The Egyptian Journal of Hospital Medicine (January 2025) Vol. 98, Page 427- 433

Value of Quantitative SPECT Myocardial Perfusion Imaging and Resting Left Ventricular Segmental Strain Analysis by 2D Speckle Tracking Echocardiography in Prediction of Angiographic Severity of Coronary Artery Disease

Fatma Elhady*, Ghada Kamel Ali, Mona Naiem Ali
Cardiology department, Faculty of Medicine (for Girls), Al-Azhar University, Cairo, **Egypt**
***Corresponding Author:** Fatma Elhady**, Mobile (**+02)1024812333
ORCID: **0009-0008-6404-2054. Email: Fatma_elhady2013@yahoo.com**

ABSTRACT

Background: SPECT Myocardial Perfusion Imaging is a widely used, non-invasive imaging modality routinely employed in the diagnosis of coronary artery disease. An advanced, non-invasive imaging technique that allows for a quick and accurate evaluation of both global and regional left ventricular function is speckle tracking echocardiography.

Objective: This study aimed to assess the predictive value of quantitative SPECT MPI and resting left ventricular segmental strain analysis using 2D Speckle Tracking Echocardiography in determining the severity of coronary artery disease.

Patients and Methods: Fifty patients with positive SPECT MPI underwent echocardiography to obtain segmental and average global longitudinal strain. Stress Gated-SPECT MPI was used to assess segmental MPI uptake. Additionally, coronary angiography was performed on all patients.

Results: Patients' mean age was 55.5 ± 8.16 years. Dyslipidemia was present in (70%) of the patients. The LAD, LCX and RCA were affected in 40%, 26% and 34% of patients respectively. A strong positive correlation was found between LAD and LCX MPI uptake during stress and GLS, but no significant correlation was observed in RCA territories. A positive correlation was observed between the degree of LAD stenosis and basal anterior, basal anteroseptal GLS, and a Significant negative correlation with apical anterior GLS. However, for RCA and LCX no segmental GLS were correlated. A positive correlation was found between MPI EF and average GLS, circumferential and peak radial strain.

Conclusion: Speckle tracking Echocardiography is superior to conventional Echo and non-inferior to myocardial perfusion imaging in the detection of coronary artery disease.

Keywords: Gated SPECT imaging, Speckle tracking Echo cardiography, coronary angiography

INTRODUCTION

Coronary artery disease (CAD) is One of the main cardiovascular disorders and is considered the leading cause of death worldwide **(1)**. For many years, myocardial perfusion scintigraphy has been a crucial cornerstone in the diagnosis and risk assessment of heart failure, stress-induced ischemia, and CAD **(2)**.

The use of quantitative SPECT datasets to compute absolute regional blood flow as well as segmental uptake has been suggested for a wide range of clinical applications and partially verified according to studies conducted by many authors **(3-5)**.

A potentially helpful technique for assessing left ventricular function is two-dimensional speckle tracking echocardiography (2D-STE), which can detect subclinical myocardial damage early in the course of the disease. It has been applied to CAD diagnosis. It has not yet been thoroughly investigated, if myocardial strain and strain rate (SR) can predict the severity of coronary artery stenosis in patients with CAD. Compared to other diagnostic instruments, catheterization is invasive even if coronary angiography is the gold standard for identifying coronary artery stenosis **(6)**.

This aim of this study was to assess the predictive value of quantitative SPECT MPI and resting left ventricular segmental strain analysis using 2D Speckle Tracking Echocardiography in determining the severity of coronary artery disease.

PATIENT AND METHODS

This study included a total of 50 patients with positive SPECT MPI, aged over 18 years, who were able to exercise on a treadmill, and attended the Department of Cardiology, Faculty of Medicine (for Girls), Al-Azhar University Hospitals. The study was conducted between January 2023 and February 2024.

Exclusion criteria: Patients with acute coronary syndrome, advanced liver or kidney disease, severe COPD, arrhythmias, pregnancy or breastfeeding, and false-positive SPECT imaging results.

For eligible patients, a detailed history with risk factors assessment for coronary artery disease was obtained, resting twelve lead surfaces ECG was also done.

Transthoracic echocardiographic Doppler examination was performed on the same day, prior to myocardial perfusion imaging, using a VIVID-E95 GE system (GE, USA) with a multi-frequency (1.4-4.6 MHz) matrix probe M5Sc-D. Simultaneous ECG physio signals were displayed. The studied individuals were examined in both the left lateral and supine positions using the standard windows and views. Cine loops were recorded for offline analysis using Echo PAC software version 204.

Received: 14/08/2024
Accepted: 14/10/2024

Evaluation of left ventricular size and function was performed according to the American Society of Echocardiography (ASE) chamber quantification standards (7). Ejection fraction was measured using the modified Simpson's equation. Peak early diastolic (E) velocity, atrial contraction (A) velocity, and the E/A ratio were calculated.

The following indices were measured on tissue Doppler cine loops collected from 3 beats in apical 4- and 2-chamber views at a depth of 14, with a pulse repetition frequency of 1 kHz, Nyquist velocity range ± 16 cm/sec, and frame rate 99 ± 9 Hz: early diastolic (Em) and late diastolic (Am) myocardial velocity, as well as peak systolic myocardial velocity (SMV). The average E/Em ratio and the average global longitudinal strain (average GLS) were also calculated (8).

2D speckle tracking echocardiography (2D-STE) was used to assess left ventricular average global longitudinal, circumferential, radial, and segmental strain. Imaging was obtained with high-quality ECG-gated images from the apical 4-chamber, 2-chamber, and 3-chamber views for longitudinal strain assessment, as well as from the short-axis view at the basal and papillary muscle levels to obtain circumferential and radial strain. These were acquired at nearly equal heart rates. The grayscale frame rate was kept between 60 and 90 frames per second, with a minimum of three cardiac cycles obtained for each loop. The Automated Functional Imaging (AFI) algorithm used for 2D-STE analysis automatically calculates the peak systolic strain values for each segment (9).

Using the 17-segment Bull's-eye model, GLS for each territory was obtained by averaging the GLS of segments supplied by each territory.

Myocardial Perfusion Imaging (MPI):

Using a dual-head Philips Cardio-MD system, a stress gated-SPECT MPI was performed following a two-day procedure. Quantitative and qualitative analysis of the results was carried out by experts in nuclear cardiology.

A score (0-4) was assigned to each segment: (0) for normal uptake, (1), (2), and (3) for mild, moderate, and severe reduction of uptake, respectively, and (4) for absent uptake. The Sum Stress Score (SSS), Sum Rest Score (SRS), and Sum Difference Score (SDS) were reported. Quantified gated SPECT software was used to process the gated images and calculate left ventricular ejection fraction (LVEF). Transient ischemic dilatation (TID) and an increased lung-heart ratio (LHR) are additional high-risk perfusion scan markers (10).

Using the 17-segment Bull's-eye model, MPI for each segment and each territory was obtained by averaging the MPI of segments supplied by each territory.

Global longitudinal strain (GLS) for the LAD was obtained by averaging the GLS of basal anterior, basal anteroseptal, mid anterior, mid anteroseptal, apical anterior, apical septal, and apex proper segments.

For the LCX, GLS was calculated by averaging the GLS of basal anterolateral, basal inferolateral, mid inferolateral, mid anterolateral, and apical lateral segments. For the RCA, GLS was calculated by averaging the GLS of basal inferoseptal, basal inferior, mid inferoseptal, mid inferior, and apical inferior segments. Diagnostic angiography was performed for anatomical assessment of the degree of stenosis.

Ethical consideration: This study was ethically approved by Al Azhar University's Research Ethics Committee (IRB 2023011719). Written informed consent of all the participants was obtained. The study protocol conformed to the Helsinki Declaration, the ethical norm of the World Medical Association for human testing.

Statistical analysis

IBM SPSS 23.0 for Windows, a database software tool, was used to code, input, and analyze the gathered data (SPSS Inc., Chicago, IL, USA). Simirnonv Kolmgrov A test was employed to assess the normality of the data.

The mean ± standard deviation (SD) was used to express quantitative data with a normal distribution. Frequencies and percentages were used to express the qualitative data. The tests listed below were conducted: Two means of normally distributed data were compared using the independent-samples t-test of significance.

Mann Whitney When the dependent variable is continuous but not normally distributed, the U test was utilized to compare the differences between two independent groups. To determine whether two categorical variables are related.

The chi-square (X2) test—also known as Pearson's chi-square test or the chi-square test of association—was employed. To forecast a variable's value based on the values of two or more other variables, multivariate regression analysis was employed. Probability (p-value): a p-value of less than 0.05 was regarded as significant, and a p-value of less than 0.001 as very significant.

RESULTS

The current study included 50 patients aged 55.5 ± 8.16. among them dyslipidemia was detected in 70 % of cases while hypertension was present in 66% of cases. Aspirin was used by 90% of the patients, while the least frequently used drug was calcium channel blocker (CCB) in only 2% of patients. Other sociodemographic data and risk factors were presented in **(Table 1)**.

The mean Average systolic tissue doppler velocity (Average Ś) was 5.7±1.07 while the mean average LV 2D GLS was 14.6 ± 2.48, other echocardiographic and Gated SPECT parameters are shown in (**Table 2)**. In addition, **Table 2** shows that LAD, LCX, RCA were affected in the Coronary angiographic in 40%, 34%% and 26% respectively.

Table (1): Demographic data, risk factors and drug used

Variables	N=50	
Age (year)	Mean± SD	55.5 ± 8.16
Sex Females Males	N (%)	34 (68%) 16 (32%)
BMI (kg/m^2)	Mean± SD	29.7 ± 2.63
Comorbidities		
Diabetes mellitus	N (%)	23 (46%)
Hypertension	N (%)	33 (66%)
Dyslipidemia	N (%)	35 (70%)
Smoking	N (%)	31 (62%)
Family history of CAD	N (%)	11 (22%)
Menopause	N (%)	7 (14%)
Drug used		
Beta blockers	N (%)	40 (80%)
Aspirin	N (%)	45 (90%)
Plavix	N (%)	24 (48%)
Nitroglycerin	N (%)	34 (68%)
Dyslipidemic drugs	N (%)	38 (76%)
ACE	N (%)	28 (56%)
Calcium channel blockers	N (%)	1(2%)

Table (2): Echocardiographic, MPI, and affected vessels by coronary angiography findings among studied patients:

Variables		All patients (n=50)
LVEDV 2D(mL)	Mean ± SD	115.22 ± 22.59
LVESV 2D(mL)	Mean ± SD	57.5±18.17
EF 2D (%)	Mean ± SD	50.48 ± 6.65
MVE Vel	Mean ± SD	70.26 ± 16.78
MVA Vel	Mean ± SD	77.82 ± 19.42
E/A	Mean ± SD	0.95±0.27
Average Ś(cm/s)	Mean ± SD	5.7±1.07
E/Ém	Mean ± SD	10.4±2.16
LV 2D average GLS (%)	Mean ± SD	14.6 ± 2.48
Circumferential strain	Mean ± SD	11.2 ± 3.96
Peak radial strain	Mean ± SD	25.7 ± 11.88
EDV (Gated SPECT)	Mean ± SD	78 ± 23.03
ESV (Gated SPECT)	Mean ± SD	48.7±23.8
EF (Gated SPECT)	Mean ± SD	57.43 ± 8.77
SSS	Mean ± SD	12.26±10.3
SRS	Mean ± SD	5.74±8.3
SDS	Mean ± SD	6.12±4.14
LHR	Mean ± SD	32±9.23
TID	Mean ± SD	0.96±0.25
Distribution of affected vessels by coronary angiography N%		
LAD	20(40%)	
LCX	13 (26%)	
RCA	17 (34%)	

Table 3 shows a statistically significant correlation between LAD and LCX MPI rest, stress and GLS but no statistically significant correlation in RCA territories**.**

There was a significant positive correlation between degree of LAD stenosis and basal anterior GLS (r=.448 P=0.011), basal anteroseptal GLS (r=0.442, P=0.02) and there was a significant negative correlation with apical anterior GLS (r=-0.616, P<0.001).Additionally, a significant positive correlation was found between the degree of LAD stenosis and basal anteroseptal rest, stress MPI, and apex rest MPI (r = 0.547, P = 0.022), (r = 0.429, P = 0.022), and (r = 0.422, P = 0.022), respectively. These results are further illustrated in Table 4 and Figure 1.

Table (3): Correlation between different coronary territories by MPI at stress, rest and GLS

	Mean ±SD	Pearson's correlation	P value
LAD MPI stress	**69.44±10.19**	**0.396**	**0.004**
LAD GLS	**14.27±2.39**		
LAD MPI rest	**71.96±7.86**	**0.342**	**0.01**
LAD GLS	**14.27±2.39**		
RCA MPI stress	**63.48±12.46**	**0.255**	**0.07**
RCA GLS	**15.22±2.87**		
RCA MPI rest	**74.30±4.84**	**0.256**	**0.07**
RCA GLS	**13.65± 4.83**		
LCX MPI stress	**72.52±7.97**	**0.437**	**0.002**
LCX GLS	**13.65±4.83**		
LCX MPI rest	**64.30±9.33**	**0.488**	**<0.001**
LCX GLS	**15.22± 2.87**		

Table (4): Correlation of Degree of stenosis with MPI among patients with LAD stenosis

Variables		Degree of stenosis	
		R	P
Basal anterior	rest MPI	0.164	0.391
	stress MPI	0.229	0.221
	GLS	0.448	0.011
Mid anterior	rest MPI	-0.073	0.71
	stress MPI	-0.254	0.182
	GLS	-0.264	0.162
Apical anterior	rest MPI	-0.034	0.861
	stress MPI	-0.146	0.441
	GLS	-0.616	<0.0012
Basal anteroseptal	rest MPI	0.422	0.022
	stress MPI	0.547	0.0022
	GLS	0.429	0.022
Mid anteroseptal	rest MPI	0.204	0.281
	stress MPI	0.295	0.112
	GLS	-0.121	0.531
Apical anteroseptal	rest MPI	0.109	0.571
	stress MPI	0.180	0.341
	GLS	-0.258	0.171
Apex	rest MPI	0.422	0.022
	stress MPI	0.252	0.181
	GLS	0.212	0.261

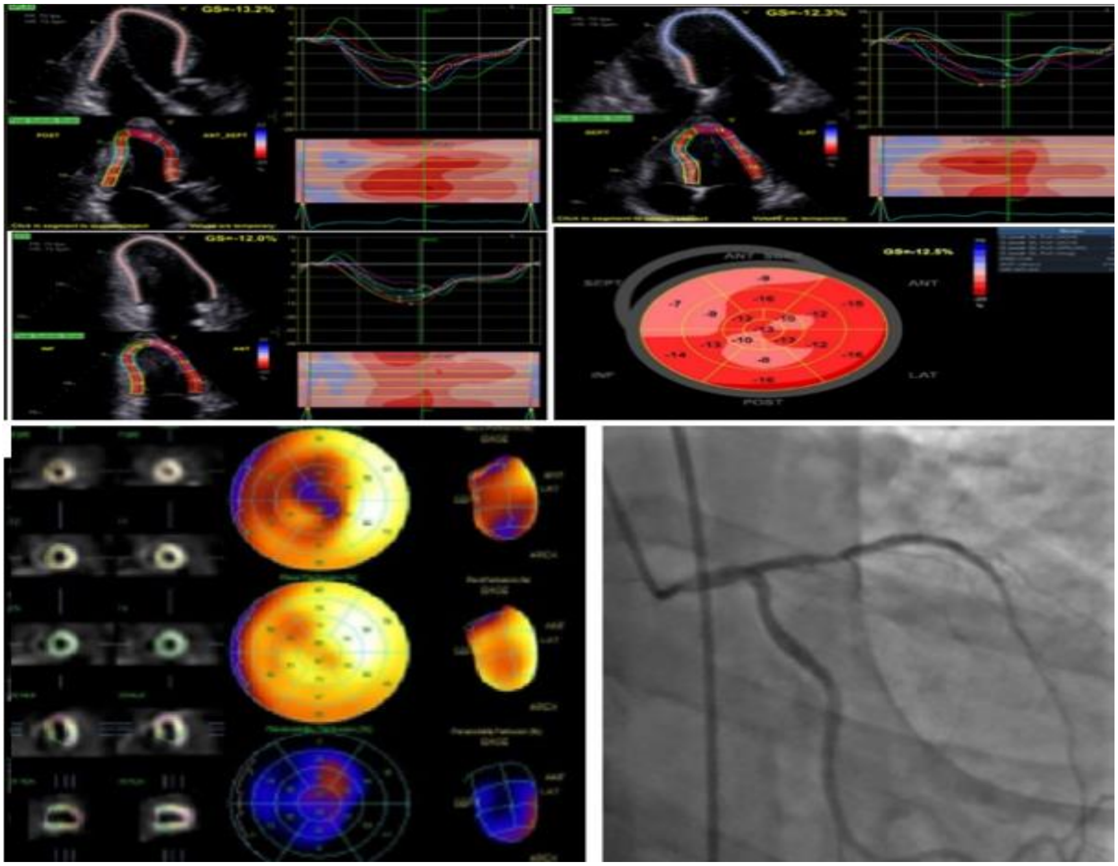

Figure 1: Speckle tracking Echocardiography bull's eye showing impaired GLS (-12.3) at anteroseptal, septal, apex proper and all apical segments, Segmental MPI, Coronary angiography showing significant lesion at proximal LAD.

There was a significant positive correlation between degree of LCX stenosis and Basal inferolateral stress MPI (r=0.704, P=0.007) as shown in **(Table 5).** There was a significant positive correlation between degree of RCA stenosis and basal infer-septal stress MPI and with basal inferior stress MPI (r=0.670, P=0.004) as in (**Table 6).**

The best cutoff value of GLS to predict presence of stenotic LAD is -14.43 with sensitivity 68.18% and specificity 78.57%, LCX stenosis is -14.8 with, sensitivity 67.57%, specificity 61.54%, RCA is -13.2 with sensitivity 85.71% as shown in **(Table 7).**

Table (5): Correlation of Degree of stenosis with MPI parameters among patients with LCX stenosis

Variables		**Degree of stenosis**	
		R	**P**
Basal Inferolateral	**rest MPI**	**0.394**	**0.181**
	stress MPI	**0.704**	**0.0072**
	GLS	**0.369**	**0.222**
Mid Inferolateral	**rest MPI**	**0.379**	**0.211**
	stress MPI	**0.379**	**0.211**
	GLS	**-0.194**	**0.532**
Basal anterolateral	**rest MPI**	**-0.019**	**0.952**
	stress MPI	**-0.197**	**0.522**
	GLS	**-0.188**	**0.542**
Mid anterolateral	**rest MPI**	**0.432**	**0.141**
	stress MPI	**0.482**	**0.092**
	GLS	**-0.480**	**0.092**
Apical anterolateral	**rest MPI**	**0.044**	**0.891**
	stress MPI	**0.049**	**0.871**
	GLS	**-0.412**	**0.162**

Table (6): Correlation of Degree of stenosis with MPI parameters among patients with RCA stenosis

Variables		Degree of stenosis	
		R	P
Basal Infer-septal	rest MPI	0.389	0.141
	stress MPI	0.536	0.031
	GLS	0.061	0.822
Mid Infer-septal	rest MPI	0.404	0.121
	stress MPI	0.420	0.111
	GLS	0.122	0.652
Basal inferior	rest MPI	0.372	0.161
	stress MPI	0.670	0.0042
	GLS	0.419	0.111
Mid inferior	rest MPI	0.299	0.262
	stress MPI	0.398	0.131
	GLS	0.039	0.892
Apical inferior	rest MPI	0.065	0.811
	stress MPI	0.092	0.741
	GLS	-0.255	0.342

Table (7): Performance of GLS in prediction of coronary artery stenosis

Variables	Cut-point	Sensitivity (%)	Specificity (%)	PPV (%)	NPP (%)	AUC (%)	P Value
LAD	-14.43	68.18%	78.57%	64.71%	66.67%	0.699	0.002
LCX	-14.8	67.57%	61.54%	83.33%	40%	0.641	0.006
RCA	-13.2	85.71%	75%	94.74%	50%	0.732	<0.001

DISCUSSION

A crucial first step in choosing the best course of treatment for coronary artery disease (CAD) is obtaining an accurate noninvasive diagnostic and functional assessment of the condition. Anatomical and functional data are needed for a thorough evaluation of CAD. This can be acquired in several ways, and the common imaging modalities have capabilities that overlap, especially when it comes to evaluating the viability, function, and anatomy of the heart **(11)**.

In order to assess the potential of 2D-STE as an early diagnostic tool for coronary artery stenosis, the current study concentrated on the association between regional myocardial deformation and myocardial perfusion picture at detection of CAD. An approachable, non-invasive, economical, non-radiative, high sensitivity, and specificity usefulness is ideal. All these conditions are met by 2D-STE **(6)**.

The specificity of nuclear thallium stress tests was 70%, while the sensitivity ranged from 70 to 92% for the detection of CAD in the study conducted as reported by several studies **(12,13)**.

According to this assessment, LAD was affected in (40%) of the patients, the right coronary artery (RCA: 34%) and the left circumflex artery (LCX: 26%).

The current study demonstrated positive correlation between segmental MPI and segmental GLS as regard LAD significant patients and positive correlation between basal anterior GLS, basal anteroseptal, apicoanterior GLS and degree of LAD stenosis and negative correlation between apico anterior GLS and degree of stenosis this confirmed that the lower GLS, The more degree of stenosis and the result are concordant with the result of **Montgomery *et al*.** **(14)** who described that individuals with severe LAD stenosis had peak segmental strain readings in the LAD territory that were significantly lower than those of patients without significant LAD stenosis.

additionally, this was consistent with the analysis conducted by **Chaichuum *et al.*** **(6)** who assessed 170 arteries using coronary angiography and the accompanying echocardiography in order to measure global and segmental left ventricular myocardial strain and it was discovered that the lower the vessel myocardial strain (VMS) and vessel myocardial strain rate (VMSR), the greater the likelihood of severe coronary stenosis

The current study demonstrated positive correlation between GLS and rest MPI at apico anterior, apico-septal, basal inferior, basal inferolateral , mid inferolateral and apex segments and positive correlation between GLS and

MPI stress at mid , apico anterior segments, apicoseptal, basal and apico inferior ,basal and mid anterolateral, apicolateral and apex segments**.** This matched **El-Hefny *et al.*** **(15)** who studied 120 patients had clinically stable coronary artery disease with 80 patients had significant CAD

In line with many studies, the correlation between the affected artery and the identified segment using strain parameters revealed that basal anterior, Basal anteroseptal, mid anterior, mid anteroseptal, Apico anterior, apicolateral segments were found to be significant predictor of LAD stenosis and basal inferolateral and mid posterolateral are significant predictor of LCX stenosis while basal inferior is a predictor to RCA stenosis **(16,17).**

This does not mismatch the result of **Pereztol-Valdes *et al.*** **(18)** who reported that no segment can be solely assigned to the RCA and the most specific segments (anteroseptal, anterior, and all apical segments save the infero-apical) correlate to LAD. Also, the inferoseptal segments can be assigned to RCA or LAD, inferior and inferolateral segments to either RCA or LCX, and mid-anterolateral segments to either LCX or LAD.

In the current study the best cutoff of GLS to predict presence of stenotic LAD is -14.43 with sensitivity 68.18% and specificity 78.57%, LCX is -14.8 with sensitivity 67.57%, specificity 61.54%, RCA is -13.2 with sensitivity 85.71%, specificity 75%.

In contrast to the findings of **Yadav *et al.*** **(19)** study, which showed the sensitivity of the GLPSS value in identifying the number of diseased vessels, the cut-off values for single-vessel CAD were -20 (79.69% sensitivity and 70.27% specificity, AUC: 0.783); two-vessel disease was -18 (77.78%, sensitivity 86% specificity, AUC: 0.87); and three-vessel CAD was -16 (81.82% sensitivity and specificity, 98.20% AUC: 0.94).

In agreement, the best GLS cutoff value for CAD prediction was shown to be -15.6% [AUC 0.88, 95% CI 0.78-0.96 $p < 0.000$]. According to **Biering-Sørensen *et al.*** **(17)** GLS has a sensitivity, specificity, and accuracy of 93.1%, 81.8%, and 90% for identifying substantial CAD.

Various factors, such as different equipment, study designs, vendor-dependent 2D-STE software, operator skills, and the influence of diastolic function and hemodynamic parameters (e.g., blood pressure) during image acquisition, could all impact GLS. These factors may help explain the notable variation in the ideal GLS diagnostic cutoff value observed across prior studies.

Hamada *et al.* **(20)** demonstrated that while rest 2D-STE is more sensitive than SPECT, it is far less specific in identifying severe CAD. According to a recent meta-analysis, 2D-STE has 67.1% sensitivity and 49.2% specificity for predicting coronary artery disease, which suggests the need for an additional stress test. In some other results, wall motion abnormality evaluation and longitudinal strain under dobutamine stress are integrated to achieve the best accuracy of CAD identification. At least in individuals with suspected CAD, the strain should probably be utilized in conjunction with a stress test rather than rest

According to research by **Biering-Sørensen *et al.*** **(17)** patients with CAD had a significantly lower GLS compared to those without CAD. Even after multivariable correction for activity evaluations, baseline records, and conventional echocardiogram data, GLS remains an independent predictor of CAD.

The present investigation aligned with the findings of **Stević *et al.*** **(21)** who investigated the use of myocardial perfusion scintigraphy in the prediction of the presence of hemodynamically significant coronary artery stenosis.

CONCLUSION

It could be concluded that the two-dimensional speckle tracking echocardiography (STE) has a strong correlation with segmental myocardial perfusion uptake in each affected territory, it is a sensitive tool for diagnosing myocardial disorders. In patients suspected of having an ischemic heart disease, STE allows for the quantitative grading of the severity of segmental or global myocardial dysfunction and may be used to identify the affected artery.

LIMITATION

The main limitation of the current study is the small number of patients; therefore, a larger sample size is needed. Additionally, the territorial strain is based on the schematic distribution of territories, which may overlook individual variations in coronary topography and dominance.

Funding: NIL.
Conflict of interests: NIL.

REFERENCES

1. **Malakar A, Choudhury D, Halder B *et al.* (2019):** A review on coronary artery disease, its risk factors, and therapeutics. Journal of Cell Physiology,234(10):16812-23.
2. **Rischpler C, Nekolla S, Schwaiger M (2013):** PET and SPECT in heart failure. Cur Cardio Rep.,15(3):337-43.
3. **Bellevre D, Bailliez A, Delelis F *et al.* (2022):** Quantitation of myocardial ^{99m}Tc-HMDP uptake with new SPECT/CT cadmium zinc telluride (CZT) camera in patients with transthyretin-related cardiac amyloidosis: Ready for clinical use?. Journal of Nuclear Cardiology, 29(2):506-514.
4. **Lacalzada J, de la Rosa A, Izquierdo M *et al.* (2015):** Left ventricular global longitudinal systolic strain predicts adverse remodeling and subsequent cardiac events in patients with acute myocardial infarction treated with

primary percutaneous coronary intervention. International Journal of Cardiovascular Imaging, 31(3):575-584.

5. **Gunasekaran P, Panaich S, Briasoulis A *et al.* (2017):** Incremental value of two-dimensional speckle tracking echocardiography in the functional assessment and characterization of subclinical left ventricular dysfunction. Current Cardiology Reviews,13:32–40.
6. **Chaichuum S, Chiang S, Daimon M *et al.* (2022):** Segmental Tissue Speckle Tracking Predicts the Stenosis Severity in Patients with Coronary Artery Disease. Front Cardiovasc Med.,3; 8:832096.
7. **Lang R, Bierig M, Devereux R *et al.* (2005):** Chamber Quantification Writing Group; American Society of Echocardiography's Guidelines and Standards Committee; European Association of Echocardiography. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr., 18(12):1440-63
8. **Phatak N, Maas S, Veress A *et al.* (2009**): Strain measurement in the left ventricle during systole with deformable image registration. Med Image Anal., 13(2):354-61.
9. **Cardinale D, Iacopo F, Cipolla C (2020):** Cardiotoxicity of anthracyclines. Frontiers in cardiovascular medicine,18; 7:26-32.
10. **Paul A, Hasegawa S, Yoshioka J *et al*. (2000):** Assessment of left ventricular function by gated myocardial perfusion and gated blood-pool SPECT: can we use the same reference database? Ann Nucl Med., 14(2):75-80.
11. **Magdalena K (2015):** Myocardial perfusion imaging in coronary artery disease. Cor et Va\olsa., 57(6): 446–452.
12. **Stolzenberg J, London R (1979):** Reliability of stress thallium-201 scanning in the clinical evaluation of coronary artery disease. Clin Nucl Med., 4(6):225-8.
13. **Liou K, Negishi K, Ho S *et al.* (2016):** Detection of obstructive coronary artery disease using peak systolic global longitudinal strain derived by two-dimensional speckle-tracking: a systematic review and meta-analysis. Journal of the American Society of Echocardiography, 29(8):724-735.
14. **Montgomery D, Puthumana J, Fox J *et al.* (2012):** Global longitudinal strain aids the detection of non-obstructive coronary artery disease in resting echocardiogram. European heart journal-Cardiovascular Imaging,13(7):579-587.
15. **El Hefny E, Ibraheem A, Eldieb M (2016)**: Role of 2-dimensional speckle tracking echocardiography in diagnosis of coronary artery stenosis instable angina pectoris patients. Interventional cardiology, 8(6) :731-738.
16. **Choi J, Cho S, Song Y *et al.* (2009):** Longitudinal 2D strain at rest predicts the presence of left main and three vessel coronary artery disease in patients without regional wall motion abnormality. European Journal of Echocardiography, 10(5):695-701.
17. **Biering-Sørensen T, Hoffmann S, Mogelvang R *et al.* (2014):** Myocardial strain analysis by 2-dimensional speckle tracking echocardiography improves diagnostics of coronary artery stenosis instable angina pectoris. Circulation. Cardiovascular Imaging, 7(1): 58–65.
18. **Pereztol-Valdés O, Candell-Riera J, Santana-Boado C *et al.* (2005):** Correspondence between left ventricular 17 myocardial segments and coronary arteries. European Heart Journal, 26(24):2637-43.
19. **Yadav K, Prajapati J, Singh G *et al.* (2022):** The correlation between speckle-tracking echocardiography and coronary angiography in suspected coronary artery disease with normal left ventricular function. Journal Cardiovasc Thoracic Research, 14(4):234-239.
20. **Hamada A, Taha M, Osama M *et al.* (2022)**. Comparison between two-dimensional speckle tracking echocardiography and technetium sestemibi myocardial perfusion imaging in detecting coronary artery disease, Teikyo Medical Journal, 45(8):7217-7237.
21. **Stević M, Vlajković M, Veličković F *et al*. (2024):** Myocardial Perfusion Scintigraphy in the Prediction of the Existence of Hemodynamically Significant Coronary Artery Stenosis. Acta facultatis medicae Naissensis, 41(1): 1-12.