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Original Article

Predictive value of speckle tracking technique for coronary artery stenosis in patients with coronary heart disease

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Abstract: Objective: To observe the predictive value of speckle tracking technique (STI) for the degree of coronary artery stenosis in patients with coronary heart disease (CHD). Methods: The clinical data of 120 patients with coronary artery stenosis admitted to Affiliated Hospital of Chengde Medical University from Feb. 2022 to Sep. 2022 was analyzed retrospectively. The other 63 patients who sought for medical help because of chest pain underwent Coronary Arteriography (CAG) examination during the same period but with Gensini score > 0 were selected as the control group. Coronary artery stenosis was divided into three subgroups according to the coronary Gensini score: mild, moderate, and severe stenosis. Routine ultrasound and STI techniques were performed in all patients. In addition, left ventricular global radial peak systolic strain (GRS), left ventricular global longitudinal peak systolic strain (GLS), left ventricular global peak systolic strain (GAS) and left ventricular global circumferential peak systolic strain (GCS) were measured and compared between the two groups and among the three subgroups. Results: There were no marked differences identified in conventional ultrasound parameters between the coronary artery stenosis group and control group, but the absolute values of GLS, GRS, GCS, and GAS were lower in the former group compared to control group; and the severe group had the lowest levels of above indexes, followed by moderate group, then mild group and control group (all $P < 0.05$). The results showed that the area under the curve (AUC) for GLS, GRS, GCS, and GAS in diagnosing coronary artery stenosis were 0.973, 0.933, 0.947, and 0.901, respectively. The AUCs of GLS, GRS, GCS, and GAS for the diagnosis of moderate/severe coronary artery stenosis were 0.968, 0.908, 0.901, and 0.942, respectively, with GAS and GLS assessed with the largest AUC values and higher sensitivity and specificity than other parameters. Conclusion: The global longitudinal strain of left ventricle obtained by STI technique was more sensitive to coronary artery stenosis than that by ultrasound technique, and it had a higher predictive value for coronary artery stenosis.

Keywords: Speckle tracking technique, coronary heart disease, coronary artery stenosis, predictive value

Introduction

With the improvement of living standards and lifestyle, the incidence of coronary heart disease (hereinafter referred to as CHD) shows an upward trend yearly with a gradually younger age of onset [1]. Coronary atherosclerotic stenosis can lead to myocardial tissue ischemia and hypoxia, which causes ventricular dysfunction, with left ventricular involvement being the most common [2]. Therefore, it is critical to evaluate patient's condition as early as possible and provide a more targeted treatment for CHD patients.

In recent years, coronary angiography (CAG) has been clinically applied as the gold standard for CHD diagnosis, and the application in percutaneous coronary intervention has also gradually been favored, bringing certain benefits to both patients and doctors [3, 4]. However, being an invasive test, CAG has limitations in the diagnosis and screening of CHD [5]. Finding a noninvasive method to screen coronary artery lesions therefore has important clinical significance in reducing cardiac mortality and improving prognosis. In recent years, ultrasonography has been widely adopted because of its convenience and repeatability. Although it has achieved a good application effect, the traditional ultrasonic Doppler examination based on two-dimensional ultrasound examination cannot evaluate the cardiac systolic function very precisely because cardiac movement is performed in a three-dimensional space, thereby resulting in parameter errors [6, 7]. Speckle tracking (STE) is a new noninvasive and simple method to assess myocardial motion, of which three-dimensional speckle tracking imaging (3D-STE) can track the three-dimensional spatial motion of myocardial speckle in real time, so as to more accurately evaluate myocardial regional and global myocardial motion [8, 9]. However, there are relatively few comprehensive studies on the comparison of the performance of STE technology and B-ultrasound and its assessment of the degree of coronary artery stenosis.

In this study, we adopted STE technique to obtain global longitudinal strain parameters of the left ventricle to assess the severity of coronary artery stenosis in CHD patients, so as to provide more reference ideas for future CHD diagnosis.

Materials and methods

Clinical data

The clinical data of 120 patients with coronary artery stenosis admitted to Affiliated Hospital of Chengde Medical University from February 2022 to September 2022 were retrospectively analyzed. The other 63 patients sought medical help because of chest pain and underwent CAG examination but were assessed with Gensini score [10] > 0 during the same period and they were enrolled as the control group. The final cause of their chest pain was found to be either pleurisy or pericarditis. The degree of coronary artery stenosis was evaluated according to the coronary Gensini score. Patients with coronary artery stenosis were divided into three subgroups: mild stenosis group (39 cases) (Gensini score < 25 points), moderate stenosis group (50 cases) (Gensini score 25 to 50 points), and severe stenosis group (31 cases) (Gensini score > 50 points). Routine ultrasound and STI techniques were performed in all patients.

Inclusion criteria: Patients with coronary artery stenosis confirmed by CAG; patients without history of myocardial infarction and PCI; patients with complete case data; patients who had undergone routine ultrasonography and STI examination. Exclusion criteria: patients with any concomitant myocardial disease (including heart failure); previous history of myocardial infarction; combined severe heart valve disease; combined arrhythmia; combined malignant tumor disease; or combined liver and kidney dysfunction. This study was in accordance with the Helsinki Declaration and approved by the ethics committee of Affiliated Hospital of Chengde Medical University.

Instrument

Philips EPIQ 7C color Doppler ultrasound diagnostic apparatus was used. Two-dimensional S5-1 cardiac probe with a frequency of 1.4-2.8 MHz, and real-time three-dimensional full-volume X5-1 probe with the frequency of 1.6-3.2 MHz were applied.

Inspection method and data extraction

All patients were instructed to lie in the left lateral decubitus position and connected to the electrocardiogram. Cross-sectional images of the parasternal left ventricle were collected using a S5-1 two-dimensional probe to measure left ventricular end-diastolic volume (EDV), end-systolic volume (ESV), early diastolic mitral inflow velocity (E), late diastolic mitral inflow velocity (A) and early diastolic mitral annular velocity (e') and left ventricular ejection fraction (LVEF). Then the probe was switched to X5-1 three-dimensional volume probe to collect apical four-chamber heart in full volume mode and to store three-dimensional full volume dynamic diagram of heart. After weaning, the corresponding three-dimensional full-volume dynamic map of the heart was extracted, three-dimensional speckle tracking mode was selected, the image baseline and angle were adjusted, with endocardium, mitral annulus, apex and other parts clearly displayed and with the left and right mitral annuli and apex marked by speckles. Once the software was started, the automatic ultrasound echo speckle tracking was performed by the system to depict the endocardial curve. Indexes of the global long-axis peak systolic strain (GLS) of the left ventricle, global radial peak systolic strain (GRS) of the left ventricle, global circumferential peak systolic strain (GCS), and global peak systolic strain (GAS) of the left ventricle were subse-

Table 1. Comparison of general data

Variables	Coronary artery stenosis group n=120	Control group n=63	t/χ^2	P
Gender			0.067	0.795
Male	70 (58.33)	38 (60.32)		
Female	50 (41.67)	25 (39.68)		
Age (years)			0.540	0.462
≥ 65	56 (46.67)	33 (52.38)		
< 65	64 (53.33)	30 (47.62)		
Body mass index (kg/m^2)			0.001	0.996
≥ 23	61 (50.83)	32 (50.79)		
< 23	59 (49.17)	31 (49.21)		
Smoking history			0.011	0.917
Yes	81 (67.50)	43 (68.25)		
No	39 (32.50)	20 (31.75)		
Alcohol history			0.005	0.943
Yes	66 (55.00)	35 (55.56)		
No	54 (45.00)	28 (44.44)		
Diabetes			0.155	0.694
Yes	63 (52.50)	35 (55.56)		
No	57 (47.50)	28 (44.44)		
Hypertension			0.023	0.880
Yes	71 (59.17)	38 (60.32)		
No	49 (40.83)	25 (39.68)		
Degree of coronary stenosis				
Mild stenosis	39 (32.50)	-		
Moderate stenosis	50 (41.67)	-		
Severe stenosis	31 (25.83)	-		

quently measured. Then, by analyzing the diagnostic receiver operating characteristic (ROC) of GLS, GRS, GCS, and GAS, the diagnostic value of STI for carotid artery stenosis was determined.

Statistical methods

SPSS 19.0 statistical software was used for statistical analysis. The results were expressed as mean ± standard deviation. Student t-test or One-way analysis of variance was used for comparison between two groups or among multiple groups. Enumeration data were expressed as percentage and detected with χ^2 test. The sensitivity and specificity of each index in CHD diagnosis were analyzed by ROC curve analysis, ROC curves were compared using the DeLong test, and sensitivity and specificity were compared using the 3-dimensional squared paired chi-squared test. A statistical difference was determined when $P < 0.05$.

Results

General data comparison

There was no evident difference in terms of gender, age, BMI and other data between the two groups (all $P > 0.05$, **Table 1**), and subjects were reasonably comparable.

Routine ultrasound parameters

There were no significant differences in conventional ultrasound parameters between patients with coronary artery stenosis and those without (all $P > 0.05$, **Table 2**).

Comparison of STI parameters between the two groups

Absolute values of GLS, GRS, GCS, and GAS in patients with coronary artery stenosis were lower than those in their counterparts (all $P < 0.05$, **Table 3**; **Figure 1**).

Table 2. Comparison of routine ultrasound parameters

Parameter	Coronary artery stenosis group n=120	Control group n=63	t	P
EDV (ml)	88.82±4.2	89.24±4.34	0.635	0.526
ESV (ml)	35.55±3.86	34.89±3.56	1.128	0.261
E (cm/s)	78.05±4.13	76.97±3.66	1.746	0.083
A (cm/s)	83.92±3.81	83.8±4.81	0.185	0.854
LVEF (%)	62.73±4.09	62.97±3.82	0.386	0.700

EDV, end-diastolic volume; ESV, end-systolic volume; E, early diastolic mitral inflow velocity; A, late diastolic mitral inflow velocity; LVEF, left ventricular ejection fraction.

Table 3. Comparison of STI parameters between the two groups

Parameter	Coronary artery stenosis group n=120	Control group n=63	t	P
GLS	-18.19±2.2	-25.97±1.89	23.82	< 0.001
GRS	34.64±2.24	46.22±2.2	33.43	< 0.001
GCS	-22.91±2.31	-31.39±5.03	15.62	< 0.001
GAS	-35.46±4.22	-44.13±5.31	12.06	< 0.001

GRS, global radial peak systolic strain; GLS, left ventricular global longitudinal peak systolic strain; GAS, left ventricular global peak systolic strain; GCS, left ventricular global circumferential peak systolic strain.

Comparison of STI parameters among patients with different degrees of coronary artery stenosis

In the coronary artery group, all 3D-STI parameters were markedly lower in the severe coronary artery stenosis group those in the other 2 groups (all $P < 0.05$); and it is noticeable that all these four indexes were lower in the moderate coronary artery stenosis group than those in the mild one (all $P < 0.05$), as detailed in **Table 4**.

Analysis of the diagnostic value of 3D-STI parameters for coronary artery stenosis with CAG as the gold standard for diagnosing coronary heart disease, the diagnostic value of 3D-STI parameters, including GLS, GRS, GCS and GAS, in diagnosing coronary artery stenosis was evaluated. The results showed that the AUCs for GLS, GRS, GCS, and GAS in diagnosing coronary artery stenosis were 0.973, 0.933, 0.947, and 0.901, respectively. All AUC values were greater than 0.9, indicating a high diagnostic performance (**Table 5**; **Figure 2**).

Predictive value of STI parameters in CHD patients with different degrees of stenosis

Using CAG results as the gold standard for CHD diagnosis, 3D-STI parameters such as GLS, GRS, GCS, and GAS were used to differentiate different degrees of coronary artery stenosis, with ROC curves established subsequently. The results showed that the AUCs of GLS, GRS, GCS, and GAS for differentiating moderate/severe coronary artery stenosis were 0.968, 0.908, 0.901, and 0.942, respectively, with the AUC values of GAS and GLS being the highest, of which the sensitivity and specificity were higher than other parameters (**Table 6**; **Figure 3**).

Discussion

CHD, a common clinical disease, poses an increased incidence in recent years that seriously affects the life quality of patients [11]. However, due to the strong compensatory ability of the coronary arteries, CHD patients often experience typical clinical manifestations after many years of onset and thereby overlook the best time for prevention and treatment [12]. Echocardiography has long been an important means to examine myocardial function and cardiac blood flow supply, for it can effectively determine whether there are functional abnormalities in the myocardium [13]. However, traditional echocardiography, based on two-dimensional planar diagnostic techniques, cannot evaluate cardiac systolic function accurately because it is often affected by the angle of wall motion during ventricular motion, resulting in errors in parameters [14]. Therefore, finding more accurate and convenient methods is an urgent clinical problem to be solved.

STI is a new technique based on two-dimensional ultrasound speckle tracking technique and real-time three-dimensional dynamic echocardiography. 3D-STI technology can assess strain in different directions of the left ventricle from a three-dimensional perspective, overcomes the shortcomings of two-dimensional speckle tracking imaging technology, and can directly quantify global strain and systolic function of the left ventricle by measuring peak strain in radial, longitudinal, and circumferential directions, providing richer information for assessing subclinical myocardial injury of the

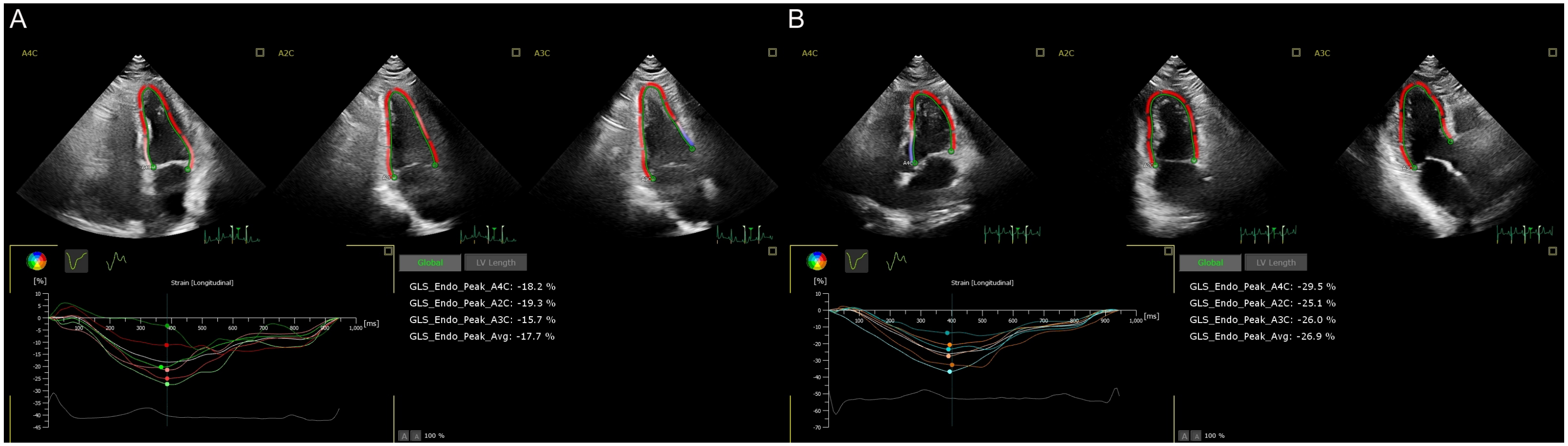

Figure 1. Sonogram of global peak systolic strain in patients. A: Patients with coronary artery stenosis; B: Patients without coronary artery stenosis.

Table 4. Comparison of STI parameters between the two groups

Parameters	Mild stenosis group n=39	Moderate stenosis group n=50	Severe stenosis group n=31	F	P
GLS	-20.41±1.44	-18.01±0.71	-15.67±1.64	124.1	< 0.001
GRS	36.84±1.5	34.63±1.12	31.89±0.9	144.6	< 0.001
GCS	-25.2±1.4	-22.79±1.49	-20.21±0.86	122.8	< 0.001
GAS	-39.89±2.57	-35.08±2.12	-30.48±1.93	154.7	< 0.001

GRS, global radial peak systolic strain; GLS, left ventricular global longitudinal peak systolic strain; GAS, left ventricular global peak systolic strain; GCS, left ventricular global circumferential peak systolic strain; STI, speckle tracking technique.

Table 5. Analysis of the diagnostic value of 3D-STI parameters for coronary artery stenosis

Predictors	AUC	95 CI%	Specificity	Sensitivity	Cut-off
GLS	0.973	0.949-0.997	97.50%	82.54%	-24.28
GRS	0.933	0.889-0.978	94.87%	74.60%	44.67
GCS	0.947	0.908-0.987	94.17%	82.58%	-27.01
GAS	0.901	0.852-0.950	90.83%	76.19%	-41.66

GRS, global radial peak systolic strain; GLS, left ventricular global longitudinal peak systolic strain; GAS, left ventricular global peak systolic strain; GCS, left ventricular global circumferential peak systolic strain; STI, speckle tracking technique.

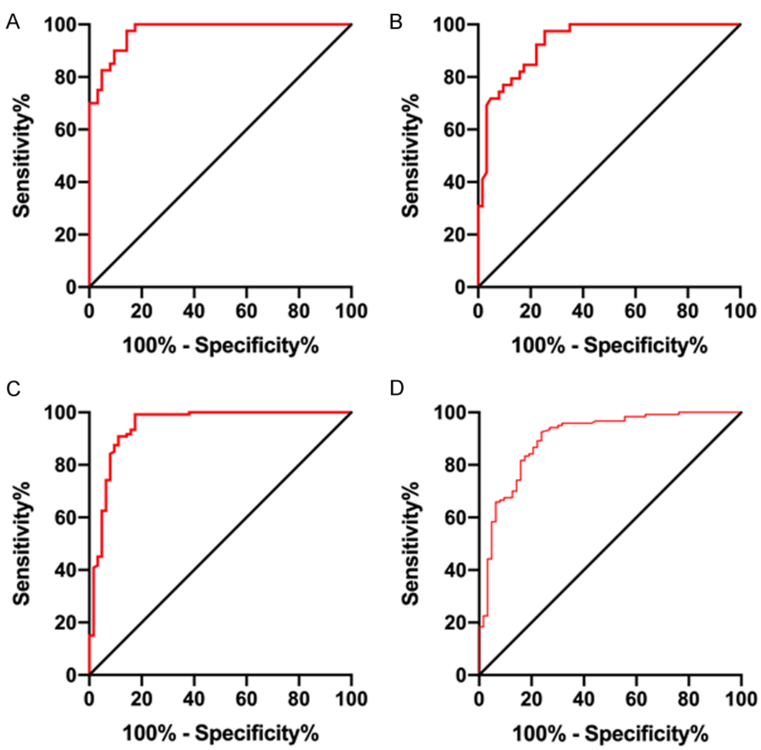

Figure 2. Analysis of the diagnostic value of 3D-STI parameters for coronary artery stenosis. A. ROC curve for GLS in the prediction of coronary artery stenosis; B. ROC curve for GRS in the prediction of coronary artery stenosis; C. ROC curve for GCS in the prediction of coronary artery stenosis; D. ROC curve for GAS in the prediction of coronary artery stenosis. GRS, Global radial peak systolic strain; GLS, left ventricular global longitudinal peak systolic strain; GAS, left ventricular global peak systolic strain; GCS, left ventricular global circumferential peak systolic strain; STI, speckle tracking technique.

left ventricle [15, 16]. Overall, STI technique measures cardiac strain and strain rate with less angular and subjective dependence and better reproducibility, which can evaluate the mechanical characteristics of myocardial contraction and relaxation more accurately, objectively and quantitatively, as well as reflecting myocardial motion [17]. Studies have shown that the sensitivity and accuracy of STI technique in CHD diagnosis are higher than those of wall motion scoring method [18]. In this study, there were no evident differences in conventional echocardiographic parameters between the coronary artery stenosis group and the control group, while differences existed in GLS, GRS, GCS, and GAS values between the two groups, suggesting that STI technique is more sensitive in the diagnosis of coronary artery stenosis.

Subsequently, we compared the STI parameters of patients with different degrees of coronary artery stenosis, and all STI parameters in the severe coronary artery stenosis group were observed to be significantly lower than those in the other two groups; and moderate coronary artery stenosis group had lower indexes of those parameters than those in the mild coronary artery ste-

Table 6. Predictive value of STI parameters in CHD patients with different degrees of stenosis

Predictors	AUC	95 CI%	Specificity	Sensitivity	Cut-off
GLS	0.968	0.918-1.000	94.87%	96.00%	-19.18
GRS	0.908*	0.842-0.974	87.17%	90.00%	35.44
GCS	0.901*	0.837-0.973	87.18%	90.00%	-23.92
GAS	0.942	0.882-1.000	92.31%	94.00%	-37.17

Note: *Compared with GLS and GAS, P < 0.05. GRS, global radial peak systolic strain; GLS, left ventricular global longitudinal peak systolic strain; GAS, left ventricular global peak systolic strain; GCS, left ventricular global circumferential peak systolic strain.

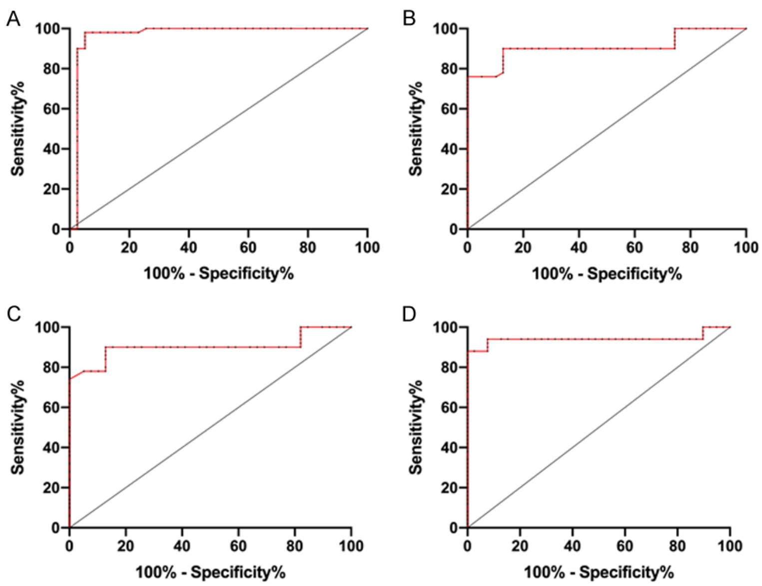

Figure 3. Predictive value of STI parameters in patients with moderate/severe CHD. A. ROC curve for GLS to differentiate moderate/severe stenosis; B. ROC curve for GRS to differentiate moderate/severe stenosis; C. ROC curve for GCS to differentiate moderate/severe stenosis; D. ROC curve for GAS to differentiate moderate/severe stenosis.

nosis group. This suggests that 3D-STI can comprehensively detect wall motion at all stages of the left ventricle, evaluate myocardial function changes more sensitively, and is conducive to clinical identification of moderate to severe coronary artery stenosis. It has also been clearly pointed out that 3D-STI can quantitatively evaluate left ventricular segmental and global systolic function and reflect the degree of coronary artery stenosis in CHD patients, which is consistent with our results [19]. The endocardium is the end of the coronary blood supply, and insufficient blood supply first occurs in the subendocardial myocardium when the coronary artery is stenotic, which manifests clinically as diminished longitudinal motion and further deepening of ischemia involving the central ring myocardium, eventually leading to diminished circumferential and radial motion [20, 21]. It has been found that when coronary artery stenosis exceeds 50%, the absolute value of myocardial strain decreases to varying degrees with the severity of stenosis [22], which is also consistent with our observations. We adopted ROC curve analysis to analyze the prediction of 3D-STI parameters for myocardial ischemia in CHD patients with different degrees of stenosis, and the results showed that the AUC of each parameter for the diagnosis of moderate-severe coronary artery stenosis was above 0.9, with GLS and GAS having the highest AUC values and higher sensitivity and specificity than other parameters. GLS values can reflect left ventricular longitudinal systolic function, and when coronary artery stenosis occurs, myocardial perfusion is insufficient and longitudinal systolic function is impaired; with the worsening of stenosis, myocardial ischemia in the corresponding area leads to myocardial ischemia. Although collateral circulation can partially improve the clinical symptoms in the early stage, myocardial blood flow will continue to be hypoperfused until decompensated, resulting in gradually aggravated myocardial systolic function impairment [23]. In addition, area strain represents the percentage of myocardial area reduction during myocardial contraction and is a strain composite in the longitudinal and circumferential directions of the myocardium, so it can comprehensively and truly reflect the motion of the ventricular wall [24]. Previous studies have shown that [25, 26] area strain can not only detect ischemic myocardial segments caused by severe coronary artery stenosis, but also help to identify coronary artery stenosis lesions with high accuracy and reproducibility. This explains our observations.

However, there are certain limitations in this study. For one thing, 3D-STE technique requires high image acquisition requirements, and may affect the image quality due to various reasons during acquisition, thus affecting the accuracy of speckle tracking; for another, the number of cases with single severe stenosis included in present study is relatively small, which may affect the conclusion to certain extent. In summary, the strain parameters obtained by STI technique have certain value in assessing the severity of coronary artery stenosis in CHD patients and can indirectly reflect its degree by analyzing the impaired left ventricular myocardial motion function.

Disclosure of conflict of interest

None.

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