

Original Article

Echocardiographic parameters for left ventricular function assessment and predictive value in coronary heart disease patients undergoing elective percutaneous coronary intervention

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Abstract: Objective: To evaluate the prognostic value of specific echocardiographic parameters, particularly myocardial strain indices, in patients with coronary heart disease (CHD) undergoing elective percutaneous coronary intervention (PCI). Methods: This retrospective study included 135 CHD patients who underwent PCI (observation group) and 100 healthy controls. Echocardiographic parameters (cardiac output [CO], left ventricular volumes [LVESV, LVEDV], ejection fraction [LVEF], cardiac index [CI], global longitudinal strain peak [GLSP], and global radial strain peak [GRSP]) were measured. Patients were followed up for 12 months post-PCI. Prognosis was determined based on the occurrence of major adverse cardiovascular events (MACE) during this follow-up period, including recurrent angina, acute coronary syndrome, arrhythmia, or heart failure. A good prognosis was defined as event-free survival with improved quality of life, while a poor prognosis was defined by the occurrence of any MACE. Parameters were compared between groups and correlated with prognosis. Results: Pre-PCI, CHD patients had impaired parameters (lower CO, LVEF, CI; higher LVESV, LVEDV) versus controls (all $P < 0.05$). Post-PCI, these parameters improved but remained suboptimal. Patients with a poor prognosis had significantly worse post-PCI parameters (lower GLSP, higher GRSP, LVESV, LVEDV) than those with a good prognosis (all $P < 0.05$). A predictive model combining GLSP and GRSP showed an AUC of 0.865 for poor prognosis. Left ventricular diameters (LVESD, LVEDD) were negatively correlated with GRSP and positively correlated with GLSP (all $P < 0.05$). Conclusion: Echocardiographic parameters, especially the combined model of myocardial strain indices (GLSP and GRSP), provide significant predictive value for prognosis in CHD patients after elective PCI. These findings support the use of strain imaging for risk stratification and early intervention.

Keywords: Echocardiographic parameters, percutaneous coronary intervention, coronary heart disease, prognosis, left ventricular wall motion analysis

Introduction

Coronary heart disease (CHD), a common cardiovascular condition, is the leading cause of death among single-disease internal medicine cases [1, 2]. It has been classified into five subtypes: myocardial ischemia, acute coronary syndrome, myocardial infarction, ischemic heart failure, and sudden death [3]. Epidemiological studies show that the incidence and mortality rates of CHD are gradually rising

worldwide, making it an important disease type that threatens public health [4].

The principle of treatment for CHD is to achieve revascularization, and PCI can restore coronary blood flow through interventional treatment, thereby alleviating symptoms and achieving clinical treatment objectives [5, 6]. However, in clinical practice, some patients still experience in-stent restenosis or new-onset coronary syndrome after PCI. Thus, effective non-inva-

sive monitoring after surgery is of great significance for improving the comprehensive treatment of CHD. Transthoracic echocardiography parameters can macroscopically assess the overall structure and function of the heart, reflecting the haemodynamic level and evaluating cardiac function after PCI [7, 8]. Given that post-operative cardiac function is inherently related to patient prognosis, it is therefore important to explore the predictive value of echocardiographic parameters for patients after PCI to enhance the treatment of CHD. However, current prognostic prediction studies based on echocardiographic parameters mostly focus on traditional macroscopic indicators such as left ventricular ejection fraction (LVEF), and their predictive efficacy has limitations. With the development of ultrasound technology, myocardial strain analysis can more sensitively detect the microscopic deformation of myocardial fibers, providing a new dimension for evaluating myocardial function. This study aims to go beyond the traditional assessment framework. By systematically analyzing conventional ultrasound parameters and emerging myocardial strain parameters (global longitudinal strain peak GLSP and global radial strain peak GRSP), it constructs and verifies a more accurate prognostic prediction model, with the expectation of providing better evidence-based rationale for the early clinical identification of high-risk patients and the implementation of individualized intervention.

Materials and methods

General information

This retrospective study included total of 135 patients with CHD who received PCI treatment in the Department of Cardiology of the Nantong University Affiliated Hospital from March 2022 to March 2024, enrolled as an observation group. In addition, 100 healthy individuals during the same period were selected as a control group. The prognosis of patients in the observation group was further divided into a good prognosis group and a poor prognosis group. This study was approved by the Ethics Committee of the Nantong University Affiliated Hospital (Ethics No.: KYLL-2024-0078).

Inclusion criteria: 1. Age over 18 and under 80 years; 2. Diagnosed with CHD by coronary angiography; 3. Complete clinical data including

echocardiographic parameters; 4. First-time PCI treatment.

Exclusion criteria: 1. Acute coronary syndrome; 2. Emergency PCI; 3. Previous PCI treatment; 4. Previous coronary artery bypass graft surgery; 5. Major organ dysfunction such as liver or kidney; 6. Incomplete clinical data.

Methods

The cardiac color Doppler ultrasound examination was performed using the HD40S cooler Doppler ultrasound diagnostic instrument (Qingdao Hisense Medical Equipment Co., Ltd.). Before the examination, all study subjects were instructed to check for and remove any metal accessories, and to adjust their breathing to maintain a steady rhythm. During the examination, the subjects lay on their left side on the functional bed, with the inner clothing opened to expose the chest skin, mainly covering the area from the 2nd to the 5th intercostal spaces, the sternum, and the supraclavicular fossa. After connecting to the electrocardiogram, the operator applied coupling gel to the probe, set the frequency at 3.0-5.5 Hz, and used the cardiac long-axis, major artery short-axis, and four-chamber views to overall assess the cardiac structure. The related parameters were measured, including cardiac output (CO), left ventricular end-systolic volume (LVESV), left ventricular end-diastolic volume (LVEDV), left ventricular ejection fraction (LVEF), and cardiac index (CI), as well as global radial strain peak (GRSP) and global longitudinal strain peak (GLSP) levels. Global longitudinal strain peak (GLSP) and global radial strain peak (GRSP) were analyzed offline using the dedicated speckle tracking software independent of the supplier (2D cardiac performance analysis, TomTec Imaging Systems, Germany). The endocardial boundary is hand-drawn at the end of the systolic period. Then, the software automatically tracks the spot patterns throughout the entire heart cycle. For GLSP, tracking is performed in root tip four-chamber, two-chamber, and long-axis views. The software generated longitudinal strain curves of 18 left ventricular segments (based on the American Heart Association model). GLSP automatically calculates the peak negative value of the average piecewise strain curve of the three vertices. For GRSP, tracking is performed on the parasternal short-axis view at the mastoid muscle level. GRSP

automatically calculates the peak positive value of the average radial strain curve for the entire short-axis region of interest. Analyses with insufficient tracking quality (such as those indicated by software or visual evaluations) were excluded or manually corrected.

Follow-up analysis

Patients in the observation group were followed up for 12 months, and the incidence of adverse events within one year after PCI treatment was recorded. The criteria for a good prognosis were good recovery within one year after PCI, significant improvement in quality of life, no recurrence of angina or adverse risk events. Those for a poor prognosis were recurrence of angina within one year after PCI, or occurrence of acute coronary syndrome, arrhythmia, heart failure, or other adverse cardiovascular events. Among them, 108 patients had a good prognosis, and 27 patients had a poor prognosis.

Data acquisition

Patients' general information was obtained through electronic system review, including baseline data, liver and kidney function records, incidence of hyperlipidemia, and history of hypertension and diabetes.

Observational indicators

Primary observational indicators: Changes in baseline data and echocardiographic parameters between two groups were assessed, the changes in parameters before and after treatment in CHD patients were recorded, and changes in parameters between the post-PCI poor prognosis group and the good prognosis group were also assessed.

Secondary observational indicators: The efficacy of echocardiographic parameters in predicting cardiovascular adverse events, and the correlation between echocardiographic indicators of cardiac structure and function and myocardial strain parameters, were evaluated.

Statistical analysis

Data were analyzed using SPSS 23.0 statistical software. Normally distributed measurement data for the two groups were expressed as "Mean \pm SD". Independent sample t-tests

were used for comparisons within normally distributed groups with equal variances, and chi-square tests were used for count data [n (%)]. Multivariate analysis was performed using multivariate logistic regression to establish a predictive model for poor prognosis following PCI in CHD patients, and the model performance was evaluated using ROC curves. Pearson correlation analysis was used to assess the relationship between echocardiographic indicators of cardiac structure and function and myocardial strain parameters. $P < 0.05$ was considered statistically significant.

Results

Comparison of baseline data

As shown in **Table 1**, the burden of traditional cardiovascular risk factors in the CHD group was significantly higher than that in the healthy control group. The prevalence of hypertension (55.6% vs. 28.0%, $P < 0.001$), diabetes (38.5% vs. 15.0%, $P < 0.001$), hyperlipidemia (50.4% vs. 22.0%, $P < 0.001$) and smoking (52.6% vs. 30.0%, $P < 0.001$) were significantly increased. These differences are completely consistent with the expected epidemiological characteristics of the coronary heart disease cohort, providing key background validity for our study population. In addition, supportive objective indicators such as LDL-C levels were significantly higher (3.2 vs. 2.5 mmol/L, $P < 0.001$), and the use of statins was more common in the patient group (83.0% vs. 10.0%, $P < 0.001$), reflecting their pathological status and standard clinical management.

Comparison of cardiac function indicators

Before treatment, CO, LVEF and CI in CHD patients were lower than those in normal subjects, while LVESV and LVEDV were higher than those in normal subjects (all $P > 0.05$). After PCI treatment in the observation group, CO, LVEF and CI were higher than those before PCI treatment, while LVESV and LVEDV were lower than before PCI treatment, and these indicators were still inferior to those in the normal control group (all $P < 0.05$). See **Table 2** and **Figure 1**.

Analysis of prognostic outcomes in CHD patients

Among 135 CHD patients who underwent PCI, a total of 28 patients had poor prognostic

Table 1. Comparison of general information and cardiovascular risk profile between groups

Characteristic	Healthy Control Group (n=100)	CHD Patient Group (n=135)	χ^2/t	P Value
Demographics				
Age (years), Mean \pm SD	60.2 \pm 8.5	62.8 \pm 9.1	-2.321	0.021
Male, n (%)	58 (58.0)	89 (65.9)	1.620	0.203
BMI (kg/m ²), Mean \pm SD	23.8 \pm 2.9	24.5 \pm 3.3	-1.732	0.085
Traditional Risk Factors, n (%)				
Hypertension	28 (28.0)	75 (55.6)	18.950	<0.001
Diabetes Mellitus	15 (15.0)	52 (38.5)	16.242	<0.001
Hyperlipidemia	22 (22.0)	68 (50.4)	20.112	<0.001
Current or Former Smoker	30 (30.0)	71 (52.6)	12.561	<0.001
Cardiovascular History, n (%)				
Previous MI	0 (0)	29 (21.5)	Fisher's Exact Test	<0.001
Heart Failure History	0 (0)	18 (13.3)	Fisher's Exact Test	<0.001
Laboratory & Medication				
LDL-C (mmol/L), Mean \pm SD	2.5 \pm 0.6	3.2 \pm 0.9	t=-6.89	<0.001
Statin Use, n (%)	10 (10.0)	112 (83.0)	$\chi^2=124.50$	<0.001

Note: BMI: Body mass index; MI: Myocardial Infarction; LDC-C: low-density lipoprotein cholesterol.

Table 2. Comparison of cardiac function indicators before and after PCI

Groups	CO (L/min)	LVEF (%)	CI (L/min/m ²)	LVESV (ml)	LVEDV (ml)
Control group	5.8 \pm 0.6	64.3 \pm 4.1	3.3 \pm 0.3	45 \pm 8	112 \pm 14
Observation group (before treatment, n=135)	5.1 \pm 1.0*	58.5 \pm 7.2*	2.9 \pm 0.5*	68 \pm 15*	138 \pm 22*
Observation group (after treatment n=135)	5.5 \pm 0.8*#	61.2 \pm 5.9*#	3.1 \pm 0.4*#	58 \pm 12*#	125 \pm 18*#
F/t	21.35	25.18	18.92	75.41	45.66
P	<0.001	<0.001	<0.001	<0.001	<0.001

Note: PCI: percutaneous coronary intervention; CO: cardiac output; LVESV: left ventricular end-systolic volume; LVEDV: left ventricular end-diastolic volume; LVEF: left ventricular ejection fraction; CI: cardiac index. *P<0.05 vs. Control group; #P<0.05 vs. Observation group (before treatment).

outcomes within one year of follow-up, including recurrence of angina, acute coronary syndrome, malignant arrhythmias, heart failure, etc., as shown in **Figure 2**.

Comparison of function indicators between patients with poor and good prognosis after PCI

In the observation group, patients with a good prognosis had higher levels of CO, LVEF, CI, and GLSP, while lower levels of GRSP, LVESV, and LVEDV than those with a poor prognosis (all P<0.05). See **Table 3**.

Univariate analysis of poor prognosis in CHD patients after PCI

There was no statistical significance between the two groups of CHD patients in terms of gender, BMI, hypertension, diabetes, hyperlip-

idemia, smoking, and drinking history, while patients in the poor prognosis group were older than those in the good prognosis group (P=0.049). See **Table 4**.

Multivariate analysis of poor prognosis after PCI

According to the univariate difference results in **Tables 3** and **4**, further analysis showed that GLSP and GRSP were factors affecting poor prognosis, among which GRSP was a risk factor, while GLSP and GCSP were protective factors. See **Table 5**.

Prognostic ROC curve for PCI in CHD

The predictive model for PCI in CHD was established using GLSP and GRSP with an AUC of 0.885, 95% CI 0.820-0.949, while the Hosmer-

Left ventricular function assessment and prognostic value in CHD patients undergoing PCI

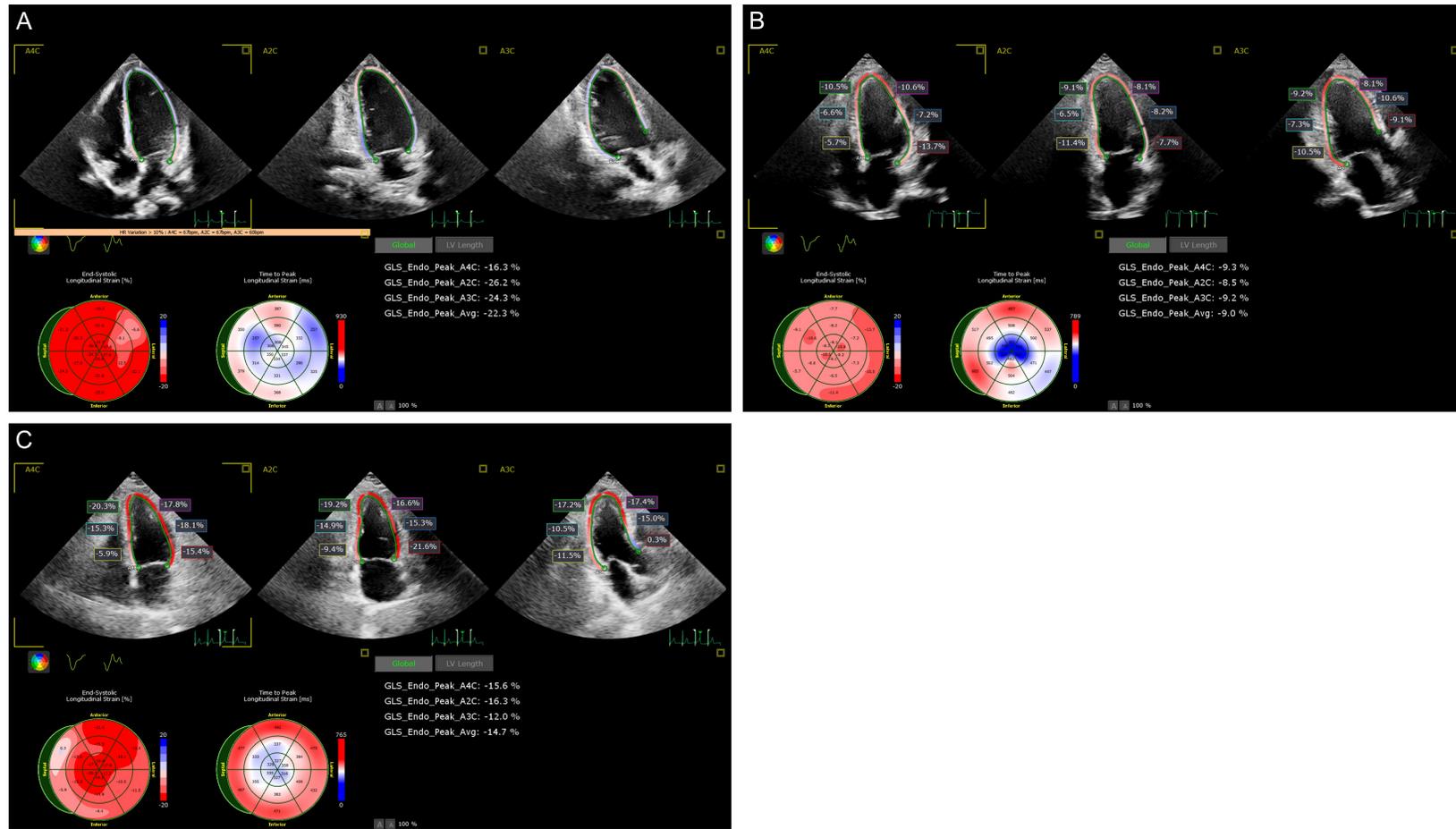


Figure 1. A. Normal control group echocardiographic strain rate; B. Echocardiographic strain rate of coronary heart disease patients before PCI surgery; C. Echocardiographic strain rate of coronary heart disease patients after PCI surgery. PCI: percutaneous coronary intervention.

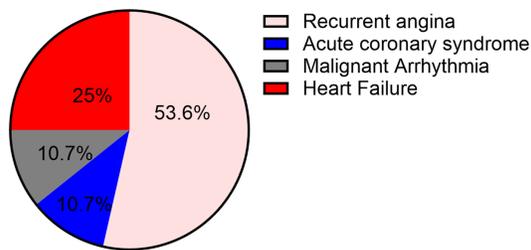


Figure 2. Distribution of poor prognostic outcomes in patients with coronary heart disease.

Lemeshow test yielded a chi-square value of 6.383, $P=0.496$, indicating model stability. See **Figure 3**. Model analysis also revealed that this model had excellent predictive capability for cognitive impairment in the endocrine treatment group, as shown in **Figure 4**.

Analysis of the correlation between cardiac structural indicators and myocardial strain parameters in CHD patients

In CHD patients, the echocardiographic parameters LVESD and LVEDD were negatively correlated with GRSP and positively correlated with GLSP (all $P<0.001$). See **Table 6**.

Discussion

Epidemiological studies show that cardiovascular diseases are the main types of diseases affecting public health worldwide, and their incidence increases annually with changes in diet, lifestyle, and other factors, seriously affecting patients' quality of life [9, 10]. CHD is a severe type of cardiovascular disease, which can cause patients to experience chest tightness, shortness of breath, chest pain, and difficulty breathing. In severe cases, it even leads to malignant arrhythmias or myocardial infarction causing pump failure, endangering patients' lives [11, 12].

PCI is a commonly used and effective interventional procedure for treating CHD. By professionally implanting stents into narrowed coronary arteries to reopen blocked vessels, it offers advantages such as no need for general anesthesia, minimal trauma, and rapid recovery, making it highly applicable and highly acceptable to patients [13, 14]. Furthermore, the literature confirms that PCI quickly alleviates patient symptoms, and reduces the local vascular microenvironment, benefiting endo-

thelial cell nuclear tissue and improving the prognosis of CHD [15, 16]. Simultaneously, studies show that patients' left ventricular function is a key indicator for evaluating the efficacy of PCI treatment [17]. Currently, magnetic resonance imaging and radionuclide myocardial perfusion imaging are important imaging modalities for observing left ventricular function after PCI, but their high cost limits their application [18]. Echocardiography, as a non-invasive and economical examination method, is significant in evaluating cardiac structure, as it can comprehensively provide information on heart-related structures and myocardial-related parameters. Therefore, it can be used to assess left heart function after PCI, while additionally evaluating the relationship between myocardial parameters and patient prognosis, which also helps improve the overall diagnosis and treatment level of CHD.

Previous scholars have confirmed that CHD patients have lower CO, LVEF and CI parameters compared to normal study subjects, while LVESV and LVEDV are higher than controls, suggesting to some extent that CHD patients have alterations in cardiac structure [19]. The potential mechanisms include: coronary artery atherosclerotic stenosis causing blood flow obstruction, leaving myocardial cells in a sustained state of ischemia and hypoxia, and reduced myocardial energy efficiency (switch from aerobic to anaerobic glucose metabolism) leading to insufficient ATP production affecting myocardial contraction, resulting in decreased cardiac output; simultaneously, ischemia and hypoxia cause myocardial apoptosis and necrosis, further reducing myocardial contractility, consistent with previous research findings [20]. Moreover, altered coronary blood flow may induce partial myocardial hibernation or hibernating state, reflected as reduced contractile function to maintain survival, ultimately manifesting as a reduction in ejection fraction. In addition, myocardial ischemia and hypoxia can activate the endocrine system, triggering myocardial ventricular remodeling, causing myocardial dilation, coupled with post-myocardial infarction leading to thinning and elongation of the infarcted region, resulting in local chamber bulging, and the heart producing eccentric hypertrophy to maintain output. These changes reduce forward left ventricular function, further impairing myocardial diastolic and systolic fun-

Table 3. Comparison of function indicators between patients with poor and good prognosis after PCI

Indicators	Good prognosis group (n=107)	Poor prognosis group (n=28)	t	P
CO (L/min)	5.5±0.9	5.0±1.0	2.891	0.005
LVEF (%)	61.5±5.5	58.2±6.2	3.112	0.002
CI (L/min/m ²)	3.1±0.5	2.8±0.6	2.985	0.004
GLSP (%)	-18.8±1.9	-13.5±2.5	12.854	<0.001
GRSP (%)	37.5±6.8	47.2±7.9	-6.785	<0.001
LVESV (ml)	52±12	61±15	-3.452	0.001
LVEDV (ml)	120±18	135±22	-3.912	<0.001

Note: PCI: percutaneous coronary intervention; CO: cardiac output; LVESV: left ventricular end-systolic volume; LVEDV: left ventricular end-diastolic volume; LVEF: left ventricular ejection fraction; CI: cardiac index; GLSP: Global Longitudinal Strain Peak; GRSP: Global Radial Strain Peak.

Table 4. Comparison of baseline data between the good prognosis and poor prognosis group after PCI

Indicators	Good prognosis group (n=107)	Poor prognosis group (n=28)	X ² /t	P
Gender (Male), n (%)	63.8±7.5	66.9±8.1	-1.992	0.049
Age (years)	68 (63.6%)	19 (67.9%)	0.188	0.665
BMI (kg/m ²)	25.9±3.0	26.5±3.2	-0.964	0.337
Hypertension, n (%)	65 (60.7%)	20 (71.4%)	1.125	0.289
Diabetes, n (%)	39 (36.4%)	13 (46.4%)	0.943	0.331
Dyslipidemia, n (%)	72 (67.3%)	22 (78.6%)	1.365	0.243
Smoking History, n (%)	55 (51.4%)	17 (60.7%)	0.776	0.378
Alcohol Drinking History, n (%)	43 (40.2%)	13 (46.4%)	0.358	0.550

Note: PCI: percutaneous coronary intervention; BMI: Body mass index.

Table 5. Multivariate logistic analysis of poor prognosis after PCI in patients with coronary heart disease

Variables	β Coefficient	Standard Error	Wald χ ² Value	P Value	Odds Ratio	95% CI
Constant	-2.810	1.205	5.432	0.020	0.060	-
Age	0.031	0.025	1.537	0.215	1.031	0.982-1.083
GLSP	-0.512	0.118	18.821	<0.001	0.599	0.475-0.755
GRSP	0.198	0.045	19.358	<0.001	1.219	1.116-1.331

Note: GLSP: Global Longitudinal Strain Peak; GRSP: Global Radial Strain Peak.

ction, eventually increasing LVESV and reducing LVEF, forming a vicious cycle [21]. Finally, the heart may develop secondary mitral valve dysfunction due to ischemia and hypoxia, with partial regurgitant blood increasing left atrial load and reducing ineffective left ventricular preload, further promoting an increase in LVEDV and decrease in LVEF, which has also been reported in previous studies [22].

It has been reported that echocardiographic parameters can effectively predict patient prognosis, particularly showing a correlation between LVEF and patient prognosis [23]. However,

due to potential inaccuracies in LVEF measurement, there are certain limitations in evaluating patient prognosis. This study showed that GLSP level was higher in patients with a good prognosis, while levels of GRSP, LVESV and LVEDV were lower than in patients with a poor prognosis. Further analysis indicated that GRSP was a risk factor and that a predictive model established with GLSP demonstrated good predictive efficacy. More importantly, the combined prediction model constructed by integrating GLSP and GRSP in this study has a predictive performance that significantly exceeds a single traditional parameter (such as LVEF),

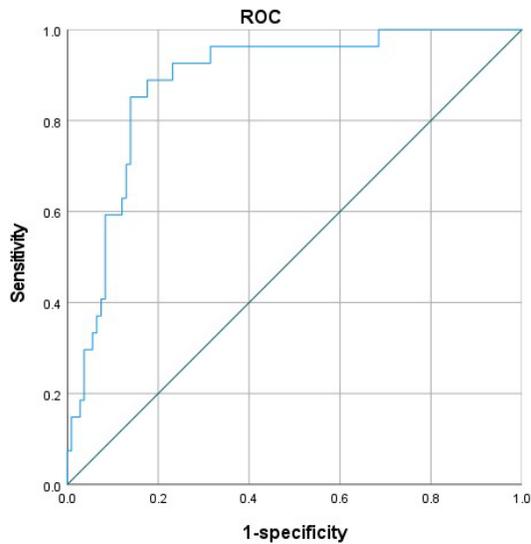


Figure 3. ROC curve for prognosis of patients with coronary heart disease after PCI. ROC: Receiver Operating Characteristic.

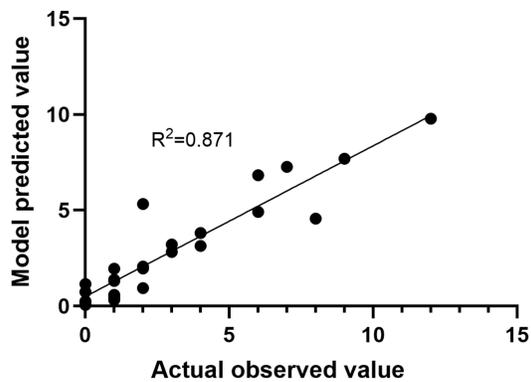


Figure 4. Model calibration plot.

which provides a more accurate and sensitive risk stratification tool for clinical practice. This may be attributed to the following factors. GLSP is a direct index reflecting subendocardial fiber function and myocardial circumferential coordination in CHD patients, being central to maintaining effective cardiac pumping, whereas reduced GRSP indicates left ventricular dilation, suggesting impaired myocardial radial contractile function and pathological remodeling [24]. Based on these three indices reflecting direct myocardial contraction, the postoperative PCI poor prognosis prediction model constructed using myocardial strain parameters and volume indices shows good clinical applicability, allowing early effective prediction of PCI patient

Table 6. Analysis of the correlation between echocardiographic parameters and myocardial strain parameters

Indicators	GRSP		GLSP	
	r	P	r	P
LVESD	-0.758	<0.001	0.723	<0.001
LVEDD	-0.812	<0.001	0.785	<0.001

Note: LVESD: Left ventricular end-systolic diameter; LVEDD: left ventricular end-diastolic diameter; GRSP: global radial strain peak; GLSP: global longitudinal strain peak.

prognosis and supporting previous research findings [25].

Left ventricular systolic and diastolic function is somewhat correlated with ventricular dilatation, suggesting that ventricular dilatation affects overall myocardial function [26]. The results of this study indicated that in CHD patients, LVESD and LVEDD were negatively correlated with GRSP and positively correlated with GLSP. The primary mechanism is based on pathological remodeling of the left ventricle. It causes the heart to lose its original structural morphology, leading to changes in strain that restrict myocardial fiber function. While myocardial hypoxia and ischemic injury primarily affect the oxygen-demanding subendocardial longitudinal fibers, collectively causing a significant reduction in GLSP due to ventricular dilatation, consistent with previous studies [27, 28]. This study further reveals the intrinsic connection between cardiac structural remodeling (ventricular dilation) and microscopic myocardial mechanical changes (strain), providing a deeper pathophysiological explanation for the classic clinical observation that “poor cardiac function leads to poor prognosis”, that is, structural changes drive the functional impairment of myocardial fibers, jointly determining the clinical outcome. Additionally, the results suggested that actively preventing left ventricular dilatation after PCI can reduce the occurrence of adverse postoperative cardiovascular events to some extent.

Several potential limitations of this study should be acknowledged. First, as a retrospective study, there is a possibility of selection and information bias. Second, this is a single-center study with a limited sample size, and the lack of external data limits external validation, which

may reduce the generalizability of the findings. Furthermore, the measurement of left ventricular parameters involves a degree of subjectivity, which may locally influence the results. Finally, the follow-up period is relatively short, and whether improvement in myocardial remodeling can reduce postoperative adverse events also requires further investigation.

In conclusion, this study confirmed that the ultrasound assessment model integrating myocardial strain parameters (GLSP and GRSP) can more effectively predict the prognosis of patients with coronary heart disease after elective PCI. Echocardiographic parameters can effectively predict the prognosis of elective PCI in CHD, and the left ventricular wall motion analysis correlated with left ventricular dimensions. This can aid in assessing cardiac function and predicting PCI patient prognosis, providing a theoretical basis for clinicians to identify high-risk patients early after PCI and implement targeted interventions.

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Disclosure of conflict of interest

None.

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