Al-Azhar International Medical Journal

Volume 5 | Issue 1 Article 14

2024
Section: Radiology & Radiodiagnosis

Correlation Between Left Ventricular Structural and Functional Changes and Coronary Artery Disease in Hypertensive Patients (Speckle Tracking Echocardiographic Study)

Asmaa M. Nour
Department of Cardiovascular Medicine, Faculty of Medicine, Al-Azhar University, Assiut, asmaanour419@gmail.com

Mohamed S. Abd Elsalam
Department of Cardiovascular Medicine, Faculty of Medicine, Al-Azhar University, Assiut

Mohamed B. Khedrawy
Department of Cardiovascular Medicine, Faculty of Medicine, Al-Azhar University, Assiut

Ahmed El Tayeb
Department of Cardiovascular Medicine, Faculty of Medicine, Al-Azhar University, Assiut

How to Cite This Article

Nour, Asmaa M.; Elsalam, Mohamed S. Abd; Khedrawy, Mohamed B.; and Tayeb, Ahmed El (2024) "Correlation Between Left Ventricular Structural and Functional Changes and Coronary Artery Disease in Hypertensive Patients (Speckle Tracking Echocardiographic Study)," *Al-Azhar International Medical Journal*: Vol. 5: Iss. 1, Article 14.
DOI: https://doi.org/10.58675/2682-339X.2194

ORIGINAL ARTICLE

Correlation Between Left Ventricular Structural and Functional Changes and Coronary Artery Disease in Hypertensive Patients: Speckle-tracking Echocardiographic Study

Asmaa Mohamed Nour*, Mohamed Salah Abd Elsalam, Mohamed Bahaa Khedrawy, Ahmed El Tayeb

Department of Cardiovascular Medicine, Faculty of Medicine, Al-Azhar University, Assiut, Egypt

Abstract

Background: **Hypertension is an important risk factor for cardiovascular morbidity and mortality. Spot echocardiography is a sensitive, noninvasive method to detect early regional and global myocardial dysfunction that cannot be seen with traditional two-dimensional echocardiography visualization.**

Aim: **To evaluate the association between structural and functional changes in the left ventricle (LV) and the burden of coronary artery disease in hypertensive patients using speckle-traced echocardiography.**

Patients and methods: **Sixty patients underwent elective coronary angiography, all hypertensive, and consented to spot-trace echocardiography. They were recruited from the Department of Cardiology catheterization at Al-Azhar University Hospital.**

Results: **A statistically significant inverse relationship exists between systolic blood pressure, diastolic blood pressure, and global longitudinal strain (GLS) and a very strong inverse relationship between indicated LV mass and GLS. Regarding GLS, there is a significant difference between the different types of LV techniques. With the deterioration of the LV technique, the GLS gradually decreased. GLS was significantly impaired in the group with coronary obstructions.**

Conclusion: **Echocardiography detects changes in LV mechanics in hypertensive patients at a very early stage of the disease and provides new insights into the pathophysiology of the myocardial response to hypertension. A GLS, as assessed by two-dimensional-spot-tracking echocardiography at rest, indicates severe coronary artery disease.**

Keywords: Coronary artery disease, Hypertension, Speckle-tracking echocardiography

1. Introduction

Hypertensive heart disease results from a series of changes in the blood supply pathways to the left ventricle (LV), LV, and coronary arteries due to a sustained increase in heart rate.[1]

In hypertension, myocardial oxygen demand increases for two reasons: the resulting impedance increase for LV initiation, and hypertension can cause LV hypertrophy. There is a strong association between hypertension and coronary artery disease, pointing to the prevalence of hypertension in patients with myocardial infarction (MI) at a 4-year follow-up.[2]

This combination of decreased oxygen delivery and/or increased oxygen demand is particularly detrimental and explains why hypertensive patients are strongly affected as normotonic are more likely to develop angina pectoris, MI, or other serious coronary artery disease, and have a higher risk of dying after a heart attack. There is a pathophysiological link between hypertension and computational design, as

Accepted 30 August 2023.
Available online 15 March 2024

* Corresponding author at: Faculty of Medicine, Al-Azhar University, Assiut, Egypt.
E-mail addresses: Asmaanour419@gmail.com (A.M. Nour), Mohamed.Bahaa.2044@azhar.edu.eg (M.B. Khedrawy), Ahmedeltayeb598@yahoo.com (A. El Tayeb).

https://doi.org/10.58675/2682-339X.2194

atherosclerosis can be exacerbated by vascular hypertension.[3]

Despite the unrestricted use of the initial LV phase [left ventricular ejection fraction (LVEF)], it has significant disadvantages: as a volume-based dataset, it is mathematically assumption-dependent and heavily exercise-dependent, resulting in a significant loss of reproducibility; it may have anomalies of calculus and not reflect the actual contractility of the LV; it is not sensitive enough to detect the decline in ventricular function.[4]

Over the past 10 years, the LV worldwide longitudinal strain [global longitudinal strain (GLS)] has emerged as a viable option for assessing LV systolic capacity. Longitudinal strain derived from speckle tracking is a semiautomated method for analyzing myocardial contraction with less between-observer and within-observer variability.[5]

The work aims to assess the correlation between LV structural and functional changes and coronary artery disease burden in patients with hypertension using speckle-tracking echocardiography.

2. Patient and methods

Verbal and written consent were obtained from all participate in the study and Privacy of the data were assured.

From November 2021 to August 2022, 60 patients matured somewhere in the range of 38–63 years. Every one of them is hypertensive and giving thought stable coronary course sickness wase remembered for the review. Stable coronary course sickness was characterized as ordinary chest torment encouraged by exertion and eased by rest without irritation over the most recent 2 months, conceded electively for coronary angiography at Al-Azhar College Medical Clinic, Assiut.

Sixty patients were specifically examined and participated in the examination. The patients on this are divided into two groups: group I: 30 known hypertensive patients with a controlled heart rate on this included. Group II includes 30 patients with continuous hypertension and uncontrolled circulatory stress.

The patients were specially examined. Men and women who will perform elective coronary angiography and confirm that these are treated with follow-up echocardiography are being recruited from the Catheterization Unit of the Department of Cardiology, Department of Emergency, Al-Azhar University. Patients with irregular local wall motion at rest on echocardiography, reduced LV systolic capacity (EF < half), more than mild valvular lesions and congenital coronary artery disease, refractory arrhythmia or continuous cardiac arrest, hemodynamically hemodynamic patients were arrested. We exclude patient with liver or kidney failure.

Each patient underwent the following evaluations: complete history, clinical evaluation, superior and inferior artery evaluation, thoracic and cardiac evaluation, and research site evaluations: lipid profile, renal function tests, complete blood count, international normalized ratio, blood glucose, transthoracic echocardiography, and 12-lead ECG (GE/Eg5).

Simpson's method, also known as Simpson's biplanar method, involves manual tracing of the endocardium in the LV chamber at end systole and end diastole using the apical four-chamber view and apical two-chamber view, respectively. Tissue Doppler imaging: the channel setting is kept low (50 Hz) and the gain is set to the ideal value for good quality. Two-dimensional spot-tracking echocardiography: at the end of the cycle, three consecutive cardiovascular cycles were recorded. Second contraction estimate: the software then displays the longitudinal and transverse contractions for the respective segments (maximal systolic contraction, PSS) and the GLS for the entire U-shaped length of the left myocardium. Follow-up for each segment was reviewed and approved individually. The control cycle is automatically displayed in the basal, median, and apical segments.[6]

Patient preparation: coronary angiography will be performed under local anesthesia. The procedure is sterile, and all potential access sites must be disinfected, shaved, and sterilized. Lesions with more than or equal to 70 % narrowing in one or more of the major epicardial arteries and/or more than or equal to 50 % narrowing in the left main coronary artery were considered significant angiographic stenosis.

The collected data were analyzed using SPSS (Statistical Package for Social Science, version 20; IBM, Armonk, New York, USA). Significant statistical results were considered if P value less than 0.05. Highly significant results were considered if P value less than 0.01. Very highly significant results were considered if P value less than 0.001. Before patient recruitment, the study protocol was reviewed and approved by the research ethics committee of the Faculty of Medicine, Al-Azhar Assiut University.

3. Results

The uncontrolled group had significantly greater interventricular septal thickness, posterior wall thickness, LV mass, and indexed ventricular mass than the controlled group. According to the M-mode and Simpson method, the controlled group

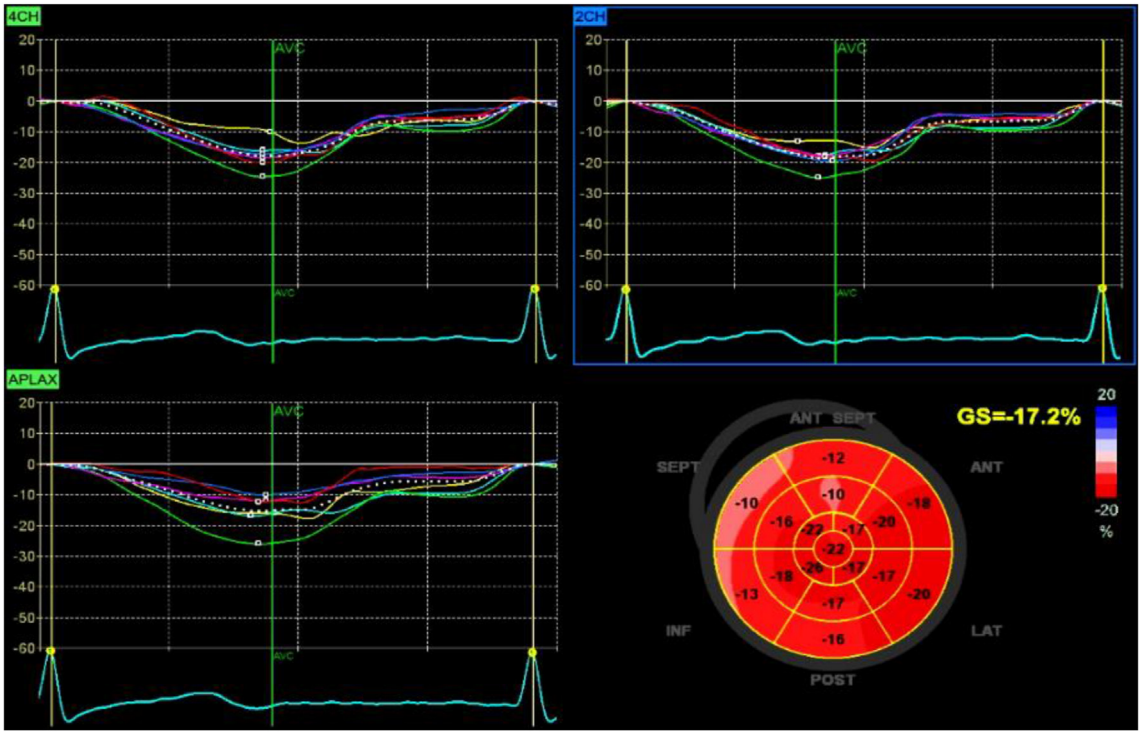

Fig. 1. Global longitudinal strain (GLPS) measured in apical four-chamber (GLPSA4C), two-chamber (GLPS-A2C), and long-axis (GLPS-LAX) view, respectively. Bull's eye map GLS = 17.2 %.

had a significantly higher LVEF than the uncontrolled group. LA region and LA volume were generally higher in the uncontrolled pool than in the controlled group. The uncontrolled group had significantly higher ratios than the controlled group. The total longitudinal stress was less during uncontrolled harvesting compared to controlled harvesting. Huge contrast regarding GLS between different types of LV math. The presence of obstructive coronary artery disease was deductively higher in the uncontrolled collection. The GLSs were completely blocked in the computer-aided obstructive design group. GLS decreased gradually with an increasing number of stenotic coronary ducts. Exceptionally critical inverse relationship between systolic blood pressure, diastolic blood pressure, and GLS. Deep, huge, and strong inverse association between mass registered LV and GLS. GLS receiver operating characteristic analysis to predict coronary artery disease (CAD) keys; area under the curve (AUC) 0.88 (95 % confidence limit 0.78–0.96 $P < 0.0001$; Figs. 1–5, Tables 1–10).

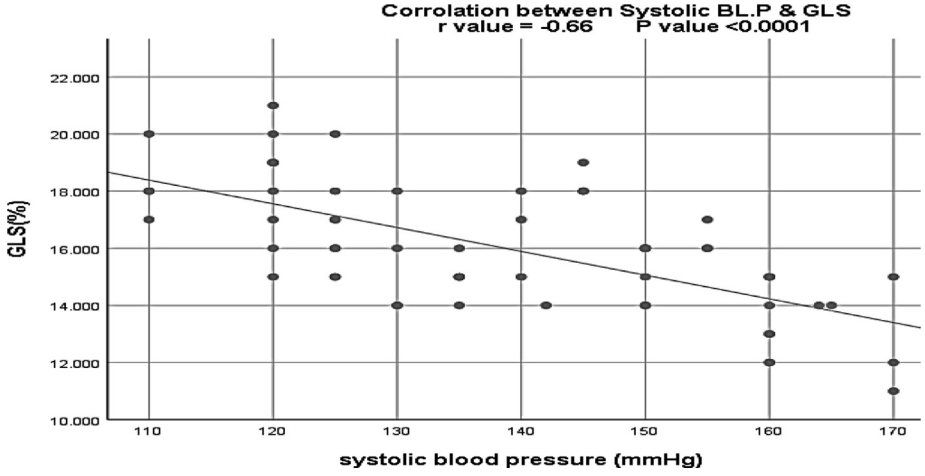

Fig. 2. Correlation between systolic blood pressure and GLS. GLS, global longitudinal strain.

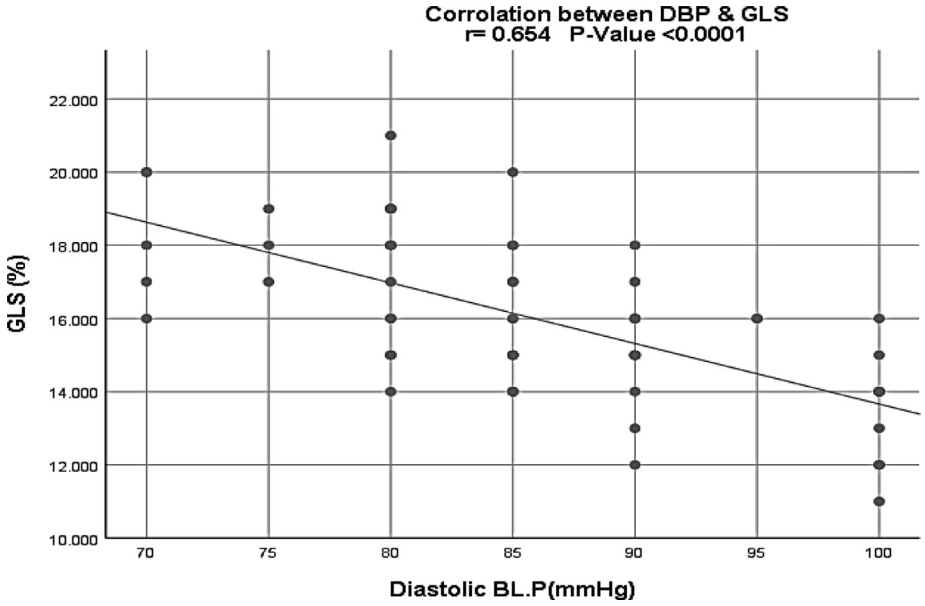

Fig. 3. Correlation between diastolic blood pressure and GLS. GLS, global longitudinal strain.

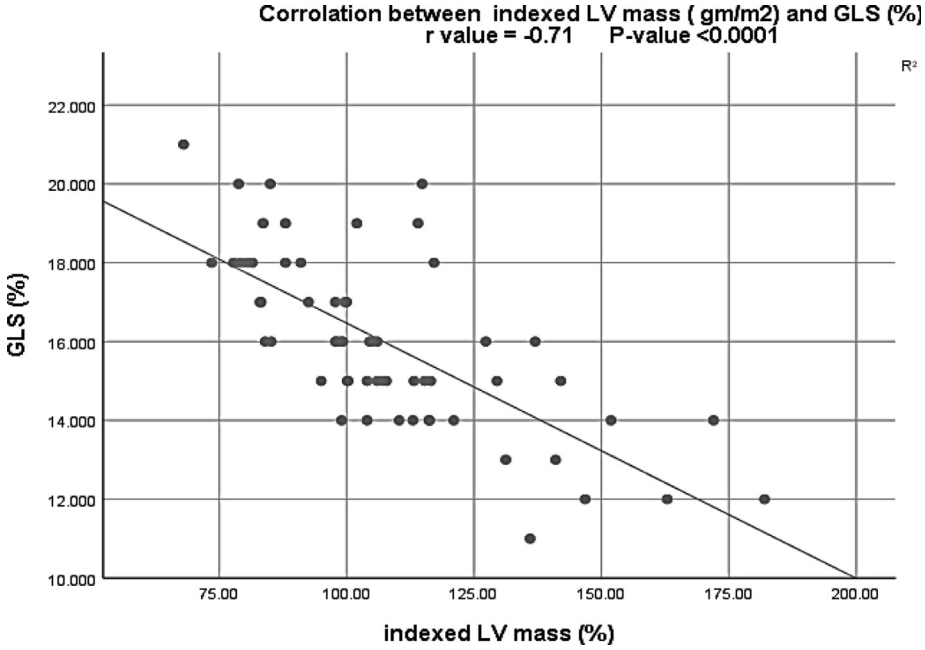

Fig. 4. Correlation between indexed LV mass and GLS. GLS, global longitudinal strain; LV, left ventricular.

4. Discussion

A notable and normal cardiovascular gamble factor, hypertension, might cause LV systolic hindrance through relentless strain overload.[7]

This study utilized spot following echocardiography to look at the connection between coronary course illness trouble in hypertensive patients and LV underlying and practical changes. Left ventricular hypertrophy (LVH) is a compensatory cycle due to expanded wall pressure.

The ongoing survey showed that the mean of interventricular septal thickness and back wall thickness in diastole were higher in bundle II and stood out from pack I with truly colossal worth

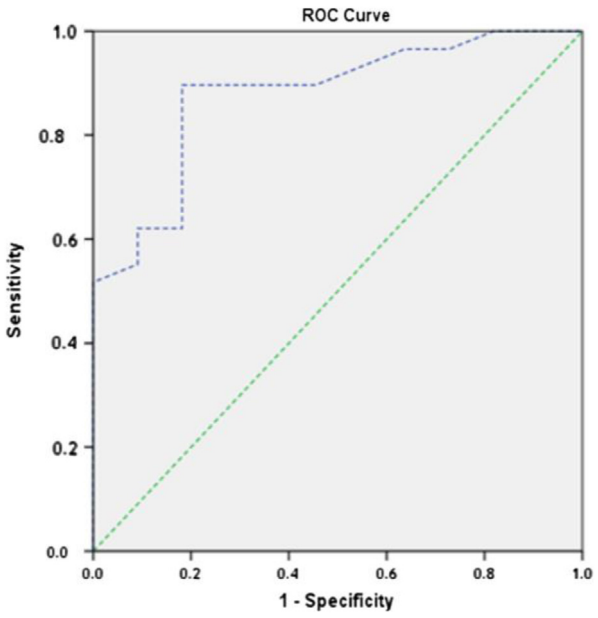

Fig. 5. ROC curve for predicting significant CAD using GLS. CAD, coronary artery disease; GLS, global longitudinal strain; ROC, receiver operating characteristic.

($P < 0.0001$ and 0.001 for interventricular septum in diastole (IVSd) and PWTd, posterior wall thickness in diastole independently). Our results were maintained by examination of Tadic *et al.*[8] as they reported that LV wall thickness (septal, back, and relative wall thickness), per definition, was higher in patients with concentric revamping and concentric LVH than in patients with normal math and capricious modifying. Moreover, Rabea *et al.*[9] saw that both the mean of the interventricular septum (IVS) and LV back wall (LVPW) thickness were out and out higher in the uncontrolled assembling diverged from the benchmark bunch (IVS; 1.20 ± 0.13 cm vs. 0.90 ± 0.17 cm independently; $P < 0.001$).

Bunch one had a mean relative wall thickness of 0.3897 ± 0.5641, while bunch two had a mean of 0.4110 ± 0.4626, as per the ongoing review. The mean LV mass of social occasion one was 175.9967 ± 33.1305 while the mean of get-together two was 218.2392 ± 48.6013, and the mean documented LV mass of social affair one was 96.8017 ± 15.6300 while the mean of social affair two was 118.6040 ± 26.5190. Both LV mass and requested

Table 1. Baseline characteristics of enrolled patients' groups (controlled and uncontrolled groups).

Variables	Controlled group ($N = 30$)	Uncontrolled groups ($N = 30$)	*P* value
Age (years)	54.20 ± 5.168	53.93 ± 6.0511	0.855
Sex [*n* (%)]			
Male	15 (50)	16 (53.33)	0.76
Female	15 (50)	14 (46.67)	
BMI (kg/m^2)	24.8233 ± 0.9933	24.966 ± 1.3516	0.640
Smoking [*n* (%)]			
Smoker	10 (33.33)	9 (30)	0.77
Nonsmoker	20 (66.67)	21 (70)	
Duration of hypertension (years)	5.0333 ± 2.7099	5.3667 ± 2.8098	0.642

Table 2. Echocardiographic data of enrolled patients' groups (controlled and uncontrolled groups).

Variables	Group I (controlled HTN) ($N = 30$)	Group II (uncontrolled HTN) ($N = 30$)	*P* value
LVEDD	4.9933 ± 0.4076	5.2333 ± 0.3933	0.024
LVESD	3.3367 ± 0.5436	3.5167 ± 0.4348	0.162
PWT	0.9767 ± 0.1072	1.0867 ± 0.13060	0.001
IVS	0.9700 ± 0.1022	1.073 ± 0.1142	<0.0001
RWT	0.3897 ± 0.5641	0.4110 ± 0.4626	0.115
LV mass	175.9967 ± 33.1305	218.2392 ± 48.6013	<0.0001
Indexed LV mass	96.8017 ± 15.6300	118.6040 ± 26.5190	<0.0001
LVEDV	116.3033 ± 32.1303	131.2780 ± 23.8351	0.045
LVESV	42.9333 ± 14.0262	53.1653 ± 14.9397	0.008
EF% by M-mode	65.2667 ± 2.5452	62.7667 ± 3.2976	0.02
EF% by Simpson	63.3830 ± 3.7456	60.0023 ± 5.0649	0.005

IVS, interventricular septum; LVEDD, left ventricular end diastolic dimension; LVEDV, left ventricular end diastolic volume; LVESD, left ventricular end systolic dimension; LVESV, left ventricular end systolic volume; PWT, posterior wall thickness; RWT, relative wall thickness.

Table 3. Description of different left venrticular geometry among all studied patient groups.

Groups	Normal LV geometry [*n* (%)]	Concentric remodeling [*n* (%)]	Concentric LVH [*n* (%)]	Eccentric LVH [*n* (%)]
Group I (controlled HTN) ($N = 30$)	12 (40)	3 (10)	8 (26.67)	7 (23.33)
Group II (uncontrolled HTN) ($N = 30$)	5 (16.67)	0	7 (23.33)	18 (60)
Total ($N = 60$)	17 (28.33)	3 (5)	15 (25)	25 (41.67)

LVH, left ventricular hypertrophy.

Table 4. Comparison between the study groups regarding left atrial area and volume.

	Group I (controlled HTN)	Group II (uncontrolled HTN)	*P* value
LA area	20.7500 ± 1.9420	24.9133 ± 2.5390	<0.0001
LA volume	57.2000 ± 7.5265	76.1333 ± 11.8196	<0.0001

LA, left atrial.

Table 5. Comparison between the study groups regarding mitral E/A and E/e′ ratios.

	Group I (controlled HTN)	Group II (uncontrolled HTN)	*P* value
E/A ratio	0.7460 ± 0.2153	1.6613 ± 0.5789	<0.0001
E/e′	7.2833 ± 1.4340	12.8600 ± 3.5019	<0.0001

Table 6. Comparison between the study groups regarding global longitudinal strain.

Groups	Global longitudinal strain	*P* value
Group I (controlled HTN)	−16.9333 ± 1.9988	<0.0001
Group II (uncontrolled HTN)	−15.0000 ± 1.9826	

HTN, hypertension.

Table 7. Comparison between various left ventricular geometry regarding global longitudinal strain.

	Normal LV geometry ($N = 17$)	Concentric remodeling ($N = 3$)	Concentric LVH ($N = 15$)	Eccentric LVH ($N = 25$)
GLS	−18.17 ± 1.38	−17.66 ± 1.52	−15.06 ± 1.33	−14.80 ± 1.91
P value	<0.0001			

GLS, global longitudinal strain; LVH, left ventricular hypertrophy.

Table 8. Comparison between the studied groups regarding the prevalence of significant obstructive coronary artery disease.

	Groups [*n* (%)]		Total [*n* (%)]
	Group I (controlled HTN)	Group II (uncontrolled HTN)	
Nonobstructive CAD	18 (60)	9 (30)	27 (45)
Obstructive CAD	12 (40)	21 (70)	33 (55)
Total	30 (100)	30 (100)	60 (100)
P value	0.02		

CAD, coronary artery disease.

Table 9. Comparison between two groups of coronary artery disease regarding global longitudinal strain.

	Group I nonobstructive CAD ($N = 27$)	Group II obstructive CAD ($N = 33$)
GLS	−17.85 ± 1.45	−14.42 ± 1.32
P value	<0.0001	

CAD, coronary artery disease; GLS, global longitudinal strain.

LV mass were especially gigantic differentiation between the two social affairs ($P < 0.0001$ for both of them). Galderisi *et al.*[10] upheld our discoveries as they detailed that patients with hypertension had a higher LV mass record than controls. Moreover, Tadic *et al.*[9] revealed that LVMI consistently and extended from patients with normal LV estimation to those with concentric LVH.

Table 10. Comparison between various groups of coronary artery diseases regarding global longitudinal strain.

	Single vessel disease ($N = 16$)	Two vessel disease ($N = 12$)	Three vessel disease ($N = 2$)	Multivessel disease ($N = 3$)
GLS	−15.12 ± 0.80	−14.16 ± 1.26	−12.00 ± 1.44	−13.33 ± 1.15
P value	<0.0001			

GLS, global longitudinal strain.

In our audit, the mean LVEF (M-strategy) for social event one was 65.2667 ± 2.5452 while the mean of get-together two was 62.7667 ± 3.2976, and the mean of LVEF (Simpson) of bundle one was 63.3830 ± 3.7456 while the mean of social affair two was 60.0023 ± 5.0649. Both LVEF by M-mode and by Simpson system showed enormous qualification between the two social events ($P = 0.02$ for M-mode strategy and $P = 0.005$ for Simpson method). Whereas in the examination of Xu *et al.*[11] the hypertensive and normotensive patients had conventional reach (55–75 %) and similar mean levels of LV send-off division ($P = 0.54$). Taamallah *et al.*[12] exhibited that the LVEF of the two gatherings were practically identical. Also, Rabea *et al.*[9] mean LVEF of the patients in each gathering did not contrast fundamentally.

Our results showed that the mean LA area of social event one was 20.7500 ± 1.9420 while the mean of get-together two was 24.9133 ± 2.5390, and the mean recorded LA Volume of social event one was 57.2000 ± 7.5265 while the mean of social event two was 76.1333 ± 11.8196. Both left atrial (LA) locale and volume were incredibly gigantic qualifications between the two social occasions ($P < 0.0001$ for both of them). According to our results examination of Taamallah *et al.*[12] because they detailed that the HTN bunch had an essentially bigger LA greatest volume.

The ongoing survey showed that the mean E/A extent of social affair one was 0.7460 ± 0.2153 while the mean E/A extent of get-together two was 1.6613 ± 0.5789. There was uncommonly colossal differentiation between the two social occasions regarding the E/A extent ($P < 0.0001$). The mean EE proportion of get-together one was 7.2833 ± 1.4340 while the mean E/E extent of social occasion two was 12.8600 ± 3.5019. Regarding the E/E proportion, there was a massive distinction between the two gatherings ($P = 0.0001$). Our results were as per examination of Tadic *et al.*[9] as they uncovered that E/An and E/e' extent bit by bit debilitated from patients with average LV math to those with concentric LVH. In the examination of Taamallah *et al.*[12] all diastolic capability boundaries showed a tremendous contrast between the two gatherings.

The continuous survey showed that the mean overall longitudinal sort of social affair one was −16.9333 ± 1.9988 while the mean overall longitudinal some kind of get-together two was −15.0000 ± 1.9826. There was an uncommonly huge differentiation between the two social events concerning overall longitudinal strain ($P < 0.0001$). Additionally, there is an extraordinarily tremendous reverse association between recorded LV mass and GLS ($P < 0.001$). While, in the examination of Xu *et al.*[11] the sufficiency of endocardial longitudinal strain antagonistically connected with LVMI ($P < 0.01$), while the endocardial circumferential strain determinedly associated with send off segment ($r = 0.30$, $P < 0.01$).

In our audit, we used the two-dimensional layer-express dab following methodology to analyze ventricular misshapening per different LV numerical models in hypertensive patients. Next are the fundamental discoveries: inside seeing hypertension and normal computation, longitudinal strain stays average, yet with constant basic redesigning GLS decline for patients with standard LV math, concentric modifying, concentric LVH, and eccentric LVH independently, *P* value less than 0.0001. Our results were maintained by examination of Nwabuo and Vasan[13] they declared that longitudinal and circumferential strains were lower in patients with capricious and concentric LVH than in patients with standard math and concentric remaking.

Patients with obstructive computer-aided design performed fundamentally more awfully in the GLS bunch than in the nonobstructive computer-aided design bunch (P esteem = 0.0001). Moreover, for patients with SVD, DVD, TVD, and multivessel infection, GLS diminished gradually with an expanding number of stenotic coronary supply routes (P esteem = 0.0001). That was in line with Moustafa *et al.*[14] There was a genuinely huge contrast between typical coronaries and different levels of coronary supply route sickness (computer-aided design) in the mean of worldwide longitudinal pinnacle systolic strain.

The analytical exhibition of GLS in foreseeing critical computer-aided design is shown by our review ($P = 0.000$). The mindfulness, expressness, positive farsighted worth, negative insightful worth, and accuracy of mean GLS were 93.1, 81.8, 93.1, 81.8, and 90 % independently for expecting basic PC helped plan. Moreover, in the examination of Zhu *et al.*[15] the uncontrolled gathering had a lower GLS very still (the benchmark group $P = 0.004$). GLS

exceptionally still had the most important locale under the receiver operating characteristic twist (AUC) (AUC = 0.78, responsiveness 61 %, expressness 91 %, $P = 0.009$) with the cut-off of −14.5 %, which is comparable to farsighted power of wall development scoring list at top strain to perceive basic PC supported plan (AUC = 0.76; $P = 0.016$) with the cut-off worth of 1.21).

4.1. Conclusion

Spot following echocardiography uncovers LV mechanics changes in hypertensive patients in an early phase of the disorder and gives new information on the pathophysiology of myocardial response to hypertension. There is tremendous differentiation with respect to GLS between different sorts of LV computation, GLS declined slowly as LV math became decay. Critical computer-aided design is anticipated by the worldwide longitudinal strain (GLS) surveyed by two-dimensional-spot-tracking echocardiography very still. GLS was essentially lower among patients with gigantic PC-supported plans than those with nonsignificant PC-helped plans. There was a gigantic difference between controlled and noncontrolled hypertensive patients for the presence of basic obstructive coronary channel ailment.

Conflicts of interest

No conflict of interest.

References

1. Mogi M, Higashi Y, Bokuda K. Annual reports on hypertension research. *Hypertens Res*. 2022;45:15–31.
2. Anghel L, Georgescu CA. Particularities of coronary artery disease in hypertensive patients with left bundle branch block. *Maedica*. 2014;9:333.
3. Boutouyrie P, Chowienczyk P, Humphrey J. Arterial stiffness and cardiovascular risk in hypertension. *Circ Res*. 2021;128(7): 864–886.
4. Mirea O, Pagourelias E, Duchenne J. Intervendor differences in the accuracy of detecting regional functional abnormalities: a report from the EACVI-ASE strain standardization task force. *JACC Cardiovasc Imag*. 2018;11:25–34.
5. Alsharari R, Oxborough D, Lip G. Myocardial strain imaging in resistant hypertension. *Curr Hypertens Rep*. 2021;23:1–8.
6. Vijayaraghavan K, Govindan L, Sivasubramonian S. Global longitudinal strain: a practical step-by-step approach to longitudinal strain imaging. *J Indian Acad Echocardiogr Cardiovasc Imag*. 2022;4:22–30.
7. Tadic M, Majstorovic A, Pencic B. The impact of high-normal blood pressure on left ventricular mechanics: a three-dimensional and speckle tracking echocardiography study. *Int J Cardiovasc Imag*. 2014;30:699–711.
8. Tadic M, Cuspidi C, Saeed S. The influence of left ventricular geometry on myocardial work in essential hypertension. *J Hum Hypertens*. 2022;36:524–530.
9. Rabea M, Ismail E, Al-Ganady E. Early detection of left ventricular subclinical systolic dysfunction in hypertensive patients: speckle tracking at rest and after dobutamine stress echocardiography study. *Al-Azhar Int Med J*. 2020;1: 43–48.
10. Galderisi M, Lomoriello S, Santoro A. Differences of myocardial systolic deformation and correlates of diastolic function in competitive rowers and young hypertensives: a speckle-tracking echocardiography study. *J Am Soc Echocardiogr*. 2010;23:1190–1198.
11. Xu Y, Yang Y, Li J. Left ventricular deformation in relation to the geometric pattern in hypertensive patients. *Medicine*. 2019; 98:2110–2118.
12. Taamallah K, Besbes B, Raddaoui H. Is there a latent left ventricular dysfunction in hypertensive patients with preserved ejection fraction? *La Tunisie Med*. 2021;99:456–460.
13. Nwabuo C, Vasan S. Pathophysiology of hypertensive heart disease: beyond left ventricular hypertrophy. *Curr Hypertens Rep*. 2020;22:1–8.
14. Moustafa S, Elrabat K, Swailem F. The correlation between speckle tracking echocardiography and coronary artery disease in patients with suspected stable angina pectoris. *Indian Heart J*. 2018;70:379–386.
15. Zhu H, Guo Y, Wang X. Myocardial work by speckle tracking echocardiography accurately assesses left ventricular function of coronary artery disease patients. *Front Cardiovasc Med*. 2021; 8:90–101.