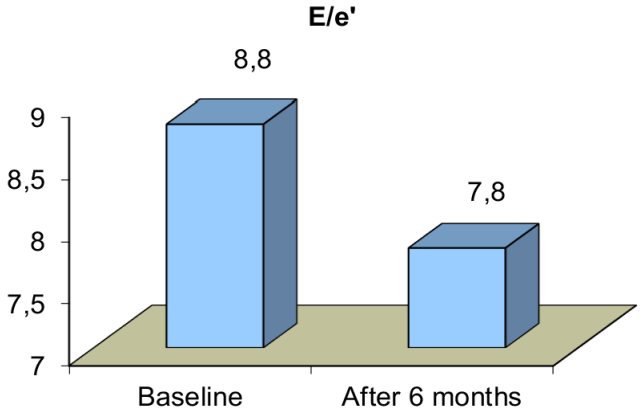

Figure 10: E/e' at baseline and follow-up after 6 months

e': Mitral annular velocities, E: Mitral peak early

Table 3: Baseline electrocardiogram and follow-up after 6 months among the studied patients

		Baseline	After 6 months	Change % Median (IQR)	Test value	*P*-value	Sig.
Wave amplitude (mV)	Mean ± SD	0.19±0.01	0.19±0.01	0 (0-0)	-1.520*	0.135	NS
	Range	0.16-0.21	0.16-0.21				
Wave duration (ms)	Mean ± SD	89.22±5.96	89.30±5.89	0 (0-0)	-0.275*	0.785	NS
	Range	80-100	80-100				

P-value > 0.05: Non-significant (NS), *: Paired t-test, SD: Standard deviation, IQR: Inter quantile range, Sig.: Significance

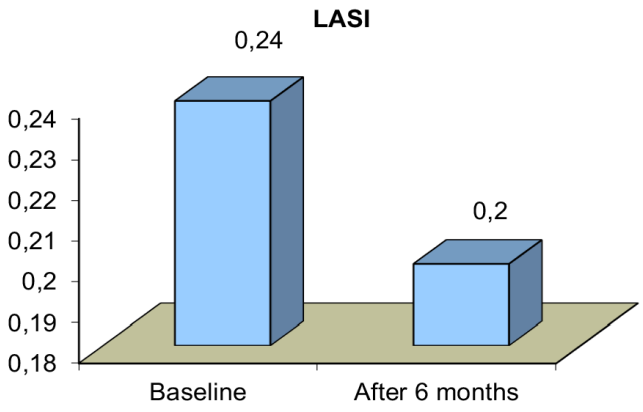

Figure 11: LASI at baseline and follow-up after 6 months
LASI: Left atrial strain index

Description of the correlation between age, body mass index (BMI) and Echo parameters: The E and A waves had a positive correlation with age coefficient of 0.4, with a *P*-value of 0.002 for the E wave and 0.001 for the A wave, yet it showed mild change. The E wave was higher in patients with a BMI 30 kg/m^2, with a *P*-value of 0.034 (Table 5).

Description of the different drugs in relation to changes in echocardiographic parameters: Gender, smoking status, and drug type showed no statistically significant correlation with changes in echocardiography parameters after 6 months of proper BP control (Table 6-8).

Table 4: ECHO at baseline and follow-up after 6 months of properly controlled blood pressure among the study patients

		Baseline	After 6 months Median (IQR)	Change %	Test value	*P*-value	Sig.
EF %	Mean ± SD	60.92±3.47	60.92±3.47	-	0.000	1.000	NS
	Range	55-66	55-66				
PALS	Mean ± SD	35.04±4.33	38.92±5.52	7.71 (3.33-13.89)	-7.768•	<0.001	HS
	Range	22-43	27-53				
PACS	Mean ± SD	17.38±4.67	20.46±4.39	10 (7.14-26.67)	-9.182•	<0.001	HS
	Range	7-25	10-32				
E wave	Mean ± SD	0.68±0.17	0.69±0.16	2.27 (-12.86-15.15)	-0.215•	0.830	NS
	Range	0.4-1.02	0.45-1.07				
A wave	Mean ± SD	0.82±0.12	0.84±0.15	0 (-9.46-7.41)	-0.931•	0.357	NS
	Range	0.59-1.08	0.6-1.16				
e'	Mean ± SD	0.08±0.02	0.08±0.01	0 (-10-12.5)	-0.522•	0.604	NS
	Range	0.06-0.11	0.06-0.11				
E/e'	Mean ± SD	8.8±0.93	7.8±1.16	-9.01 (-16.38- -3.09)	6.484•	<0.001	HS
	Range	6.21-10	5.1-9.8				
E/A	Mean ± SD	0.83±0.16	0.83±0.16	-0.59(-11.54-14.93)	0.149•	0.882	NS
	Range	0.57-1.19	0.61-1.4				
Diastolic dysfunction	No	8 (16.0%)	8 (16.0%)	-	0.000*	1.000	NS
	Yes	42 (84.0%)	42 (84.0%)				
LAVI	Mean ± SD	27.12±2.97	27.12±2.97	-	0.000	1.000	NS
	Range	20-33	20-33				
Emptying fraction	Mean ± SD	64.68±5.02	64.68±5.02	-	0.000	1.000	NS
	Range	53-70	53-70				
Maximum volume	Median (IQR)	34 (29-44)	34 (23-38)	-5.41 (-17.78-6.67)	-1.733≠	0.083	NS
	Range	14-55	13-54				
Minimum volume	Median (IQR)	12 (8-14)	11 (6-13)	0 (-26.67-8.33)	-1.345≠	0.179	NS
	Range	3-23	2-23				
LASI	Mean ± SD	0.24±0.04	0.2±0.03	-13.64 (-24- -8)	9.090•	<0.001	HS
	Range	0.18-0.33	0.16-0.31				

P-value > 0.05: NS: Non-significant, *P*-value < 0.05: Significant, *P*-value < 0.01: Highly significant (HS), •: Paired t-test, ≠: Wilcoxon signed ranks test, *: Chi-square test, ECHO: Echocardiography, EF: Executive function, PALS: Peak atrial longitudinal strain, PACS: Peak atrial contraction strain, e': Mitral annular velocities, E: Mitral peak early, A: Atrial contraction, LAVI: Left atrial volume index, LASI: Left atrial strain index, SD: Standard deviation, IQR: Inter quantile range, Sig.: Significance

Table 5: Correlations of changes in ECHO parameters with age and BMI among the studied parameters

Change %	Age		BMI	
	r	*P*-value	r	*P*-value
P-wave	-0.146	0.313	-0.068	0.639
P-R interval	-0.063	0.664	-0.053	0.716
PALS	-0.277	0.051	-0.107	0.460
PACS	0.011	0.940	0.085	0.558
E wave	0.421**	0.002	0.301*	0.034
A wave	0.450**	0.001	0.127	0.381
e’	0.202	0.160	0.230	0.108
E/e’	0.147	0.307	0.127	0.381
E/A	0.032	0.826	0.010	0.943
Maximum volume	-0.058	0.689	-0.172	0.233
Minimum volume	-0.165	0.253	0.136	0.348
LASI	0.193	0.178	-0.042	0.774

P-value > 0.05: Non-significant (NS), *P*-value < 0.05: Significant, *P*-value < 0.01: Highly significant (HS), **:Spearman correlation coefficient, *: Chi-square test, ECHO: Echocardiography, PALS: Peak atrial longitudinal strain, PACS: Peak atrial contraction strain, e’: Mitral annular velocities, E: Mitral peak early, A: Atrial contraction, LASI: Left atrial strain index, BMI: Body mass index

Table 6: Relationship between sex and changes in ECHO parameters among the study patients

Change %		Sex		Test value	*P*-value	Sig.
		Female	Male			
		no=36	no=14			
PALS	Median (IQR)	1.28 (-2.86-12.13)	3.45 (0-13.51)	-0.400≠	0.689	NS
	Range	-23.91-34.29	-18.52-40.54			
PACS	Median (IQR)	8.7 (-4.55-18.93)	0 (0-10)	-0.674≠	0.500	NS
	Range	-33.33-157.14	-37.5-87.5			
E wave	Median (IQR)	4.17 (-9.93-14.72)	-3.51 (-15.71-20.45)	-0.735≠	0.462	NS
	Range	-24.74-30	-36.11-25			
A wave	Median (IQR)	0 (-10.64-7.41)	1.33 (-3.53-7.46)	-0.606≠	0.545	NS
	Range	-98.72-37.29	-11.84-17.86			
e’	Median (IQR)	0 (0-14.29)	0 (-14.29-0)	-1.639≠	0.101	NS
	Range	-45.45-66.67	-27.27-33.33			
E/e’	Median (IQR)	-1.46 (-15.89-4.67)	-9.49 (-26.44-3.06)	-1.383≠	0.167	NS
	Range	-25.29-43.33	-43.33-42.77			
E/A	Median (IQR)	-1.38 (-11.54-5.75)	5.42 (-13.64-17.54)	-0.627≠	0.531	NS
	Range	-27.36-37.25	-35.11-22.58			
Maximum volume	Median (IQR)	-2.27 (-17.24-7.75)	-12.39 (-20.69- -2.17)	-1.405≠	0.160	NS
	Range	-32.08-80	-36.36-33.33			
Minimum volume	Median (IQR)	0 (-26.43-33.33)	-16.03 (-26.67- -6.25)	-1.432≠	0.152	NS
	Range	-81.82-228.57	-44.44-53.33			
LASI	Median (IQR)	-8.55 (-16.59-4.88)	-12.5 (-30.3-0)	-1.364≠	0.173	NS
	Range	-32.14-35	-37.5-29.41			

P-value > 0.05: NS: Non-significant, *P*-value < 0.05: Significant, *P*-value < 0.01: Highly significant (HS), ≠: Mann-Whitney test, ECHO: Echocardiography, PALS: Peak atrial longitudinal strain, PACS: Peak atrial contraction strain, e’: Mitral annular velocities, E: Mitral peak early, A: Atrial contraction, LASI: Left atrial strain index, SD: Standard deviation, IQR: Inter quantile range

Table 7: Relation between types of drugs and changes in ECHO parameters among the study patients.

		Drugs			Test value	*P*-value	Sig.
		BB	ACEI and ARBs	CCB			
		no=26	no=18	no=6			
PALS	Median (IQR)	5.88 (-2.7-12.9)	0 (-11.11-13.51)	1.72 (-2.5-3.45)	2.126≠	0.345	NS
	Range	-23.91-34.29	-18.52-40.54	-4.88-5			
PACS	Median (IQR)	8.89 (0-26.09)	0 (-18.75-10.53)	0 (0-8.33)	1.653≠	0.438	NS
	Range	-33.33-57.14	-37.5-157.14	0-8.33			
E wave	Median (IQR)	6.54 (-7-21.28)	-3.51 (-15.71-14.29)	5.45 (-4.26-13.33)	2.023≠	0.364	NS
	Range	-24.74-30	-36.11-25	-4.26-13.33			
A wave	Median (IQR)	0 (-9.46-15.58)	1.52 (-1.27-7.46)	-11.84 (-98.72-1.33)	4.888≠	0.087	NS
	Range	-27.71-37.29	-15.24-17.86	-98.72-1.33			
e’	Median (IQR)	0 (0-14.29)	0 (-11.11-12.5)	0 (-27.27-22.22)	0.531≠	0.767	NS
	Range	-45.45-33.33	-14.29-66.67	-27.27-22.22			
E/e’	Median (IQR)	1.05 (-16.38-11.95)	-14.18 (-15.89-0)	-7.3 (-9.49-3.06)	2.395≠	0.302	NS
	Range	-25.29-43.33	-43.33-42.77	-9.49-3.06			
E/A	Median (IQR)	-1.38 (-10.47-16.46)	0.41 (-13.64-4.29)	17.54 (-11.54-22.58)	2.401≠	0.301	NS
	Range	-27.36-37.25	-35.11-14.93	-11.54-22.58			
Maximum volume	Median (IQR)	0 (-17.78-20.69)	-3.36 (-13.16-3.33)	-17.24 (-17.78--11.63)	5.150≠	0.076	NS
	Range	-32.08-80	-36.36-33.33	-32.08--11.63			
Minimum volume	Median (IQR)	0 (-7.69-33.33)	-6.25 (-26.67-8.33)	-33.09 (-53.85--21.74)	4.157≠	0.125	NS
	Range	-81.82-228.57	-50-155.56	-53.85-53.33			
LASI	Median (IQR)	-10.1 (-17.39-5.26)	-9.2 (-29.63-0)	-6.08 (-10-0)	1.017≠	0.601	NS
	Range	-32.14-35	-37.5-29.41	-15-0			

P-value > 0.05: NS: Non-significant, *P*-value < 0.05: Significant, *P*-value < 0.01: Highly significant (HS), ≠: Kruskal-Wallis test, ECHO: Echocardiography, PALS: Peak atrial longitudinal strain, PACS: Peak atrial contraction strain, e’: Mitral annular velocities, E: Mitral peak early, A: Atrial contraction, LASI: Left atrial strain index, SD: Standard deviation, IQR: Inter quantile range, ACEI: Angiotensin-converting enzyme inhibitors, ARBs: Angiotensin II receptor blockers

Table 8: Relation between smoking and changes in ECHO parameters among the study patients.

Change %		Smoker		Test value	*P*-value	Sig.
		No	Yes			
		no=39	no=11			
PALS	Median (IQR)	5 (-2.86-12.9)	3.23 (-11.11-5)	-0.645≠	0.519	NS
	Range	-23.91-40.54	-18.52-20.69			
PACS	Median (IQR)	8.7 (-4.55-26.09)	0 (-18.75-8.33)	-1.425≠	0.154	NS
	Range	-33.33-157.14	-37.5-87.5			
E wave	Median (IQR)	5.26 (-12.86-15.15)	-3.51 (-15.71-5.45)	-1.136≠	0.256	NS
	Range	-26.58-30	-36.11-20.45			
A wave	Median (IQR)	0 (-9.46-9.86)	1.33 (-3.9-3.03)	-0.035≠	0.972	NS
	Range	-98.72-37.29	-11.84-7.46			
e’	Median (IQR)	0 (-9.09-14.29)	0 (-14.29-12.5)	-0.942≠	0.346	NS
	Range	-45.45-66.67	-27.27-33.33			
E/e’	Median (IQR)	-2.27 (-16.38-5.88)	-9.49 (-15.02-3.06)	-0.996≠	0.319	NS
	Range	-35-43.33	-43.33-42.77			
E/A	Median (IQR)	-1.18 (-11.54-5.75)	14.93 (-13.64-17.54)	-0.785≠	0.433	NS
	Range	-27.36-37.25	-35.11-22.58			

Table 8: Continued

Change %		Smoker		Test value	*P*-value	Sig.
		No	Yes			
		no=39	no=11			
Maximum volume	Median (IQR)	0 (-17.24-11.11)	-13.16 (-20.69--2.17)	-1.699≠	0.089	NS
	Range	-36.36-80	-32.08-33.33			
Minimum volume	Median (IQR)	0 (-26.67-33.33)	-16.67 (-35.71--6.25)	-1.800≠	0.072	NS
	Range	-81.82-228.57	-44.44-53.33			
LASI	Median (IQR)	-8 (-17.39-5)	-15 (-30.3-0)	-1.771≠	0.076	NS
	Range	-32.14-35	-37.5-0			

P-value > 0.05: NS: Non-significant, *P*-value < 0.05: Significant, *P*-value < 0.01: Highly significant (HS), ≠: Mann-Whitney test, ECHO: Echocardiography, PALS: Peak atrial longitudinal strain, PACS: Peak atrial contraction strain, e': Mitral annular velocities, E: Mitral peak early, A: Atrial contraction, LASI: Left atrial strain index, SD: Standard deviation, IQR: Inter quantile range

DISCUSSION

HTN is a complex, multifactorial condition with considerable heterogeneity. This condition poses a major global public health challenge because of its widespread prevalence and strong association with increased cardiovascular risk. The burden of cardiovascular morbidity and mortality is intensified by delayed diagnosis, inadequate awareness, and poor BP management in affected individuals, thereby placing further strain on healthcare systems and resources.

The LA is vulnerable to both structural and functional changes in individuals with HTN.[7] The effect of HTN on LA function has been explored to a limited extent, particularly in hypertensive patients with normal LA dimensions. Therefore, this study was designed to evaluate LA function in patients with normal or mildly enlarged LA using deformation imaging techniques. Strain rate imaging has emerged as a reliable tool for accurately measuring regional myocardial function, independent of the tethering effect and cardiac rotational dynamics. However, only a few studies have focused on quantifying LA function in hypertensive patients to date.[8]

LA functional parameters and systemic arterial HTN: The association between well-controlled HTN and LA functional assessment has been minimally explored in the literature. HTN often results in both LA enlargement and compromised functionality. Nevertheless, alterations in LA function initiate in the early stages, even before measurable changes in atrial dimensions are observed. Identifying subclinical LA dysfunction early is crucial because it provides an opportunity to maintain the reservoir function of the LA in hypertensive individuals without LA dilation.[8]

In this study, our objective was to identify early signs of LA dysfunction in hypertensive patients with optimal BP control, with "early" defined as preceding significant structural alterations in LA size, specifically reflected by LA volume. To assess LA function, 2DSTE. Furthermore, we aimed to establish a correlation between various risk factors and clinical parameters observed in hypertensive individuals and their impact on LA strain function. Adequate BP control was achieved after 6 months of follow-up, with a substantial drop in both mean systolic and diastolic measurements with a delta change of -15.4 mmHg systolic and -11.1 mmHg diastolic, and a *P*-value of 0.005 and 0.01 respectively. This modest decrease in androgen binding protein (ABP) had a significant effect on LA strain measurements, as will be discussed.

The PALS: In the current study, PALS was improved in the hypertensive group at the 6-month follow-up controlled on medications compared with the baseline. PALS showed an increase with change of the mean from 35.04±4.33 to 38.92±5.52 with *P*-value 0.001.

These outcomes aligned with the findings of Taamallah et al.,[9] the hypertensive group, with values of 31.23±9.93 in hypertensive group versus 46.43±11.06 in the control group ($P = 0.000$).

This was in concordance with the study done in 2020 by Sahin et al.[10] which was done in 30 hypertensive patients and follow-up done after 12 weeks of BP control showed an increase in LA reservoir strain (%) mean at baseline (31.4±8.8) then mean after 12 weeks (34.7±9.6) with a *P*-value of 0.020.

The peak atrial contraction strain (PACS): In the current study, PACS was improved in the hypertensive group at the 6-month follow-up controlled on medications compared with the baseline. PACS showed an increase with change of the mean from 17.38±4.67 to 20.46±4.39 with *P*-value 0.001.

This contrasts with the findings presented by Taamallah et al.[9] in 2021, in which their study demonstrated no statistically significant difference between the hypertensive and non-hypertensive cohorts in terms of peak strain values, reported as 16.73±3.84% and 15.29±2.75%, respectively ($P = 0.07$).

E/e' and arterial HTN: In the current study, a short-term follow-up of 6 months showed a significant decrease in E/e' with a change in the mean from 8.8±0.93 to 7.8±1.16 with *P*-value 0.001.

This is in concordance with Piskorz et al.[11] who showed that the frequency of an E/e' ratio >14 was reduced from 38 patients (13.3%) to 3.6% ($P < 0.001$) in medium to long-term follow-up with a mean of 5 years.

LASI and arterial HTN: In our study, short-term follow-up after 6 months of properly controlled arterial HTN showed a significant decrease in LASI. LASI showed a decrease with change of the mean from 0.24±0.04 to 0.2±0.03 with *P*-value 0.000. These findings are consistent with the results of Sun et al.,[12] which revealed that the LASI was notably elevated in non-dippers [0.29 (0.21, 0.41)] compared with dippers [0.26 (0.21, 0.33)], with a statistically significant difference ($P < 0.05$).

Type of Medications and Echocardiography Parameters

In our study, different types of drugs showed no statistically significant differences between the types of drugs and changes in echocardiographic parameters after 6 months of proper BP control below 140/90 mmHg. This result is in concordance with that of Degirmenci et al.[13] and showed no significant difference between patients on irbesartan and patients on nebivolol. This finding highlights the importance of ABP control in the selection of medication.

Age and Echocardiography Parameters

In our study, the only significance was that the E and A waves were higher in age groups 50 and older, with a *P*-value of 0.002 for the E wave and 0.001 for the A wave. In concordance with our study in 2021, Piskorz et al.[11] showed that E and A waves were higher in the age group above 55.

Study Limitation

The cohort of patients in this study was comparatively limited, and the research was conducted at a single center with a short follow-up period. It was better to perform ambulatory BP monitoring. It is also recommended to assess the effect of BP control on LA strain parameters. All patients enrolled in the current study were newly diagnosed hypertensive patients with no significant co-morbidities; however, other risk factors should have been addressed, such as dyslipidemia and DM in a sub-analysis. LV hypertrophy was not correlated with LA functions in this study, as all candidates were newly diagnosed hypertensive patients. This should be addressed in future research.

CONCLUSION

The current study demonstrated that speckle tracking imaging can be used to detect subtle impairment of LA function in patients with HTN. Proper control of BP in hypertensive patients leads to improvement in LA strain parameters (PALS, PACS, E/e' and LASI). The clinical applicability of assessing LA function through STE in hypertensive patients warrants additional research to refine the role of LA evaluations in predicting atrial fibrillation and assessing the risk of heart failure with preserved EF.

Ethics

Ethics Committee Approval: This study was approved by the Ain Shams University Faculty of Medicine Research Ethics Committee (approval number: MS 87/2023, date: 15.02.2023)

Informed Consent: Informed consent was obtained.

Footnotes

Authorship Contributions

Concept: M.M., Z.A., K.A., Design: Z.A., K.A., Data Collection or Processing: M.E., A.O., Analysis or Interpretation: M.M., Literature Search: M.E., Writing: M.M.

Conflict of Interest: No conflict of interest was declared by the authors.

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