Left ventricular and atrial global strain evaluation within subtypes of ventricular remodeling

Nilda Espinola-Zavaleta[1], Neftali Antonio-Villa[2], Nidia Briseño-Diaz[3], Diego Oregel-Camacho[3], Gyselle Camacho-Camacho[3], Candace Keirns[4], and Erick Alexanderson-Rosas[3]

[1]Instituto Nacional de Cardiología
[2]UNAM Facultad de Medicina
[3]National Institute of Cardiology Ignacio Chavez
[4]International Medical Interpreters Association

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Abstract

Background: Left ventricular hypertrophy is associated with poor prognosis and ad-verse events. Left ventricular and left atrial global strain and left atrial reservoir strain (LV-GS; LA-GS; LA-RS) could be used as markers for myocardial function in different forms of ventricular remodeling. The aim of this study was to evaluate LV-GS and LA-GS scores in different ventricular remodeling variants and identify risk factors for myo-cardial dysfunction. Methods and Results: This cross-sectional study was divided into four groups of ventricular remodeling: normal geometry, eccentric hypertrophy (EH), concentric hypertrophy (CH) and concentric remodeling (CR). Strain analysis was obtained using standardized protocols. We included 121 subjects, 33 with previous myocardial infarction (MI). We found that EH had the lowest LV-GS and CH the lowest LA-GS and LA-RS. Atrial and ventricular dysfunction was present in 40 (33%) and 14 (11.5%) subjects, respectively. Smoking, male sex and previous MI were associated with LV dysfunction and smoking and dyslipidemia with LA dysfunction. EH was closely associated with LV dysfunction and CH with LA dysfunction. Conclusions: We conclude that different types of ventricular geometry had echocardiographic profiles associated with different risk factors for dysfunction assessed by strain. The assessment of ventricular remodeling by global strain could be used as a complementary tool in the echocardiographic evaluation of ventricular and atrial function.

INTRODUCTION

Several studies have suggested that left ventricular hypertrophy (LVH) is associated with a higher prevalence of comorbidities and adverse cardiovascular outcomes in subjects with previous cardiovascular events (1–4). Moreover, ventricular remodeling causes atrial distortion such as left atrial (LA) enlargement, which is a significant predictor of adverse cardiovascular events (5). Evidence suggests that LVH could be the mechanism that produces left ventricular dysfunction rather than a compensatory mechanism to maintain left ventricular wall stress and forward output (6). This condition was evaluated in subjects with mild to moderate aortic stenosis, where LVH occurred in 17%; in asymptomatic severe aortic stenosis and in subjects with arterial hypertension LVH was found in up to 67% of the cases (7). This has led to the hypothesis that ventricular remodeling could be evaluated using other global myocardial parameters such as global strain, especially to determine myocardial dysfunction. Left atrial volume and function are sensitive indicators of left ventricular (LV) filling pressure and diastolic dysfunction. Evaluation of left atrial and left ventricular global-strain (LA-GS; LV-GS) using 2-D speckle tracking analysis has been shown to be an accurate automatized diagnostic tool for functional evaluation of different cardiomyopathies (8). Furthermore, decrease of LA-GS has been associated with increased incidence of atrial fibrillation, sudden cardiac arrest and increased

mortality (9-11). Both ventricular geometry and strain evaluation by speckle tracking have been proposed as complementary tools. The aim of this study was to compare LV-GS and LA-GS values, assessed by 2D-velocity vector imaging in different geometric remodeling variants in adult patients. Additionally, the associated risk factors for ventricular and atrial dysfunction, as defined using LV-GS and LA-GS were assessed. We hypothesize that global strain is correlated with ventricular function and could be impaired with different ventricular geometric variants. Thus, a specific ventricular variant could be associated with ventricular and atrial dysfunction.

METHODS

Study population and clinical evaluation

We designed a cross-sectional study in which we included subjects with stable angina who visited the Nuclear Cardiology Department (NCD) between January of 2018 and June 2019. We performed complete clinical histories in which we asked for self-reported histories of arterial hypertension, dyslipidemia, smoking, obesity, type 2 diabetes (T2D) and previous myocardial infarction. Body weight quantification was performed to the nearest 0.1 kg using a calibrated stadiometer with the subject in light-weight clothes. Height was measured to the nearest 0.1 cm using a stadiometer with 1 mm gradations. Body mass index (BMI) was calculated as weight in kilograms divided by the squared product of height in meters. Obesity was defined as BMI >30 kg/m^2. Body surface area (BSA) was estimated using the square root of the product of weight in kilograms multiplied by height in centimeters and divided by 3,600. All anthropometric evaluations were performed after an 8-hr fast.

Patients signed consent forms before all echocardiographic evaluations.

Echocardiographic data acquisition

We performed a conventional transthoracic echocardiogram with subjects in lateral decubitus using a Siemens Acuson 2000 (Germany) with a phased array transducer that provided M-mode, color and tissue Doppler, with two and three-dimensional capabilities and software for atrial and ventricular mechanics following current guide-lines (11). Briefly, two-dimensional data were acquired from the parasternal long-axis and short axis views and three standard apical views. We recorded three consecutive cardiac cycles during expiration and obtained in a frame sequence of 50 to 80 frames per second. Left ventricular end-diastolic and end-systolic diameters (LVEDd; LVESd), interventricular septal thickness (IVST) and posterior wall thickness (PWT) were measured in the parasternal long axis view. Left ventricular ejection fraction (LVEF) was calculated based on the apical 4- and 2-chamber views, using the modified Simpson‘s biplane method or by 3D. LVEF was considered normal when it was [?]52% for men and [?]54% for women. Pulsed-wave Doppler of mitral valve inflow was used to measure the mitral peak early (E) and late (A) velocities and the ratio of early-to-late (E/A) diastolic flow velocities in the apical four chamber view, with the sample volume between mitral leaflet tips. Diastolic dysfunction was classified as: Grade I diastolic dysfunction (E/A<0.8, deceleration time >200 ms), impaired relaxation, Grade II (E/A >0.8 -1.5, deceleration time: 160-200 ms), pseudonormalization, Grade III, restrictive filling (E/A >2.0, deceleration time <160 ms). The septal early diastolic myocardial velocity e´ and the ratio between early transmitral flow velocity E and e´ (E/e´ ratio) was measured in the four chamber view by pulsed Doppler and tissue Doppler, and the normal value was <14. **(Figure 1)** . Left atrial (LA) volume was assessed in the apical four chamber view at end-systole and was indexed to the BSA. The upper normal limit for LA volume index was 34 mL/m^2 for both genders.

Left ventricular mass was calculated from the formula: 0.80*(1.04*[LVEDd + PWd + IVSd)^3 - (LVEDd)^3] + 0.6 gr (11). Left ventricular mass (LVM) was indexed to BSA in gr/m^2. LV hypertrophy was identified when the derived LVMI was [?]115 g/m^2 for men and [?]95 g/m^2 for women (11). The relative wall thickness (RWT) was calculated as (2 x PW thickness)/LV internal diameter at end-diastole. The RWT permits categorization of an increase in LV mass as either concentric (RWT > 0.42) or eccentric (RWT < 0.42) hypertrophy and makes it possible to identify concentric remodeling (normal LV mass with increased RWT >0.42) (11). The subjects were divided into four ventricular geometric groups: normal geometry (normal LVMI and normal RWT), concentric remodeling (normal LVMI and increased RWT), concentric hypertrophy

(increased LVMI and increased RWT), eccentric hypertrophy (increased LVMI and normal RWT) (11).

Left ventricular wall motion was assessed with the 16-segment model. Each segment was evaluated in four, three and two-chamber views, and a four-grade score was applied: (1) normal or hyperkinetic, (2) hypokinetic (reduced thickening), (3) akinetic (absent or negligible thickening), and (4) dyskinetic (systolic thinning or stretching)

Analysis of strain parameters

Left ventricle

For two-dimensional global longitudinal peak strain, three consecutive cardiac cycles in the apical two, three and four-chamber views were acquired for analysis with frame rates between 50 to 80 frames/second using velocity vector imaging. The automatized software tracked the contour of the endocardium and automatically divided the left ventricle into six segments. Deformation was assessed frame by frame. Left ventricular global longitudinal strain represents the apical to base deformation, and it is expressed with negative values because the LV shortens during systole. More negative values are associated with a better longitudinal performance. Decreased LV-GS was defined as values [?]-20% as previously described (**Figure 2A)** (13).

Left atrium

The endocardial border of the left atrium (LA) was traced in the apical 4-chamber view, excluding the appendage and pulmonary veins from the LA cavity. We acquired 3-5 consecutive, regular beats. The region of interest (ROI) started delineating the endocardial border from de mitral annulus on one side and ends at the mitral annulus on the opposite side. A ROI of 3 mm was used. Accuracy of the automated border tracking was verified and manually adjusted if needed. LA longitudinal strain curves were generated throughout the cardiac cycle with R-R gating. LA stretches its walls during LV systole and for this reason, LA longitudinal deformation is usually expressed with positive values. The LA reservoir in systole, conduit in early diastole and contraction strain in late diastole were measured. The normal value of reservoir strain was 39% and the contraction strain 18%. The conduit strain was obtained with the following formula: Reservoir strain – Contraction strain. Decreased LA-GS and LA reservoir function was considered to be present when it was <39%, as previously reported (**Figure 2B)** (13).

Statistical analysis

Frequency distribution of categorical variables were reported as frequencies and percentages and compared between groups using chi-squared test (X^2). Data were presented as mean (standard deviation) or median (interquartile range) where appropriate. To compare differences of echocardiographic parameters among each ventricular geometry variant, we performed one-way ANOVA or Kruskal-Wallis test wherever it followed parametric distribution. Zidak-test or Dunn's post hoc test was also used to evaluate differences among ventricular groups.

Correlation of global longitudinal strain parameters with myocardial function

To assess the correlation of both LV-GS and LA-GS with ventricular function by traditionally echocardiographic evaluation, we performed partial correlation analysis to obtain correlation coefficients after adjusting for age. In order to evaluate the prediction capacity of global strain on myocardial function, we performed linear regression analysis to assess the association and variability adjusted for age.

Risk factors for myocardial dysfunction

To identify independent factors associated with left ventricular and atrial dysfunction, we performed logistic regression models using stepwise analysis. The closeness of fit of the logistic regression model was assessed using the Hosmer & Lemeshow test. In addition, we evaluated the performance of the model using the area under the receiver operator curve (AUC) with its respective 95% confidence interval. All statistical analyses were performed using the Statistical Package for Social Sciences software (SPSS, version 21.0), R software (version 3.5.1) and GraphPad Prism (Version 6.0). A p value <0.05 was considered statistically significant.

RESULTS:

Study population

We recruited 121 subjects with a median age of 60 (IQR: 49-68) years with female predominance (51.2%); previous myocardial infarction was present in 33 (27.3%) cases. Comorbidities and anthropometric evaluations are presented in **Table 1** . Using ventricular geometry categorization, we found that the predominant abnormal geometry was eccentric hypertrophy in 31 (25.6%) cases, followed by concentric remodeling in 24 (19.8%) cases and concentric hypertrophy in 12 (9.9%) cases.

Echocardiographic evaluation

All the echocardiographic data is shown in **Table 2** . Briefly, median LVEF using 2D was 57% (IQR: 47-61) and by 3D 56% (IQR: 46.5-62), with median RWT of 0.38 (SD: 0.089), LVMI of 94 g/m^2 (IQR: 77-109.5), LV-GS of -19.6% (IQR: -21.8 to -16.5) and LA-GS of 39.3% (IQR: 27.3-52.2) and LA-Reservoir Strain (LA-RS) of 39.1% (IQR:27.3-51.7). Among the different geometry groups, we found that the left ventricular parameters, LVEDd, LVESd, IVSd, PWd, S wave and E/e' differed from group to group. As expected, we found that cardiac indexes showed differences in RWT, LV mass and LVMI. There were also differences among LA-volumes. In the evaluation of left ventricular and atrial strain, we found significant differences in LV-GS, LA-GS and LA-RS among our geometry groups. The eccentric hypertrophy group had the lowest LV-GS with a median of -17.68% (IQR: -19.82 to -13.6), and the concentric hypertrophy group had the lowest LA-GS and LA-RS with a median of 31.5% (IQR: 20.1-39.3) and 31.3 % (IQR: 19.9-39.3), respectively. Further evaluation of the left atrium showed that the eccentric hypertrophy group had the highest LA-volume and the lowest contraction phase **(Table 3, supplementary Figure 1)** . We found decreased LV-GS in 40 (33%) subjects, while decreased LA-GS or LA-RS was present in only 14 (11.5%) subjects, while the presence of both conditions was evident in 14 (11.5%) cases.

Correlation of strain parameters with myocardial function

We observed that LV-GS had a significant correlation with LVEF (r=-0.726; 95% CI: -0.801 to -0.629) and LVMI (r=0.451; 95% CI: 0.296-0.582). Additionally, we found that LA-GS had its strongest correlation with LA-Volume (r=-0.453, 95%CI: -0.584 to -0.298) and with LVMI (r= -0.398, 95% CI: -0.538 to -0.236)**.** In the prediction of myocardial function, we found that LV-GS predicted 64.6% and LA-GS 14.1% of LVEF variability. Also, both LV-GS and LA-GS predicted LVMI and RWT parameters (**Figure 3**). Exploring the subgroups of subjects with previous myocardial infarction, we found that these patients had lower LV-GS ($p<0.001$) and lower LA-GS ($p<0.032$) compared to subjects without myocardial infarction. As expected, these subjects also had decreased LVEF ($p<0.001$) and eccentric hypertrophy with RWT ($p<0.021$) and LVMI ($p<0.113$) **(Supplementary Figure 2)** .

Factors associated with myocardial dysfunction

We found that smoking, previous history of myocardial infarction and male gender were risk factors associated with left ventricular myocardial dysfunction. For left atrial myocardial dysfunction, we found smoking and dyslipidemia were associated factors. Finally, for both LV and LA myocardial dysfunction, we found that the only associated factor was male gender **(Table 4)** . Also, we found that those subjects with eccentric hypertrophy had up to 3.4-fold (95% CI: 1.34-8.76) higher probability for LV-dysfunction and a 2.3-fold (95% CI: 1.10-5.29) higher probability of having LA-dysfunction after adjusting for the previously mentioned associated risk factors

(Supplementary Table 1).

DISCUSSION

Here we describe the differences in echocardiographic values together with the LV-GS, LA-GS and LA-RS profiles in different ventricular geometric variants. Furthermore, we assessed the factors associated with left ventricular and atrial dysfunction and found that they were previous myocardial infarction and eccentric hypertrophy. We found that those subjects with eccentric hypertrophy had up to 3.4-fold higher

probability of LV-dysfunction and a 2.3-fold higher probability of having LA-dysfunction after adjusting for the previously mentioned associated risk factors. Further examination of the left atrium showed that the group with eccentric hypertrophy had the highest LA-volume and the lowest contraction phase.

The utility of global strain assessed by speckle tracking by echocardiography has been previously explored in several conditions including atrial fibrillation, cardiac myopathy, arrhythmia, heart failure, and overall cardiovascular outcomes in subjects with left bundle branch block (9,11,14,15). Overall, its clinical utility in cardiology has been attributed to its high reproducibility and its capacity for detecting structural and functional abnormalities compared with other imaging methods and without requiring extensive echocardiographic training (16). Furthermore, including subjects with previous myocardial infarction does not introduce bias into the use of global strain in functional analysis. This could be a noteworthy advantage since the evidence suggests that global strain is a reliable predictor of myocardial function and has good correlation in subjects with previously diagnosed myocardial infarction (16). Our results support the idea that strain is an excellent automatized method for evaluating structural myocardial changes in subjects with LVH.

The link between ventricular geometry, especially LVH and strain has been previously reported. Soufi Taleb Bendiab, et al. evaluated the association of ventricular geometry with LV-GS in 200 subjects with high blood pressure and found that reduced LV-GS was correlated with long-lasting, uncontrolled blood pressure and metabolic changes which were more pronounced in those with eccentric and concentric hypertrophy (17). Another study by Hare, et al. evaluated global longitudinal strain (GLS) in subjects with left ventricular hypertrophy for hypertensive heart disease and found that GLS values were decreased in subjects with concentric remodeling and concentric hypertrophy (18). Mizuguchi Y, et al. assessed the deterioration of systolic left ventricular myocardial deformation by two-dimensional strain echocardiography as early evidence of isolated diastolic heart failure in patients with hypertension and LVH in 98 patients and 22 age-matched normal controls, and they found that concentric LVH caused impairment of longitudinal, circumferential and radial myocardial deformation in patients with hypertension. Circumferential shortening was the major compensatory mechanism for maintaining LV pump function (19).

Our results suggest that the GLS measurements could be a complementary tool in the assessment of left ventricular function, independent of the ventricular geometry. Furthermore, its automated methodology could be performed by any medical personnel.

Our study also found that cardiovascular risk factors could be explored to identify subjects at risk for decreased myocardial function. This was previously reported by our group, in which T2D, arterial hypertension and dyslipidemia were frequent conditions among subjects who were referred to the NCD. The fact that these conditions were associated with myocardial dysfunction may suggest that our population has increased risk factors for cardiovascular events that predispose to develop structural changes which lead to a higher incidence of adverse outcomes and other cardiac complications (20).

Strengths and limitations

Although our study provides evidence of the role of GLS in the echocardiographic evaluation of different types of ventricular geometry, some strengths and limitations must be recognized. The strength of this study is based on echocardiographic measurements made in these subjects, in which we combined GLS and conventional echocardiographic parameters according to standardized protocols and current guidelines. Furthermore, we were able to identify that a specific type of ventricular geometry was closely associated with LV and LA dysfunction, indicating an opportunity for early detection of the associated complications that these subjects could develop.

However, our study has some limitations. First, the number of subjects included is small, and a larger sample size is required to replicate and validate the results. Second, we were unable to obtain biochemical values or use another imaging method to correlate these associations with our findings and conduct a follow-up of these subjects to assess prognosis and cardiac complications.

CONCLUSION

We found that different types of ventricular geometry had different echocardiographic profiles and risk factors for LV and LA dysfunction assessed by strain.

The assessment of ventricular remodeling by global strain could be used as a complementary tool in the echocardiographic evaluation of ventricular and atrial function.

We found that eccentric hypertrophy is as a mayor risk factor for myocardial dysfunction.

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DECLARATION

Declaration of interest : None

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Conflict of interest/Competing interests : None

ETHICAL APPROVAL

This study was approved by the Human Research Ethics Committee of the National Institute of Cardiology Ignacio Chavez with a reference number: PT-17-087. The study therefore has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

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FIGURE LEGENDS

Figure 1 . Transthoracic two-dimensional echocardiography of a patient with concentric remodeling (RWT: 0.45 and LVMI: 94.35 gr/m2), showing: A) type I left ventricular diastolic dysfunction (E/A ratio: 0.9) and B) end-diastolic hypertension (E/e´ratio:13.6) and C) left ventricular ejection fraction by 3D-echocardiography of 57%. RA=right atrium; RV= right ventricle.

Figure 2. Left ventricular global longitudinal strain (A) and left atrial global strain (B) assessed by velocity vector imaging were normal. RA=right atrium; RV= right ventricle; LV=left ventricle.

Figure 3. Correlation between LV-Strain and LVEF (A), Left Ventricular Mass Index (B), Relative Wall Thickness (C), LA-Strain (D), Left Atrial Volume (E) and E/e' Index (F). *Abbreviations* : LVEF= left ventricular ejection fraction; LV= left ventricle; LA= left atrium.

Supplementary Figure 1 : Differences among groups in LVEF (A), LV-GS (B), LA-GS (C), Left Ventricular Mass Index (D), E/e' Index (E) and LA Volume. *Abbreviations* : NG= Normal Geometry; CR= Concentric Geometry; CH= Concentric Hypertrophy; EH= Eccentric Hypertrophy; LV= Left Ventricle; LA= Left Atrium; LVEF= Left Ventricle Ejection Fraction.

Supplementary Figure 2 : Differences in LVEF (A), LV-GS (B) and LA-GS (C), Left Ventricular Mass Index (D), E/e Index (E) and Relative Wall Thickness (F) in subjects with previous myocardial infarction.*Abbreviations* : LVEF=Left Ventricular Ejection Fraction; LV GS= Left Ventricular global strain; LA GS= Left Atrial global strain.

Table 1: Characteristics of population of study assessed with echocardiography. Data is presented as frequency (%), mean (SD) and median (IRQ) where appropriate. *Abbreviations* : T2D=Type 2 Diabetes

Parameter	**Frequency**
Female Sex (%)	62 (51.2%)
Age (years)	60 (49-68)
Comorbidities	
Arterial Hypertension	69 (57%)
T2D	59 (48.8%)
Dyslipidemia	42 (34.7%)
Smoking	19 (15.7%)
Obesity	10 (8.3%)
Previous Myocardial Infarction	33 (27.3%)
Anthropometry	
Weight (kg)	72.41 ($\pm$15.55)
Height (mts)	1.60 (1.53-1.69)
BSA (cm^2)	1.76 ($\pm$0.21)
BMI (kg/m^2)	27.63 (24.79-30.48)
Ventricular Geometry	n=121
Normal (%)	54 (44.6%)
Eccentric Hypertrophy (%)	31 (25.6%)
Concentric Hypertrophy (%)	12 (9.9%)
Concentric Remodeling (%)	24 (19.8%)

Table 2: Echocardiographic assessment of study population. Data is presented as frequency (%), mean (SD) and median (IR) where appropriate. *Abbreviation* : LVEF= Left Ventricular Ejection Fraction, LVEDd= Left Ventricular End-Diastolic Diameter; LVESd= Left Ventricular End-Systolic Diameter, IVSd= Interven-

tricular Septal Thickness Diameter, PWd= Posterior Wall Thickness at End-Diastole; RWT= Relative Wall Thickness; LVMI= Left Ventricular Mass Index; LA= Left Atrium.

Echocardiographic Parameters	**Data**
LVEF 2D (%)	57 (47-61)
LVEF 3D (%)	56 (46.5-62)
LVEDd (mm)	48 (44-52)
LVESd (mm)	30 (25-35)
IVSd (mm)	10 (9-11)
PWd (mm)	9 (8-10)
E Wave	0.67 (±0.16)
A Wave	0.75 (±0.22)
E/A ratio	0.87 (0.73-1.17)
S Wave	11 (10-13)
E/e' ratio	9.05 (7.53-11.44)
Ventricular Indexes	
LV-GS	-19.6 (-21.8 to -16.5)
RWT	0.377 (±0.089)
LV Mass (gr)	163 (132.5-199)
LVMI (g/m^2)	94 (77-109.5)
Left Atrial Values	
LA Volume (cm3)	20 (16-26.5)
Reservoir Phase (%)	39.1 (27.3-51.7)
Conduit Phase (%)	20.1 (11.3-27.9)
Contraction phase (%)	18.6 (12.7-26.0)
LA-GS	39.3 (27.3-52.2)

Table 3: Echocardiographic assessment in subjects with normal geometry, concentric remodeling, concentric hypertrophy and eccentric hypertrophy. Data is presented as frequency (%), mean (SD) and median (IR) where appropriate. *Abbreviation* : LVEF= Left Ventricular Ejection Fraction, LVEDd= Left Ventricular End-Diastolic Diameter; LVESd= Left Ventricular End-Systolic Diameter, IVSd= Interventricular Septal Thickness Diameter, PWd= Posterior Wall Thickness at End-Diastole; RWT= Relative Wall Thickness; LVMI= Left Ventricular Mass Index; LA= Left Atrium.

Echocardiographic Parameter	**Normal Geometry n= 54**	**Concentric Remodeling n= 24**	**Concentric Hypertrophy n= 12**	**Eccentric Hypertrophy n= 31**	**P value**
LVEF 2D (%)	57 (47.5-61)	60 (56.2-65.2)	50.5 (35.2-60)	53 (37-61)	0.007
LVEF 3D (%)	56 (49-60.2)	60.5 (55.65)	48 (36.7-57.2)	55 (38-62)	0.011
LVEDd (mm)	48 (44-50)	42 (40-46)	49 (46.2-52)	53 (49-62)	<0.001
LVESd (mm)	29 (25-33.2)	26 (23.2-28)	34.5 (28.7-37.5)	35 (31-44)	<0.001
IVSd (mm)	10 (9-11)	11 (9-11)	12.5 (11-14)	10 (9-11)	0.002
PWd (mm)	8 (7-9)	10 (9.7-11)	11.1 (11-12)	9 (8-10)	<0.001
E Wave	0.63 (0.57-0.76)	0.68 (0.6-0.74)	0.67 (0.42-0.81)	0.71 (0.56-0.89)	0.545
A Wave	0.71 (0.58-0.86)	0.74 (0.65-0.88)	0.81 (0.54-0.97)	0.79 (0.54-0.97)	0.575
E/A Index	0.87 (0.73-1.2)	0.92 (0.78-1.12)	0.77 (0.54-0.88)	0.81 (0.66-1.27)	0.313

Echocardiographic Parameter	**Normal Geometry n= 54**	**Concentric Remodeling n= 24**	**Concentric Hypertrophy n= 12**	**Eccentric Hypertrophy n= 31**	**P value**
S Wave	11 (10-13)	12 (10-13)	10 (9-13)	10 (9-11.2)	0.010
E/e'	7.9 (6.5-9.9)	9.3 (7.9-11.9)	11.6 (9.7-14.2)	10.2 (8.9-12.5)	<0.001
Indexes					
LV-GS	-19.77 (-21.8 to -17.43)	-20.94 (-22.97 to -18.96)	-19.13 (-20.91 to -11.77)	-17.68 (-19.82 to -13.6)	0.008
RWT	0.35 (0.30-0.38)	0.46 (0.43-0.52)	0.45 (0.43-0.50)	0.34 (0.28-0.38)	<0.001
LV Mass (gr)	148 (121-172)	141 (116-165)	215.5 (172.2-264)	206 (179-232)	<0.001
LVMI (g/m^2)	83.5 (69-94)	83 (66.7-93.7)	126 (103.2-147)	121 (105-134)	<0.001
Left Atrial Values					
LA Volume (ml/m^2)	18 (14-24.2)	18 (13.2-21)	22 (17.5-26.7)	27 (17-38)	0.007
Reservoir Phase (%)	42.1 (29.4-60.9)	43.5 (33.6-56.4)	31.3 (19.9-39.3)	34.4 (14.3-48.1)	0.023
Conduit Phase (%)	23.3 (14.4-32.3)	22.7 (14.0-31.2)	12.57 (8.3-17.8)	17.4 (9.1-22)	0.008
Contraction phase (%)	18.1 (12.1-29.7)	23.1 (15.1-26)	19.1 (8.9-23.7)	16.3 (7.2-24)	0.279
LA-GS	42.2 (29.5-61)	43.6 (34.1-56.5)	31.5 (20.1-39.3)	34.5 (14.5-48.1)	0.025

Table 4: Logistic regression model for LV Strain adjusted for age. *Abbreviations* : B: Beta coefficient; OR: Odds ratio; AUC: Area under the curve; CI: Confidence interval.

Model	**Parameter**	**B**	**SE**	**Wald**	**OR**	**95% CI**	**P Value**
LV-Dysfunction (LV-GS [?]-20) *Hosmer and Lemen-show= 3.758 P value= 0.585 R^2= 0.304 AUC= 0.675 (95% CI= 0.579-0.771)*	Constant	0.367	0.277	1.748	0.693		0.186
	Smoking	-1.952	0.647	9.107	0.142	0.04-0.50	0.003
	Previous Myocar-dial Infarction	1.508	0.595	6.435	4.52	1.41-14.50	0.11

Model	Parameter	B	SE	Wald	OR	95% CI	P Value
	Male Gender	1.366	0.450	9.215	3.92	1.62-9.47	0.002
LA-Dysfunction (LA-GS [?]39%) *Hosmer and Lemenshow=7.507 P value= 0.483 R^2=0.186 AUC= 0.677 (95% CI=0.580-0.774)*	Constant	-2.064	0.920	5.028	0.127		0.025
	Smoking	-1.496	0.623	5.754	0.224	0.07-0.761	0.016
	Dyslipidemia	-0.934	0.436	4.596	0.393	0.17-0.92	0.032
Both LA&LV Dysfunction *Hosmer and Lemenshow=16.58 P value= 0.035 R^2=0.162 AUC= 0.642 (95% CI=0.524-0.723)*	Constant	-2.782	1.026	7.351	0.062		0.007
	Male Gender	1.130	0.433	6.823	3.10	1.33-7.23	0.009