



# The Role of Layer-Specific Strain Echocardiography in The Diagnosis of Severe Coronary Artery Disease

Ciddi Koroner Arter Hastalığının Tanısında Katman Spesifik Strain Ekokardiyografinin Rolü

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## ABSTRACT

**Aim:** Several imaging techniques are in use for diagnosis and risk assessment in patients with suspected stable coronary artery disease (S-CAD). Measurement of global longitudinal strain (GLS) by two-dimensional speckle tracking (2D-STM) is a more accurate and reliable technique compared to transthoracic echocardiography. It provides a quantitative measure of left ventricular function. The aim of this prospective study was to determine the relationship between resting layer-specific longitudinal strain values and severe coronary lesions in patients with suspected S-CAD.

**Materials and Methods:** A total of 242 patients with suspected S-CAD were included in this study. They were scheduled for elective coronary angiograph. Patients were divided into two main groups: with (n=117) and without severe coronary artery disease (CAD) (n=125). Layer-specific GLS values were compared between groups as mid-myocardial, endocardial and epicardial layers, using 2D-STM.

**Results:** This study showed that GLS values of all layers were significantly lower in patients with severe CAD compared to controls (p<0.001). ROC curves were constructed to evaluate the diagnostic performance of GLS values and the area under the curve was 81-82% in three slices. The cut-off values were calculated to be -19.5 for the GLS mid-myocardium, -22.6 for the GLS endocardium, and -16.5 for the GLS epicardium.

**Conclusion:** As a result, GLS assessment by 2D-STM showed that GLS values were lower in all layers with severe CAD, suggesting that GLS assessment may be useful for detecting severe CAD. However, layer-specific strain analysis showed no incremental value over GLS analysis. These findings should be further investigated and improved in subgroups with a more homogeneous distribution. Further larger studies are needed.

**Keywords:** Strain echocardiography, coronary artery disease, speckle tracking

## ÖZ

**Amaç:** Stabil kronik koroner arter hastalığı (S-KAH) şüphesi olan hastalarda tanı ve risk değerlendirmesi için çeşitli görüntüleme teknikleri kullanılmaktadır. İki boyutlu strain ekokardiyografi (2D-STM) ile global longitudinal strain (GLS) ölçümü, transtorasik ekokardiyografiye kıyasla daha doğru ve güvenilir bir tekniktir. Sol ventrikül fonksiyonunun kantitatif bir ölçümünü sağlar. Bu prospektif çalışmanın amacı, S-KAH şüphesi olan hastalarda istirahat katmanına özgü gerinim değerleri ile ciddi koroner lezyonlar arasındaki ilişkiyi belirlemektir.

**Gereç ve Yöntem:** S-KAH şüphesi olan toplam 242 hasta bu çalışmaya dahil edildi. Bu hastalar elektif koroner anjiyografi için planlanmıştı. Hastalar iki ana gruba ayrıldı: ciddi koroner arter hastalığı (KAH) olan (n=117) ve olmayanlar (n=125). Katman spesifik GLS değerleri 2D-STM kullanılarak orta miyokardiyal, endokardiyal ve epikardiyal katmanlar olarak gruplar arasında karşılaştırıldı.

**Bulgular:** Bu çalışma, tüm katmanların GLS değerlerinin KAH olanlarda kontrollere kıyasla anlamlı derecede düşük olduğunu göstermiştir (p<0,001). GLS değerlerinin tanılal performansını değerlendirmek için ROC eğrileri oluşturulmuş ve eğri altındaki alan üç kesitte %81-82 olarak bulunmuştur. Kesim noktaları GLS orta miyokard için -19,5, GLS endokard için -22,6 ve GLS epikard için -16,5 olarak hesaplanmıştır.

**Sonuç:** Sonuç olarak, 2D-STM ile GLS değerlendirmesi, GLS değerlerinin KAH olanlarda tüm katmanlarda daha düşük olduğunu gösterdi ve GLS değerlendirmesinin KAH tespit etmek için yararlı olabileceğini düşündürdü. Bununla birlikte, katmana özgü gerinim analizi, GLS analizine göre artan bir değer göstermemiştir. Bu bulgular daha homojen dağılıma sahip alt gruplarda daha fazla araştırılmalı ve geliştirilmelidir. Daha büyük çalışmalara ihtiyaç vardır.

**Anahtar Kelimeler:** Strain ekokardiyografi, koroner arter hastalığı, benek izleme

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## INTRODUCTION

Coronary heart disease caused by atherosclerosis remains the leading cause of mortality and morbidity worldwide. Early diagnosis and effective treatment are of great importance in current practice. Non-invasive imaging techniques such as electrocardiography (ECG), transthoracic echocardiography (TTE), exercise testing (EST) and myocardial perfusion scintigraphy (MPS) are recommended for the diagnosis and risk assessment of patients with suspected coronary artery disease (CAD)<sup>1</sup>. The ECG is the basic test for assessing CAD. On the other hand, EST is a widely used technique that is easy to perform but has limited sensitivity and specificity. Although the diagnostic accuracy of MPS is high, it has important limitations such as radiation exposure and limited availability<sup>2</sup>. Resting TTE is one of the leading tests used to measure systolic and diastolic ventricular function in patients with stable CAD<sup>3</sup>. The echocardiographic examination assesses regional myocardial function using visual and numerical parameters such as wall thickness, wall motion, volumetric measurements, diastolic parameters, and tissue Doppler measurements<sup>4</sup>. However, many patients with stable CAD do not have echocardiographic pathology that is predictive of ischemia, such as wall motion abnormalities. Therefore, additional investigations are required to assess for ischemia. In addition, despite these detailed examinations, some studies have shown that many patients have non-critical coronary stenosis on elective coronary angiography (CAG), as opposed to emergency angiography<sup>5</sup>. Therefore, different methods need to be used to diagnose severe CAD. Two-dimensional echocardiography is used for global and layer-specific analysis of the left ventricle (LV). This method allows numerical measurement of regional myocardial functions by evaluating each myocardial segment separately<sup>6</sup>. Longitudinal analysis provides more accurate information for the early detection of endocardial ischemia and the prediction of myocardial dysfunction. This is because the endocardium is more sensitive to ischemia<sup>7</sup>. This study aimed to determine the relationship between resting strain echocardiographic measurements and severe CAD and to increase patient selectivity using the layer-specific strain technique in planning CAG.

## MATERIALS AND METHODS

Eight hundred and seventy-six patients with suspected stable CAD and a CAG decision were assessed for the study between 11/2018 and 07/2019. Patients were excluded if they had a history of acute coronary syndrome (ACS), myocardial infarction (MI), coronary artery bypass graft surgery or coronary intervention, heart failure, moderate or severe valvular disease, reduced ejection fraction, poor image quality, segmental wall motion abnormalities, malignancy, or atrial fibrillation. A detailed medical history was obtained

and recorded, including diabetes mellitus, hypertension, and hyperlipidemia. Of these, 296 patients were selected according to the inclusion criteria. The echocardiographic images of 296 patients selected according to the exclusion/inclusion criteria were recorded and assessed for suitability by an experienced cardiologist. 242 images suitable for analysis were selected and included in the study. Patients were divided into two main groups, as significant and non-significant CAD, according to the results of CAG. The flowchart used to select patients for evaluation is shown in Table 1. The Trakya University Ethics Committee approved this study (decision no: 2018/384-18/26, date: 05.11.2018). Our study was conducted following the Declaration of Helsinki.

## Echocardiography Assessment

All enrolled patients underwent 2D echocardiograms at rest by a cardiologist blinded to CAG results or patient clinical information. Echocardiographic images were acquired using Vivid S70 systems (Horton, Norway, GE Healthcare.). The images were transferred to the Echo-PAC workstation. Patients were not included if the image quality was insufficient for speckle tracking analysis. All patient measurements were performed according to echocardiography guidelines<sup>8</sup>. Apical 4-chamber, apical long-axis, and apical 2-chamber images were obtained from the recordings. LV M-mode measurements, pulsed-wave Doppler measurements (mitral inflow velocities; E, A), and tissue Doppler recordings (lateral-septal e') were also obtained. The Modified Simpson's method was used to calculate LV ejection fraction in two planes. In the parasternal long-axis view, we measured left atrial diameter (LAD), LV end-diastolic/systolic diameters, and wall thicknesses in M-mode. E/e values were averaged from septal and lateral E values. All images were transferred to the Echo-PAC workstation for 2D speckle tracking analysis. Three beats of 2D images (apical 2-chamber, apical long-axis, and 4-chamber view at 50-80 fps) were considered adequate for measurements. All measurements were calculated by an experienced two cardiologists blinded to the enrolment group. Current guidelines for measurement were used to calculate analyses<sup>9,10</sup>. Three points were measured, one each side of the mitral annulus and apex. The program automatically traced the myocardial boundaries and curves were generated (Figure 1A). Images were optimized for measurement through manual adjustments by the examiner. Images with poorly traced myocardial borders were excluded. Out of 296 patients, 54 were excluded due to poor image quality or more than 2 unanalyzed segments. After adjustments, the software automatically calculated the measurements. In apical long-axis images, the closure of the aortic valves was defined as the end of systole. After processing the images from three different axes, a 17-segment bull's eye model was generated (Figure 1B). Global longitudinal values were automatically calculated by the software as epicardial, endocardial, and



### Statistical Analysis

Normal distribution was tested using the Shapiro-Wilk test. The Student's t test is used for normally distributed variables, and the Mann-Whitney U test for non-normally distributed variables. In examining relationships between quantitative variables, the Pearson correlation was calculated for normally distributed variables and the Spearman's correlation was calculated for non-normally distributed variables. The Pearson chi-square test was used to assess relationships between qualitative variables. Cut-off point values were obtained using ROC analysis. Risk factors for coronary heart disease were determined by logistic regression analysis. Bland-Altman plots were generated to determine interobserver and intraobserver agreement. Mean and standard deviation were used as descriptive statistics for variables that followed a normal distribution, and median and interquartile range for variables that did not follow a normal distribution. Frequencies and percentages were used for qualitative variables. The significance level for all statistical analyses was set at 0.05. TURCOSA statistical software (Turcosa Analytics Ltd Co, Turkey, www.turcosa.com.tr) was used for all statistical analyses.

### RESULTS

A total of 242 patients were enrolled. According to the results of CAG, all patients were divided into two main groups. 117 (48.3%) patients were in the significant CAD group. One hundred twenty-five (51.7%) patients with normal or atherosclerotic coronary arteries were classified as having non-significant CAD. The non-significant CAD group was defined as the control group. Indications for CAG were evaluated in 3 groups: 66 (27.3%) typical angina, 66 (27.3%) positive exercise and 110 (45.5%) positive MPS. The control group had a higher proportion of female patients. Predictably, CAD was found to be significantly higher in patients with advanced age, male sex, diabetes mellitus, and hyperlipidemia (HL) ( $p < 0.005$ ). Table 2 shows all clinical characteristics and angiographic results. There were 48 (41.0%) single-vessel disease, 26 (22.2%) two-vessel disease, and 43 (36.8%) three-vessel disease. LAD lesions (76.0%) were most common in the significant CAD group. The conventional echocardiographic parameters and the values of global longitudinal are shown in Table 3. Wall thicknesses were significantly higher in the significant CAD group. The high number of hypertensive patients in the CAD group (79.50%) may explain this. There was no difference in ejection fraction (EF) between the two groups. The significant CAD group had higher left ventricular mass index and LAD. There was no

**Table 2. The Clinical characteristics of patients**

	Non-significant CAD (n=125)	Significant CAD (n=117)	p-value
Age	56.65±9.57	61.75±9.45	<0.001
Male n (%)	48 (38.4%)	78 (66.7%)	<0.001
BMI kg/m <sup>2</sup>	29.01±4.28	29.35±4.76	0.560
Systolic BP mm Hg	129.44±15.85	132.26±17.62	0.192
Diastolic BP mm Hg	78.08±9.00	78.67±9.97	0.626
Heart rate bpm	72.40±8.60	71.44±7.36	0.355
DM n (%)	26 (20.80%)	50 (42.7%)	<0.001
HT n (%)	88 (70.40%)	93 (79.50)	0.104
Smoker n (%)	58 (46.40%)	70 (59.80%)	0.036
Family History n (%)	42 (33.60%)	30 (25.60%)	0.176
HL n (%)	44 (35.20%)	71 (60.70%)	<0.001
B-Blocker n (%)	7 (5.60%)	6 (5.10%)	0.871
CCB n (%)	24 (19.20%)	24 (20.50%)	0.798
1 vessel disease	-	48 (41.0%)	-
2 vessel disease	-	26 (22.2%)	-
3 vessel disease	-	43 (36.8%)	-
LMCA	-	6 (5.1%)	-
LAD	-	90 (76.9%)	-
CX	-	70 (59.8%)	-
RCA	-	70 (59.8%)	-

BMI: Body-mass index, CAD: Coronary artery disease, Cx: Circumflex artery, DM: Diabetes mellitus, HL: Hyperlipidemia, HT: Hypertension, LAD: Left anterior descending artery, LMCA: Left main coronary artery, RCA: Right coronary artery, CCB: Calcium channel blocker, BP: Blood pressure

**Table 3. Conventional echocardiographic parameters and longitudinal values**

	Non-significant CAD (n=125)	Significant CAD (n=117)	p-value
<b>Echocardiographic parameters</b>			
LV EF (%)	65.78±4.43	64.92±4.97	0.156
LV EDD (mm)	46.05±3.98	45.86±4.21	0.726
LV ESD (mm)	29.35±3.38	29.63±4.13	0.563
Interventricular thickness (mm)	10.94±1.24	11.77±1.52	<0.001
Posterior wall thickness (mm)	10.45±1.20	10.86±1.33	0.011
LV mass index (gr/m <sup>2</sup> )	93.01±17.09	98.12±20.44	0.036
LAD (mm)	34.52±3.80	35.91±4.02	0.006
LA volume index (mL/m <sup>2</sup> )	21.64±4.58	21.83±5.33	0.761
E (m/s)	0.77±0.16	0.79±0.18	0.415
A (m/s)	0.80±0.21	0.85±0.22	0.067
E/A ratio	1.01±0.29	1.05±0.95	0.681
E' (m/s)	0.10±0.03	0.09±0.02	0.081
E/e'	9.11±7.91	9.10±2.96	0.994
Dt. (ms)	235.50±44.44	231.62±49.64	0.522
<b>2D global longitudinal parameters</b>			
GLS mid-myocardial %	-21.68±2.27	-18.25±2.92	<0.001
GLS endocardium %	-24.58±2.57	-20.78±3.31	<0.001
GLS epicardial %	-19.18±2.05	-16.07±2.72	<0.001
GLS endo-epi %	5.40±1.07	4.71±1.11	<0.001
GLS endo/epi ratio	1.28±0.057	1.30±0.076	0.10
CAD: Coronary artery disease, EDD: End-diastolic diameter, EF: Ejection fraction, ESD: End-systolic diameter, Dt: Deceleration time, LAD: Left atrial diameter, E: Pulsed wave trans-mitral early diastolic velocity, e' Early myocardial diastolic velocity, GLS: Global longitudinal, LA: Left atrium, LV: Left ventricle			

significant difference in diastolic filling parameters (such as E, A, E') between the two groups. The GLS values of all segments (endocardium, myocardium, and epicardium) were lower in the significant CAD group, as shown by layer-specific measurements. Comparison of the difference between GLS-endo and GLS-epi (GLS endo-epi) showed a smaller difference in the significant CAD group. No difference was observed at the GLS-endo / epi ratio. No correlation was found between GLS and syntax scoring. Syntax groups and GLS measurements were compared. The GLS values of all layers were measured to be significantly lower in Group 2 than in Group 1. The relationship between the GLS and the syntax groups is shown in Table 4. ROC curves were constructed for the evaluation of the diagnostic performance of the GLS values (Figure 2). The cut-off values were calculated to be -19.5 for the GLS mid-myocardium, -22.6 for the GLS endocardium and -16.5 for the GLS epicardium. There was a significant difference in all three of the slices. The area under the curve was 81-82% in all three slices. All RLS values of coronary territories were lower in all layers in patients with significant stenosis. The RLS values are shown in Table 5. There was no relationship between the RLS values of the vessel-specific myocardial regions and the lesions that were detected in the corresponding region. ROC

curves for vessel specific RLS are shown in Figure 3. Analyses of GLS were compared for both sexes. There was no significant difference in the GLS measurements in either gender (GLS midmyocardial; -21.75 / -21,56 p: 0.658). Intra- and inter-observer variability was assessed by Bland-Altman analysis. (Figure 4). Intra-observer reliability was 96%, 95%, and 93% for the endocardium, myocardium, and epicardium, respectively. The inter-observer reliability was 86%, 86%, and 86% for the endocardium, myocardium, and epicardium, respectively. Independent predictors were assessed by multivariate regression analysis. Risk factors (age, hypertension, smoking, diabetes, HL, and family history) and GLS endocardial-mid-myocardial-epicardial measurements were included in the regression analyses. Age, sex, and diabetes were determined as independent variables [age odd ratio (OR): 1.08, confidence interval (CI): 0.098-3.05; male OR: 3.27 CI: 1.43-7.82; DM OR: 2.94 CI: 1.33-6.76].

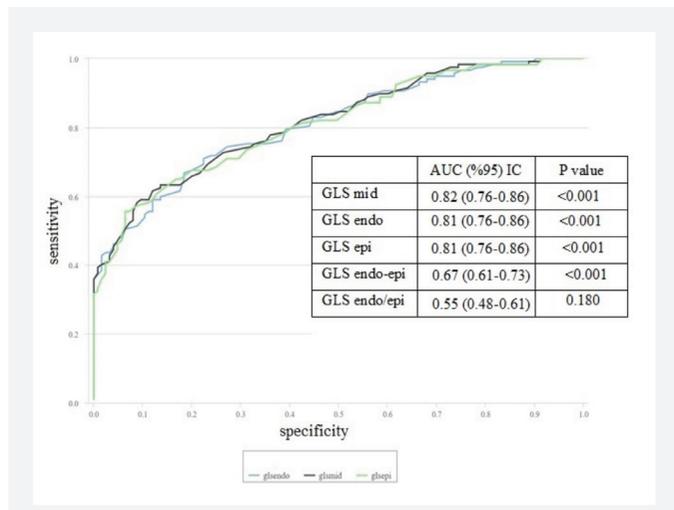
## DISCUSSION

The importance of non-invasive imaging for assessing CAD severity is growing. Routine TTE's ability to evaluate LV function is limited, and more accurate results require advanced quantitative techniques. While echocardiography is

**Table 4. The relationship between Syntax scoring and GLS in the severe CAD group (n=117). Additionally, the relationship between Syntax scoring and GLS**

	Correlation (r)		p-value	
GLS mid-myocardium	-0.1064		0.254	
GLS endocardium	-0.010		0.279	
GLS epicardium	-0.1252		0.179	
GLS endo-epi	0.006		0.950	
GLS endo/epi	0.0949		0.309	
	Syntax<22 (1. Group) (n=94)	Syntax 22-32 (2. Group) (n= 19)	Syntax>32 (3. Group) (n=4)	p-value
GLS mid-myocardium	-18.80 (16.63-20.28)	-15.80 (14.15-18.50)	-21.10 (19.13-21.25)	0.019
GLS endocardium	-21.45 (18.93-22.98)	-18.50 (15.75-21.25)	-23.60 (22.55-24.00)	0.009
GLS epicardium	-16.30 (14.80-18.20)	-14.10 (12.30-16.40)	-18.35 (16.70-19.08)	0.034
GLS endo-epi	4.70 (4.00-5.65)	4.20 (3.45-4.75)	5.35 (4.52-6.35)	0.023
GLS endo/epi	1.29 (1.24-1.34)	1.28 (1.25-1.32)	1.34 (1.24-1.43)	0.486

GLS: Global longitudinal, CAD: Coronary artery disease, GLS: Global longitudinal



**Figure 2.** ROC curves demonstrate the value of layer-specific GLS for the diagnosis of CAD

GLS: Global longitudinal, CAD: Coronary artery disease, AUC: Area under the curve, IC: Confidence interval, ROC: Receiver operating characteristic

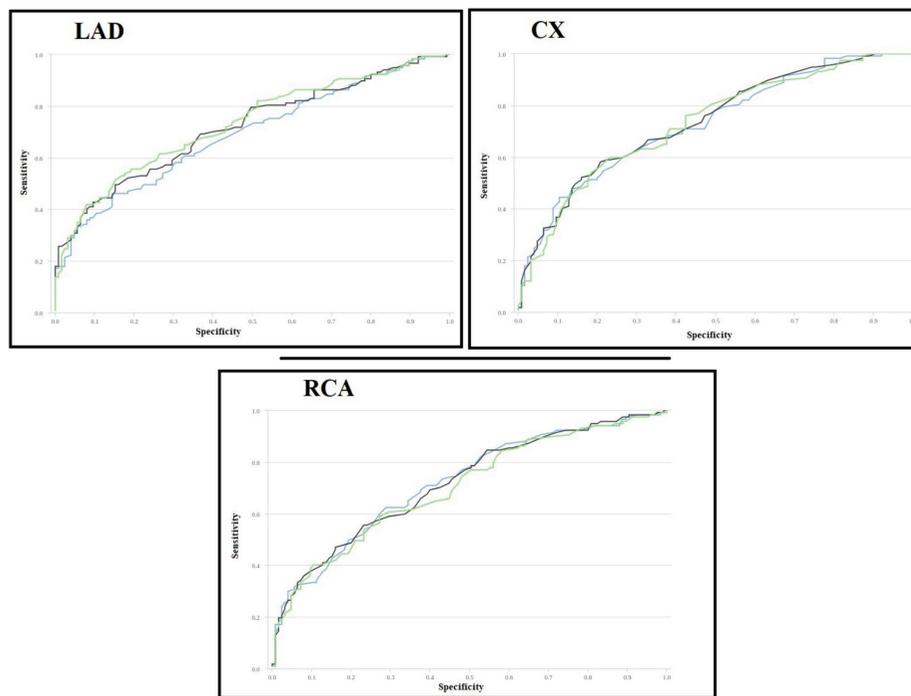
effective for assessing LV systolic dysfunction, routine 2D-TTE is inadequate for patients without prior MI or structural heart disease. Analysis may show early myocardial deterioration even in patients with normal EF. Some published studies have shown an association between CAD and strain testing. In the study by Anwar<sup>14</sup>, peak systolic values were lower in patients with CAD. Our study also showed significantly reduced GLS

values for all layers in CAD patients. Myocardial fibers in the longitudinal direction are more sensitive to ischemia<sup>15</sup>. Therefore, longitudinal assessment provides better results for the detection of CAD. Longitudinal measurements using 2D speckle tracking are critical for the diagnosis and follow-up of patients with ACS in several published studies<sup>16</sup>. Our study evaluated the success of strain echocardiography by using speckle tracking before CAG in patients with suspected CAD.

A recently published similar small study by Zhang et al.<sup>17</sup> found that longitudinal values measured by 2D speckle tracking were significantly reduced in patients with ACS. A retrospective study by Montgomery et al.<sup>18</sup> compared resting GLS values with strain echocardiographic wall motion index in patients undergoing CAG within 10 days of strain echocardiography. It was found that similar results were obtained. It was therefore suggested that strain assessment could replace strain echocardiography. In a study conducted by Yılmaztepe and Uçar<sup>19</sup>, 79 patients were evaluated retrospectively, and a significant decrease in peak systolic GLS values was detected in all layers in the group with severe CAD like our study. In their studies, it was stated that transmural GLS was an independent predictor. However, GLS measurements were not found to be a significant predictor for all layers in the logistic regression analysis of our research. Likewise, in a more recent study designed by Hagemann et al.<sup>20</sup>, it was found that mid-myocardial and epicardial GLS measurements might be independent predictors in the determination of severe CAD. However, unlike that study, our study did not measure circumferential. Looking at the results of three recent studies, we can see that the GLS measure alone

Table 5. Regional longitudinal values			
	Non-significant CAD (n=125)	Significant CAD (n=117)	p-value
<b>LAD</b>			
RLS mid-myocardium	-21.90±2.88	-18.98±3.89	<0.001
RLS endocardium	-26.01±3.48	-23.02±4.44	<0.001
RLS epicardium	-18.85±2.58	-16.19±3.29	<0.001
<b>CX</b>			
RLS mid-myocardium	-20.75±4.74	-17.56±3.27	<0.001
RLS endocardium	-22.91±3.32	-19.81±3.58	<0.001
RLS epicardium	-18.55±3.19	-15.82±3.12	<0.001
<b>RCA</b>			
RLS mid-myocardium	-21.65±3.18	-18.92±3.55	<0.001
RLS endocardium	-23.67±3.43	-20.66±3.93	<0.001
RLS epicardium	-20.01±3.00	-17.90±5.23	<0.001

RLS: Regional longitudinal, CAD: Coronary artery disease, CX: Circumflex artery, LAD: Left anterior descending artery, RCA: Right coronary artery



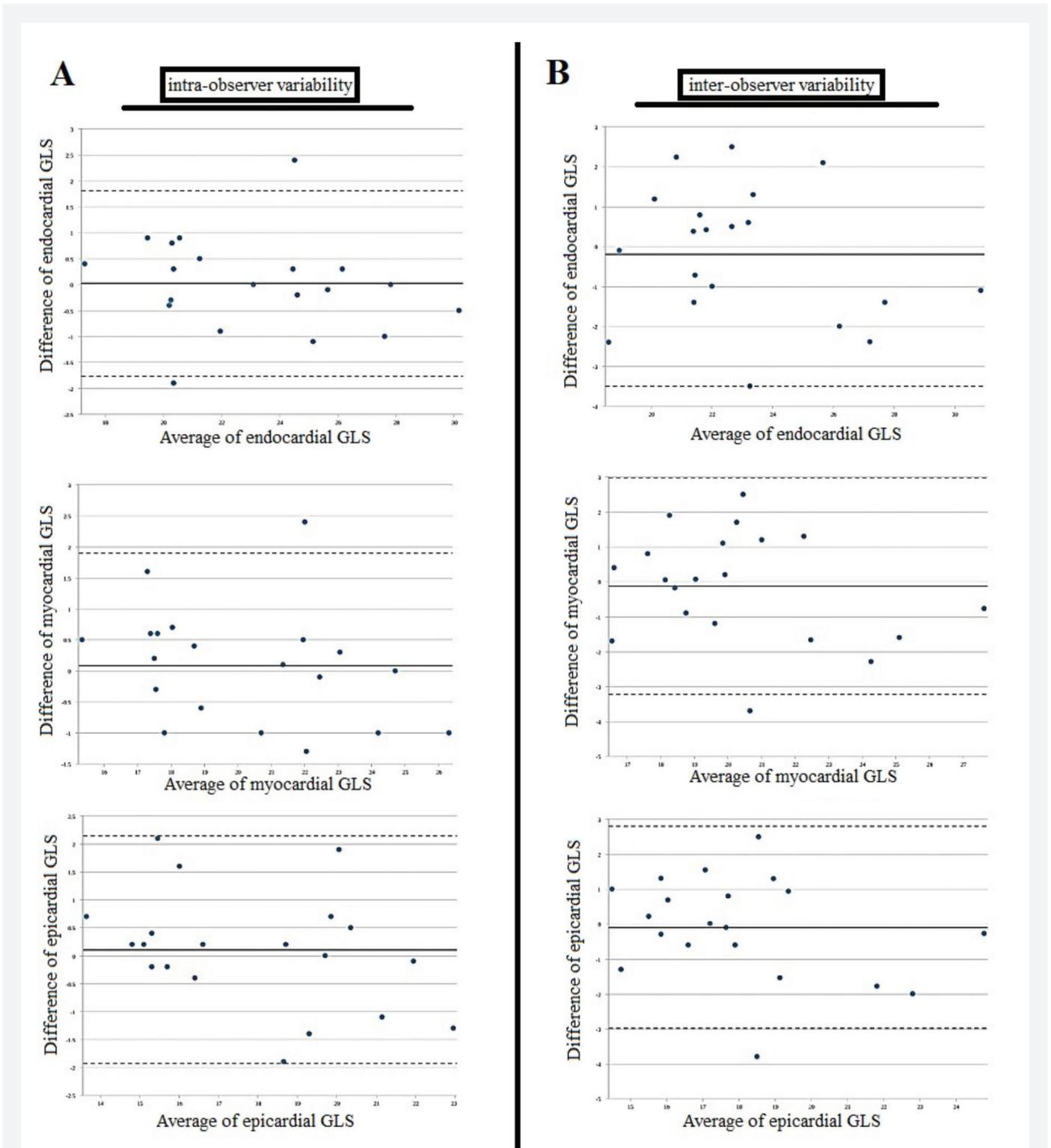
**Figure 3.** ROC analysis for diagnostic evaluation in regional analysis

LAD: Left anterior descending artery, CX: Circumflex artery, RCA: Right coronary artery, ROC: Receiver operating characteristic

may not be significant at any layer. The clinical significance of layer-specific assessment has not been fully demonstrated in recent studies in the literature. In another recent article, it has been stated that GLS measurements of the whole wall provide more accurate information than layer-specific measurements because of the adjacent layers. It has also been highlighted that

current technology is not able to separate the deformation in all layers<sup>10</sup>.

Strain echocardiography is more sensitive than EF in assessing LV function, but is influenced by age, sex, and hemodynamic factors such as preload, afterload, and mechanical desynchrony



**Figure 4.** Intra-observer and inter-observer variability statistics are shown in the Bland / Altman Chart. A-intra-observer variability, B-inter-observer variability

GLS: Global longitudinal

due to MI. We excluded patients with previous MI, wall motion abnormalities, moderate to severe valvular disease, pulmonary hypertension, bundle branch block, and atrial fibrillation. Blood pressure and medication were similar, and all patients were euvoletic. We believe that these factors did not significantly influence our study. Although the limits of the normal range of GLS and LSS were not clearly defined in our study, cut-off values were identified similar to the studies performed by Nagata et al.<sup>21</sup> and Shi et al.<sup>22</sup> with the same software (GLSendo: -19.5 %, GLSmyo: -22.6%, GLSsepi: -16.5%). In a recent review, cut off values of -17.82 in acute patients and -17.41 in chronic patients were reported<sup>23</sup>.

In a study performed by Hagemann et al.<sup>24</sup> with 80 patients diagnosed with ischemia in MPS were retrospectively evaluated. The groups were divided into true positive and false positive groups. It was found that GLS values were lower in the true positive group and there was no significant difference between the false positive group and the control group. In our study, lower GLS values were found in patients with MPS positivity and severe stenosis (GLS mid myocardial -18.42, -21.66 p<0.001).

Recent studies have used the SS in ACS to determine the severity of CAD. In our study, the SS and stress echocardiography were also evaluated in chronic CAD<sup>25</sup>. The group's syntax scores were classified as <22 (Group 1), 22-32 (Group 2), and > 32 (Group 3) as stated in the guideline. In multiple comparison tests, there was a significant difference only between Group 1 and Group 2 (Table 4). We initially thought that a decrease in peak systolic strain might correlate with a higher group, but no differences were found between the third group and others, likely due to its small size (n=4). Homogeneously distributed groups in future studies may reveal significant differences across all groups.

In our study, regional measurements were lower in the severe CAD group compared to the control group, aligning with previous research. However, no correlation was found between the ischemic coronary artery and low regional values, potentially due to differences among coronary arteries, collateral vessels, and microvascular dysfunction. Thus, we advise against using this for lesion prediction. While echocardiography remains controversial due to interpretation challenges, advancements in analysis programs and automatic calculations have made it easier for even inexperienced users to perform image evaluations.

Another issue to be analyzed should be artificial intelligence. Today, there are some studies on the use of artificial intelligence in CAD<sup>26</sup>. Probably, artificial intelligence support will be added to strain echocardiography as well as all imaging techniques in the future. In this way, even more optimal results will be obtained. Recent studies are showing the superiority of

coronary computed tomography and MPS over each other<sup>27</sup>. In the future, strain echocardiography will be developed in addition to these examinations and its use will become widespread in the pre-diagnosis.

### Study Limitations

Our study has some limitations. There was a difference in gender distribution between groups, and diabetes, which can affect microvascular values, was more common in the severe CAD group. Therefore, a larger study can be planned in a more homogeneous population for these two conditions. Although analysis provides more quantitative and accurate results than visual analysis, it is an operator-dependent technique. It is therefore subject to operator error and subjective assessment. Furthermore, patient echocardiographic image quality varies with many factors, and some images are difficult to process. Our study is prospective and cross-sectional. Multicenter trials with larger patient groups can be designed to overcome these limitations and provide clearer results.

### CONCLUSION

In our study, values were lower and significant in all layers in patients with suspected CAD and without wall motion disorder in TTE.

Especially, in patients with preserved LVEF, 2DSTE resting layer-specific GLS was significantly reduced in all myocardium layers in patients with significant CAD. Strain echocardiography will be very useful in diagnosis and follow-up, in addition to ECG, biochemical markers, and standard echocardiographic measurements.

The technique of speckle-tracking echocardiography is open to research and needs to be developed. In this way, it provides advanced patient management in diagnosis, treatment, and follow-up, and it gives us a new perspective on the physiology of the heart.

### Ethics

**Ethics Committee Approval:** The Trakya University Ethics Committee approved this study (decision no: 2018/384-18/26, date: 05.11.2018). Our study was conducted following the Declaration of Helsinki.

**Informed Consent:** Retrospective study

### Footnotes

### Authorship Contributions

Surgical and Medical Practices: Ç.K., Concept: Ç.K., M.Y., Design: Ç.K., M.Y., S.K., H.Y.G., Data Collection or Processing: Ç.K., M.Y.,

S.K., Analysis or Interpretation: Ç.K., S.K., Literature Search: Ç.K., M.Y, H.Y.G., Writing: Ç.K., M.Y, H.Y.G., S.K.

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