

# Carotid Artery Intimal-Medial Thickness and Left Ventricular Longitudinal Systolic Strain in Patients with Coronary Artery Disease

## Abstract

**Background:** Carotid intima-media thickness (CIMT) is a non-invasive, inexpensive, reliable marker of coronary artery disease (CAD). LV global longitudinal strain function (LV GLS) can be accurately assessed by 2D speckle-tracking strain echocardiography (2D-STE).

**Objectives:** This study aimed to assess the relationship between carotid IMT and left ventricular global longitudinal strain (LV GLS) assessed by 2D speckle-tracking strain echocardiography (2D-STE) in patients with CAD. It also aimed to assess the ability of both LV global longitudinal strain (LV GLS) and carotid IMT to predict CAD severity.

**Methods:** It included 156 patients with suspected CAD by history of angina admitted electively for coronary angiography (CA). We excluded patients with acute coronary syndrome and concomitant disease or drug therapy which affect cardiac function. Patients underwent transthoracic echocardiography (TTE), 2-D speckle tracking echocardiography (2D-STE), B-mode ultrasound of the carotid arteries and coronary angiography. The patients were divided into two groups: group 1 (106 patients) with significant (>70%) CAD, and group 2 (50 patients) with non-significant CAD obstruction. Conventional 2D echocardiographic examinations were done by using General Electric VIVID 9 with M4S transducer, with a frequency of 1.5-4.3 MHz. Examinations included measurements of cardiac dimensions and LV ejection fraction. Images were obtained in the apical long-axis, four-chamber, and two chamber views for the global peak systolic longitudinal strain (PSLS). Measurement of CIMT was performed at the far wall of the common carotid artery (CCA) 1cm proximal to the bifurcation.

**Results:** There were significant increase in the mean CIMT and significant decrease in GLS in group 1 compared to group 2 ( $1.43 \pm 0.41$  vs  $0.72 \pm 0.4$ ,  $p < 0.001$ ), and ( $-12.2 \pm 2.93$  vs  $-16.65 \pm 3.5$ ,  $p < 0.001$ ) respectively. The cut-off value for LVGLS less than -15.8 % using ROC curve was a predictor of significant CAD with AUC 0.82, 95%CI 0.71-0.94,  $p < 0.001$ . The sensitivity, specificity and accuracy of GLS for detecting significant CAD were 96.2%, 68.0%, and 87.2% respectively. The cut-off value of the CIMT > 1.1 mm using ROC curve was a predictor of significant CAD with AUC 0.89, 95% CI 0.81-0.96,  $p < 0.001$ . The sensitivity, specificity and accuracy of mean CIMT were 92.5%, 84.0% and 89.7%. There was significant negative correlation between global LVGLS and mean carotid IMT ( $r = -0.88$ ,  $p < 0.0001$  and positive correlation with EF ( $r = 0.37$ ,  $p = 0.001$ ).

**Conclusion:** Increased CIMT was associated with decreased LV function assessed by 2D strain echocardiography. Decreased GLS and increased CIMT were associated with significant CAD; So these findings support the use of CIMT measurements to predict subclinical LV dysfunction and the risk of CAD.

**Keywords:** Carotid artery intimal-medial thickness; LV global longitudinal strain function; Speckle tracking echocardiography; CAD

## Research Article

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## Introduction

The atherosclerotic process is a generalized process affecting the arterial tree which begins in child-hood, progresses over decades and may remain clinically silent in the majority of

people. In the coronary arteries, it remains asymptomatic until it progresses to cause a hemodynamically significant flow limiting lesion leading to symptoms of myocardial ischemia. However, a substantial proportion of patients progress abruptly from unapparent disease to a myocardial infarction or possible

death, due to thrombus formation following acute rupture or erosion of non-stenotic plaques [1]. Identification of patients at high risk in the early phase is critical to allow for modification of cardiovascular risk by effective preventive strategies. Coronary angiography (CA) is currently considered the gold standard for detecting obstructive coronary artery disease. However, its inability to detect early atherosclerotic changes, its invasive nature, as well as exposure to ionizing radiation, make it an unattractive primary screening tool in preventive cardiology [2].

Ultrasound measurement of carotid intima-media thickness (CIMT) has become a valuable tool for detecting and monitoring progression of atherosclerosis [2]. The American College of Cardiology Foundation/American Heart Association guidelines recommend CIMT measurements for patients at intermediate CVD risk [3]. The longitudinally arranged subendocardial fibers are more vulnerable to ischemia due to their direct exposure to the intraventricular blood pressure and the anatomy of the coronary circulation [4-6]. As a result, longitudinal function is impaired first in CAD. Measurements of longitudinal motion and deformation are therefore, the most sensitive markers of coronary artery disease especially in patients with severe coronary stenosis, where intermittent ischemia may result in subtle forms of stunning that may be detectable with strain measurements. Severe CAD is known to lead to LV dysfunction. However, the LV ejection fraction is usually normal at a relatively early stage [7] which can be explained by that impairment in longitudinal systolic function is known to be compensated by augmentation of circumferential deformation. Global longitudinal peak systolic strain (GLS) can be detected by two-dimensional speckle tracking echocardiography (2D-STE) [4-6].

### Aim of the Work

This study aimed to assess the relationship between carotid IMT and left ventricular global longitudinal strain (LV GLS) assessed by 2D speckle-tracking strain echocardiography (2D-STE) in patients with coronary artery disease (CAD). It also aimed to assess the ability of both LV global longitudinal strain (LV GLS) and carotid IMT to predict CAD severity.

### Patients and Methods

#### Patients

The study was done in cardiology department in Zagazig University. It included 156 patients with suspected CAD by history of angina and either resting ECG changes or positive exercise stress test admitted electively for coronary angiography (CA). Exclusion criteria were; patients with acute coronary syndrome, previously known CAD as a history of myocardial infarction (MI), previous coronary artery bypass grafting surgery (CABG) or percutaneous coronary intervention (PCI), patients with LV systolic dysfunction (EF < 45 %), patients with resting wall motion abnormalities, atrial fibrillation, left bundle-branch block, severe valvular disease, concomitant disease as connective tissue disease or drug therapy which affect cardiac function and patients with poor acoustic window unsuitable for speckle tracking echo. Patients underwent transthoracic echocardiography (TTE), 2-D speckle tracking echocardiography (2D-STE), B-mode ultrasound of the

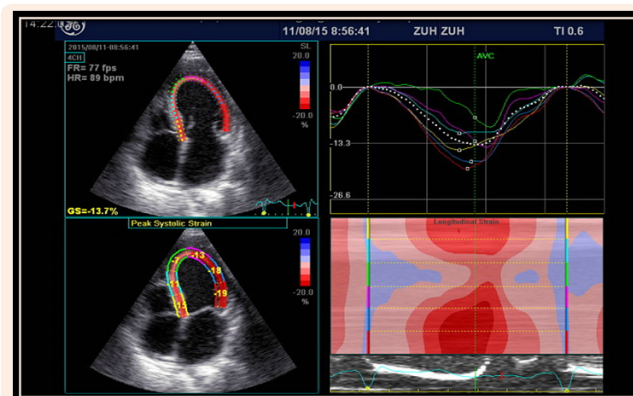
carotid arteries and coronary angiography. The patients were divided into two groups: group 1 (106 patients) with significant (>70%) CAD, and group 2 (50 patients) with non-significant CAD obstruction.

### Transthoracic echocardiographic (TTE)

Examination was done by using General Electric VIVID 9 with M4S transducer, with a frequency of 1.5-4.3 MHz and high frame rate (60-90 frame/s), Examinations included measurements of cardiac dimensions and LV ejection fraction by M-mode method [8].

### Strain analyses

Two consecutive heart cycles at rest, from the three standards apical planes (four-chamber, two-chamber, and long-axis), were considered by conventional 2D gray scale echocardiography. In each of the apical views, the endocardial contour was manually drawn and tracking of deformation was automatically performed by the software, once visual confirmation of good quality tracking was given by the operator. The software algorithm automatically segmented the LV into six equidistant segments and selected suitable speckles in the myocardium for tracking. The software algorithm then tracked the speckle patterns on a frame by frame basis using the sum of absolute difference algorithm. Regional longitudinal peak systolic strain (RLS) was measured in all views between aortic valve opening and closing for the 6 basal, 6 midventricular, and 4 apical segments and 17<sup>th</sup> segment was apical cap and averaged from the 17 segments to provide global longitudinal peak systolic strain (GLS)8 (Figure 1A & 1B).



**Figure 1A:** Left panel demonstrates apical four-chamber view. Corresponding strain curves are shown in the right panel. GLS is decreased with strain values of - 13.7 %.

### Carotid ultrasound

The carotid ultrasound examination was carried out according to the American Society of Echocardiography guidelines [9]. The extracranial common carotid arteries (CCAs) were sequentially assessed using a high-resolution 5- to 10-MHz linear-array ultrasound transducer (GE-VingMed) by an experienced physician. Patients were examined in the supine position with the head angled approximately 45 degrees towards the contralateral side. IMT measurements were synchronized with the QRS complex on

the ECG. Measurements were made in each carotid artery at the peak of the R wave where the lumen is widest. IMT was defined as the distance between the lumen-intima and media-adventitia borders of the vessel identified as a double line pattern in a longitudinal image [10]. Measurement of CIMT was performed at the far wall of the common carotid artery (CCA) 1cm proximal to the bifurcation over an area of 10 mm of the distal CCA recorded in longitudinal mode, ensuring the CCA was parallel to the transducer surface (horizontal in the image). Focal zone was set to the far CCA wall, and gain was adjusted high enough so echoes were just observed in the lumen. The reader selected frames with good perpendicular alignment and image quality and adjusted IMT box position if necessary to ensure measurement of mean CIMT over the distal 10 mm of the far wall of the CCA. For every patient, mean IMT measurements were taken at the same phase of the cardiac cycle (electrocardiography gated) on each artery (right/left). All CIMT measurements from both arteries were averaged to create mean CIMT. Plaque diameter was included in the CIMT measurements if present in the areas of interest.

to compare percentages. Pearson's correlation coefficients were used to assess the strength of relationship between continuous variables. ROC curve was plotted to get cut off value, sensitivity and specificity. A p value of less than 0.05 was considered significant.

## Results

The patients were divided into two groups, group 1 (106 patients) with significant CAD >70% stenosis, and group 2 (50 patients) with non significant CAD. Comparison of the basic characteristic of the study population in patients with and without significant coronary obstruction are summarized in Table 1. Regarding age; it was  $51.3 \pm 8.8$  in group 1 versus  $53.7 \pm 5.8$  in group 2,  $p=0.28$ . Sex and risk factors were comparable in both groups in spite high prevalence of risk factors in patients with significant CAD. Group 1 had significant decrease in GLS & EF ( $-12.2 \pm 2.93$  vs  $-16.65 \pm 3.5$ ,  $p < 0.000$ ), LVEF ( $62.5 \pm 6.5$  vs  $66.1 \pm 6.8$ ,  $p=0.033$ ) and significant increase in mean CIMT ( $1.43 \pm 0.41$  vs  $0.72 \pm 0.4$ ,  $p < 0.000$ ) compared to group 2.

Angiographic findings of the study population were summarized in Table 2: 50 patients (32.1%) with non significant CAD-and 106 patients (67.9%) with significant CAD+, 102 patients (96.2%) had LAD, 86 patients (64.2%) had LCX, 38 patients (35.8%) had RCA. 28 patients (26.4%) had SVD, 32 patients (30.2%) had DVD, 46 patients (43.4%) had TVD. Diagnostic accuracy of CIMT & GLS for detection of significant epicardial coronary stenosis (Table 3, Figure 2 & 3); The optimal cutoff value of mean CIMT was  $> 1.1$  mm [AUC 0.89, 95% CI 0.81-0.96,  $p < 0.000$ ] and for GLS was  $< -15.8\%$  [AUC 0.82, 95% CI 0.71- 0.94  $p < 0.000$ ]. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of mean CIMT was 92.5%, 84.0%, 92.5% 84.0% and 89.7% respectively. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of mean GLS was 96.2%, 68.0%, 86.4%, 89.5% and 87.2% respectively.

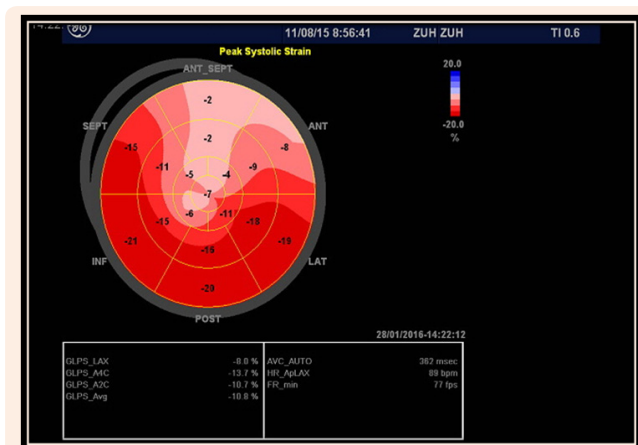


Figure 1B: Ball's eye showed averaged GLS= -10.6%.

Coronary Angiography (CA) was performed by the percutaneous femoral approach. Coronary angiograms were obtained for each coronary vessel in  $\geq 2$  projections, and stenosis with  $\geq 70\%$  reduction of the arterial lumen area were considered significant. The analysis of the coronary angiograms was performed visually by an experienced operator who was blinded to the results of the echocardiographic examinations [11].

## Ethics

Informed parental consent was obtained to be eligible for enrollment into the study. The study was done according to the rules of the Local Ethics Committee of Faculty of Medicine, Zagazig University, Egypt.

## Statistical Analysis

All analyses were made using the "SPSS 17 for Windows" software package. Continuous variables were expressed as mean  $\pm$  standard deviation; categorical variables were expressed as percentages. Independent T-test was used to compare means, ANOVA to compare multiple groups. Chi-square test was used

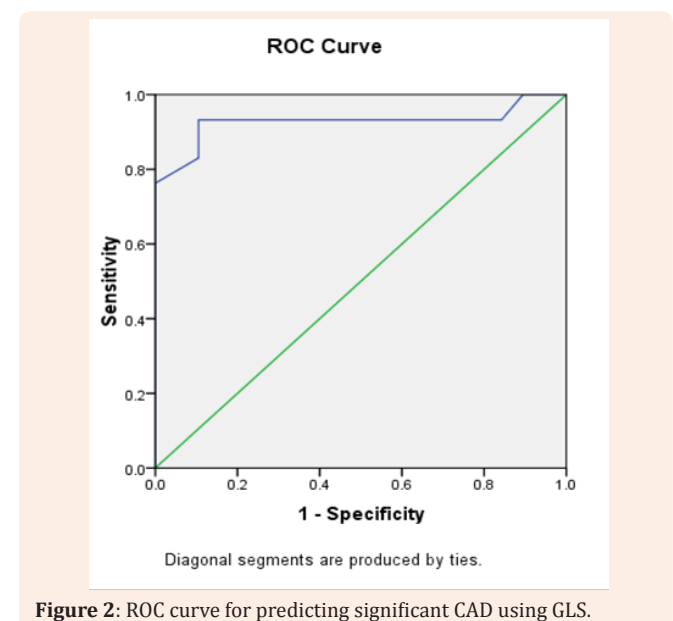


Figure 2: ROC curve for predicting significant CAD using GLS.

**Table 1:** Comparison of the basic characteristic, echo and CIMT finding of the study population in patients with and without significant coronary obstruction.

		Significant Obstruction Group (1) N= (106)	Not Significant Obstruction Group (2) N= (50)	X <sup>2</sup>	P
Age (y) Mean ± SD		51.62 ± 8.8	53.7 ± 5.8	t= -1.09	0.28
Gender	F n (%)	24 (22.6%)	16 (32%)	0.78	0.38
	M n (%)	82 (77.4%)	34 (68%)		
Smoking n (%)		70 (66%)	22 (44%)	3.4	0.07
DM n (%)		44 (41.5%)	16 (32%)	0.65	0.42
Family history n (%)		4 (3.8%)	4 (8%)	0.62	0.43
HTN n (%)		48 (45.3%)	20 (40%)	0.19	0.66
Dyslipidemia n (%)		48 (45.3%)	12 (24%)	3.25	0.07
Resting ECG Positive Normal		88 (83%) 18 (17%)	26 (52%) 24 (48%)	23.9	0.002
LVEDD(mm) Mean ± SD		51.9 ± 4.7	49.9 ± 2.8	2.3	0.024
LVESD(mm) Mean ± SD		33.26 ± 5.6	30.18 ± 3.73	2.1	0.04
EF (%) Mean ± SD		62.5 ± 6.5	66.1 ± 6.8	-2.2	0.033
GLS (%) Mean ± SD		-12.2 ± 2.93	-16.65 ± 3.5	5.8	0
Mean CIMT (mm) Mean ± SD		1.43 ± 0.41	0.72 ± 0.4	7.6	0

LV: Left Ventricle; EDD: End Diastolic Dimension; ESD: End Systolic Dimension; EF: Ejection Fraction; GLS: Global Longitudinal Strain; CIMT: Carotid Intimal Medial Thickness

**Table 2:** Angiographic findings of the study population.

Angiographic Findings	N (%)
Non significant (group 2)	50 (32.1%)
Significant (group 1)	106 (67.9%)
LAD	102 (96.2%)
LCX	86 (64.2%)
RCA	38 (35.8%)
SVD	28 (26.4%)
DVD	32 (30.2%)
TVD	46 (43.4%)

LAD: Left Anterior Descending; LCX: Left Circumflex, RCA: Right Coronary; SVD: Single Vessel Disease; DVD: Double Vessel Disease; TVD: Triple Vessel Disease.

Multivariate regression analysis for prediction severity of CAD showed that CIMT is the only predictor of CAD severity (OR 125, 95% CI 5.798 - 2694.9, p = 0.002) as shown in Table 4. For the group with normal global strain value, defined by the cut-off strain value of -15.8, carotid IMT was 0.6 ± 0.3 mm and for

the group with reduced global strain values, carotid IMT was 1.4 ± 0.4 mm, (t = 8.5, p < 0.000). There were significant negative correlation between global LVGLS and mean carotid IMT (r = -0.88, p < 0.000) and positive correlation with EF (r = 0.37, p = 0.001) as shown in Table 5 & Figure 4. GLS declined incrementally with increasing number of stenotic coronary arteries (GLS --16.65 ± 3.5, - 14.1 ± 2.01, -13.7 ± 2.1\* and - 9.7 ± 2.2\*\*\$) for patients with non-significant CAD, SVD, DVD and TVD, respectively p < 0.000. CIMT increased incrementally with increasing number of stenotic coronary arteries (CIMT 0.72 ± 0.3, 1.15 ± 0.38, 1.4 ± 0.3 and 1.76 ± 0.18) for patients with non-significant CAD, SVD, DVD and TVD, respectively with P < 0.000 (Table 6).

### Discussion

Impaired endocardial longitudinal function has been shown to be a sensitive marker for identifying early-stage diseased myocardium, particularly in patients with hypertrophy and ischemia, which may be exacerbated by elevated mechanical stress [12]. Arterial remodeling, which means larger carotid IMT-to-lumen ratio, can result either wall thickening through collagen matrix deposition or increased internal diameter may share a similar pathophysiology with ventricular remodeling and worsened myocardial deformation, which may lead to the development of heart failure [13,14].

**Table 3:** Diagnostic accuracy of CIMT & GLS for detection of significant epicardial coronary stenosis.

	AUC	95%CI	P	Sensitivity	Specificity	PPV	NPV	Accuracy
CIMT (mm) > 1.1	0.89	0.81-0.96	0	92.50%	84%	92.50%	84%	89.70%
GLS (%) < - 15.8	0.82	0.71-0.94	0	96.20%	68%	86.40%	89.50%	87.20%

**Table 4:** Multivariate regression analysis for prediction severity of CAD.

	OR	95% CI	P
LVEDD	0.89	0.69-1.12	0.38
LVESD	1.08	0.84-1.38	0.56
LVEF (%)	0.91	0.79-1.04	0.18
GLS (%)	0.85	0.58-1.3	0.85
Mean CIMT (mm)	125	5.798 -2694.9	0.002

**Table 5:** Correlation between GLS and other parameters CIMT and EF.

	GLS (%)	
	R	P
LVEDD (mm)	-0.287	0.012
LVESD (mm)	-0.263	0.023
Mean CIMT (mm)	-0.877	0
EF (%)	0.369	0.001

**Table 6:** Relation between severity of coronary angiographic findings and GLS and mean CIMT.

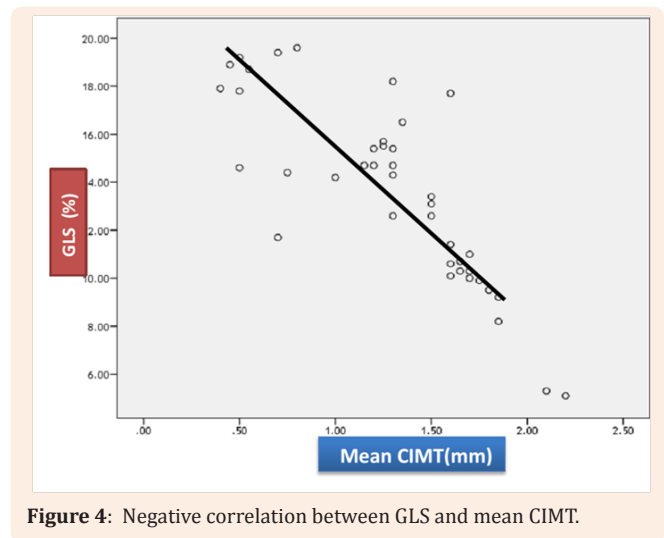
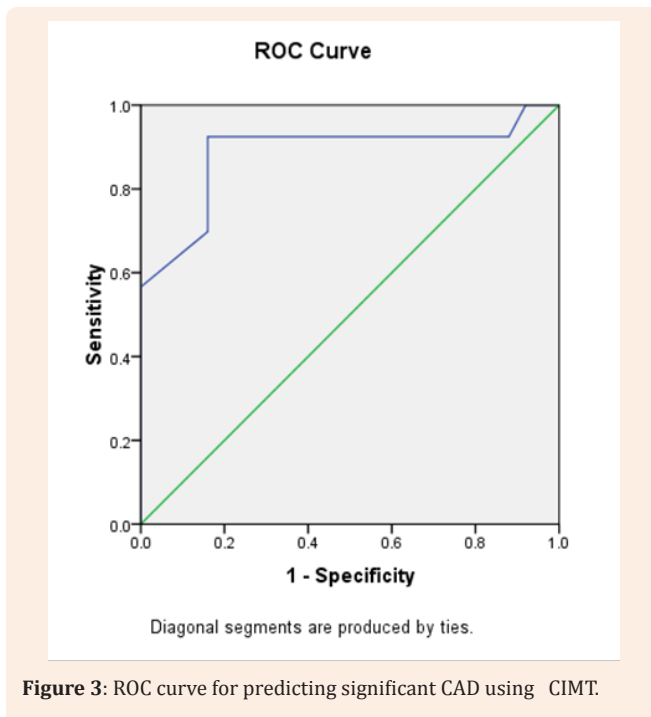
	Not significant	SVD	DVD	TVD	F	P
	N (50)	N (28)	N (32)	N (46)		
GLS (%)	-16.65±3.5	-14.1± 2.01	-13.7±2.1*	-9.7±2.2** \$	23.5	0
Mean CIMT (mm)	0.72±0.3	1.15±0.38	1.4±0.3@	1.76±0.18***	23.13	0

\*p: 1.000 versus SVD (non sign.)

\*\*\$p: 0.000 versus SVD&DVD

@p: 0.029 versus SVD (sign.)

\*\*\*p: 0.000 versus SVD&DVD (highly sign.)



**Association between GLS and severity of CAD**

We found that GLS was significantly lower among patients with significant CAD (> 70%) than those with non-significant CAD (<70%) with mean values of GLS were (- 12.2 ± 2.93 vs -16.65 ± 3.5, p < 0.000). This finding was similar to the results reported by

previous studies [15- 20]. We found that GLS less than -15.8 % may predict of significant obstructive CAD (>70%) in 87.2 % of patients with sensitivity 96.2% and specificity 68.0% as shown Table 3, Figure 2. So we concluded that GLS measurements had high diagnostic accuracy in predicting significant CAD among patients presenting with stable chest pain. These findings were different from previous studies 15-20 as they found that GLS measurements only have modest diagnostic accuracy in predicting obstructive CAD. This difference may be explained by lower cutoff value of GLS (-15.8 %) in our study compared to other studies where their cut-off level of GLS varied between -17.4 % and - 19.7 %.

Shimoni et al. [15] showed that  $GLS \leq -19.7$  may predict significant obstruction (>50%) of CAD with sensitivity 81% and specificity 67%. Montgomery et al. [16] found that  $GLS \leq -17.8$  may predict significant obstruction (>50%) of CAD, with sensitivity 66% and specificity 76%. Biering- Soerensen et al. [17] showed that cut-off level of GLS was  $\leq -18.4\%$  for prediction of significant CAD (>70%) with sensitivity 74% and specificity 58%. Evensen et al. [18] found the endocardial strain GLS value less than -16.7% may predict significant obstruction (>50%) of CAD with sensitivity 80% and specificity 60%. Billehaug Norum et al. [19] used 6 studies (778 patients with suspected CAD). They found the cut-off level of GLS for prediction of CAD+ varied between -17.4 % and -19.7 % with a sensitivity from 51 % to 81 % and specificity between 58 % to 81 %. So they concluded GLS measurements at rest only have modest diagnostic accuracy in predicting CAD+ among patients presenting with chest pain. These finding possibly could be explained by the effect of diastolic function and afterload on GLS, and there were overlap in distribution of GLS values between the CAD+ and CAD- groups. Gaibazzi et al. [20] found that GLS using vendor-independent software, has similar accuracy compared with stress-echo wall motion analysis for the prediction of significant CAD. They concluded that  $GLS \leq -20.7$  may predict significant obstruction (>50%) of CAD, with sensitivity 81.6% and specificity 84.9%.

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 [21], by using different equipment, different design, vendor-dependent 2D-STE software and operator skills [16,22,23]. Another data have indicated that GLS is more dependent on the 2D-STE software used, rather than ultrasound equipment used to acquire images [24-26]; 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. We found that GLS declined incrementally with increasing severity of CAD defined by increasing number of stenotic coronary vessels. This finding was similar to results of Biering- Soerensen et al. [17] and also the studies reported by Gaibazzi et al. [20] and Choi et al. [22] which showed similar GLS values through different CAD categories. Patients with normal

coronaries had a mean GLS of  $-22 \pm 1.5\%$ , single or double vessel disease  $-19.4 \pm 2.4 \%$ , and triple-vessel or left main disease  $-18 \pm 2.3\%$ .

### Correlation between CIMT and GLS

Our study found that for the patients with normal global strain value, defined by the cut-off strain value of  $\geq -15.8 \%$ , the carotid IMT was  $0.6 \pm 0.3$  mm and for the patients with reduced GLS values  $< -15.8 \%$ , the carotid IMT value was  $1.4 \pm 0.4$  mm ( $p < 0.000$ ). Also we found that GLS had highly significant negative correlation with mean CIMT ( $p < 0.000$ ). Fernandes et al. [27] support our result as their MESA study is a prospective observational study including four ethnic groups free from clinical cardiovascular disease using tagged MRI for assessment of LV function. They found increased carotid IMT was associated with alterations of myocardial strain parameters reflecting reduced systolic and diastolic myocardial function. These observations indicate a relationship between subclinical atherosclerosis and incipient myocardial dysfunction in a population free of clinical heart disease. Liao et al. [28] demonstrated that enlarged carotid artery diameter was associated with reduction of myocardial deformation indices including global longitudinal, circumferential and radial strain in subjects with hypertension (HTN) and heart failure with preserved ejection fraction (HFpEF), so it could be a useful clinical marker in early identifying ventricular functional decline. Evensen et al. [18] support our results as they found increased carotid IMT values were associated with decreased left ventricular function they stated that the group with normal endocardial strain, defined by the cut-off strain value of -16.7, carotid IMT was  $1.2 \text{ mm} \pm 0.2$  and for the group with reduced strain, the carotid IMT was  $1.7 \text{ mm} \pm 0.5$ . There was significant correlation between endocardial LVGLS and maximum carotid IMT ( $p = 0.006$ ).

Therefore, the presence of increased carotid IMT may lead to detection of very early cardiac dysfunction which may benefit from cardiovascular risk management. B-mode ultrasound of the carotid artery is a non-invasive, inexpensive and widely used examination and may therefore be an additional appropriate tool for the assessment of possible CAD. IMT measurements in patients with cardiovascular risk factors may therefore be of value when estimating the risk of subclinical coronary artery disease.

### Correlation between GLS and EF

We found that patients with significant CAD had significant decrease of left ventricle ejection fraction [ $62.5 \pm 6.5$  vs  $66.1 \pm 6.8$ ,  $p = 0.033$ ] compared to patients with non-significant CAD. This finding is in agreement with Sharma et al. [29]. The present study found that GLS had highly significant positive correlation with EF ( $r = 0.37$ ,  $p = 0.001$ ). This result in concordant with results of, Biering- Soerensen et al. [17], Evensen et al. [18] and Delgado et al. [30].

Delgado et al. [30] showed a good correlation between GLS and biplane LVEF for the overall study population, 222 patients with CAD ( $r = 0.83$ ;  $p < 0.001$ ). However, in patients with STEMI and patients with heart failure the correlation was less strong ( $r = 0.42$  and  $r = 0.62$ ) respectively suggesting that these two parameters reflect different aspects of systolic LV function.

## Association between CIMT and severity of CAD

The present study showed carotid artery IMT was higher in patients with significant CAD + >70% ( $1.43 \pm 0.41$  vs  $0.72 \pm 0.4$ ,  $p < 0.000$ ) compared to group 2 with non-significant CAD. This finding was similar to the results reported by previous studies [18,31-33]. Thickening of the carotid intima-media (CIMT) to just over 1.1 mm may prove to be predictive of significant CAD in nearly 89.7% of patients with sensitivity (92.5%) and specificity (84.0%). There was incremental significant increase in CIMT with increasing severity of CAD defined by increasing number of stenotic coronary vessels. Tarzamni et al. [31], found that the mean CIMT was ( $0.83 \pm 0.26$ ) in significant CAD (stenosis >70%) compared to ( $0.53 \pm 0.16$ ) in non significant CAD ( $p = 0.001$ ). Holland et al. [32], reported that a maximal CIMT value of 0.956 mm had 85.7% sensitivity and 85.1% specificity to predict angiographic CAD. Coskun et al. [33] showed CIMT was higher in patients with significant CAD ( $1.48 \pm 0.28$  mm vs  $0.78 \pm 0.21$  mm). CIMT thickening > 1.0 was predictive of significant (> 50%) CAD. They found the mean CIMT was significantly higher in CAD + groups, with single vessel disease, multi-vessel disease, and left main CAD compared to CAD - group (0.78mm) ( $1.2 \pm 0.34$  mm,  $p = 0.02$ ;  $1.6 \pm 0.32$  mm,  $p = 0.001$ ; and  $1.8 \pm 0.31$  mm,  $p = 0.0001$ , respectively).

## Limitations

1) Small sample size 2) Since the study was cross-sectional, the clinical endpoints were not followed so prognostic value of GLS not determined 3) Potential selection bias due to the need to enroll only patients with normal resting wall motion 4) Segmental RLS was not assessed because there were different methods used for obtaining regional strain. as a 16-segment or a 17-segment anatomical model for LV so the results represent a problem as this anatomical model does not necessarily reflect the individual coronary artery distribution because there is individual variability in the coronary blood supply to myocardial segment, also we need for proper standardization of how to uniformly obtain regional longitudinal strain (RLS) data.

## Conclusion

Increased carotid IMT values were associated with decreased left ventricular strain function. So the presence of increased IMT may lead to detection of very early cardiac dysfunction which may benefit from cardiovascular risk management. These findings support the use of carotid IMT measurements to predict the risk of coronary heart disease. In patients with suspected coronary artery disease, GLS assessed by 2D-STE at rest can predict significant CAD. So, 2D-STE has the potential to improve the value of echocardiography in the detection of the CAD, identifying high-risk patients and to provide more information for clinical physician. Increased CIMT is associated with the presence and extent of CAD. Patients with a mean CIMT over 1.1 mm have a high likelihood (90 %) of significant CAD. So ultrasound examination of the carotid arteries can effectively predict atherosclerosis of the coronary arteries.

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