Journal of the Saudi Heart Association

Manuscript 1096

Diagnostic Accuracy Of Global Longitudinal Strain For Detecting Significant Coronary Artery Disease In Diabetic Patients Without Regional Wall Motion Abnormality

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Abstract

Aims: **Speckle-tracking imaging is a novel method for assessing left ventricular (LV) function and ischemic changes. The aim of this prospective study was to assess the diagnostic accuracy of global longitudinal strain (GLS) and regional longitudinal strain (RLS) parameters at rest in comparison to stress echocardiography findings for detecting significant coronary artery disease (CAD) in patients with diabetes mellitus (DM).**

Methods: **We prospectively studied echocardiographic characteristics at rest with Speckle tracking echocardiography (2D STE) measures; then stress echocardiography and coronary angiography data in 34 diabetic patients without regional wall motion abnormality (RWMA) at rest. Patients were grouped according to coronary angiography and stress echocardiography results into two groups CAD (+) vs control group CAD (−).**

Results: **GLS at rest was lower in the CAD (+) group ((-14.2 % ± 3.1 vs -17.8 % ± 3.1 in the control group CAD (−), P=0.004). GLS at rest had the highest area under the ROC curve (AUC) (AUC 0.78, sensitivity 61%, specificity 91%,P=0.009) with the cut-off of -14.5% which is equal to predictive power of wall motion scoring index (WMSI) at peak stress to detect significant CAD (AUC=0.76 (95% CI 0.58−0.94, P= 0.016) with the cut-off value of 1.21).**

Conclusions: **Global longitudinal strain at rest by STE showed excellent specificity (>90%) and good sensitivity (60%) for the diagnosis of severe CAD among the diabetic population with unknown CAD. This is the first study showing that GLS at rest with cutoff value at -14.5% had good and equal diagnostic accuracy as WMSI at peak stress to detect significant CAD among the diabetic population.**

Keywords: Coronary artery disease, Diabetes mellitus, Global longitudinal strain, Speckle tracking

1. Introduction

Non-invasive diagnosis of coronary artery disease in patients with no acute or previous myocardial infarction has been a clinical challenge [1].

Resting echocardiography is usually conducted to evaluate ventricular function or to rule out other causes of cardiovascular diseases such as valvular heart disease, but not to make a diagnosis of CAD since wall motion abnormalities are usually absent even in patients with left main CAD or severe three-vessel CAD [2].

Stress echocardiography (exercise or pharmacologic) is often indicated to establish the likelihood of advanced CAD; it requires expertise, is technically challenging with respect to the acquisition of images, and is associated with inter-operator variability and subjectivity in the interpretation of regional wall motion abnormalities. Moreover, in some patients, stress echocardiography may be non-conclusive because of failure to achieve the required

Received 26 May 2020; revised 25 August 2020; accepted 31 August 2020.
Available online 23 September 2020

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https://doi.org/10.37616/2212-5043.1096

heart rate or of occurrence of rare severe cardiovascular complications [3,4].

Given the clear limitations of the exercise testing, widely used for selecting patients for coronary angiography, we are in need of a simple, non-invasive method to improve the selection of patients who are referred to coronary angiography [5,6].

Therefore; measurement of strain by echocardiographic strain imaging, also known as deformation imaging, has been introduced as a quantitative means to objectively assess regional myocardial function and has proven useful in several clinical settings i.e. evaluation of cardiotoxicity, ventricular function in heart transplant recipients and in acute coronary syndrome. Such measurements are obtained by the 2-D STE [7–10].

Several studies have reported that global longitudinal strain measured by 2-D STE at rest were significantly lower in patients with advanced CAD, as compared with patients without CAD [11–13].

Moreover, GLS measured by 2-D STE at rest has been recognized as the most sensitive and reproducible indicator of ischemia used in the detection of the significant CAD where RWMA is often not detected by resting echocardiography. Studies have shown that when GLS, as an independent predictor for significant CAD, is combined with stress echocardiography; it could improve diagnostic concordance between observers and enhance the accuracy of novice readers [1,4,12,13].

Although DM is one of the most common comorbidities associated with CAD and could affect independently GLS and left ventricular function; the changes in left ventricular GLS in patients with DM associated with significant CAD are not clear [4,14,15].

In this context; we carried out this prospective study among patients with DM to evaluate whether global and/or segmental longitudinal strain measured by 2-D STE can predict hemodynamically significant CAD (defined as stenosis ≥70% with positive stress echocardiography) in patients with DM. We sought to investigate the optimal cut-point of GLS at rest in this population and its diagnostic accuracy for detecting a significant CAD.

2. Materials and methods

2.1. Study population and exclusion criteria

In a prospective study conducted in the cardiology department of Ibn Sina Hospital, Rabat, Morocco, a total of 54 patients were evaluated from September 2019 to December 2019, in which twenty patients whose echocardiographic images were unsuitable for strain measurement were excluded subsequently. Therefore, 34 patients (62.9% recruitment rate) were included in the study. These patients were all diabetic and had LVEF ≥50% without visual RWMA. The participants had undergone echocardiographic evaluation at rest and at stress protocol then coronary angiography within 24 h before enrolment in the study.

Abbreviation list

CAD	Coronary artery disease
DM	Diabetes mellitus
GLS	Global longitudinal strain
LV	Left ventricle
RLS	Regional longitudinal strain
RWMA	Regional wall motion abnormality
ROC:	Receiver operator characteristics
STE	Speckle tracking echocardiography
WMSI	Wall motion scoring index

Other exclusion criteria consisted of having a history of chronic kidney disease or cardiomyopathy, significant valvular heart disease, congenital heart disease, previous cardiac surgery, arrhythmias such as atrial fibrillation, frequent ventricular premature complexes that affect the analysis of the images. All patients had consented to participate in our study.

2.2. Data collection

2.2.1. Echocardiographic evaluation

We used a Vivid E9 echo machine equipped with a multi-frequency 3.5 MHz transducer. All participants underwent an echocardiographic examination at rest. All echocardiographic evaluations were carried out by a single operator who was unaware of clinical and angiographic results. The harmonic image recordings of apical views, including four, three, or two-chamber (4C, 3C, and 2C) views and good quality electrocardiogram signals were obtained and stored to be analyzed offline using X strain™ software.

For each of the patients; the left ventricle end-diastolic and -systolic diameters were measured, and ejection fraction was calculated using a modified Simpson's biplane method either. Moreover; the diameter and area of the left atrium were measured. The transmitral flow (E/A and E/E′) was calculated using the doppler modes. Then the strain graphics for the longitudinal view at the long axis were automatically obtained by a velocity vector imaging (VVI) method, and average values for different parameters were calculated. GLS and RLS

of each wall segment values of the left ventricle were calculated by averaging 4C, 3C, and 2C values. Then, all the participants underwent the stress echocardiography (effort or dobutamine) and we calculated the WMSI (wall motion score index) at stress peak for each patient.

2.2.2. Coronary angiography

An experienced interventional cardiologist who was blinded to the patients' clinical and echocardiographic results assessed the angiograms and evaluated the location of lesions and diameter of stenosis for either of the coronary lesions.

Given the cut-off diameters of stenosis >70% for three epicardial vessels and >50% for the left main coronary artery as a diseased artery, we defined the number of affected vessels. Accordingly, all patients were categorized into two groups as follows: (1) 1- or 2-vessel or 3-vessel CAD, as the main group with significant CAD (+); and (2) the control group with no detected CAD (−).

2.3. Statistical analysis

The data were collected and transposed on an Excel table and analyzed by the SPSS software version 20.0 (SPSS Inc., Chicago, IL, USA).

The normality of the distribution of quantitative variables was assessed using the Kolmogorov–Smirnov test. The quantitative variables in asymmetric distributions were expressed as median [interquartile range] (IQR) and in symmetric distribution, were presented as mean ± standard deviation. Categorical variables were summarized as numbers (percentages). Comparisons between the two groups "CAD (−)" and "CAD (+)"were performed through the Student's t-test and the Mann–Whitney test for quantitative variables and by the Pearson Chi-square test and Fisher 's exact test for categorical variables.

Receiver operating characteristic (ROC) curve analysis was used to test the diagnostic accuracy of GLS at rest, E/E′ at rest, number of segments with abnormal RLS at rest, and WMSI at stress peak for detecting the patients with significant CAD.

All p-values were considered significant at <0.05. All areas under the curves (AUC) were reported with a 95% confidence interval.

3. Results

A total of 34 patients were evaluated in the study and categorized into two groups: normal group without CAD (n1 = 11), and high-risk group with 1- or 2-or 3-vessel CAD (n2 = 23). The mean age of

Table 1. Clinical characteristics of the study population.

	Total (n = 34)	CAD (−) (n1 = 11)	CAD (+) (n2 = 23)	P value
Age (years)	67.5[58.7; 70]	68[60; 68]	67[58; 70]	0.95*
Sexe				
*Male	24(70.6%)	7(63.6%)	17(73.9%)	0.69**
*Female	10(29.4%)	4(36.4%)	6(26.1%)	
Risk factors				
*Diabetes	34(100%)	11(100%)	23(100%)	NS***
Duration(years)	8 ± 0.2	7.8 ± 0.2	8.1 ± 0.3	0.8°
HbA1C (%)	7 ± 0.2	6.9 ± 0.3	7.2 ± 0.1	0.9°
*Hypertension	26(76.5%)	8(72.7%)	18(78.3%)	1**
*Smoking	11(32.4%)	3(27.3%)	8(34.7%)	0.64***
*Dyslipidemia	15(44.1%)	3(27.3%)	12(52.2%)	0.27**
*Obesity	6(17.6%)	0(0%)	6(26.1%)	0.14**
*Cerebrovascular accidents	4(11.6%)	0(0%)	4(17.2%)	0.7**
Symptoms				0.38**
*No symptoms	8(23.5%)	1(9.1%)	7(30.4%)	
*Typical angina	9(26.5%)	2(18.2%)	7(30.4%)	
*Atypical angina	11(32.4%)	5(45.5%)	6(26.1%)	
*Dyspnea	6(17.6%)	3(27.3%)	3(13%)	
Medication prior to coronary angiography				
*Aspirin	15(44.1%)	3(27.3%)	12(52.2%)	0.27**
*B-Blockers	8(23.5%)	2(18.2%)	6(26.1%)	1**
*ACEi	10 (29.4%)	3(100%)	7 (87.5%)	1**
*ARB	10 (29.4%)	2 (18.2%)	8 (37.8%)	0.43**
*Statin	17(50%)	4(36.4%)	13(56.5%)	0.27***
*Calcium channels blockers	7(20.6%)	2(18.2%)	5(21.7%)	1**

CAD: coronary artery disease; ACEi: Angiotensin-Converting Enzym inhibitor; ARB: Angiotensin II receptor antagonist *: Mann–Whitney test **: Fisher's exact test ***: Pearson Chi-square test °: student's *t*-test.

Table 2. Echocardiographic parameters at rest of the study population.

	Total (n = 34)	CAD(−) (n1 = 11)	CAD (+) (n2 = 23)	P value
LV hypertrophy	12 (35.3%)	4 (36.4%)	8 (34.8%)	1**
LV end diastolic diameter (mm)	51.9 ± 3.5	51.4 ± 4.2	52.1 ± 3.2	0.62*
LV end systolic diameter (mm)	31 ± 3.7	31.5 ± 4.4	30.8 ± 3.3	0.57*
LV ejection fraction (%)	68 ± 6	68.5 ± 5.6	67.7 ± 6.4	0.72*
LV fractional shortening (%)	38.5 ± 3.9	38.5 ± 4.4	38.6 ± 3.8	0.99*
LA size (mm)	35.2 ± 3.4	35.4 ± 3.3	35 ± 3.5	0.74*
LA area (cm^2)	16.2 ± 1.8	16.4 ± 2	16.1 ± 1.7	0.58*
E/A				
*< 1	19 (55.9%)	5 (45.5%)	14 (60.9%)	0.47**
*> 1	15 (44.1%)	6 (54.5%)	9 (39.1%)	
E/E′	7.7 ± 3.8	9.7 ± 5.8	6.8 ± 1.8	0.13*
GLS (%)	−15.4 ± 3.5	−17.8 ± 3.1	−14.2 ± 3.1	**0.004***
Number of segments with abnormal RLS	7.6 ± 4.6	6.45 ± 4	8.1 ± 4.8	0.32*

CAD: coronary artery disease; LV: left ventricle; LA: left atrium; E/E': Early transmitral velocity to tissue Doppler mitral annular early diastolic velocity ratio, A: peak transmitral late diastolic inflow velocity; GLS: global longitudinal strain; RLS: regional longitudinal strain. *Student 's *t*-test ** Fisher 's exact test.
Bold values denote statistical significance at the $p < 0.05$ level.

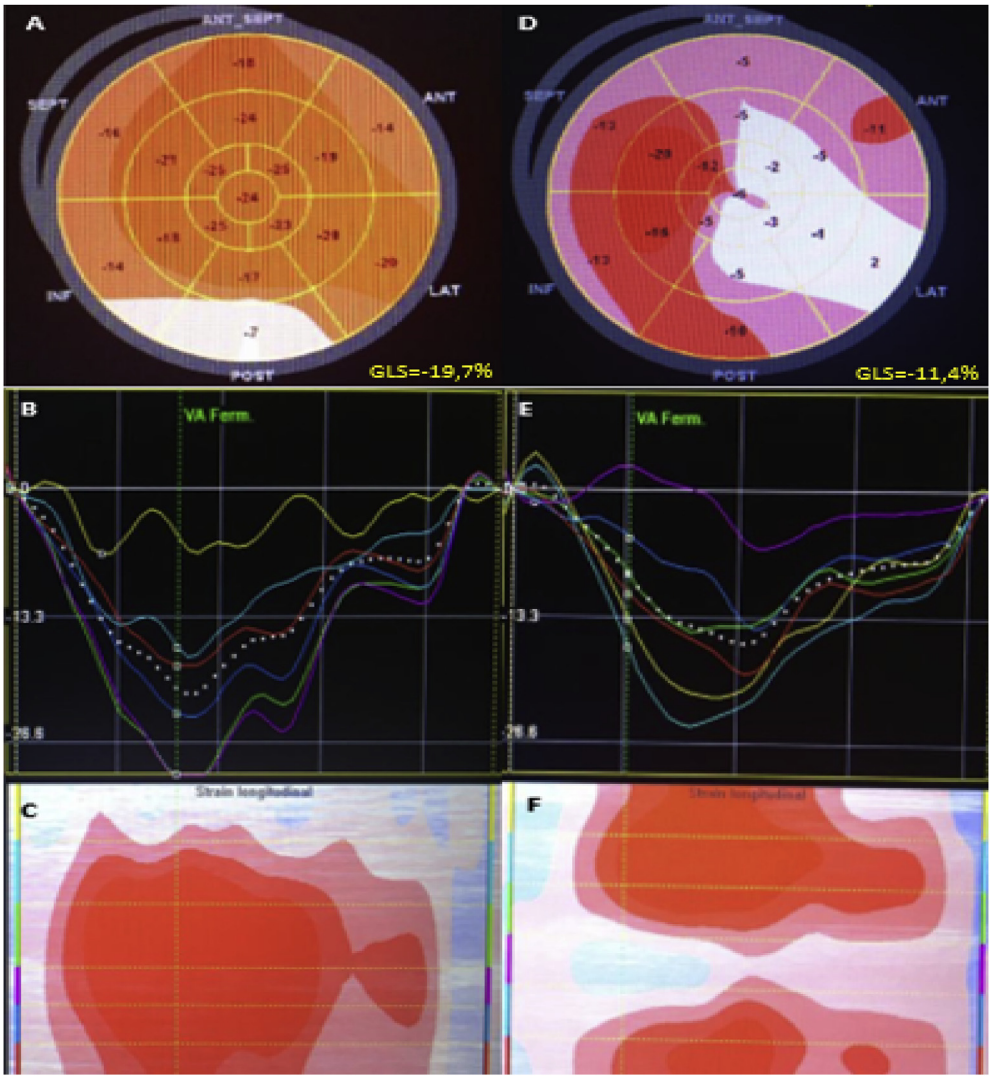

Fig. 1. (A, D): Representative bull's-eye displays with segmental peak systolic longitudinal strains; (B, E): Longitudinal strain curves of each segment from the apical two-chamber view;(C, F): Curved anatomic M-mode of the longitudinal strain. Images obtained from selected patients: Panel (A, B, C) of the patient n° 1 with normal GLS at rest at −19.7% with no significant CAD at coronary angiogram and Panel (D, E, F) of the patient n°2 with decreased GLS at rest of −11.4% with severe CAD.

patients was 67.5[58.7–70] years, and with no significant difference among groups (P = 0.95). Most of patients in the two groups were males. Diabetes Mellitus (100%) and hypertension (76.5%) followed by dyslipidemia (44,1%) were most frequent risk factors in the two groups with no significant difference among groups. Only, 9 patients (26.5%) presented « typical angina » as a symptom of CAD (Table 1).

The data of echocardiographic examination at rest are summarized in Table 2. No significant differences were found among the two groups concerning conventional echocardiographic parameters. The GLS of the left ventricle was significantly lower in the high-risk group CAD (+) when compared with that in control group CAD (−) (−14.2% ± 3.1 vs −17.8% ± 3.1 respectively, P = 0.004) (Fig. 1). There was no significant difference among the two groups concerning the number of wall segments with abnormal RLS at rest (8.1 ± 4.8 for group CAD (+) vs 6.45 ± 4 for the group CAD (−), P = 0.32).

During echocardiographic evaluation at stress, there was more clinical positivity among the high-risk group CAD (+) compared with the control group CAD (−) (12 patients (52.2%) vs 1 patient (9.1%) respectively, P = 0.02). The WMSI of the left ventricle at stress peak was significantly higher in the high-risk group CAD (+) when compared with that in control group CAD (−) (1.39 ± 0.14 vs 1.23 ± 0.16 respectively, P = 0.01). More findings of stress echocardiography and coronary angiography of the study population are presented in Table 3.

Based on the ROC curve analysis (Fig. 2, Table 4), the optimal cut-off values for GLS at rest and WMSI

Table 3. Findings of stress echocardiography and coronary angiography of the study population.

	Total (n = 34)	CAD (−) (n1 = 11)	CAD (+) (n2 = 23)	P value
Clinical positivity	13 (38.2%)	1 (9.1%)	12 (52.2%)	**0.02****
EKG positivity	23 (67.6%)	6 (54.5%)	17 (73.9%)	0.17**
WMSI (at peak of stress)	1.34 ± 0.17	1.23 ± 0.16	1.39 ± 0.14	**0.01***
Coronary artery stenosis:				**0.001****
*0 vessel stenosis	11 (32.4%)	11(100%)	0(0%)	
*1 vessel stenosis	10(29.4%)	0(0%)	10 (43.5%)	
*2 vessels stenosis	7 (20.6%)	0(0%)	7 (30.4%)	
*3 vessels stenosis	6 (17.6%)	0 (0%)	6 (26.1%)	
Coronary anatomy				
*stenosis in LAD	15 (44.1%)	0 (0%)	15 (44.1%)	**0.014****
*stenosis in RCA	18 (52.9%)	0 (0%)	18 (52.9%)	**0.006****
*stenosis in LCX	12(35.3%)	0 (0%)	12(35.3%)	**0.034****

CAD: coronary artery disease; EKG: Electrocardiogram; WMSI: wall motion scoring index; LAD: left artery descending; RCA: right coronary artery; LCX: left circumflex artery.
*: Student's *t*-test **: Fisher 's exact test.
Bold values denote statistical significance at the p < 0.05 level.

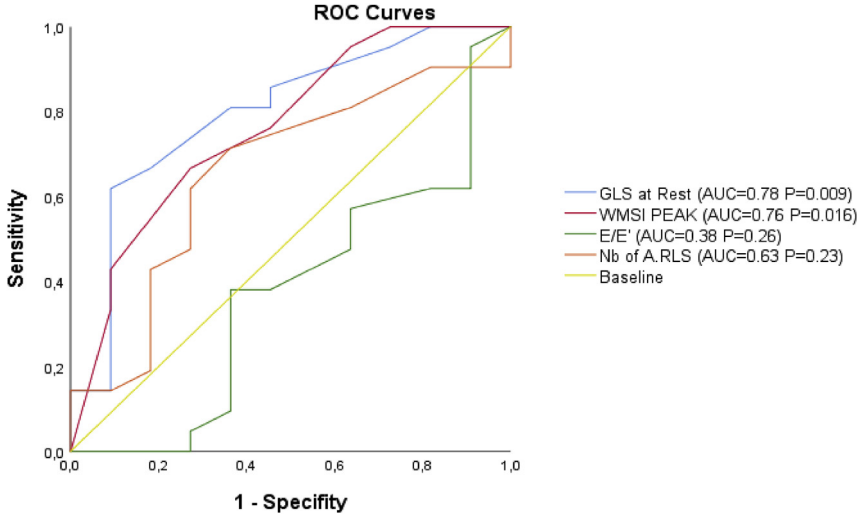

Fig. 2. ROC curve analysis for the detection of CAD. Receiver operator characteristics. ROC plots showing the predictive power of echocardiographic parameters in the study. A GLS at rest cut point value of − 14.5% had the most optimal sensitivity/specificity (61/91%) combination. GLS at rest and WMSI at stress peak had equal predictive power to detect significant CAD (AUC = 0.78 and 0.76; respectively). Both were better than the number of segments with abnormal RLS (Nb of A.RLS) and resting E/E'. AUC: Area under the curve; E/E': Early trans-mitral velocity to tissue Doppler mitral annular early diastolic velocity ratio; WMSI: wall motion scoring index; GLS: global longitudinal strain; CAD: Coronary artery disease.

Table 4. Diagnostic value of different parameters for CAD.

Parameter	AUC	95% CI	P value	Optimal cutpoint	Sensitivity (%)	Specificity (%)
E/E'	0.38	0.17–0.59	0.26	≥7.11	43	46
GLS % (at rest)	**0.78**	0.61–0.95	**0.009**	**≥ − 14.5**	61	91
Number of segments with abnormal RLS	0.63	0.42–0.83	0.23	≥5.5	65	64
WMSI (at peak of stress)	**0.76**	0.58–0.94	**0.016**	**≥ 1.218**	85	46

CAD: coronary artery disease; E/E': Early transmitral velocity to tissue Doppler mitral annular early diastolic velocity ratio; WMSI: wall motion scoring index; GLS: global longitudinal strain; RLS: regional longitudinal strain.
Bold values denote statistical significance at the $p < 0.05$ level.

at stress peak of the left ventricle for the detection of patients with significant CAD were −14.5% (sensitivity 61% and specificity 91%), and 1.21 (sensitivity 85% and specificity 46%), respectively. A GLS at rest cut-off value of −14.5% had the most optimal sensitivity/specificity (61/91%) combination. Both GLS at rest and WMSI at stress peak had equal predictive power to detect significant CAD. The AUC was 0.78 (95% CI 0.61–0.95, p = 0.009) for GLS at rest and 0.76 (95% CI 0.58–0.94; P = 0.016) for WMSI at stress peak.

4. Discussion

A resting echocardiographic study is an important clinical tool that provides important information about cardiac function and anatomy. LV ejection fraction is often normal in patients with stable CAD. A decreased LV function and/or RWMA may increase the suspicion of ischemic myocardial damage [16–19].

Likewise, the visual assessment of RWMA can be challenging and detection of early systolic lengthening, decreased systolic shortening, or post-systolic shortening by strain imaging techniques might be helpful in patients with apparently normal LV function but with clinical suspicion of CAD. Therefore, on cardiovascular risk assessment, echocardiographic assessment of GLS is recommended to be considered when LVEF is >35% [20–23].

In the same context, ESC 2019 [24] recommended a new concept of clinical likelihood of CAD based on incorporating information on risk factors for CVD (diabetes), resting ECG changes, LV dysfunction suggestive of ischemia or coronary calcification that can be used as modifiers to improve the identification of patients with obstructive CAD compared with age, sex, and symptoms alone (used for pretest probability (PTP) estimate). According to new guidelines of ESC 2019; being diabetic and/or having LV dysfunction suggestive of CAD (early assessed by GLS) increases the clinical likelihood of CAD to preferentially consider the invasive coronary angiography [5,25–27].

Accumulating evidence shows that 2D-STE detects early signs of left ventricular dysfunction; however, it is unknown whether myocardial strain analysis at rest in patients with diabetes Mellitus predicts the presence of significant coronary artery disease (CAD) [21], as well as the power of the GLS at rest in detecting the severity of CAD among this population, remains uncertain [1]. By this present study, we tried to investigate the diagnostic value of GLS at rest in detecting significant CAD among the diabetic patients given myocardial strains could be affected independently by diabetes mellitus.

Then our findings show that assessment of GLS at rest identifies diabetic patients with significant CAD with predictive power comparable to the wall motion scoring of stress images.

Therefore, we reported GLS at rest cut-off at −14.5% that had the most optimal sensitivity/specificity (61/91%) combination with diagnostic accuracy AUC at 0.78 (95% CI 0.61–0.95, P, 0.009) similar to that of stress wall motion scoring.

Our results are consistent with those of one systematic review conducted in 2015 [6]. The overall weighted mean GLS was −17.2% ± 2.6 among CAD + vs. −19.2% ± 2.8 in CAD-patients. Mean AUC in 4 studies for predicting CAD + ranged from 0.68 to 0.80. The study cut-off levels for prediction of CAD+ in the ROC analysis varied between −17.4% and −19.7% with sensitivity from 51% to 81% and specificity between 58% and 81% [11,20,21,28]. Our cut-off of GLS at rest at −14.5% is lower than those reported in this metanalysis, which could be explained by the prevalence of DM of 100% in our study population and DM is an independent contributing factor for reduced LV GLS.

There is a growing number of consistent reports that validate the use of 2D strain in the identification of various levels of CAD. Biering-Sorensen et al. demonstrated that myocardial strain analysis by 2-D STE improves the diagnostic of CAD in a stable angina pectoris with AUC (ROC) for exercise test and global longitudinal peak systolic strain in combination was significantly higher than that for exercise test alone (0.84 versus 0.78; P = 0.007) [21]. Also; A. Rostamzadeh et al. studied in a prospective study including 119 patients the diagnostic accuracy of myocardial deformation indices for detecting

high-risk coronary artery disease in patients without regional wall motion abnormality. Then, they found GLS at rest was significantly lower in the high-risk group with optimal value at −17%, sensitivity of 77%, and the specificity of 63% [29]. The same result was found by RADWAN.H et al., in 2016 with AUC 0.88, 95% CI 0.78−0.96 p < 0.000, however with the lower cut-off at −15.6% (like in our study) and higher sensitivity and specificity at 93.1% and 81.8% respectively; of GLS for detecting significant CAD [30].

It is known that the longitudinally orientated myocardial fibers are the most susceptible to ischemia and are located subendocardially. Measurements of longitudinal motion and deformation are therefore the most sensitive markers of CAD. The 2D-STE is more suitable for diagnosing impaired segmental longitudinal mechanics caused by CAD. This subclinical impairment of the LV has been demonstrated by 2D-STE in the setting of many disorders, including hypertension, diabetes mellitus, atrial fibrillation, and heart failure, with preserved ejection fraction. Many previous studies have also demonstrated impaired peak global longitudinal strain in patients with CAD [31,32].

As it is reported, DM is an independent contributing factor for impaired LV GLS and the level of strain reduction is correlated with the duration of diabetes [15,33,34]. Then, the presence of DM would confound the predictive cut-off point of strain. That's why, in the present study, we performed a comparison of GLS at rest between two matched groups with no statistically significant difference concerning the prevalence and duration of DM. One previous study of H.ZUO et al. [4] found that both global and segmental longitudinal strains were significantly lower in CAD patients with DM than those without DM, and a reduced sensitivity and specificity in the entire cohort and particularly in the patients with DM (sensitivity and specificity (61.1% and 52.9%)) with a lower cutoff point of GLS at rest −17.15% vs −18.35% in patients without DM [4]. The diagnostic accuracy of GLS at rest among patients with DM was AUC = 0.67; P = 0.048. Later in 2018, H.ZUO et al. reported the cut off of GLS at rest to predict the severe CAD in non -DM patients at −19.05% (higher than before) with higher diagnostic accuracy [1].

When 2D STE-GLS at rest was compared with WMSI at stress peak in the present study, we found that the assessment of WMSI at stress peak was not superior to the assessment of deformational characteristics at rest (with almost similar AUC at 0.76 and at 0.78, respectively). Those findings are consolidated by those of D.E. Montgomery et al. that found a reduced GLS measured by 2D STE in rest images had similar accuracy to the traditional WMSI measured in stress echocardiography to identify significant CAD [28].

Furthermore, our data suggest that the number of segments with abnormal RLS may be useful as a tool for screening of significant CAD in the diabetic population.

These data add to the accumulating evidence that resting 2D strain echocardiography(2D SE) is a powerful diagnostic tool which may increase the diagnostic accuracy and specificity of stress echocardiography, complement conventional wall motion assessment, supplant the need for additional non-invasive testing for certain patients with suboptimal stress tests and may help identify the high-risk patients who should benefit from an aggressive risk factor modification strategy.

To our knowledge, this represents the first report that specifically evaluates global 2D strain at rest in diabetic patients with significant CAD (validated by stress echocardiography) using coronary angiography as the gold standard.

In conclusion, the present study even conducted in a small group of diabetic patients, demonstrated that a great reduction of GLS at rest could predict significant CAD in DM patients. A threshold of GLS at −14,5% is proposed to be used in the detection of advanced CAD in patients with DM with high and equal diagnostic accuracy as WMSI at peak stress.

Study limitations

We recognize some limitations for our study that are:(1) Small sample size and single-center study. (2) The potential selection bias due to the need of enrolling only patients with normal wall motion at baseline echocardiogram. (3) Due to the cross-sectional design of the study, the clinical endpoints were not followed so the prognostic value of GLS was not determined. (4) Segmental RLS was not analyzed in absolute value because of the heterogeneity of CAD among the study population. (5) The apical longitudinal strain wasn't removed from GLS estimation when it's suggested by some previous studies to improve the diagnostic performance of GLS in the detection of CAD since myocardial fibers in the apical region are rather circular than longitudinal (6)A 17-segment anatomical model for LV, somehow, biased the results as this anatomical model does not necessarily reflect the individual coronary artery distribution because of the individual variability in the coronary blood supply to myocardial segment (7) The cut-off value of GLS at rest found at −14.5% which is lower than cut-off

values reported in the literature because of the synergistic effect of diabetes mellitus and significant CAD on the impairment of strain.

5. Conclusion

Based upon the findings; GLS assessed by 2-D STE at rest has high diagnostic accuracy in predicting significant CAD among patients with diabetes mellitus.

GLS measurements at rest showed equal diagnostic power in comparison to WMSI at peak stress. Therefore, GLS at rest is an independent predictor of significant CAD with optimal cut-off value at −14.5% and could improve the diagnostic performance of stress echocardiography for the diagnosis of severe CAD among the diabetic population with excellent specificity (>90%) and good sensitivity (60%). Furthermore, RLS at rest showed greater potential in detecting CAD, but these findings have to be verified in larger studies. Then, more refined strain measurements at rest are needed to identify diabetic patients with significant coronary heart disease and the introduction of practical models using 2-D STE and including pretest probability and the clinical likelihood of CAD should be developed.

Recommendation

Further prospective studies are needed to determine the clinical relevance of reduced rest GLS, in addition to its statistically significant diagnostic accuracy, to detect patients with DM presenting a significant CAD.

Author contribution

Conception and design of Study; Literature review; Acquisition of data; Analysis and interpretation of data; Analysis and interpretation of data; Research investigation and analysis; Research investigation and analysis; Revising and editing the manuscript critically for important intellectual contents; Data preparation and presentation; Research coordination and management: Oumaima Alaika; Souad Jamai; Nawal Doghmi; Mohamed Cherti. Data collection; Drafting of manuscript: Oumaima Alaika; Souad Jamai; Nawal Doghmi. Supervision of the research; Funding for the research: Souad Jamai; Nawal Doghmi; Mohamed Cherti.

Conflicts of interest

We have no conflict of interest associated with this publication, and there has been no significant financial support for this work that could have influenced the outcome of this study.

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