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# The Application Value of Speckle Tracking Imaging in Patients with Coronary Artery Disease without Regional Wall Motion Abnormalities

**Yu Dong[1†], Ao Sun[1†], Qian Hu[1], Tong Lin[1], Wenxiu Wang[2], Qingxiong Yue[1]***

[1]Department of Ultrasound, Central Hospital of Dalian University of Technology, Dalian 116000, Liaoning, China
[2]Department of Ultrasound, Dalian Public Health Clinical Center, Dalian 116000, Liaoning, China
[†]These authors contributed equally to this work and share the first authorship.

***Corresponding author:** *Qingxiong Yue, bjy77@163.com*



**Abstract:** *Objective:* To delve into the merit of employing speckle tracking imaging (STI) for procuring left ventricular function metrics in assessing coronary artery disease (CAD) without regional wall motion abnormalities (RWMA). *Methods:* A combined tally of 175 patients subjected to coronary angiography (CAG) in the Central Hospital of Dalian University of Technology from December 2023 to August 2024 were selected. As suggested by the findings derived from CAG, the patients were divided into three groups by the Gensini scoring system: the mild stenosis group ($n$ = 58, Gensini score ≤ 28), the moderate stenosis group ($n$ = 54, Gensini score > 28 and < 55), and the severe stenosis group ($n$ = 63, Gensini score ≥ 55). In addition to conventional ultrasound measurements of cardiac parameters, global work efficiency (GWE), global myocardial work index (GWI), global longitudinal strain (GLS) were measured. *Results*: No statistical contrast came to light in the general baseline specifics among mild, moderate, and severe stenosis groupings (all $P$-values exceed 0.05); Data validated striking divergences in LVEF, GLS, GWI, and GWE across the three groups (all $P$-values below 0.05), the absolute values of these parameters demonstrated a significant reduction in the severe stenosis group ($P$-value below 0.05). GWE, GWI, GLS, and LVEF illustrated a dramatic link with the Gensini score ($P$-value below 0.05). ROC curve analysis demonstrated that GLS had better sensitivity, while GWE exhibited higher specificity. *Conclusion:* STI can evaluate left ventricular function without RWMA in CAD patients, and has predictive value for severe CAD.

**Keywords:** Speckle tracking imaging; Coronary artery disease; Ventricular function; Myocardial work; Longitudinal strain rate

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## 1. Introduction

The incidence and mortality rates of CAD have shown a continuous upward trend over the past decade, posing a serious threat to public health. With the acceleration of population aging, the increased burden on healthcare systems imposes heavy costs on both the nation and families, making early detection and diagnosis of CAD particularly crucial [1]. However, in the early stages of CAD before myocardial infarction occurs, the left ventricular ejection fraction (LVEF) is preserved at rest without RWMA, posing challenges for early CAD diagnosis [2]. Currently, CAD diagnosis primarily relies on CAG, but this invasive procedure carries inherent risks [3].

Studies have shown that global longitudinal strain (GLS) derived from two-dimensional speckle tracking imaging (2D-STI) alone can achieve comparable diagnostic outcomes to stress echocardiography [4]. Mahjoob *et al.* [5] also found that GLS > -18% was significantly associated with the presence of CAD, demonstrating high sensitivity and accuracy for diagnosing CAD. Furthermore, additional studies indicated that GLS, LVEF, global work index (GWI), global comprehensive work (GCW), global wasted work (GWW), and GWE are all closely correlated with CAD severity and can predict CAD before invasive angiography [6,7]. On that account, this investigation is predominantly intended to figure out the value of parameters obtained based on STI in evaluating left ventricular function in CAD individuals free from RWMA.

## 2. Material and methods

### 2.1. Subject characteristics and classification rationale

In the time frame from December 2023 to August 2024, 175 patients experiencing chest pain and having CAG performed at the Central Hospital of Dalian University of Technology were recruited for this research. Inclusion criteria: (1) Age ≥ 18 years old; (2) Routine echocardiography showed no RWMA and (LVEF ≥ 55%, and CAG was performed within 24 hours after the echocardiographic examination; (3) Good image quality with clear visualization of the left ventricular endocardium. Exclusion criteria: (1) Congenital heart disease, severe arrhythmia, cardiomyopathy, or valvular heart disease; (2) History of cardiac pacemaker implantation or other cardiac surgery; (3) Complicated with cor pulmonale, thyroid dysfunction, severe liver disease, kidney disease, or other comorbidities.

Taking the CAG findings as a basis, the level of coronary artery obstruction was appraised through the utilization of the Gensini score system [8,9]. With reference to the tertile-focused categorization tactic [10], the patients were split into three separate factions: the mild stenosis faction (*n* = 58, where the Gensini score does not surpass 28), the moderate stenosis faction (*n* = 54, with the Gensini score lying within the 28–55 interval), and the severe stenosis faction (*n* = 63, having a Gensini score of 55 or above).

This investigative endeavor was granted the green light by the Ethics Committee of the Affiliated Central Hospital of Dalian University of Technology (Dalian Central Hospital) (Approval No.: YN2022-096-01).

### 2.2. Clinical and biochemical data

The gender, age, height, weight and history of related diseases were collected for all participants, and each participant's body surface area (BSA, $m^2$) and body mass index (BMI, $kg/m^2$) were calculated. We measured the blood pressure after the patients were seated quietly for 10–15 minutes. Blood samples were collected in the morning after overnight fasting, Serum creatinine (Scr), Total cholesterol (TC) and High-Density Lipoprotein Cholesterol (HDL-C), Low-Density Lipoprotein Cholesterol (LDL-C) were measured.

## 2.3. Conventional echocardiography measurements

The patients were placed in the left lateral decubitus position during a continuous recording using a three-lead electrocardiography. Conventional echocardiography was performed using a GE Vivid E95 scanner equipped with an M5S-D probe (1.5–4.5 MHz), the frame rate was adjusted to 35–70 frames per second.

The study documented typical two-dimensional visuals of three sequential cardiac cycles, obtaining the images from the apical four-chamber, two-chamber, three-chamber, and long-axis angles. Meanwhile, the patients were engaging in soft and relaxed breathing. We measured the LV end-systolic diameter (LVDs), left atrial maximum volume (LAV), left atrial end-systolic diameter (LAD) and LV end-diastolic diameter (LVDd) were measured. The left atrial volume index (LAVI) was calculated (LAVI = LAVmax/BSA), and LVEF was obtained using the biplane Simpson's method.

Conforming to the norms laid down in the guidelines of the American Society of Echocardiography [11], and taking the standard apical four-chamber vantage point as a starting place, pulsed-wave Doppler was used to measure the early diastolic peak flow swiftness (E) and late diastolic peak flow swiftness (A) were measured at the mitral valve passageway, and following that, EA coupled ratio was worked out; The peak tissue motion rates (e') at the septal aspect as well as the lateral periphery of the mitral annulus were quantified respectively, and the arithmetic mean e' value was utilized to work out the E/e' ratio.

## 2.4. STI measurements

Following the images having been kept and shipped out, offline evaluation was performed by means of the EchoPAC workstation: Enter the automatic functional imaging (AFI) mode to measure the global longitudinal strain (GLS); meanwhile, record and evaluate the valve timing events from the dynamic images of the apical three-chamber view, input the previously measured blood pressure values, and obtain the left ventricular pressure-strain loops and left ventricular global myocardial work images, then record the GWI and GWE.

To test intra- and inter-observer reproducibility of LV strain analyses by Speckle-tracking imaging, 15 patients were randomly selected from the study subjects. Two senior physicians analyzed the images to test the inter-observer reproducibility. The same physician re-analyzed the images of the same patients two weeks later. All variations were evaluated using the ICC.

## 2.5. Statistical analysis

Systematic numerical examination was performed by employing the Statistical Package for Social Sciences (SPSS) 27.0.1 software. Before analyzing the continuous variables, the normal distribution of the continuous variables with the normality test was determined using the Kolmogorov-Smirnov test. Normally distributed continuous data were expressed as mean ± standard deviation (SD). In the case of data that did not follow a normal distribution, an in-depth analysis was carried out. The non - non-parametric Kruskal-Wallis test was employed for this purpose. Categorical variables were presented in the form of frequency, expressed as a percentage (%). Subsequently, an analysis was conducted employing the Pearson $\chi^2$ test. When it came to the analysis of normally-distributed data from three groups, one-way ANOVA was implemented. Meanwhile, the Bonferroni test was adopted for simultaneous multiple comparisons. For the purpose of gauging how diverse ultrasound metrics are bound up with the Gensini score, Spearman correlation analysis was put into use. Receiver operating characteristic (ROC) curve analysis served as the means to gauge the prognostic significance of each STI parameter for those experiencing severe coronary artery stenosis. Whether intra-observer correlates with inter-observer was computed by employing the intraclass correlation coefficient (ICC).

# 3. Result

## 3.1. Clinical characteristics

No differences in TC, age, sex, Scr, HDL-C, and LDL-C were identified among the three groups (*P*-value over 0.05) (**Table 1**).

**Table 1.** Baseline characteristics of the study sample

| Variables | Mild stenosis group (*n*=58) | Moderate stenosis group (*n* = 54) | Severe stenosis group (*n* = 63) | *P* value |
|---|---|---|---|---|
| Age (y) | 63.00 ± 9.57 | 66.00 ± 8.87 | 64.67 ± 8.53 | 0.21 |
| Sex | | | | 0.754 |
| Male, *n* (%) | 33 (55.9) | 32 (60.4) | 40 (40.0) | |
| Female, *n* (%) | 26 (44.1) | 21 (39.6) | 23 (60.0) | |
| BMI (kg/m$^2$) | 25.93 ± 3.47 | 26.03 ± 3.89 | 25.84 ± 3.04 | 0.95 |
| Hypertension, *n* (%) | 30 (50.8) | 34 (64.2) | 35 (5.6) | 0.36 |
| diabetes, *n* (%) | 22 (37.3) | 14 (26.4) | 19 (30.2) | 0.45 |
| Smoke, *n* (%) | 11 (18.6) | 10 (18.9) | 13 (20.6) | 0.96 |
| Drink, *n* (%) | 5 (8.5) | 5 (9.4) | 9 (14.3) | 0.54 |
| TC (mmol/L) | 4.86 ± 1.12 | 4.41 ± 1.05 | 4.57 ± 1.00 | 0.08 |
| LDL-C (mmol/L) | 2.90 ± 0.89 | 2.84 ± 1.01 | 2.82 ± 0.93 | 0.89 |
| HDL-C (mmol/L) | 1.02 ± 0.25 | 0.95 ± 0.20 | 0.94 ± 0.18 | 0.09 |
| Scr (umol/L) | 69.36 ± 17.96 | 71.16 ± 21.86 | 71.95 ± 22.05 | 0.96 |

BMI: Body mass index; TC: Total cholesterol; HDL-C: High-Density Lipoprotein Cholesterol; LDL-C: Low-Density Lipoprotein Cholesterol; Scr: Serum creatinine.

## 3.2. Cardiac functional assessment features

**Table 2** displays the traits of cardiac ultrasonography for the research subjects. Regarding routine echocardiographic parameters, no conspicuous distinctions at the statistical level were observed in LAD, LAVI, E/A ratio, E/e' ratio, and LVDs, LVDd among the three groups ($P > 0.05$). The absolute values of LVEF, GLS, GWI, and GWE demonstrated a significant reduction in the severe stenosis group (*P*-value below 0.05), and these parameters progressively decreased across the three groups with increasing severity of coronary artery lesions (**Table 2**, **Figure 1**).

**Table 2.** Echocardiographic parameters of the study sample

| Variables | Mild stenosis group (*n* = 58) | Moderate stenosis group (*n* = 54) | Severe stenosis group (*n* = 63) | *P* value |
|---|---|---|---|---|
| LAD (mm) | 38.59 ± 3.91 | 38.34 ± 3.87 | 37.87 ± 3.80 | 0.58 |
| LVDd (mm) | 48.97 ± 4.90 | 48.13 ± 6.12 | 48.03 ± 5.86 | 0.84 |
| LVDs (mm) | 31.12 ± 11.96 | 29.51 ± 9.29 | 28.56 ± 9.39 | 0.097 |
| LAVI | 28.34 ± 3.16 | 26.88 ± 3.37 | 26.86 ± 3.45 | 0.181 |
| E/A | 0.84 ± 0.13 | 0.85 ± 0.14 | 0.89 ± 0.16 | 0.084 |
| E/e’ | 12.17 ± 4.08 | 10.56 ± 3.05 | 10.89 ± 3.09 | 0.046 |
| LVEF (%) | 67.39 ± 3.71 | 62.08 ± 4.56* | 57.02 ± 4.52*▲ | < 0.001 |
| GLS (%) | -19.06 ± 1.93 | -17.65 ± 2.02* | -15.88 ± 2.40*▲ | < 0.001 |
| GWI (mmHg%) | 1975.90 ± 227.47 | 1850.91 ± 287.15* | 1608.73 ± 281.29*▲ | < 0.001 |
| GWE (%) | 93.36 ± 2.16 | 91.38 ± 4.09* | 88.86 ± 5.46*▲ | < 0.001 |

**P*-value below 0.05 versus the mild stenosis group. ▲*P*-value below 0.05 versus the moderate stenosis group.

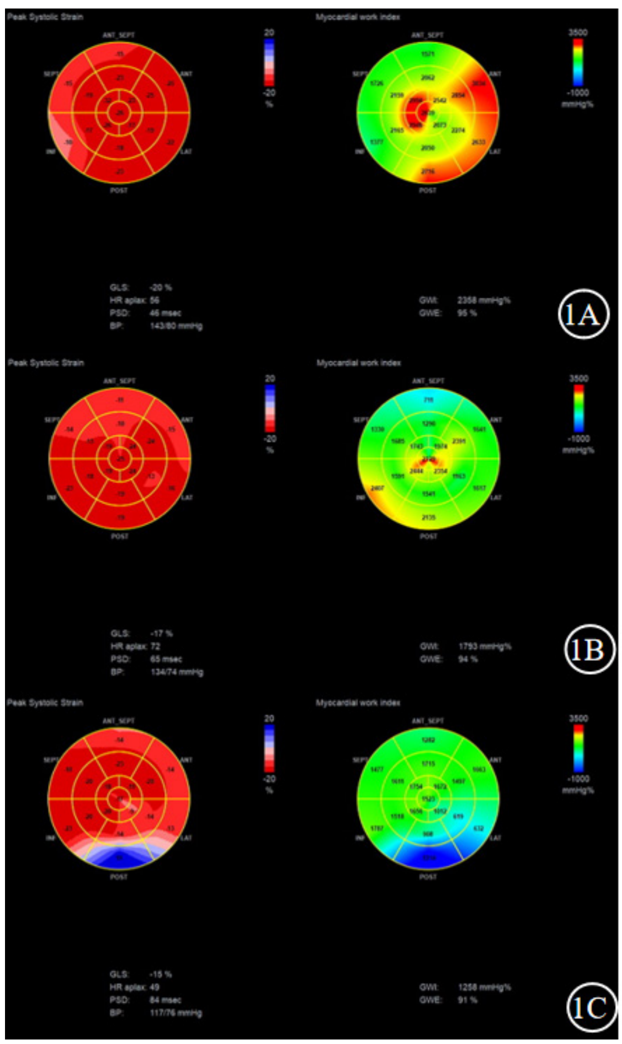


**Figure 1.** Left ventricular longitudinal strain and myocardial work.Examples of patients from: (1A) mild stenosis group, (1B) moderate stenosis group, (1C) severe stenosis group. Each graph shows the bull’s eye map of segmental longitudinal strain and myocardial work index.

## 3.3. Correlations between the Gensini score and LV function parameters

The correlations between the four parameters and the Gensini score are shown in **Figure 2**. LVEF, GWE, GLS, and GWI were all bound up with the Gensini score ($P$-value below 0.05). Specifically, LVEF ($r = -0.714$, $P < 0.01$), GWI ($r = -0.756$, $P < 0.01$), and GWE ($r = -0.775$, $P < 0.01$) demonstrated substantial and negative correlations, whereas GLS ($r = 0.742$, $P < 0.01$) illustrated a conspicuous and positive link with the Gensini score.

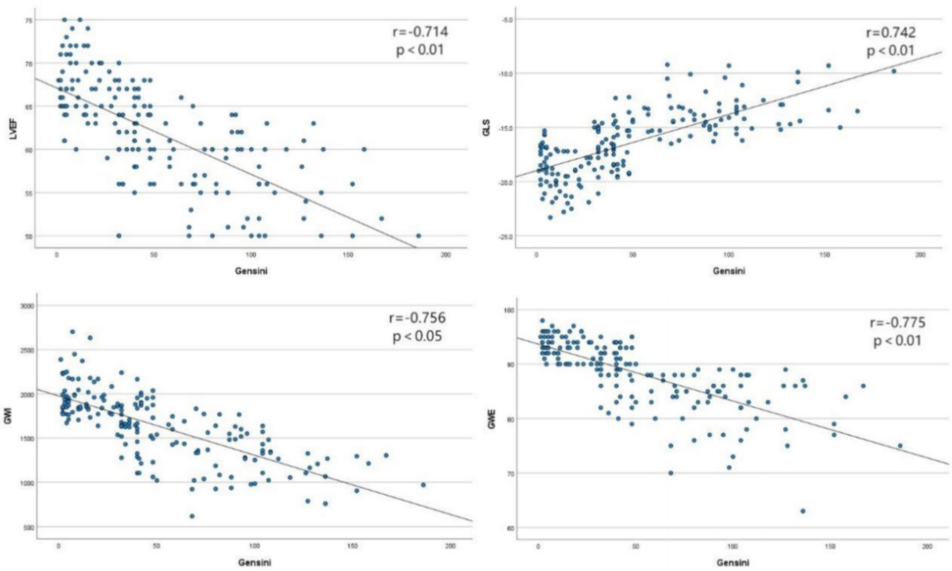


**Figure 2.** Spearman's correlation coefficient analysis to assess the strength of association between the Gensini score and LV function parameters.

## 3.4. ROC curve analysis

As displayed in **Figure 3**, the area under the ROC curve (AUC) for GLS was 0.830, with an optimal cutoff value of -17.1% for predicting high-risk coronary artery disease patients, yielding a sensitivity of 81.0% and specificity of 74.7%. For GWI, the AUC was 0.819, with an optimal cutoff value of 1689 mmHg%, achieving a sensitivity of 76.0% and specificity of 81.3%. The AUC for GWE was 0.863, with a cutoff value of 90%, resulting in a sensitivity of 76.0% and specificity of 82.7%.

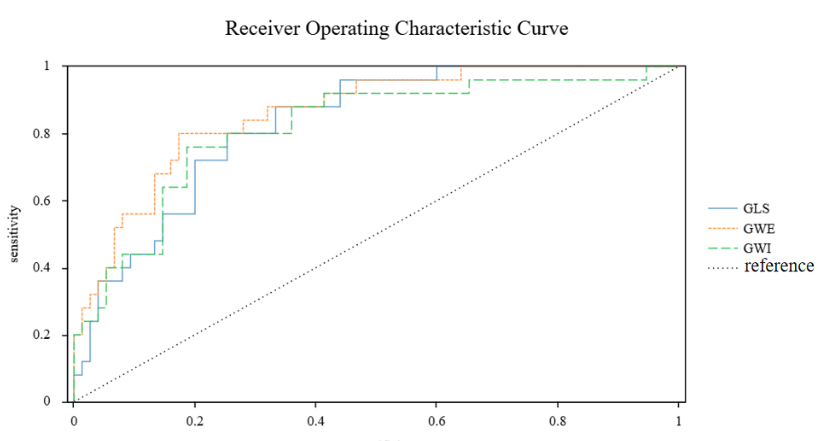


**Figure 3.** ROC curve on the predictive significance of the STI parameter for the individuals enduring severe coronary artery stenosis.

## 3.5. Reproducibility

For GLS, GWI, and GWE, the intra-observer intraclass correlation coefficients (ICC) registered as 0.93, 0.98, and 0.90 correspondingly. And the inter-observer ICCs came to 0.91, 0.73, and 0.80 in turn. These outcomes suggest superb consistency for these indices.

# 4. Discussion

CAD is a prevalent clinical condition, with its incidence showing an upward trend in recent years, significantly impacting patients' quality of life [12]. When coronary artery stenosis occurs, blood perfusion to the corresponding myocardial area decreases. The active relaxation process of the myocardium requires oxygen consumption. During myocardial diastole, hypoxia leads to restricted relaxation, accompanied by various pathological changes such as myocardial energy metabolism disorders and microcirculatory dysfunction, which collectively promote increased myocardial stiffness. Concurrently, diminished myocardial deformation capacity during systole shortens ejection time, further exacerbating myocardial perfusion insufficiency. This intensifies ischemia and hypoxia, simultaneously impairing myocardial contractile function [13].

However, in clinical examinations, it is found that some stable CAD individuals are free from RWMA and their LVEF remains within the normal range, and such CAD patients are often overlooked, leading to delayed treatment [14]. Although CAG remains the "gold standard" for diagnosing CAD, its invasive nature and complexity limit its applicability for early clinical screening. Conventional echocardiographic parameters fail to comprehensively and early reflect true changes in ventricular function and myocardial work. Therefore, identifying more accurate and convenient methods for the early detection of individuals suffering from severe CAD is a critical clinical challenge.

GLS as a parameter for assessing ventricular systolic function outperforms LVEF in evaluating subclinical myocardial injury and patient prognosis [15]. GLS is a quantitative analysis method based on 2D-STI. Unlike conventional tissue Doppler techniques, it is angle-independent. GLS evaluates myocardial systolic and diastolic function by performing speckle tracking of myocardial motion [16]. Myocardial ischemia and hypoxia resulting from coronary stenosis predominantly affect the subendocardial layer first, before extending to the mid-myocardial and subepicardial layers. In the early stage, due to impaired perfusion in the subendocardium, myocardial deformation capacity decreases, leading to a reduction in regional myocardial work. However, since the global left ventricular systolic function remains preserved at this point, it may not result in RWMA [17].

Studies indicate that a preserved LVEF does not equate to normal cardiac function in CAD patients, as GLS often shows significant abnormalities, signaling early impairment like reduced strain [18]. The study found that despite an LVEF >50% in all patients, nearly one-third had severe stenosis requiring intervention, and all exhibited GLS reduction. Furthermore, GLS demonstrated a statistically significant difference among the mild, moderate, and severe groups (P-value below 0.05), decreasing progressively with increasing CAD severity.

Myocardial work, which integrates myocardial strain and cardiac afterload, enhances diagnostic sensitivity and accuracy [19]. Studies have shown that GWI correlates well with ventricular systolic function, and myocardial work parameters can correct GLS for afterload variations [20]. In the correlation analysis, GLS, GWI, and GWE had the highest correlation coefficient with the Gensini score. Therefore, the study suggests that the STI parameter was more closely to disease burden and risk factors in CAD patients. Our study also found that GLS, GWI, and GWE were significantly reduced in the severe stenosis group. The ROC curves demonstrated that the STI parameter has a significant discriminative ability to predict individuals suffering from severe CAD. The AUC for GWE was 0.863, with a cutoff value of 90% (sensitivity: 76.0% and specificity: 82.7%), GWE exhibited higher specificity.

GWE is a key parameter reflecting cardiac pumping function, representing the proportion of myocardial work converted into effective work [21].

As research findings validated, GWE had superior sensitivity for predicting severe coronary artery stenosis compared to other parameters and serves as an isolated anticipation index of myocardial work in individuals suffering from severe stenosis, which coincides tremendously with the findings reported by Wang *et al.* [22]. With the augmentation of the degree linked to coronary artery stenosis, GWE gradually decreases. When coronary forward blood flow is severely obstructed, the corresponding myocardium supplied by that artery loses partial or even complete contractile capacity. This results in reduced shortening of myocardial fibers during systole, decreased effective work, increased lengthening of myocardial fibers, and decreased GWI and GWE [23].

## 5. Limitations

The limitations of this study include: (1) High image quality requirements, limiting its application in individuals suffering from excessive lung inflation or narrow intercostal spaces; (2) The regional work in the specific territory of the culprit vessel was not further assessed, which may have introduced some influence on the results. Future studies with an expanded sample size are planned to obtain more objective and accurate information.

## 6. Conclusion

In conclusion, STI parameters can assess left ventricular function in CAD individuals free from RVAW, while also providing an important reference value for predicting severe coronary artery stenosis.

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## Disclosure statement

The authors declare no conflict of interest.

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