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ORIGINAL ARTICLE

The Relative Importance of Echocardiographically derived Myocardial Strain Measurement versus aortic stiffness in estimating the extent of Coronary Stenosis in Angiography

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ABSTRACT

Coronary artery disease (CAD) is the leading cause of death in adults. Advanced CAD may exist with minimal or no symptoms and can progress rapidly to an abrupt closure of the artery, possibly resulting in a catastrophic presentation. Aside from history and risk factors, clinicians are increasingly using noninvasive testing to determine the presence, extent and location of coronary atherosclerosis and myocardial ischemia. The aim of this study to detect whether myocardial strain and noninvasive PWV analysis at rest in patients with suspected stable ischemic heart disease predicts the presence and severity of coronary artery disease (CAD). In this cross-sectional study, 50 Patients with a clinical indication of coronary angiography was assessed with echocardiography in a day before angiography. All echocardiographic images were registered in standard four, two and apical long axis chambers for measuring peak longitudinal strain in each 17 segments by two dimensional Speckle tracking (2D-STE). Then the GLS (global longitudinal strain) was determined. Aortic pulse wave velocity (PWV) was measured by Doppler echocardiographic ally. Coronary artery stenosis was calculated by quantitative angiography. The statistical relationship between the presence and extent of coronary stenosis, measured by PWV and strain reviewed and evaluation of the conformity of these two methods is compared with angiographic findings. of 52 patients whom enrolled in this study, 37were male (71.15%) and 15 were female (28.85%).mean of GLS and 2c strain evaluated by independent t test .only the echocardiographically stimated GLS has significant difference between two group (angigraphically normal coronary arteries or non significant coronary artery disease and significant coronary artey disease) in all three vessle (p value: LAD=0.03, LCX=0.04, RCA=0.03) otherwise median of echocardiographically stimated PWv.(p value: LAD=0.12, LCX=0.13, RCA=0.25), 4c strain (p value: LAD=0.09 LCX=0.14, RCA=0.09) and ALX (p value: LAD=0.44, LCX=0.015, RCA=0.06) has no significant difference between two groups (mann whitney U test). In patients with suspected CAD, GLS assessed by 2DSE at rest is an independent predictor of significant CAD. This study also showed that arterial stiffness measured through noninvasive PWV appears not to be an independent and complementary cardiovascular factor.

Key words: *coronary artery disease, coronary angiography; global longitudinal strain; myocardial strain; pulse wave velocity,*

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INTRODUCTION

Coronary artery disease (CAD) is the major cause of death in adults.[1] Advanced CAD may exist in patient with minimal or no symptoms and can progress rapidly to a sudden closure of the artery may resulting in a catastrophic presentation. Sudden death as the initial manifestation of coronary heart disease is possible in 18% of patients.[2] Fortunately, the mortality rate owing to CAD has decreased in the past 20 years.[3] This is, partly, a consequence of better detection of patients with known or suspected CAD and better succeeding treatment. Aside from history and risk factors, clinicians are incrementally using noninvasive testing to define the existence, extent and location of coronary atherosclerosis and myocardial ischemia. Plenty of studies have demonstrated that the response to stress testing can help risk-stratify patients, and may safely lead to treatment options (medical vs interventional approach).[4]

Echocardiographic strain and strain-rate imaging (deformation imaging) is a new non-invasive modality for myocardial function assessment with a wide spectrum comprehensive evaluation of potential clinical application. Which able to differentiate between active and passive movement of myocardial segments, it also can evaluate components of myocardial function, that are not visually assessable such as longitudinal myocardial shortening. Both tissues Doppler imaging (TDI) derived and two dimensional (2D) speckle tracking derived myocardial deformation (strain and strain rate) data for the early detection of myocardial dysfunction are highly sensitive. Numerous studies have also recognized the prognostic importance of arterial stiffness (AS) in different populations as an independent predictor of cardiovascular morbidity and all-cause mortality. Measurement of AS by applanation tonometry through pulse-wave velocity has remained the gold-standard method and is well-authenticated in enormous populations as a strong predictor of confrontational cardiovascular consequences.

Frequently used points are the carotid and femoral artery for the reason that they are superficial and easy to access. Furthermore, it covers the area over the aorta that shows greatest age-related stiffening.[11] Studies examining the association between arterial stiffness and the presence of plaque have also reported conflicting findings.

MATERIALS AND METHODS

This study was conducted in cross sectional design at a single tertiary coronary care center (IMAM REZA hospital, school of medicine Mashhad University of medical science, Iran). The study group contains 52 Patients with a clinical indication of coronary angiography, who also underwent echocardiography in the same day before angiography. Basic demographic information including age, sex and coronary risk factors was recorded. Systolic blood pressure, diastolic blood pressure and pulse pressure are measured in standard conditions and were repeated three times. The acquisition of the echocardiography files for this study was done during the routine in-hospital echocardiographic assessment.

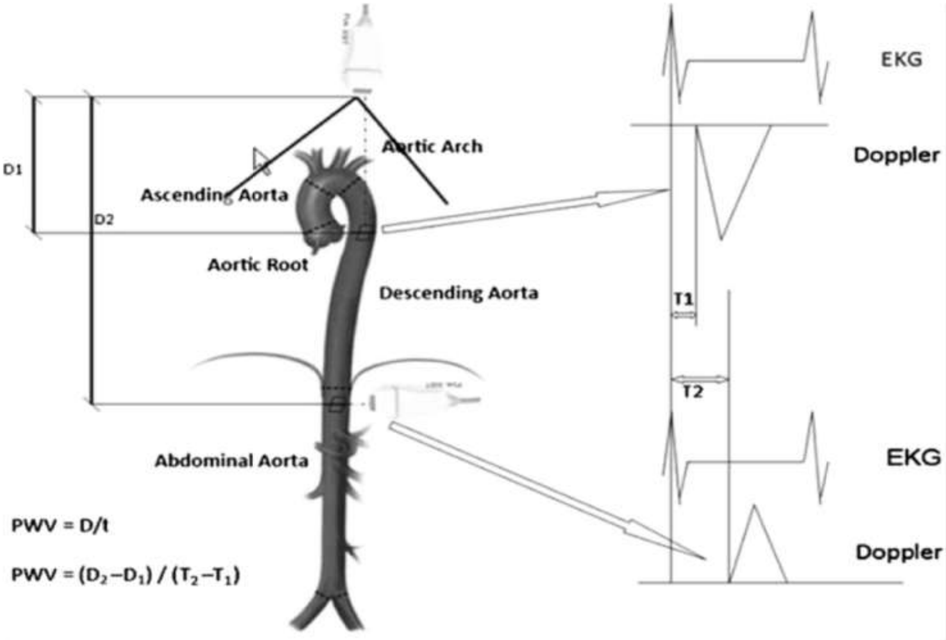
(3-6) Inclusion criteria

Patients with a clinical indication of coronary angiography including stable angina and unstable angina.

(3-7) Exclusion criteria

1) History of previous percutaneous/surgical revascularization, aortic or valve surgery,
2) Significant valvular disease (moderate or more)
3) Atrial fibrillation or atrial flutter rhythm.
4) Non ischemic cardiomyopathy.
5) Poor echo window in echocardiography.
6) History of hypertension, smoking or diabetes mellitus.

All the studies were performed using a Philips iE33 scanner (Philips Ultrasound, Bothell, WA, USA), equipped with standard probe matrix X5-1. LV volumes were traced manually at end-diastole and end-systole in apical four- and two-chamber views and LVEF was derived from the modified biplane Simpson's methods. All images were registered in standard 4c, 2c and apical longitudinal axis with gray scale method in frame rate of at least fifty. Then automatically peak longitudinal strain in each segment was registered in 17 segment model. Then the GLS (global longitudinal strain), which actually means the average of all peak values archived in each segment, determined. Aortic pulse wave velocity was measured by Doppler echocardiography (in m/sec) Schematic representation of the method used for measuring aortic PWV by echo-Doppler, illustrating the methodology used to measure thoracic aorta PWV.



The echo probe is located at the suprasternal notch. A pulse Doppler sample size is placed at the aortic isthmus level and Doppler velocity tracing is registered. The time (T1) between the peak of R wave at electrocardiography and the onset of aortic flow at Doppler is measured. Then the echo probe is located at the subcostal site where the better imaging of the abdominal aorta is reached. There is no landmark point but one must be sure that the Doppler stream is perpendicular to the aortic

Site where the pulse Doppler sample size is placed. Then Doppler velocity tracing is registered and the time (T2) between peak R wave (time reference) and the onset of Doppler flow is measured. T2-T1 is the time used by the pulse wave to travel between the aortic. Isthmus and the point considered of the abdominal aorta. The distance between the points where:

The probe is applied is measured at the skin level by using a tape measure (D_2). The distance

(D_1) between the skin and the sample volume at the aortic isthmus was then measured in 2D frame. Accordingly, the distance between the sites where the 2 pulse Doppler sample volumes were placed is given by the difference between D2 and D1.

Coronary Angiography

Coronary angiography was performed in the routine angiography laboratory for clinical indications with use of the standard technique. Coronary artery stenosis was calculated by quantitative angiography. After accomplishing angiography, the stenosis in the main coronary artery and its branches determined. A stenosis of 50% or more in diameter was considered significant in left main artery and 70% or more in other vessels (LAD, RCA and LCX). The statistical relationship between the presence and extent of coronary stenosis, measured by PWV and strain reviewed and evaluation of the conformity of these two methods is compared with angiographic findings.

Ethics

This study was carried out in accordance with the code of ethics of the world medical association (declaration of Helsinki) for experiments involving humans and obtained the approval of research ethics committee of the Mashhad University of Medical Science .the informed written consent was obtained from each participant.

Statistical evaluation

All the statistical analysis were performed using the SPSS statistical software (statistical package for social sciences version 16.0) continuous variable were presented as mean +/- standard deviation (SD) normality test (Kolmogorov-sminov) were used to assess the distribution pattern of variables. Level of significance was set at 0.05.

Data were expressed as mean ± SD. We used ROC, mann Whitney u test and independent t- test for analysis of quantitative data. Degree of freedom was calculated and P value was obtained. The results of P value were interpreted as follows: $P > 0.05$ – Not significant.

RESULT

Of 52 patients whom enrolled in this study, 37were male (71.15%) and 15 were female (28.85%).

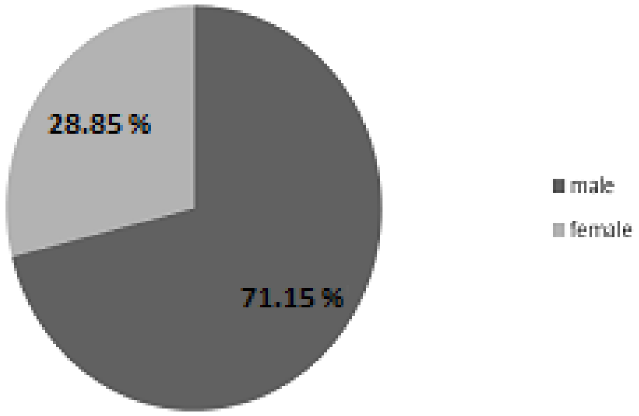


Figure 1: pie chart of study population gender

Table 2: description of study population based on age

age	
Mean	56.52
Std. Deviation	9.558
Minimum	38
Maximum	74

Result of table 3 shows that echocardiographically stimated GLS and 2c strain have no significant difference between two group of femal and male.

Table 3: correlation of two echocardiographic data GLS and 2C with gender

		GLS	2c
male	Mean	-16.76	-17.14
	Std. Deviation	4.23	5.14
	N	37.00	37.00
female	Mean	-18.27	-18.87
	Std. Deviation	3.06	4.09
	N	15.00	15.00
Total	Mean	-17.19	-17.63
	Std. Deviation	3.96	4.89
	N	52.00	52.00
	P-value	**0.21**	**0.25**

Result of table 4 shows that echocardiographically stimated ALX ,EF ,DD and 4c strain have no significant difference between two group of femal and male in contrast of PWV which has significant difference between two grooup. (P value 0.02).

Table 4: correlation of echocardiographic data 4c ,ALX ,EF and DD with gender

sex		PWV	four	ALX	EF	DD
male	N	37.00	37.00	37.00	37.00	37.00
	Median	0.00	-17.00	-17.00	55.00	1.00
	Minimum	0.00	-27.00	-30.00	25.00	0.00
	Maximum	3.00	15.00	-5.00	65.00	3.00
female	N	15.00	15.00	15.00	15.00	15.00
	Median	1.00	-19.00	-18.00	57.00	1.00
	Minimum	0.00	-23.00	-23.00	43.00	0.00
	Maximum	2.00	-13.00	-11.00	65.00	1.00
Total	N	52.00	52.00	52.00	52.00	52.00
	Median	0.00	-17.50	-17.00	55.00	1.00
	Minimum	0.00	-27.00	-30.00	25.00	0.00
	Maximum	3.00	15.00	-5.00	65.00	3.00
	P-value	0.02	0.14	0.15	0.27	0.27

For assessment af study variable being normal of them first evaluated by kolmogoro-smirnov test . For evaluation of echocardfographic data in two group of normal+non signficant and significant stenisis kolmogorov-smirnov study was done to assess normal distribution of variables .among these variables 2c and GLS have normal distribution and the mean was compared with independant T test .

Table 5: correlation of degree of different vessel's stenosis in angiography in two groups (nl +non significant /significant stenosis) with two echocardiographic data GLS and 2c.

var		**LAD**		**LCX**		**RCA**	
		GLS	2c	GLS	2c	GLS	2c
NL+	Mean	-17.76	-17.97	-17.82	-18.27	-17.89	-18.53
Non sig	SD	4.60	5.87	4.28	5.24	4.12	5.31
	N	29.00	29.00	33.00	33.00	36.00	36.00
sig	Mean	-14.88	-17.22	-15.11	-16.53	-15.02	-16.63
	SD	2.91	3.34	3.16	4.10	3.16	3.03
	N	23.00	23.00	19.00	19.00	16.00	16.00
Total	Mean	-17.19	-17.63	-17.19	-17.63	-17.19	-17.63
	SD	3.96	4.89	3.96	4.89	3.96	4.89
	N	52.00	52.00	52.00	52.00	52.00	52.00
	P-value	**0.03**	**0.58**	**0.04**	**0.21**	**0.03**	**0.22**

Echocardiographically stimated GLS had significant relationship between two group in all three vessels. Result of table 1 shows that echocardiographically stimated GLS has significant difference between two group (angigraphically normal coronary arteries or non significant coronary artery disease and significant coronary artey disease) in all three vessle.(pvalue : LAD=0.03 LCX=0.04 RCA=0.03) independant t_Test. But no dignificant difference was seen in echocardiographic 2c strain stimated between these two group in all three vessle .(p value :LAD=0.58 LCX=0.21 RCA= 0.22).

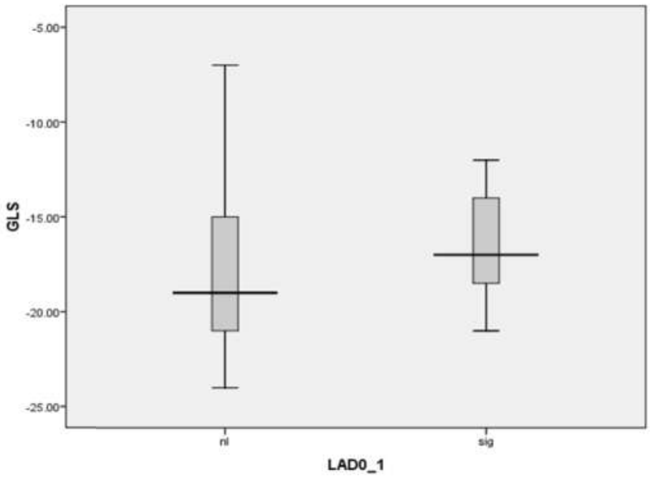


Figure 2: Box plot diagram t of echocardiographic stimated GLS between two different group of LAD vessle angiography.

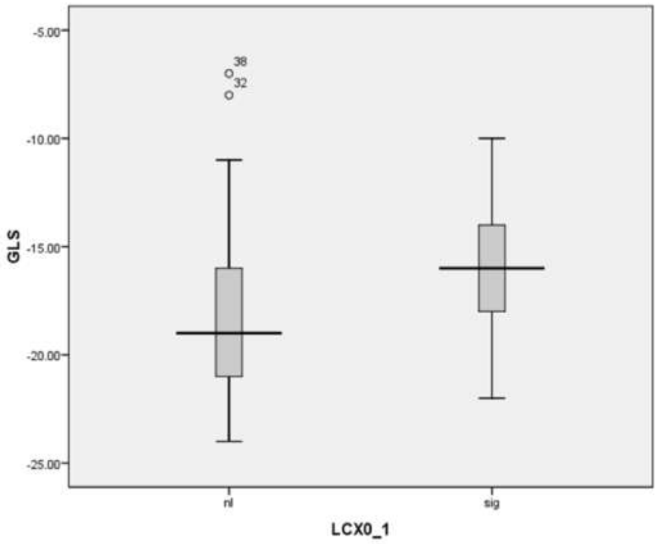


Figure 3: Box plot diagram of echocardiographic stimated GLS between two different group of LCX vessle angiography.

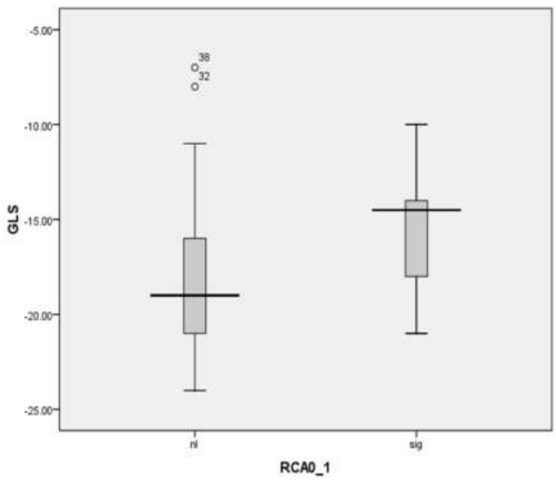


Figure 4: Bar chart diagram of echocarfiographic stimated GLS between different group of RCA vessle angiography.

Table 6: correlation of two echocardiographic data 4c and ALX with degree of stenosis in angiography between two group.

var		LAD		LCX		RCA	
		4c	ALX	4c	ALX	4c	ALX
NL +	N	-19.00	-18.00	-19.00	-18.00	-18.50	-18.00
non sig	Median	-27	-30	-27	-30	-27	-30
	Minimum	-8	-5	15	-5	15	-5
	Maximum	29	29	33	33	36	36
sig	N	-17.00	-17.00	-16.00	-16.60	-16.00	-14.00
	Median	-22	-23	-27	-23	-21	-23
	Minimum	15	-9	-11	-9	-11	-9
	Maximum	23	23	19	19	16	16
Total	N	-17.50	-17.00	-17.50	-17.00	-17.50	-17.00
	Median	-27	-30	-27	-30	-27	-30
	Minimum	15	-5	15	-5	15	-5
	Maximum	52	52	52	52	52	52
	P-value	**0.09**	**0.44**	**0.14**	**0.15**	**0.09**	**0.06**

For evaluation of echocardiographic data in two groups of normal+nonsignificant stenosis and significant stenosis ‹study variables first asessed in kolmogorov-smirnov study based on having normal distribution or not. ALX ,4c and PWV have not normal distribution and studied by man_whitney test. Result of table 9shows that echocardiographically stimated 4c strain and ALX strain have not significant difference between two group (angigraphically normal coronary arteries or non significant coronary artery disease and significant coronary artey disease) in all three vessle.
Result of table 7 shows that echocardiographically stimated PWv has no significant difference between two group (angigraphically normal coronary arteries or non significant coronary artery disease and significant coronary artey disease) in all three vessle : (LAD pw=0.12 , LCX pw=0.13, RCA pw=0.25).

Table 7: correlation of echocardiographic PWV with severity of stenosis in two different group in all three vesel.

PWV		Median	Minimum	Maximum	N	P-value
	nl	1.00	0	3	29	0.12
LAD	sig	.00	0	2	23	
	Total	.00	0	3	52	
	nl	1.00	0	2	33	0.13
LCX	sig	.00	0	3	19	
	Total	.00	0	3	52	
	nl	.00	0	3	36	0.25
RCA	sig	.00	0	2	16	
	Total	.00	0	3	52	

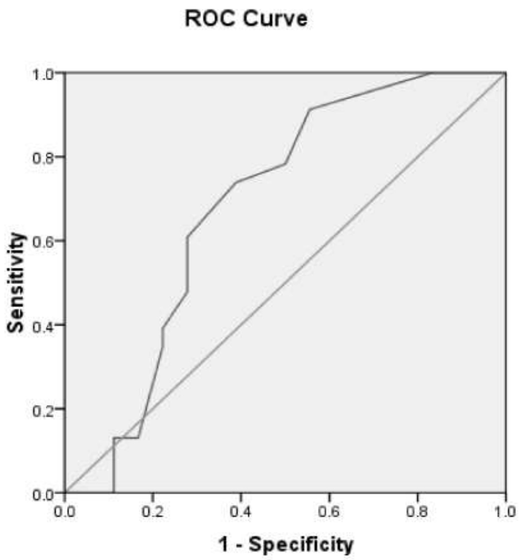


Figure 5: ROC curve analysis for correlation of angiographic stenosis in LAD with Echocardiographic GLS.

Area under the curve is c = 0.684 indicates good predictive power of the GLS to estimate severity of cornary artery stenosis in LAD.

Test Result	Area_Roc	P-value	95% Confidence	
			Lower Bound	Upper Bound
GLS	.684	.046	.505	.862

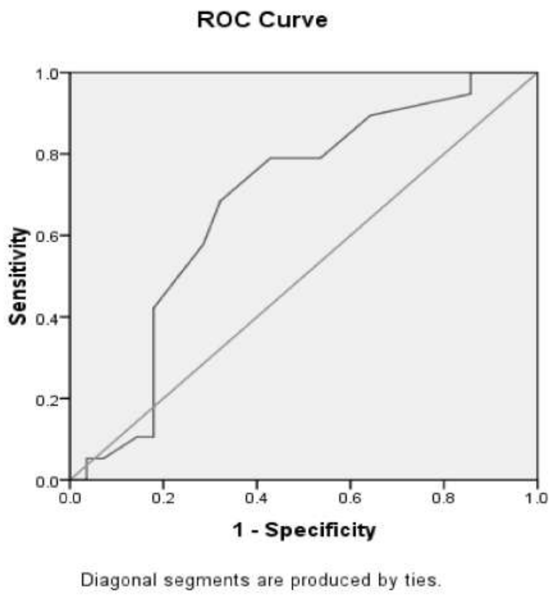


Figure 6: ROC curve analysis for correlation of angiographic stenosis in Lcx with Echocardiographic GLS. Area under the curve is c = 0.681 indicates good predictive power of the GLS to estimate severity of coronary artery stenosis in LCX.

Test Result	Area	P-value	95% CI	
			Lower Bound	Upper Bound
GLS	**.681**	**.036**	**.525**	**.837**

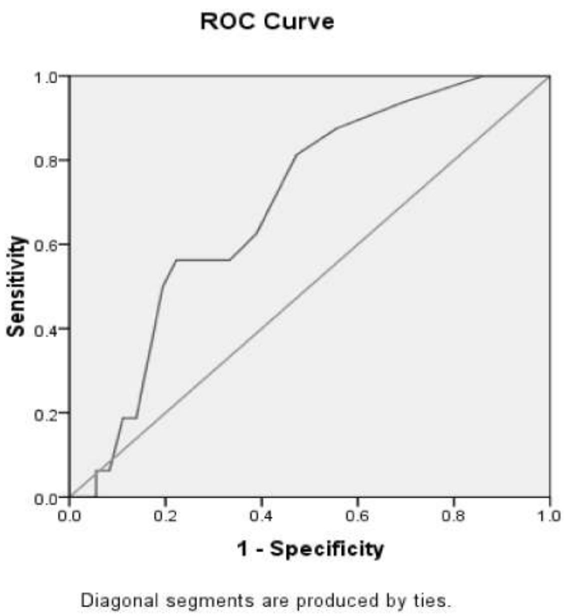


Figure7: ROC curve analysis for correlation of angiographic stenosis in RCA with Echocardiographic GLS. Area under the curve is c = 0.713 indicates good predictive power of the GLS to estimate severity of

cornary artery stenosis in RCA.

Test Result	Area	P-value	95% CI	
			Lower Bound	Upper Bound
GLS	.713	.021	.558	.868

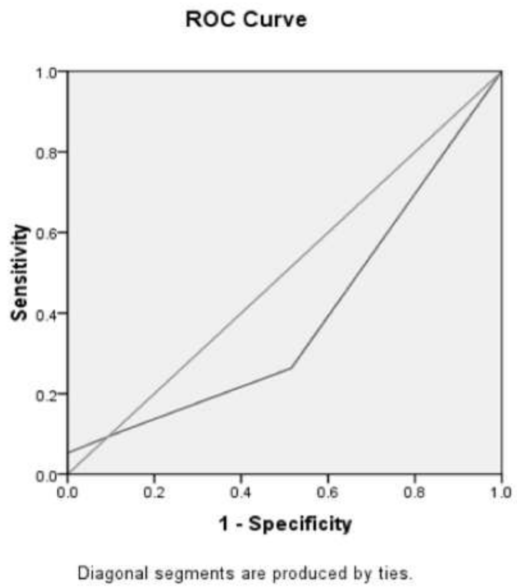


Figure8: ROC curve analysis for correlation of angiographic stenosis in LAD with Echocardiographic PWV. Area under the curve is c = 0.338 indicates poor predictive power of the GLS to estimate severity of cornary artery stenosis in LAD.

Test Result	Area_Roc	P-value	95% Confidence	
			Lower Bound	Upper Bound
PWV	.336	.074	.164	.508

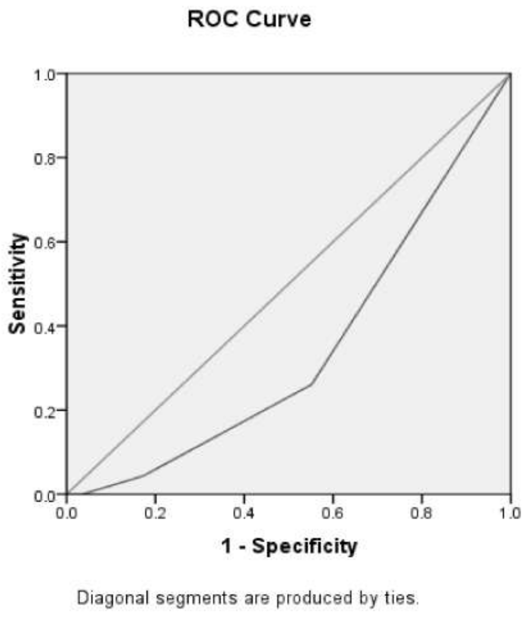


Figure 9: ROC curve analysis for correlation of angiographic stenosis in LCX with Echocardiographic PWV. Area under the curve is c = 0.361 indicates poor predictive power of the GLS to estimate severity of cornary artery stenosis in Lcx.

Test Result	Area	P-value	95% CI	
			Lower Bound	Upper Bound
PWV	.361	.109	.196	.526

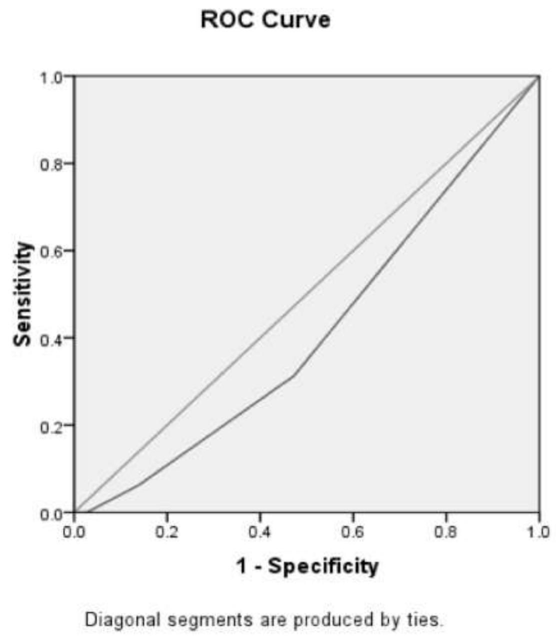


Figure 10: ROC curve analysis for correlation of angiographic stenosis in RCA with Echocardiographic PWV. Area under the curve is c = 0.390 indicates poor predictive power of the GLS to estimate severity of coronary artery stenosis in RCA.

Test Result	Area	P-value	95% CI	
			Lower Bound	Upper Bound
PWV	.390	.233	.217	.563

Figure 5 to 10 shows that echocaediographically estimated GLS has predictive ability to discriminate significant coronary artery stenosis from non significant coronary artery stenosis 0r normal coronary artery in the other hand echocardiographically estimated PWV has not this predictive ability.

DISCUSSION

2D strain data which listed in table 8-9 compared between femal and male group .non of echocardiographic evidence EF and DD have significant difference between two groups (table3**).** subclinical impairment of the LV has been demonstrated by 2DSE in the setting of many disorders, including hypertension, [86] diabetes mellitus [87.88] atrial fibrillation [89] and heart failure, with preserved ejection fraction.[90] Smaller previous studies have also demonstrated impaired peak longitudinal strain and SR in patients with CAD. [91-93] tor biering et al mentioned in their study that the myocardial fibers most susceptible to ischemia are the longitudinally orientated fibers that are located sub endocardially. Measurements of longitudinal motion and deformation are therefore the most sensitive markers of CAD. [70]

In the present study, we demonstrated that pre angiography GLS estimation by echocardiography performed at rest was able to predict significant CAD in patients with suspected CAD .These findings were independent of baseline characteristics and all other conventional echocardiographic predictors. The fact that GLS performed at rest was an independent predictor of CAD even in a low- risk population implies that GLS might be useful for risk stratification of patients with suspected ischemic heart disease (table 8). However, in our study, the usefulness of the segmental strain (in two chamber, four chamber and anterior long axis) measures, not only global estimates, was assessed in ischemic and non ischemic segments, respectively.[70] estimation of strain by two chamber ,four chamber and anterior long axis view did not provide incremental value compared with conventional echocardiography in diagnosing significant CAD (table 8-9).

Ischemic segments were assigned to a prespecifieded vascular territory. The same approach was used in a study investigating the usefulness of 2DSE in patients admitted to the emergency department with chest pain.[92]In contrast, in our study, ischemic segments were not assigned to pre-specified vascular territories because we obtained information about how significant stenosis in LAD, right coronary artery, or LCX, respectively, affects RLS in each segment (table 9) . This was done by performing multiple linear regression models, including significant stenosis in LAD, right coronary artery, and LCX as independent predictors of RLS in each of the 17 segments. A pattern closely mimicking the pre specified vascular territory appeared. Nevertheless, RLS in some territory. Therefore, if a patient admitted for suspected CAD has a normal conventional echocardiography and demonstrates a low GLS at rest, the suspicion about the presence of significant CAD should be evoked. Both 2DSE and some conventional echocardiographic measures were affected in patients with CAD compared with patients without CAD (Table 9). Still, GLS was the strongest predictor of CAD because only GLS remained an independent predictor of significant CAD after adjustment for all other predictors in our population (Table 8).

Several noninvasive parameters have been developed that allow assessment of arterial stiffness, including PWV measurement. PWV increases as arterial stiffness rises. An increase in carotid-femoral PWV reflects arterial stiffening as a result of structural and functional changes of the vascular tree in patients with vascular disease. Aortic stiffness is an important reflection of atherosclerotic vessel function, and PWV evaluates aortic stiffness noninvasively. Hence, clinical studies have demonstrated that PWV can be used to predict cardiovascular risk .[94.95] This study did not show a significant association between the severity of CAD and PWV. It is in concordance with Ouchi and colleagues [96] showed that no significant difference was observed between PWV values in a group of patients with normal angiographic findings in comparison with patients who have CAD. However Lim et al that showed when the severity of CAD was expressed as 1-, 2-, or 3-vessel disease, PWV was significantly associated with the severity of CAD.8 In this study, the authors assessed arterial stiffness through aorto-femoral PWV using fluid filled system; this was in contrast to the method used in the present study This different technique may affect the measurement of the distance (D) that is used in the calculation of PWV.

There are several independent risk factors associated with aortic stiffness; these include sex, hypertension, diabetes mellitus, hypercholesterolemia, age, atherosclerosis, renal failure, and cerebrovascular disease. [97.98] In our study, we did not analyze the results with respect to the metabolic syndrome or renal failure. In a multivariable analysis, this study showed that there is a significant association between the PWV and Sex.

Study limitations:

- Appropriate endocardial border definition is necessary for GLS measurement; we excluded patients with poor echocardiographic windows.
-None of the echocardiographic exams were performed using contrast, which was because of absence of these contrasts in our country. It could potentially diminish our results punctuality.
-for measuring PWV, appropriate acoustic window was still necessary.
- PWV was used as an index of aortic stiffness and was not measured invasively and relied on echo data.

CONCLUSIONS

In patients with suspected CAD, GLS assessed by 2DSE at rest is an independent predictor of significant CAD. This study also showed that arterial stiffness measured through noninvasive PWV appears not to be an independent and complementary cardiovascular factor.

ACKNOWLEDGMENT

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