



Role of Left Atrial Strain Using Two-Dimensional Speckle Tracking Echocardiography for Early Detection of Left Ventricular Diastolic Dysfunction in Patients with Preserved Left Ventricular Ejection Fraction

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Abstract

Background: Left ventricular diastolic dysfunction (LVDD) evaluation is challenging and difficult by using current conventional echocardiogram. Increased left atrial volume index (LAVI) is one of the established parameter of left ventricular diastolic dysfunction, but mainly reflect the chronic effect of raised left ventricular filling pressure. Recent studies have suggested that left atrial (LA) strain could be an important criteria for early assessment of left ventricular diastolic dysfunction. Considering left atrial strain along with left atrial volume index could raise the detection of left ventricular diastolic dysfunction, however it is not yet proved.

Objectives: The study was done to analyze the importance of left atrial strain for early detection of left ventricular diastolic dysfunction and whether adding left atrial strain to left atrial volume index could raise the rate of detection of left ventricular diastolic dysfunction in patients with preserved left ventricular ejection fraction (LVEF).

Methods: Using two-dimensional echocardiography, color Doppler imaging, tissue Doppler imaging and 2-dimensional speckle-tracking echocardiography, we analyzed a population of 52 patients in sinus rhythm at risk for left ventricular diastolic dysfunction such as those with systemic hypertension, diabetes mellitus, obesity, dyslipidemia or chronic coronary syndrome with preserved left ventricular ejection fraction.

Results: The study showed significant association of left atrial strain with abnormal septal e' or lateral e' , ($p < 0.05$), which are established parameters of left ventricular diastolic dysfunction. This study also showed, in patients with estimated elevated left ventricular filling pressures ($E/e' > 14$), the rate of abnormal left atrial strain was significantly higher than an abnormal left atrial volume index (100% vs. 45.5%, $p < 0.05$). Here also in patients with normal left atrial volume index, other left ventricular diastolic dysfunction parameters like $E/e' > 14$, $TRV_{max} > 2.8$ m/s and abnormal left atrial strain were present (13.6% had $E/e' > 14$, 6.8% had $TRV_{max} > 2.8$ m/s and 38.6% had abnormal left atrial strain, $p < 0.05$). Left atrial strain showed sensitivity of 54.5%, specificity of 100%, positive predictive value of 100% and accuracy of 61.5%. So, Left atrial strain could be used as a diagnostic tool for left ventricular diastolic dysfunction, and left atrial strain helps for early detection of left ventricular diastolic dysfunction ($p < 0.5$).

Conclusion: The findings of the study showed that left atrial strain can be used for early detection of left ventricular diastolic dysfunction and adding left atrial strain to left atrial volume index increases the rate of detection of left ventricular diastolic dysfunction.

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Introduction

Many patients with preserved left ventricular ejection fraction presented with features of heart failure. This group of patients may have diastolic dysfunction which remains undiagnosed due to lack of parameters for early detection of diastolic dysfunction in clinical practice. Some non-cardiac diseases like chronic pulmonary vascular obstructive disease may present with dyspnea and difficult to differentiate clinically. Precise and early diagnosis of left ventricular diastolic dysfunction has become an emerging challenge to clinicians. Left ventricular (LV) diastole depends on elastic recoil of ventricular wall, ventricular energy dependent relaxation, compliance, ventricular filling pressure. LV filling is influenced by volume status, diastolic filling time, heart rate, wall tension and contractility [1]. LV diastolic dysfunction occurs as a result of impaired energy dependent LV relaxation, reduced recoiling forces, and increased LV wall stiffness, which in turn increased LV end diastolic pressure [2]. The left atrium has a pivotal role in the sequence of events that modulate left ventricular filling. This is accomplished by means of four basic functions involving the left atrium: phase 1, reservoir function, collection of pulmonary venous flow during LV systole; phase 2, conduit function, passage of blood to the left ventricle during early diastole; phase 3, active contractile pump function, 15%–30% of LV filling in late diastole; and phase 4, suction force, the atrium refills itself in early systole [1]. There are algorithms available for LVDD diagnosis & used in the clinical setting. However, these criteria required for diagnosis include multiple echocardiography-based parameters and sometime challenging to interpret [2]. Doppler echocardiography is a cornerstone for the diagnosis and categorization of LV diastolic function. Though myocardial Tissue Doppler imaging (TDI) has been used to assess regional myocardial contractility but limited by the angle dependency [3]. Invasive measurements of LA function are not feasible in most patients. Therefore, the components of LA function (contractile, conduit, and reservoir function) are traditionally estimated using non-invasive methods like, two-dimensional (2D) echocardiography and Doppler analysis of trans-mitral and pulmonary vein flows. However, the evaluation of LA function is still challenging [4]. Non-invasive parameters for evaluation of left atrial function had a number of limitations, such as lack of a gold-standard measurement of LA function, and difficulties with the echocardiographic window and with the timing of various atrial events. Moreover, errors were frequent because of the geometric assumption of a biplane volume calculation [5]. Strain analysis by two dimensional speckle tracking echocardiography is a modern mode of echocardiography, where we can detect minute myocardial deformation by tracking & analyzing each myocardial fiber

length during both systole & diastole. Left atrial strain analysis gives valuable information regarding regional myocardial deformation, which is earlier change than left atrial dilatation. Left atrial functional & structural changes have significant impact on left ventricular diastolic function. That's why LA strain analysis is needed for complete evaluation of LVDD. LA strain has a strong correlation with invasive measurement of LV end diastolic pressure. A recent study of [6] showed, an abnormal global peak atrial longitudinal strain (GPALS or LA strain i.e <23%), had adequate sensitivity 72.8%, and specificity 76.2% to detect LV diastolic dysfunction with preserved EF. In addition, an abnormal LA strain had a significant association with the risk of HF hospitalization at 2 years [6].

Material and Methods

Type of Study: Cross sectional study

Place of study: This study was carried out at the department of cardiology, National Heart Foundation Hospital and Research Institute, Mirpur, Dhaka, Bangladesh.

Study period: This study was carried out between the period of 1st August 2022 and 28th February 2023.

Study population: Patient having at least one risk factor for developing LVDD who were admitted or visited outpatient department at national heart foundation hospital and research institute, mirpur, Dhaka, Bangladesh.

Sample size: By considering sensitivity, sample number was more than considering specificity. So final sample number was considered as 52.

Inclusion criteria:

Patient having at least one the following risk factor for developing LV diastolic dysfunction, with sinus rhythm & preserved LV EF $\geq 50\%$:

- Hypertension
- DM
- Obesity
- Chronic coronary syndrome
- Dyslipidemia

Exclusion criteria:

- Valvular heart disease
- Cardiomyopathies
- Constrictive pericarditis
- Acute coronary syndrome
- Tachyarrhythmia
- Having any device therapy (ICD/PPM/CRT)
- Acute LVF
- Acute exacerbation of bronchial Asthma/COPD/pneumonia
- Patient on steroid treatment
- Patient with ESRD or decompensated CLD

- EF<50%
- Poor echo window

Data collection procedure:

- 54 patients who were admitted in hospital or visited OPD at national heart foundation hospital and research institute at mirpur, Dhaka, fulfilling the inclusion criteria were selected for the study. 2 patients were excluded from the study due to poor echo window.
- Baseline clinical & medical history including chest pain, dyspnea were evaluated according to NYHA class. BP was measured.
- 12 lead ECG with a 25mm/s speed and 1mV/10mm standard were obtained from all patient to ensure sinus rhythm. Baseline investigations like S. creatinine, SGPT, lipid profile, HBA1C, CXR were reviewed.
- Informed consent was taken from each subject before enrolment.
- Patient brought to echo lab for analysis of LV diastolic function.

Conventional 2D and Color Doppler and TDI

- All patients were examined with conventional two dimensional (2D), M mode, Doppler echo including TDI, and 2D-speckle tracking echocardiography.
- All patients were examined at rest using a Philips Epiq CVX ultrasound system.
- 2016 ASE & EACVI guideline was followed for assessment of LVDD. Four established criteria are as given below:
 - 1) Septal or lateral mitral annular early diastolic peak velocity (e') <7 cm/s or <10 cm/s using tissue Doppler imaging, respectively;
 - 2) Mitral annular average E/e' ratio >14;
 - 3) LAVI >34 ml/m² (using the biplane Simpson method);
 - 4) TR jet peak velocity >2.8 m/s.
- LVDD was determined when >50% of these criteria were positive and normal LV diastolic function when <50% of these criteria was positive. In addition, indeterminate LV diastolic function was defined when only 50% of the criteria were positive.
- Here we needed to record other supportive criteria for LVDD like, mitral E/A ratio which helps to assess the LV filling pattern and also grading of LVDD (LVDD grade 1 or impaired when E/A is ≤0.8 & E velocity ≤50cm/sec, grade 2 or pseudo-normal when E/A ≤0.8 + E velocity >50 cm/sec or E/A >0.8 to <2 but must be clarified by other parameters of diastolic dysfunction like abnormal septal e' or lateral e', Av E/e' >14, TR Vmax > 2.8 m/s, LAVI > 34 ml/ m² & grade 3 or restrictive when E/A is >2). This algorithm is for grading of LVDD in patient with both preserved EF & depressed EF, according to 2016 ASE/ EACVI guideline (please see the appendix for illustration; figure 2B).

2D Speckle Tracking Echocardiography:

- The analysis of LA strain using 2D speckle-tracking echocardiography was performed by expert echocardiographer.
- Patients were positioned left laterally and views were obtained during a stable echocardiographic recording.
- The frame rate was set between 50 and 80 frames/sec.
- ECG gated three cardiac cycle strain video loop was taken. Starting point was from QRS complex to the next QRS complex. Machine automatically analyze the three cycle and choose the best one. Then auto strain analysis software give two images, one is at end systole & another at end diastole.
- The LA mechanical indexes (LA reservoir strain, conduit strain, contractile strain) were calculated by averaging values observed in all LA segments with a 12- segment model (six equidistant regions in the apical four-chamber view and six more in the apical two-chamber views).
- In healthy subjects an abnormal LA reservoir strain was considered when LA reservoir strain or global PALS was <23% Morris et al. [7]

Statistical analysis

After collection, data were entered, checked and analyzed in SPSS (version 23.0, IBM, USA). Results were shown as table and expressed as frequency; percentage for categorical data and mean ± SD for continuous data and association observed by using Fisher's Exact test or two proportion z test for categorical variables and ANOVA test were performed for comparison between more than two groups. Also, validity test of LA strain and LAVI were performed for better estimator. A 'p' value <0.05 was considered as statistically significant.

Results

Total 54 patients who fulfilled inclusion & exclusion criteria underwent echocardiography, but 2 patients were excluded due to poor echo window. Then a total 52 patients underwent LA strain analysis using 2D-STE along with conventional echocardiography. LA strain was compared with LAVI to assess the usefulness for detecting LV diastolic dysfunction in patient with preserved EF (Table 1-3).

Table 1: Age distribution among the study population.

Age (year)	Frequency	Percent
≤50	14	26.9
51-60	20	38.5
61-70	11	21.2
>70	7	13.5
Total	52	100.0
Mean ± SD (Min-Max)	58.27 ± 11.28 (38-95)	

Among the 52 patients mean age was 58.27± 11.28 years.

Table 2: Sex distribution among the study population.

Sex	Frequency	Percent
Male	32	61.5
Female	20	38.5
Total	52	100.0

Table 3: Distribution of the patients with chest pain according to CCS class.

CCS class	Frequency	Percent
No chest pain	4	7.7
Class II	48	92.3
Total	52	100.0

CCS= Chronic Coronary Syndrome

Among 52 patients 92.3 % patients had chronic coronary syndrome and with CCS class II presentation. In CCS Class I, III, IV there were no patient (Table 4).

Table 4: Distribution of the patients with dyspnea according to NYHA class.

NYHA Class	Frequency	Percent
No dyspnea	37	71.2
Class I	1	1.9
Class II	14	26.9
Total	52	100.0

NYHA=New York Heart Association

Among 52 patients 28.8 % patients had dyspnea; 26.9% of them with NYHA class II presentation and 1.9%of them with NYHA class I presentation. In NYHA Class III, IV there were no patient (Table 5).

Table 5: Risk factor distribution among the study population

Risk factors	Frequency	Percent
DM	29	55.8
HTN	46	88.5
Dyslipidemias	38	73.1
CCS	48	92.3
BMI (kg/m ²)		
o Normal	14	26.9
o Over weight	35	67.3
o Obese	3	5.8
Mean $\pm$ SD (Min-Max)	26.2 $\pm$ 2.5 (21.9-33.3)	

Among 52 patients, 92.3% patients had chronic coronary syndrome, 88.5% patient had HTN, 73.1% patient had dyslipidemia, 55.8% patients had DM and 67.3% were overweight as well as 5.8% were obese person (Table 6).

These are the parameters obtained from 2D , color

Table 6: Echocardiographic variables among the study population.

Variables	N	Mean $\pm$ SD	Min-Max
LVEF (%)	52	60.5 $\pm$ 4.2	50-67
LVMI (g/m ²)	52	107.3 $\pm$ 28.3	66-185
Relative LV wall thickness	52	0.5 $\pm$ 0.1	0.32-0.68
Septal e' mitral annular velocity by TDI (cm/s)	52	6.3 $\pm$ 1.6	3.48-9.68
Lateral e' mitral annular velocity by TDI (cm/s)	52	8.0 $\pm$ 2.3	3.7-14.3
Mitral early diastolic inflow velocity (E) (cm/s)	52	73.9 $\pm$ 16.9	43.3-113
E/A ratio	52	0.9 $\pm$ 0.3	0.5-2.1
Mitral average septal-lateral ratio (Av. E/e')	52	11.2 $\pm$ 3.4	6.5-21.6
LAVI (ml/m ²)	52	25.8 $\pm$ 7.3	12-48.4
LA strain (%)	52	25.5 $\pm$ 9.5	8.5-45.15
TR jet peak velocity (m/s)	43	2.5 $\pm$ 0.3	1.69-3.15

N= total number of study subjects

Doppler , TDI and 2D STE. 54 patients were enrolled but 2 patient excluded due to poor echo window. Here LA strain feasibility was 96.3% . Among 52 patients TR Vmax could not measured in 9 patient due to inadequate Doppler signal of TR jet (Table 7).

Table 7: Rate of abnormal LA Strain and other criteria for LVDD in patients with risk of developing LVDD.

Variables	Frequency(n)	Percent (%)
Septal e'<7 cm/s or Lateral e' <10cm/s	44	84.6
Average E/e'>14	11	21.2
TR jet peak velocity>2.8m/s	8	15.4
LAVI>34ml/m ²	8	15.4
LA strain<23%	24	46.2

LVDD= Left ventricular Diastolic Dysfunction

Analyzing 52 patients who had risk of developing LVDD, 46.2% patients had abnormal LA strain , whereas rate of abnormal LAVI was only 15.4% .p value between LA strain & LAVI is 0.001 by two proportion z test (Table 8).

Table 8: Left ventricular diastolic dysfunction distribution among the study patients according to 2016 ASE & EACVI guideline.

LVDD	Frequency	Percent
Negative	39	75.0
Indeterminate	5	9.6
Positive	8	15.4
Total	52	100.0

LVDD=Left ventricular diastolic dysfunction

According to 2016 guideline, among 52 patient who had risk of developing LVDD, 8 patients (15.4%) had >50% criteria of LVDD were considered as positive cases or had LVDD. Five patients (9.6%) had 50% criteria of LVDD were considered as indeterminate cases (Table 9).

Table 9: Grade of LV diastolic dysfunction among the study population according to 2016 ASE & EACVI guideline.

Grade	Frequency	Percent
Normal diastolic function	39	75.0
Grade I* LVDD	5	9.6
Grade II LVDD	7	13.5
Grade III LVDD	1	1.9
Total	52	100.0

*Here indeterminate group (5 out of 52) is also included in Grade I LVDD

According to 2016 ASE guideline of LVDD, 8 patients had LVDD with >50% criteria. Among them, 7 patient had E/A >0.8 <2 grade II. 1 patient had E/A >2 was considered as grade III. However, 5 patients had E/A either <0.8 or >0.8 <2 along with at least 50% criteria of LVDD who included both grade I & indeterminate group (Table 10).

Table 10: Association of Abnormal LA strain and abnormal LAVI in patients with estimated elevated LV filling pressure.

Variables	Average E/e' >14		P value
	Positive (n=11)	Negative (n=41)	
LA strain <23%	11 (100.0)	13 (31.7)	<0.001 ^a
LAVI >34ml/m ²	5 (45.5)	3 (7.3)	0.007 ^b

^aFisher's Exact test was done to measure the level of significance.

^bFisher's Exact test was done to measure the level of significance. Figure within parenthesis indicates in percentage.

Among 52 patients, 11 patients had both abnormal septal or lateral e' and E/e'. Among 11 patients all of them had abnormal LA strain, however, among the normal septal or lateral e' and E/e' group 13 patient had abnormal LA strain (Table 11).

Table 11: LV diastolic dysfunction parameters and abnormal LA strain in patients with normal or abnormal LAVI.

Variables	LAVI		P value*
	Abnormal >34ml/m ² (n=8)	Normal <34ml/m ² (n=44)	
Septal e' <7 cm/s or Lateral e' <10cm/s	7 (87.5)	37 (84.1)	0.999
Average E/e' >14	5 (62.5)	6 (13.6)	0.007
TR jet peak velocity >2.8m/s	5 (62.5)	3 (6.8)	0.001
LA strain <23%	7 (87.5)	17 (38.6)	0.018

*Fisher's Exact test was done to measure the level of significance. Figure within parenthesis indicates in percentage.

Again, among the 11 patients only 5 patient had abnormal LAVI and among the normal septal or lateral e' and E/e' group 3 patients had abnormal LAVI.

44 patients had normal LAVI, though among them 6 patients (13.6%) had E/e' >14, 3 patients (6.8%) had TRVmax >2.8 m/s and 17 patients (38.6%) had abnormal LA strain (Table 12).

Table 12: Association of abnormal septal e'/lateral e' with LA Strain and LAVI

Variables	Septal e' <7 cm/s or Lateral e' <10cm/s		P value*
	Positive(n=44)	Negative(n=8)	
LA strain <23%			
Positive	24 (54.5)	0 (0.0)	0.005
Negative	20 (45.5)	8 (100.0)	
LAVI >34ml/m ²			
Positive	7 (15.9)	1 (12.5)	0.999
Negative	37 (84.1)	7 (87.5)	

Fisher's Exact test was done to measure the level of significance. Figure within parenthesis indicates in percentage.

44 patients had abnormal septal e'/lateral e', among them 54.5% patient had abnormal LA strain, whereas only 15.9% were found abnormal LAVI (Table 13).

Table 13: Validity test for LA Strain and LAVI corresponding to abnormal septal e' or lateral e'

Validity test	LA Strain	LAVI
Sensitivity	54.5	15.9
Specificity	100.0	87.5
Positive predictive value	100.0	87.5
Negative predictive value	28.6	15.9
Accuracy	61.5	26.9

Considering septal or lateral e' as standard, LA strain has 54.5% sensitivity, 100% specificity, 100% positive predictive value and 61.5% accuracy.

Potential usefulness of adding LA strain to LAVI in the detection of LVDD

- Rate of detection of LVDD without adding LA strain to the 2016 ASE criteria
- Patient with risk for LVDD with normal LVEF(n=52)
 1. 1.Avg E/e' >14
 2. 2.Septal e' <7 cm/s or lateral e' < 10 cm/s
 3. 3.TR vmax >2.8 m/s
 4. LAVI > 34 ml/m²
- >50% positive (n=8/52)
- Rate of LVDD 15.38 %
- Rate of detection of LVDD with adding LA strain to the 2016 ASE criteria

➤ Patient with risk for LVDD with normal LVEF(n=52)

1. Avg $E/e' > 14$
2. Septal $e' < 7$ cm/s or lateral $e' < 10$ cm/s
3. TR $v_{max} > 2.8$ m/s
4. LAVI > 34 ml/m² or LA strain $< 23\%$

- $> 50\%$ positive (n=13/52)
- Rate of LVDD 25 %

So, absolute & relative rise of LVDD detection become 9.62% & 62.55% (p value 0.222) (Table 14).

Table 14: Association of LA Strain with the LVDD grade.

Variables	LVDD Grade				P value* (ANOVA)
	Normal (n=39)	Grade 1 (n=5)	Grade 2 (n=7)	Grade 3 (n=1)	
LA strain (mean±SD)	28.7 ± 8.7	18.3 ± 3.0	15.0 ± 3.8	11.5	<0.001
Abnormal LA strain n(%)	11 (28.2)	5 (100.0)	7 (100.0)	1 (100.0)	

*ANOVA was done to measure the level of significance

LA strain mean value is reduced in all stages of LVDD, which is statistically significant $p < 0.05$. Abnormal LA strain is present in all patients with LVDD and also in early stages.

Discussion

To our knowledge this is the first study in Bangladesh to evaluate LV diastolic dysfunction using left atrial strain analysis by 2D-STE in patients with preserved LV ejection fraction. The main findings derived from data analysis of the present study was LA reservoir strain had strong association with abnormal septal e' /lateral e' & estimated elevated LV filling pressure in comparison to LAVI. As invasive assessment of LV filling pressure was not done, considering septal e' or lateral e' as the most prevalent parameter of diastolic dysfunction, LA strain showed 54.5% sensitivity, 100% specificity, 100% positive predictive value and 61.5% accuracy to detect LVDD. In the present study the mean age was 58.27 ± 11.28 , where the maximum age was 95 and minimum age was 38. Maximum patient were distributed in 51 to 60 group. Reddy et al. [8] trial on LA strain analysis in patient with HFpEF showed that mean age of that study was 58 ± 14 , was similar to our study. Among the sample population 61.5 % were male and 38.5 were female. Male were predominant than female. Kim et al [9] trial on assessment of diastolic dysfunction by 2D-STE in post MI & CCS patients, showed female were 36.2% & male were 63.8% , which were similar to our study. Among 52 patients, we found CCS was the most common co-morbidity that was 92.3%, after that HTN was the next disease contributing LVDD that was 88.5%, others were dyslipidemia 73.1% , and DM 55.8% . Mean BMI was 26.2 ± 2.5 (21.9-33.3), where minimum BMI was 21.9 & maximum BMI was 33.3. Here,

67.3% were overweight as well as 5.8% were obese person. Singh et al [10] with trial on LA strain as a single marker for elevated filling pressure showed, 82% were associated with HTN, 58% were with DM, 38% were with CCS, 36% were with CKD. In our study CCS prevalence was high as study was done on a cardiac hospital. In our study mean LVEF was 60 ± 4.2 , minimum EF was 50 and maximum EF was 67. LV mass index mean value was 107.3 ± 28.3 , where minimum value 66 and maximum value was 185. Relative wall thickness was measured in 51 patients, mean value was 0.5 ± 0.1 , where minimum value 0.32 and maximum value was 0.68. Septal e' was measured by TDI, which revealed mean value was 6.3 ± 1.6 , where minimum value 3.48 and maximum value was 9.68. Lateral e' were measured in 51 patients by TDI, which revealed mean value was 8.0 ± 2.3 , where minimum value 3.7 and maximum value was 14.3. Mitral annular average septal-lateral ratio (Av. E/e') was measured and mean value was 11.2 ± 3.4 , where minimum value 6.5 and maximum value was 21.6. LAVI was measured in 51 patients, where mean value we found was 25.8 ± 7.3 , minimum value 12 & maximum value 48.4. LA strain was measured in 52 patient and mean was 25.5 ± 9.5 , with a minimum value 8.5 and maximum value 45.15. TR velocity could not achieved in 9 patient due to poor visualization, mean value 2.5 ± 0.3 , minimum & maximum values were 1.69 & 3.15, respectively. Morris et al [6] trial on potential usefulness of LA strain showed mean LVEF was 62.1 ± 5.7 , mean LVMI 100.3 ± 25.1 , septal e' mean 5.5 ± 1.9 , lateral e' 7.6 ± 2.4 , mean Av E/e' 11.9 ± 5.2 , mean LAVI 27.1 ± 10 , mean LA strain 26.6 ± 9.7 . Finding of both studies are quite similar. In our study, 52 patients had at least one of the risk factors enlisted in the inclusion criteria. Among them, we assessed parameters of LVDD along with LA strain. 44 patient (84.6%) had either septal e' or lateral e' abnormal values. 11 patients (21.2%) had elevated estimated LV filling pressure (E/e'). 8 patients (15.4%) had increased TR V_{max} measured by CW Doppler study. LAVI was increased in 8 patients (15.4%). However, LA strain was found abnormal in 24 patients (46.2) . P value between LA strain & LAVI is 0.001 by two proportion z test, which was statistically significant. Morris et al. [6] trial on potential usefulness of LA strain showed 81.2% abnormal septal e' or lateral e' , 36.9% LA strain abnormality, 24.5% elevated LV filling pressure and 15.5% patients with abnormal LAVI. Considering 2016 ASE/EACVI guideline, among 52 patient who had risk of developing LVDD, we found 8 patients (15.4%) had $> 50\%$ criteria of LVDD, were considered as positive cases or had LVDD. Moreover 5 patients (9.6%) had 50% criteria of LVDD were considered as indeterminate cases. Morris et al [6] trial on potential usefulness of LA strain showed 13.5% patient fulfilled the criteria of LVDD. In this study we also categorized the LVDD by 2016 ASE/EACVI guideline. Here, among the 8 patients who had LVDD, 7 (13.46%) patients had $E/A > 0.8$ - < 2 along with $> 50\%$ criteria of LVDD were considered as grade II. 1 (1.92%)

patient had E/A >2 along with >50% criteria of LVDD were considered as grade III. However, 5(9.61%) patients had E/A either <0.8 or >0.8-2 along with at least 50% criteria of LVDD, who included both grade I & indeterminate group. In Morris et al [6] trial on potential usefulness of LA strain, 21.85% were in grade I & indeterminate group, 10.83% were in grade II group and 2.12% were in grade III LVDD group. Among 52 patients, 11 (21.15%) patients had both abnormal septal or lateral e' and elevated E/e'. Among 11 patients all of them (100%) had abnormal LA strain but only 5 (45.5%) patients had abnormal LAVI, which is statistically significant (p<0.05). Nevertheless, Among the rest 41 patient, 13 patient had reduced LA strain and 3 patient had increased LAVI. Morris et al [6] trial revealed among the same group of patient, 62.4% had abnormal LA strain and 33.6% had abnormal LAVI. The proportion LA strain was more in our study may be due to small sample size. Among the patients with normal or abnormal LAVI, the parameter of abnormal septal e' or lateral e' was not statistically significant (87.5% vs 84%, p 0.999). However, even with normal LAVI other parameters of LVDD were significantly present (13.6% of E/e' > 14, 6.8% of TR Vmax > 2.8 m/s and 38.6% of LA strain <23%; p < 0.05). In Frydas et al [11] with trial on left atrial strain as a sensitive marker of LVDD in heart failure, showed LA volume index was normal in 89 (29.7%) among 300 patients and of whom 60.6% had an abnormal LA reservoir strain (i.e. ≤23%). Percentage of LA strain among normal LAVI group was more in that study because they selected all type of patient with dyspnea (NYHA I-IV), while we only selected NYHA I-II patients. In this study, among 52 patients, 44 patients had abnormal septal e' or lateral e', among them 54.5% patient had abnormal LA strain, 45.5% had normal LA strain, whereas LA strain was normal in all patients with normal diastolic function. Here true positive result is 54.4% and false positive result 0%, false negative 45.5%, true negative 100, which are statistically significant, p < 0.05. On the other hand, in patient with abnormal septal e' or lateral e', only 15.9% had abnormal LAVI, 84.1% had normal LAVI, and in patient with normal diastolic function 12.5% showed abnormal LAVI, which were not statistically significant. In this study we didn't include invasive measurement of LVFP, so by considering the most prevalent parameter of left ventricular diastolic dysfunction i.e. abnormal septal e' or lateral e' as standard, LA strain has 54.5% sensitivity, 100% specificity, 100% positive predictive value and 61.5% accuracy. Whereas LAVI has 15.9% sensitivity, 87.5% specificity, 87.5% positive predictive value and 26.9% accuracy. In the Morris et al [6] study, sensitivity, specificity and accuracy were 72.8%, 76.2% & 75.6% respectively. In Frydas et al [11] study with LA strain had a good diagnostic performance to determine severe DD with sensitivity of 80%, specificity of 77.8%, which were significantly better than that for LA volume index. Again, LA strain mean value is reduced in all stages of LVDD and in a

stepwise pattern. Prevalence of abnormal LA strain is present 100% in all patients with LVDD and also in early stages, which is statistically significant p<0.05. These would help us to detect LVDD in more earlier stages, which is also supported by Frydas et al [11], where we observed the extent of LA strain impairment was significantly associated with the severity of DD according to the 2016 ASE recommendations (DD grade I: LA strain 22.2 ± 6.6, rate of abnormal LA strain 62.9%; DD grade II: LA strain 16.6 ± 7.4, rate of abnormal LA strain 88.6%; DD grade III: LA strain 11.1 ± 5.4%, rate of abnormal LA strain 95.7%; all P < 0.01). In our study proportion are showing high values possibly due to low sample size and done on a special group of population. Moreover, in the present study by adding LA strain to LAVI, increased rate of LVDD detection from 15.38% to 25%. In Morris et al [6] trial on potential usefulness of LA strain on LVDD showed increased rate of LVDD detection from 13.5% to 23.4%, which were similar to our study. In recent years, myocardial strain analysis has proved diversity of its implication for myocardial assessment as well as clinical predictor. In our study we found that LA strain is early parameter for assessment of LVDD, which is supported by validity test.

Conclusion

The present study showed that left atrial strain analysis can be used for early detection of left ventricular diastolic dysfunction in patient with preserved EF. Adding left atrial strain to left atrial volume index increase the rate of detection of left ventricular diastolic dysfunction. Left atrial strain values also correspond adequately with the different grades of left ventricular diastolic dysfunction.

Limitations of the study

Although the results of the study support the hypothesis, there were some limiting factors which might have effect on the results.

- Data collected from a single tertiary center and may not reflect the overall population.
- Only patient with good echo window were included in this study, because the image quality is the basic requirement for strain analysis.
- Due to inadequate Doppler signal of tricuspid regurgitant jet, TR Vmax could not be measured in a number of patient, that might be affected the results.
- The study was performed on small number of patients.

Recommendation

- Left atrial strain by two-dimensional speckle tracking echocardiography might play an important role for the precise & early detection of left ventricular diastolic dysfunction in patient with preserved left ventricular ejection fraction, and may keep a significant clinical implication.

- Large scale randomized and multicenter studies are needed to validate the findings of present study. If the utility of left atrial strain is supported by further studies, this may be added to the existing modalities for evaluation of left ventricular diastolic dysfunction in patient with preserved ejection fraction.

References

1. Khan HILR, An approach to clinical & basic echocardiography, 1st edition, Asian color printing, Dhaka 5 (2021): pp: 53-55.
2. Nagueh SF, Smiseth OA, Appleton CP, et al. Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging', European Heart Journal – Cardiovascular Imaging 17 (2016): 1321-1360.
3. Pinton RV, Moreno CA, Baxter CM, et al. Two-Dimensional Speckle-Tracking Echocardiography of the Left Atrium: Feasibility and Regional Contraction and Relaxation Differences in Normal Subjects. Journal of American Society of Echocardiography 22 (2009): 299-305.
4. Saraiva RM, Demirkol S, Buakhamsri A, et al. Left Atrial Strain Measured by Two-Dimensional Speckle Tracking Represents a New Tool to Evaluate Left Atrial Function. Journal of American Society of Echocardiography 23 (2010): 172-80.
5. Vieira MJ, Teixeira R, Goncalves L, et al. Left Atrial Mechanics: Echocardiographic Assessment and Clinical Implications. Journal of the American Society of Echocardiography 27 (2014): 463-478.
6. Morris DA, Belyavskiy E, Kumar RA, et al. Potential Usefulness and Clinical Relevance of Adding Left Atrial Strain to Left Atrial Volume Index in the Detection of Left Ventricular Diastolic Dysfunction. JACC: Cardiovascular Imaging 11 (2018): 10.
7. Morris DA, Takeuchi M, Krisper M, et al. Normal values and clinical relevance of left atrial myocardial function analyzed by speckle-tracking echocardiography: multicenter study. European Heart Journal – Cardiovascular Imaging 16 (2015): 364-372.
8. Reddy YNV, Obokata M, Egbe A, et al. Left atrial strain and compliance in the diagnostic evaluation of heart failure with preserved ejection fraction. European Journal of Heart Failure 21 (2019): 891-900.
9. Kim J, Yum B, Palumbo MC, et al. Left Atrial Strain Impairment Precedes Geometric Remodeling as a Marker of Post Myocardial Infarction Diastolic Dysfunction. JACC: Cardiovascular Imaging 13 (2020): 10.
10. Singh A, Medvedofsky D, Mediratta A, et al. Peak left atrial strain as a single measure for the non-invasive assessment of left ventricular filling pressures. The International Journal of Cardiovascular Imaging. Springer Nature 35 (2018): 23-32.
11. Frydas A, Morris DA, Belyavskiy E, et al. Left atrial strain as sensitive marker of left ventricular diastolic dysfunction in heart failure. ESC Heart Failure 7 (2020): 1956-1965.