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Original article

Role of Myocardial Strain Analysis by 2-Dimensional Speckle Tracking Echocardiography in Assessment of Severity of Coronary Artery Stenosis in Coronary Artery Disease Patients

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Abstract:

Background: Myocardial strain analysis by 2D-speckle-tracking echocardiography, which is performed at resting position, offers valuable information about myocardial fiber changes in different types of myocardial diseases.

Aim: This study evaluated the role of myocardial strain analysis in assessment of severity of coronary artery stenosis in coronary artery disease patients. **Patients and methods:** The study was conducted at the Cardiology Department, Benha University Hospitals during the period from January 2023 to July 2023. This study included 100 patients with CAD, patients were divided into two groups: Group A: 50 Patients with Non-ST elevation Acute coronary syndrome. and Group B: 50 Patients with positive or equivocal stress ECG. (Stable coronary artery disease). All patients underwent full history & examination, ECG, conventional & speckle tracking Echocardiography & both Gensini & Syntax scores were calculated for every patient. **Results:** The study revealed a significant lower GLPSS in Group A compared to Group B ($p<0.001$). Also as regard the correlation of total longitudinal strain and significant coronary artery disease lesions in each Coronary Artery Territories, a significant higher territorial longitudinal strain correlated with significant lesion in LAD and LCX compared to non-significant lesions in Group A (P value= 0.001) While in Group B a significant higher Territorial longitudinal strain correlated with significant lesion in LAD, LCX and RCA compared to non-significant lesions (P value= 0.001) **Conclusion:** LVGLS and TLS have an incremental prognostic value and can be used to assess the severity of coronary stenosis in patients with coronary artery disease.

Keywords: Coronary artery disease, global longitudinal strain, speckle tracking echocardiography.

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Introduction

Coronary artery disease (CAD) is one of the most prevalent disorders that is further growing as the population grows old. Chest pain accounts for six million emergency room visits in the USA every year and leading to ten million stress tests and one million coronary angiographies [1]. Finding the best noninvasive screening test for CAD is still a matter of debate [2]. Exercise tests are the first-line screening for most patients, but lower sensitivity and specificity sometimes limited them in CAD diagnosis even combined with myocardial perfusion imaging or echocardiogram. Furthermore, these tests are not practical for patients with mobility issues [3]. On the other hand, myocardial perfusion scans and CT angiography are expensive and pose the risk of radiation exposure [4].Myocardial strain analysis with 2D-speckle-tracking echocardiography (2DSTE), which is performed at resting position, offers valuable information about myocardial fiber changes in different types of myocardial diseases [5].Invasive coronary angiography is considered the gold standard for diagnosis of CAD, consideration of this approach should be weighed against the risks of the invasive procedure [6].

Patients and Methods:

Study design:

Analytical cross section study

Ethical consideration:

Before doing echocardiography or taking blood samples, a written informed consent was taken from each patient.

Patients:

The study was conducted at the cardiology department Banha University during the period from January 2023 to July 2023. This study included 100 patients with CAD, patients were divided into two groups: Group A: 50 Patients with Non-ST elevation Acute coronary syndrome (NSTACS).and Group B: 50 Patients with positive or equivocal stress ECG (Stable coronary artery disease).

Inclusion criteria:

- Patients coming to emergency department with typical chest pain and diagnosed as non-ST elevation acute coronary syndrome and was admitted in cardiac care unit.
- Patients with chronic coronary syndrome with positive or equivocal stress ECG.
- Sinus rhythm.
- Age more than 18 years.
- Patients with creatinine clearance more than 100 ml/min.

Exclusion criteria:

- Patients with chest pain but with negative stress ECG.
- Patients with left ventricular ejection fraction <40%.
- History of previous percutaneous coronary intervention (PCI) or coronary artery bypass graft (CABG).
- Patients with poor echogenic window.
- Patients with congestive heart failure.
- Patients with significant valvular heart disease.
- Patients with any type of arrhythmias (not in sinus rhythm).

Methods:

a. Written informed consent:

It was taken before the start of the study. No risks were found and any unexpected risk appearing during the study was cleared to the patients and the committee on time.

b. Complete history taking:

Age, gender, hypertension, diabetes, smoking, dyslipidemia, family history of IHD.

c. Clinical examination:

Complete physical examination including: vital signs with general, chest, and cardiac examination.

d. 12 Lead ECG:

To detect arrhythmias and ischemic changes.

e. Routine lab investigations:

Serum creatinine and high sensitive troponin (hs-TnI).

f. Transthoracic echocardiography:

A complete conventional transthoracic echocardiographic was performed for all patients to assess left ventricular wall thickness, internal dimensions, wall motion abnormality, RV systolic function (TAPSE) , systolic and diastolic function by 2D, M-Mode and tissue doppler echocardiography.

g. Exercise ECG:

(Treadmill test): Patients were exercised according to modified Bruce protocol for screening and assessment of patients with chronic coronary syndrome when indicated.

h. 2D Speckle tracking echo-cardiography:

i. Peak systolic longitudinal strain values were recorded for each segment in the form of 17-segment bull's eye that was labeled as segmental longitudinal strain, then global longitudinal strain was automatically calculated as the mean value of three apical projections. *Territorial longitudinal strain was calculated for three major coronary arteries (LAD, LCX, and RCA) by the mean value of Segmental longitudinal strain in segments perfused by each coronary artery. We applied 17-myocardial segment popular pattern which includes 7 segments related to LAD (basal anterior, basal anteroseptal, mid anterior, mid anteroseptal, anthropical, apical septal, apex cap), 6 segments related to LCX (basal lateral, basal posterior, mid posterior, mid lateral, apicolateral), and 6 RCA-related segments (basal septal, inferobasal, mid inferior, mid septal, inferoapical).

j. Coronary angiography:

Coronary angiography was performed for all patients according to their clinical condition by the percutaneous femoral or radial approach by an interventional cardiologist, who were blinded to the echocardiography reports. Angiograms were obtained for each coronary vessel in at least 2 projections. 70% and more stenosis in at least one coronary artery, including the left anterior descending (LAD) and its large branches (i.e., diagonals), the left circumflex coronary artery and its large branches (i.e., obtuse marginal [OM] branch), and the right coronary artery (RCA), and 50% and more stenosis in the left main (LM) coronary artery were taken as significant CAD. Stenosis between 50 and 70% in the coronary arteries (except LM) was taken as moderate CAD, and stenosis less than 50% was taken as mild CAD.

k. **Gensini score was calculated:** The coronary angiography was performed for all enrolled individuals, and the results were analyzed by at least two interventional physicians. The degree of stenosis and the coronary artery lesion site were scored as follows: 1 point for ≤ 25% narrowing, 2 points for 26–50% narrowing, 4 points for 51–75% narrowing, 8 points for 76–90% narrowing, 16 points for 91–99% narrowing, and 32 points for total occlusion. Thereafter, each lesion score is multiplied by a factor that takes into account the importance of the lesion's position in the coronary circulation (5 for the left main coronary artery, 2.5 for the proximal segment of the left anterior descending coronary artery, 2.5 for the proximal segment of the circumflex artery, 1.5 for the mid-segment of the left anterior descending coronary artery, 1.0 for the right coronary artery, the distal segment of the left anterior descending coronary artery, the posterolateral artery, and the obtuse marginal artery, and 0.5 for other segments). Finally, the Gensini score was calculated by summation of the individual coronary segment scores. [7].

l. **Syntax score was calculated: Syntax I score was used,** it is an angiographic grading tool developed in an attempt to characterize the extent and complexity of CAD. The coronary tree is divided into 16 segments. The SYNTAX score is the sum of the points assigned to each

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individual lesion identified in the coronary tree with > 50% diameter narrowing in vessels > 1.5- mm diameter. Each segment is given a score of 1 or 2 based on the presence of disease. Subsequently, this score is weighted based on a chart, with values ranging from 3.5 for the proximal left anterior descending artery (LAD) to 5.0 for left main and 0.5 for smaller branches. Studies have categorized the SYNTAX score to identify patients at low (≤ 22), medium (23 to 32), and high risk (≥ 33) [8].

I. Statistical design:

Data management and statistical analysis were done using SPSS version 28 (IBM, Armonk, New York, United States). Quantitative data were assessed for normality using the Kolmogorov–Smirnov test, the Shapiro-Wilk test, and direct data visualization methods. Quantitative data were compared according to myocardial injury using the independent t-test or Mann-Whitney U test for normally and non-normally distributed quantitative data. Categorical data were compared using the Chi-square test. Correlations were done using Pearson's or Spearman's correlation. The odds ratios with 95% confidence intervals were calculated. All statistical tests were two-sided. P values less than 0.05 were considered significant.

Research ethics committee: MS.32.3.2022

Results:

Patients were divided into two groups:

- Group A: 50 patients with NSTEACS.
- Group B: 50 patients with positive or equivocal stress ECG.
- According to demographic characteristics of the study participants, the mean age of the cohort was [58.8 ± 10.4]. The majority of participants were males, accounting for 65 % of the total cohort.
- Sixty percent of participants had a history of Diabetes mellites, and 55% had dyslipidemia. Moreover, 46% of the cohort were current smokers, 18% had a family history of ischemic heart disease, and 62% were previously diagnosed with hypertension (Table 1).
- According to echocardiography data in the studied groups, No significant difference between the studied groups in IVST, PWT, TAPSE and E/E. A significant higher mean WMSI in Group A compared to Group B ($p<0.001$). There was a significant lower GLPSS in Group A compared to Group B ($p<0.001$) (Table 2, figure 1)

Table 1: Baseline Demographic Criteria.

		Mean	SD
AGE (yrs)		58.8	10.4
		N	**%**
SEX	Female	35	35
	Male	65	65
DM		60	60
HTN		62	62
SMOKING		46	46
DYSLIPIDEMIA		55	55
FH IHD		18	18

Table 2: ECHO Data in the studied groups,

	Group A	Group B	P value
Speckle tracking echo data	Mean± SD	Mean± SD	P value
GLPSS (%)	-18.4± 3.4	-21.3± 1.9	0.001*

Student t-test; *for significant; IVST: Interventricular Septum Thickness; PWT: Posterior Wall Thickness; WMSI: Wall Motion Score Index; TAPSE: Tricuspid Annular Plane Systolic Excursion; E/E, early diastolic transmitral flow velocity (E) to early diastolic mitral annular velocity; STE: Speckle Tracking Echocardiography; GLPSS: Global Longitudinal Peak Systolic Strain; * = $p<0.05$

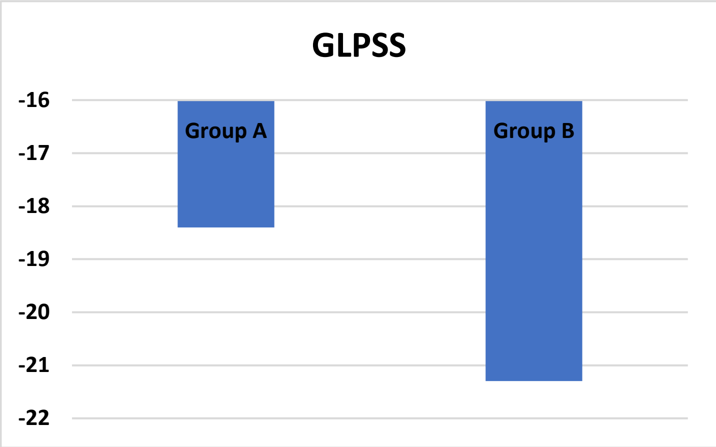

Figure 1: ECHO Data

Regarding Coronary Angiography, there was no significant difference between the studied groups according to site of affected coronaries. On the other hand, both groups had similar frequency of affected coronaries except a significantly higher frequency in three vessels affected in group B (Table 3).

According to gensini score in the studied groups, group A had higher Gensini score compared to Group B but with no significant statistical difference (figure 2). According to syntax score grades, a significant higher frequency in low syntax score in group B compared to group A ($p<0.001$) (Table 4).

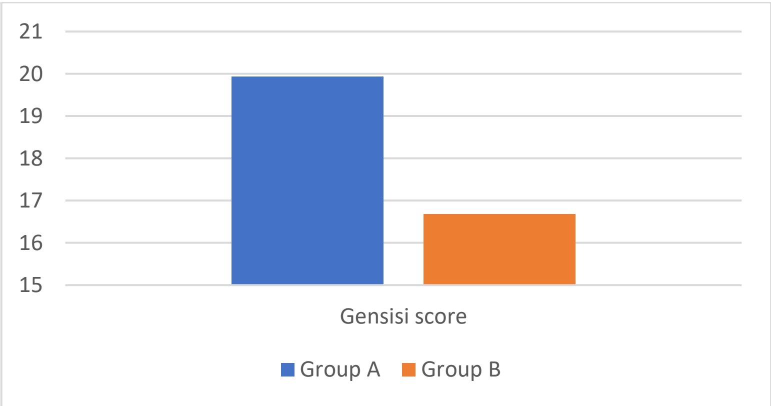

Figure 2: GENSINI SCORE in the studied groups

Table 3: Coronary Angio Data.

	Group A	Group B	Test	p
LAD	27(54%)	31(62%)	0.292	0.588
LCX	20(40%)	17(34%)	1.020	0.312
LM	3(6%)	2(4%)	0.028	0.867
non-significant lesions	6(12%)	3(6%)	0.069	0.793
normal coronaries	5(10%)	8(16%)	0.594	0.441
RCA	22(44%)	13(26%)	0.594	0.441
Number of affected vessels				
One	35(70%)	32(64%)	3.215	0.072
Two	12(24%)	10(20%)	1.020	0.312
Three	3(6%)	8(16%)	21.487	<0.001*

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Table 4: SYNTAX SCORE in the studied groups.

	Group A	Group B	Test	P
High	13(26%)	6(12%)	4.625	0.04*
Intermediate	15(30%)	11(22%)	0.083	0.773
Low	11(22%)	22(44%)	6.384	<0.001*

Test= Chi square test

According to correlation of TLS and significant CAD lesion in each Coronary Artery Territories, a significant higher TLS correlated with significant lesion in LAD and LCX compared to non-significant lesions in Group A (P value= 0.001).

While in Group B a significant higher TLS correlated with significant lesion in LAD, LCX and RCA compared to non-significant lesions (P value= 0.001), (Table 5).

We found that the cut off value of GLSPP were significant at -22.35, -19.45 and 18.25 for single, two and three vessels respectively. With sensitivity and specificity of 38.2 and 77.3% for single vessel, 69.9 and 82.4% for two vessels and 89.7, 90.9% for three vessels affections (Table 6).

Table 5: Correlation of TLS and significant CAD in each Coronary Artery Territories.

Group A		**No**	**Mean**	**SD**	**P value**
LAD segments in patients	With significant lesion	21	-17.5	0.6	**0.001***
	Without significant lesion	29	-21.7	0.68	
LCX segments in patients	With significant lesion	13	-15.1	1.1	**0.001***
	Without significant lesion	37	-21.88	0.74	
RCA segments in patients	With significant lesion	9	-18.04	0.5	0.2
	Without significant lesion	41	-20.86	6.6	
Group B		**No**	**Mean**	**SD**	**P value**
LAD segments in patients	With significant lesion	41	-16.6	1.5	**0.001***
	Without significant lesion	9	-20.7	1.2	
LCX segments in patients	With significant lesion	29	-16.4	1.6	**0.001***
	Without significant lesion	21	-21.9	0.8	
RCA segments in patients	With significant lesion	26	-16.3	1.3	**0.001***
	Without significant lesion	24	-21.8	0.9	

Independent t-test; * For significant, Test; Mann Whitney test

Table 6: Value of GLSPP in detection of number of diseased vessels.

	Cut Off	Specificity	Sensitivity	AUC (95%CI)	P value
Single	-22.35	38.2	77.3	0.240(0.148-0.333)	**0.001***
Two	-19.45	69.9	82.4	0.73(0.63-82)	**0.003***
Three	-18.25	89.7	90.9	0.94(0.89-0.99)	**0.001***

*For significant

Discussion:

One of the promising approaches in diagnosing CAD is the use of echocardiography, a widely available and non-invasive imaging technique.

Specifically, 2-Dimensional speckle tracking echocardiography (2-D STE) has gained recognition for its ability to assess myocardial deformation and strain [9].

In 2022, a study was performed to determine the diagnostic accuracy of

2DSTE in predicting CAD presence and severity [10]. Patients with stable angina pectoris with normal left ventricular function (>50%) undergoing coronary angiography were enrolled and subjected to speckle tracking echocardiography. Global longitudinal peak systolic strain was measured and correlated to the results of coronary angiography for each patient. They found that there is a significant gender difference between the groups, with a higher proportion of males in the CAD present group (63.8%) compared to the CAD absent group (36.3%), and this difference is statistically significant ($p = 0.001$)

In parallel with our results, another study was carried out to examine the value of speckle tracking echocardiography to detect the presence, extent and severity of coronary artery affection in patients with suspected stable angina pectoris [11]. Two hundred candidates with suspected stable angina pectoris and normal resting conventional echocardiography were subjected to speckle tracking echocardiography and coronary angiography. Global and segmental longitudinal peak systolic strain were assessed and were correlated to the results of coronary angiography for each patient. They found that age, diabetes, and dyslipidemia were significant factors associated with the extent of CAD, while gender, BMI, hypertension, smoking, and family history showed less pronounced associations or no statistically significant differences.

We present the findings from the analysis of Exercise Electrocardiogram (ECG) data obtained from 50 participants with stable coronary artery disease, with either a positive or equivocal exercise test. In this group, 58% of chronic coronary syndrome patients exhibited a positive exercise test, while 42% showed an equivocal exercise test. According to echocardiography data in the studied groups, there was no significant difference between the studied groups in IVST, PWT, TAPSE, and E/E. However, there was a significantly higher mean WMSI in Group A compared to Group B ($p < 0.001$). Conversely, there was a significantly lower GLPSS in Group A compared to Group B ($p < 0.001$).

Our results agree with those documented by Akiash N., et al [12] who reported that the mean GLS was −16.8% in patients with significant CAD, −16.7 % in SVD patients, −16.8 % in 2VD group, and −17.08% in 3VD population, which was significantly lower compared to the controls group with normal epicardial coronary arteries (P-value=0.0001).

Supporting our results are supported by the study done in 2018 [11] which found that there was statistically insignificant difference between the two groups as regard to the conventional ECHO parameters (dimensions and ejection fraction). They found that patients with normal coronary artery had small SD of GLPSS (-20.11 ± 0.8).

In contrast, another study [13] performed to evaluate the diagnostic accuracy of LV global longitudinal strain obtained by 2D-STE in prediction of severity of CAD. Eighty patients with suspected stable angina pectoris were included. They underwent transthoracic echocardiography (TTE) to measure LV ejection fraction, 2-D-STE to measure GLS and coronary angiography (CA). The patients were divided into two groups: group 1 (58 patients) with significant (>70%) CAD, and group 2 (22 patients) with non-significant (<70%) CAD. They found that there was a lower EF in the group of CAD (59.3 ± 3.2% vs 65.7 ± 4.7% $p < 0.000$). This may be because of the exclusion criteria as they included patients with severe wall motion abnormality and those with overt heart failure. However, they reported that there was significant decrease in GLS in group 1 compared to group 2 (-11.86 ± 2.89% versus -18.65 ± 0.79%, $P < 0.000$) *)*.

In consistent with our findings, it was observed that there was significantly lower GLS values among patients with

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significant CAD compared to those with non-significant CAD. They revealed that GLS values below -18.4% may predict significant CAD, with a sensitivity of 74% and a specificity of 58% [14].

Regarding the findings from coronary angiography, no significant difference was observed between the studied groups in terms of the site of affected coronaries. However, both groups had a similar frequency of affected coronaries, except for a significantly higher frequency of one-vessel affected cases in group B.

In the context of the correlation of TLS and significant CAD lesions in each Coronary Artery Territory, a significantly higher TLS was observed with significant lesions in LAD and LCX compared to non-significant lesions in Group A (P value = 0.001). In Group B, a significantly higher TLS was noted with significant lesions in LAD, LCX, and RCA compared to non-significant lesions (P value = 0.001).

In the study done previously the researchers showed a statistically significant correlation between TLS abnormality and significant lesions in the related coronary artery. Mean TLS of LAD segments was −17.7031 in patients with significant LAD lesions, and it was −20.6676 in patients without significant LAD stenosis (*P*-value=0.005). This correlation was also observed in LCX (*P*-value=0.016) and RCA territory (*P*-value=0.001) [12].

On the other hand, it was demonstrated that GLS is a good predictor for diagnosing LM or three-vessel CAD in detecting stenotic coronary arteries [15].

These discrepancies encouraged us to run our study to evaluate further the relationship between coronary stenosis and TLS in given territories. Further analysis showed a statistically significant correlation between low TLS and significant CAD in the LAD, RCA, and LCX territories. These results indicate that strain analysis can be used for screening of CAD in patients with no regional wall motion abnormalities at rest and may also help surmise which coronary artery may have been affected.

In harmony with our findings, some researchers reported in their study that GLPSS value showed sensitivity for detection of the number of diseased vessels with cut-off value -20 for single-vessel CAD (79.69% sensitivity and 70.27% specificity, AUC: 0.783); -18 for two vessels disease (77.78%, sensitivity 86% specificity, AUC: 0.87) and -16 for three vessels CAD (81.82% sensitivity and specificity 98.20% AUC 0.94) [10].

In concordance, it was declared that the optimal cutoff value of GLS for prediction of significant CAD was -15.6% [AUC 0.88, 95% CI 0.78-0.96 p < 0.000]. The sensitivity, specificity and accuracy of GLS for detecting significant CAD were 93.1%, 81.8%, and 90% respectively. There was a significant positive correlation between GLS and EF (r = 0.33; p = 0.036). There was incremental significant decrease in GLS with increasing number of coronary vessels involved [13].

The optimal GLS diagnostic cutoff value varies significantly among previous studies could be explained by GLS may depend on the clinical characteristics of patients, the effect of diastolic function and their hemodynamic parameters (i.e., blood pressure) during image acquisition, by using different equipment, different design, vendor-dependent 2D-STE software and operator skills [16].

Another data has indicated that GLS is more dependent on the 2D-STE software used, rather than ultrasound equipment used to acquire images, which makes the use of vendor-independent software particularly attractive to standardize GLS for widespread use. The possibility of using a fixed diagnostic GLS cutoff value to diagnose obstructive CAD, independent of the ultrasound equipment used for images acquisition, would be required to increase the clinical usefulness of strain imaging [16].

Conclusion:

LVGLS and TLS have an incremental prognostic value and can be used to assess the severity of coronary stenosis in patients with coronary artery disease.

Study limitations:

- It was a single-center study with a relatively small sample size which might limit the generalizability of the findings.
- The study focused on 2-D speckle tracking echocardiography, which, like any imaging modality, can have inherent variability in measurements. Interobserver and intraobserver variability in interpreting echocardiographic images may affect the consistency of results.
- While the study considered some cardiovascular risk factors and comorbidities, it did not comprehensively account for all potential confounders. Other factors such as medications and lifestyle choices could influence the results.

Conflict of interest

None of the contributors declared any conflict of interest.

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