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Article

Value of Echocardiographic Evaluation of Myocardial Performance Index in Predicting Major Adverse Cardiovascular Events Within 1 Year after Percutaneous Coronary Intervention in Patients with Coronary Heart Disease

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Abstract

Objective: This study aimed to evaluate the predictive efficacy of the echocardiography-derived Tei index for the occurrence of major adverse cardiovascular events (MACE) within 1 year post-percutaneous coronary intervention (PCI) in patients with coronary heart disease (CHD). **Methods**: A total of 98 patients diagnosed with CHD and admitted to our hospital between January 2021 and May 2023 were retrospectively selected for this study, and the two groups were divided into good prognosis group (n = 67) and poor prognosis group (n = 31) according to whether cardiovascular adverse events occurred within 1 year after PCI. Univariate and multivariate logistic regression analyses were conducted to identify the influencing factors of adverse cardiovascular events in patients with CHD following PCI, and receiver operating characteristic (ROC) analysis was employed to evaluate the efficacy of myocardial performance index measured by echocardiography in predicting adverse cardiovascular events within 1 year post-PCI in patients with CHD. The inflammatory factors of patients with different Tei indices were compared before and 24 h after PCI. **Results**: The differences in general data, including preoperative Tei index, left anterior descending (LAD) level, left ventricular diameter in diastole (LVDd) level, and the number of cases with left ventricular outflow tract obstruction, were not statistically significant between two groups ($p > 0.05$). Left ventricular ejection fraction (LVEF), maximum left ventricular thickness, postoperative Tei index, plaque score, and carotid intima–media thickness (IMT) showed statistically significant differences ($p < 0.05$). The findings from logistic regression analysis, considering multiple factors, indicated that Tei index, plaque score, and carotid IMT were independent predictors for adverse cardiovascular events following PCI in patients with CHD ($p < 0.05$). ROC analysis demonstrated an impressive area under the curve of 0.967 for echocardiographic assessment of myocardial performance index as a predictor for adverse cardiovascular events within 1 year after PCI in patients with CHD. The standard error was 0.017, 95% confidence interval was 0.935–0.999, optimal cut-off value was 0.88, sensitivity was 95.0%, and specificity was 93.3%. The comparison of inflammatory factors among patients with different Tei index values before PCI did not yield any statistically significant differences ($p > 0.05$), and the comparison of inflammatory factors in patients with different Tei index 24 h after PCI. The levels of inflammatory cytokines in patients with Tei $\leq$0.5 were lower than those in patients with Tei $>$0.5 ($p < 0.05$). **Conclusion**: Evaluating the myocardial performance index through echocardiography holds considerable value in predicting MACE within one year following PCI in patients diagnosed with CHD.

Keywords

adverse cardiovascular event; coronary heart disease; echocardiography; myocardial performance index; percutaneous coronary intervention

Introduction

Coronary heart disease (CHD), also referred to as coronary atherosclerotic heart disease or ischemic heart disease, is characterized by the presence of atherosclerotic lesions within the coronary arteries that result in narrowing or blockage of blood vessels. This condition results in myocardial ischemia, hypoxia, or necrosis, contributing to various heart-related complications. CHD stands as the most prevalent manifestation of organ damage resulting from atherosclerosis. It is also a common disease that seriously endangers human health [1,2]. Previous studies found that the elderly individuals had a greater risk of CHD [3]. In recent years, there has been a noticeable trend of CHD occurring at younger ages, making it one of the primary health concerns affecting individuals. Additionally, the scope of CHD may extend beyond traditional causes such as atherosclerosis to include factors such as inflammation, embolism, and other conditions leading to lumen stenosis or occlusion [4]. The classification of CHD by the World Health Organization encompasses five clinical types [5]. In clinical practice, CHD is frequently divided into two main categories: stable CHD and acute coronary syndrome [6]. Percutaneous coronary intervention (PCI) is an interventional operation for the treatment of CHD and acute myocardial infarction. Major adverse cardiovascular events (MACE) within 1 year after PCI include angina pectoris recurrence, cardiac insufficiency, acute myocardial infarction and cardiogenic death [7,8]. The occurrence of adverse events in CHD is influenced by various factors and significantly impacts the quality of life of affected individuals. Therefore, accurately predicting the occurrence of these events is crucial for effective management and improving patient outcomes. However, relevant studies on the prediction tools for major cardiovascular adverse events within 1 year after PCI are lacking [9]. The myocardial performance index, also referred to as the Tei index, serves as a crucial parameter utilized in evaluating the comprehensive function of the heart [10]. The time interval index derived from a Doppler ultrasound and Tei index has been proven to be a reliable method for evaluating left ventricular myocardial performance [11,12]. This study aims to employ echocardiography to assess the myocardial performance index of patients with CHD following PCI, examining its correlation with adverse cardiovascular events, and explore the role of Tei index in predicting adverse cardiovascular events after PCI. Through this study, we hope to provide a more accurate prediction and intervention basis for clinical practice.

Objects and Methods

Research Objects

A total of 98 patients diagnosed with CHD and admitted to our hospital between January 2021 and May 2023 were retrospectively selected for this study. The inclusion criteria were as follows: (1) patients who had been confirmed by coronary angiography and met the clinical diagnosis of patients with CHD; (2) patients who met the indications for PCI; (3) patients with complete clinical data; (4) patients with good compliance. The exclusion criteria were as follows: (1) patients with severe hepatic or renal insufficiency; (2) patients with mental disorders; (3) patients with previous pacemaker implantation; (4) patients with other ultrasound contraindications; (5) patients with congenital heart disease, valvular disease, cardiomyopathy, large vascular disease, and other structural heart disease; (6) patients with malignant tumors; (7) patients with autoimmune diseases; (8) patients with other serious and non-negligible physical illnesses. This study has been approved by the Ethics Committee, and all enrolled patients signed informed consent.

Methods

The electronic medical record system was utilized to collect general patient data, which included baseline demographics, clinical data, angiographic and laboratory parameters, and out-of-hospital medications. We utilized standardized protocols for data collection and implemented rigorous quality control measures to ensure data accuracy and completeness. According to the occurrence of adverse cardiovascular events within 1 year after PCI, patients in two groups were divided into a good prognosis group (n = 67) and a poor prognosis group (n = 31). The isovolumic systole time, isovolumic diastolic time, and ejection time of patients before and after PCI were collected by echocardiography. Cardiovascular adverse events are divided into following two conditions: (1) fatal cardiovascular disease, which refers to cardiovascular adverse events that cause arrhythmic death in patients and (2) nonfatal myocardial infarction, in which patient has not died after treatment; it includes recurrence of angina pectoris, cardiac insufficiency, acute myocardial infarction, and cardiac death. All participants included in this study gave informed consent.

Observation Indicators

(1) Myocardial performance index calculation: On basis of the acquired data, physician can calculate the myocardial performance index. The index is a comprehensive indicator used to assess the overall performance of the heart. The formula is TEI = (ICT + IRT)/ET, where ICT is isovolumic contraction time, IRT is isovolumic relaxation time, and ET is ejection time. For interpretation of results, doctor would evaluate patient's heart function based on the calculated myocardial performance index and other parameters. If necessary, doctor would recommend further examination or treatment.

(2) Comparison of inflammatory factors, including Interleukin-6 (IL-6), C-Reactive protein (CRP), and necrosis factor-like receptor (NLR) before and 24 h after PCI in patients with different Tei indices.

Statistical Analysis

The collected experimental data were analyzed using SPSS 27.0 (IBM Corporation, Armonk, NY, USA), and all experimental data were in line with normal distribution. Measurement data were expressed as the mean ± standard deviation ($\bar{x} \pm$ SD), and comparisons were made using the independent samples *t*-test. For categorical data presented as counts or rates, comparisons were conducted using the chi-square (χ^2) test, with adjustments made using the correction formula for the chi-square test or the Fisher's exact test where appropriate. The influencing factors of adverse cardiovascular events in patients with CHD after PCI were analyzed using univariated analyses, and clinicopathologic factors, which were statistically significant in univariated analysis, were included as covariables in multivariate analysis. The bootstrap method was used to assess robustness and generalizability of the model. Receiver operating characteristic (ROC) curve analysis was employed to evaluate predictive value of echocardiographic myocardial performance index for adverse cardiovascular events in these patients after PCI. A significance level of $p < 0.05$ was considered statistically significant.

Results

Demographic Characteristics of Patients in the Two Groups

No significant difference was observed in general data, preoperative Tei index, left anterior descending (LAD) level, left ventricular diameter in diastole (LVDd) level, and the number of left ventricular outflow tract obstruction cases between the good and poor prognosis group ($p > 0.05$). Significant differences were observed in left ventricular ejection fraction (LVEF), maximum left ventricular thickness, postoperative Tei index, plaque score, and carotid intima–media thickness (IMT) ($p < 0.05$), as shown in Table 1.

Multifactor Logistics Regression Analysis of Influencing Factors of Adverse Cardiovascular Events in Patients with CHD after PCI

The results of multifactor logistics regression analysis showed that Tei index, plaque score, and carotid IMT were independent influencing factors for adverse cardiovascular events in patients with CHD after PCI ($p < 0.05$), as shown in Table 2.

ROC Curve of Echocardiographic Evaluation of Myocardial Performance Index to Predict Adverse Cardiovascular Events in Patients with CHD within 1 Year after PCI

ROC analysis results showed that the area under the curve of echocardiographic evaluation of myocardial performance index for predicting adverse cardiovascular events in patients with CHD within 1 year after PCI was 0.967, and the standard error was 0.017 (95% confidence interval (CI): 0.935–0.999), the best truncation value was 0.88, the sensitivity was 95.0%, and the specificity was 93.3%, as shown in Fig. 1.

Comparison of Inflammatory Factors before and 24 h after PCI in Patients with Different Tei Indices

No statistical significance was observed in the comparison of inflammatory factors in patients with different Tei indices before PCI ($p > 0.05$), and the comparison of inflammatory factors in patients with different Tei index 24 h after PCI showed that the levels of inflammatory factors

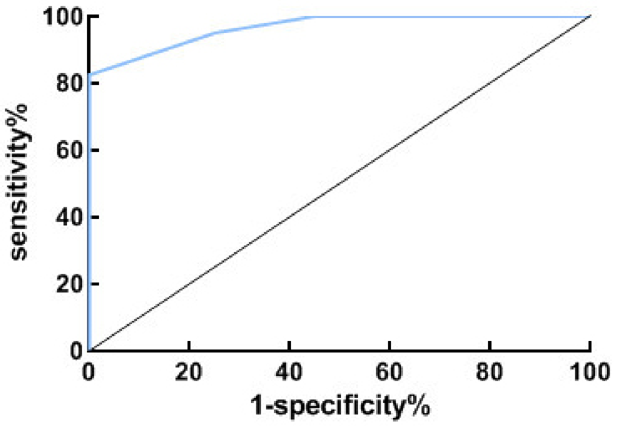

Fig. 1. Receiver operating characteristic (ROC) curve of echocardiographic evaluation of myocardial performance index to predict adverse cardiovascular events in patients with coronary heart disease (CHD) within 1 year after percutaneous coronary intervention (PCI).

in patients with Tei index ≤0.5 were lower than those in patients with Tei index >0.5 ($p < 0.05$), as shown in Table 3.

Discussion

Myocardial performance index is not affected by heart rate, ventricular geometry, and cardiac load, and thus can be applied in various heart diseases; moreover, it has the advantage of predictive value. The use of classical echocardiographic indicators to estimate systolic left ventricular function has many limitations, while Tei index has remarkable advantages compared with past indicators [13,14]. In this study, echocardiography was utilized to assess the myocardial performance index. The Tei index exhibited a high predictive value for major cardiovascular adverse events occurring within 1 year after PCI in patients diagnosed with CHD; this result is particularly meaningful for the elderly due to the inclusion of more elderly patients.

The results indicated no significant differences in the general data, LAD level, LVDd level, and the number of left ventricular outflow tract obstruction cases in good prognosis group ($p > 0.05$). Statistically significant differences were observed in LVEF, maximum left ventricular thickness, Tei index, plaque score, and carotid IMT ($p < 0.05$). Examination revealed that the left ventricular function plays a crucial role in evaluating the prognosis of patients with myocardial infarction. Impaired left ventricular systolic function may elevate risk of adverse cardiovascular events, such as myocardial ischemia and myocardial infarction. Hence, patients with a good prognosis may possess improved left ventricular function, thereby potentially lowering risk of adverse cardiovascular events [15,16]. In addition, the maximum left ventricular thickness, Tei index, plaque score, and carotid IMT of patients with good prog-

Table 1. Demographic characteristics of patients in the two groups.

Indicators	Good prognosis group (n = 67)	Poor prognosis group (n = 31)	Value of t/χ^2	Value of p
Age (years)	70.11 ± 2.16	69.74 ± 1.61	0.850	0.398
Gender			0.031	0.861
Male	42	20		
Female	25	11		
Obtain employment			0.038	0.845
Yes	59	27		
No	8	4		
Marital status			0.729	0.694
Married	45	21		
Unmarried	5	1		
Divorced	17	9		
Educational level			0.049	0.976
Primary and below	35	16		
Junior high school	16	8		
High school	16	7		
Household income (dolllars)			0.318	0.957
≤138	12	6		
138.1–461.5	21	10		
461.6–769.2	20	10		
≥769.3	14	5		
Payment method of medical expenses			3.048	0.384
Self-financing	13	7		
Medical insurance	30	13		
Free medical treatment	10	8		
Rural cooperative medical and health care services	14	3		
High blood pressure			0.024	0.878
Yes	10	5		
No	57	26		
Diabetes			0.006	0.936
Yes	3	2		
No	64	29		
LAD (mm)	40.16 ± 7.31	42.77 ± 5.49	1.769	0.080
LVDd (mm)	46.56 ± 5.38	47.04 ± 5.53	0.407	0.685
LVEF (%)	64.44 ± 7.41	61.22 ± 7.53	1.990	0.049
Maximum left ventricular thickness (mm)	17.16 ± 2.24	18.74 ± 2.16	3.283	0.001
Left ventricular outflow tract obstruction			0.311	0.577
Yes	20	11		
No	47	20		
Tei index				
Before operation	0.43 ± 0.02	0.44 ± 0.03	1.952	0.054
After operation	0.46 ± 0.03	0.59 ± 0.05	15.995	<0.001
Plaque score	1.11 ± 0.20	2.16 ± 0.16	25.655	<0.001
Carotid IMT (mm)	0.66 ± 0.17	1.33 ± 0.05	21.464	<0.001
BMI (kg/m^2)	21.46 ± 2.41	21.57 ± 1.34	0.237	0.813
Family history			2.964	0.085
Yes	13	11		
No	54	20		

LAD, left anterior descending; LVDd, left ventricular diameter in diastole; LVEF, left ventricular ejection fraction; IMT, intima–media thickness; BMI, body mass index.

nosis were higher than those of patients with poor prognosis, which may be related to the progression and prognosis of cardiovascular diseases [17]. An elevated Tei index may suggest compromised diastolic function of the heart, consequently affecting the supply of blood and oxygen to the cardiac muscle and elevating the likelihood of adverse cardiovascular events. The increase in plaque score and carotid IMT may indicate the aggravation of atherosclerosis

Table 2. Multifactor logistics regression analysis of influencing factors of adverse cardiovascular events in patients with CHD after PCI.

Risk factors	Value of β	Value of SE	Value of Ward	Value of OR	95% CI	Value of p
LVEF	0.106	0.108	0.966	1.112	0.900–1.374	0.326
Maximum left ventricular thickness	0.125	0.113	1.221	1.133	0.908–1.414	0.269
Tei index	0.414	0.168	6.075	1.513	1.089–2.103	0.014
Plaque score	0.523	0.159	10.818	1.687	1.235–2.304	0.001
Carotid IMT	0.551	0.249	4.897	1.735	1.065–2.827	0.027

CHD, coronary heart disease; PCI, percutaneous coronary intervention; SE, standard error; OR, odds ratio; CI, confidence interval.

Table 3. Comparison of inflammatory factors in patients with different Tei indices before and after PCI.

Item		Tei index >0.5 (n = 28)	Tei index ≤0.5 (n = 70)	t	p
IL-6 (ng/L)	Before PCI	10.51 ± 2.94	11.01 ± 1.13	1.222	0.225
	24 h after PCI	16.91 ± 4.16	12.00 ± 3.25	6.221	<0.001
CRP (mg/L)	Before PCI	7.69 ± 3.15	7.57 ± 2.67	0.191	0.849
	24 h after PCI	7.10 ± 0.44	6.33 ± 0.40	8.365	<0.001
NLR	Before PCI	2.14 ± 0.63	2.06 ± 0.50	0.663	0.509
	24 h after PCI	2.69 ± 0.37	2.27 ± 0.46	4.302	<0.001

IL-6, Interleukin-6; CRP, C-Reactive protein; NLR, necrosis factor-like receptor.

and increased risk of arterial stenosis or obstruction, thus affecting myocardial blood supply and leading to adverse cardiovascular events [18,19]. The results of multifactor logistics regression analysis showed that Tei index, plaque score, and carotid IMT were independent influencing factors of adverse cardiovascular events in patients with CHD after PCI ($p < 0.05$), which further indicated that cardiac systolic and diastolic function, plaque status, and carotid intima–media thickness were important influencing indicators. Previous studies have indeed highlighted the predictive significance of plaque score and carotid IMT in patients with CHD [20,21]. However, correlation analysis focusing on the Tei index is limited [22–24].

This study further performed ROC analysis to assess the predictive value of echocardiographic evaluation of the Tei index. ROC analysis results showed that the area under the curve of the echocardiographic evaluation of myocardial performance index for predicting adverse cardiovascular events in patients with CHD within 1 year after PCI was 0.967, and the standard error was 0.017 (95% CI: 0.935–0.999), best cut-off value was 0.88, sensitivity was 95.0%, and specificity was 93.3%. The results proved that echocardiography had a high value in the prediction of Tei index, indicating that this index had high accuracy in predicting cardiovascular adverse events. A previous study identified the Tei index, with a value greater than 0.60 (p = 0.015, odds ratio (OR) = 1.826, 95% CI: 1.141–4.023), as an independent predictor of MACE. This index has been demonstrated to possess significant predictive value for the short-term prognosis after PCI and can be predictors of cardiac function.

In addition, the stent implanted during PCI as a foreign body can increase the levels of various inflammatory factors, such as IL-6 and CRP. IL-6 can promote platelet aggregation, stimulate the production of intercellular adhesion molecules by vascular endothelial cells, and promote the production of fibrinogen by hepatocytes [25]. The aggregation of platelets and white blood cells and the formation of fibrin in microvessels produce microthrombosis, which is the main cause of no reflow or slow blood flow after PCI. Studies [26] has shown that elevated CRP may be associated with an increased risk of postoperative complications, including stent thrombosis and noncardiac surgery-related myocardial infarction. A high NLR value indicates the enhancement of inflammatory response and increased platelet activity, which may indicate the increased risk of postoperative cardiovascular events [27]. Hence, this study also investigated inflammatory factors in patients with varying Tei indexes before and 24 h after PCI. The results revealed notable differences in the comparison of inflammatory factors among patients with different Tei indexes 24 h after PCI. The levels of inflammatory cytokines in patients with Tei ≤0.5 were lower than those in patients with Tei >0.5 ($p <$ 0.05), indicating that the Tei index can also reflect the inflammatory response of patients and further help clinicians to judge the condition of patients well.

This study still has limitations. First, the small sample size may affect the stability and reliability of the results. In addition, some potential influencing factors, such as living habits, may not be fully considered and adjusted, which may have a certain impact on the results. Furthermore, the study adopts a retrospective design, which may cause issues of information bias and data missing; moreover, the data collection methods used in the study may contain errors or inconsistencies, which affect the credibility and accuracy of the results. Future studies must expand the sample size, extend the follow-up time, and comprehensively consider various influencing factors to assess the risk of adverse cardiovascular events after PCI more accurately and provide effective interventions [28].

Conclusion

Our study demonstrates the significant value of echocardiographic assessment of myocardial performance indices in predicting MACE within 1 year post-PCI in patients diagnosed with CHD. Clinicians can utilize this information to enhance diagnostic accuracy. By incorporating parameters such as the Tei index into routine clinical assessments, healthcare providers can better predict and manage the risk of post-PCI cardiovascular events, thereby adjusting management strategies accordingly. Furthermore, our findings hold crucial implications for treatment decisions and therapy response monitoring. Patients with elevated Tei indices may benefit from more aggressive therapeutic interventions or closer monitoring to prevent the development of cardiovascular events post-PCI, offering valuable insights into the effectiveness of therapeutic interventions. Last, the association between the Tei index and post-PCI inflammatory response provides a novel perspective for further understanding the mechanisms underlying occurrence of MACE post-PCI.

Availability of Data and Materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

JY designed the study and performed the research. FY and JW analyzed the data and were involved in writing the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study has been approved by the ethics committee of Dongying People's Hospital (approval no. 2024041). All participants gave written consent to take part in the experiment.

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Conflict of Interest

The authors declare no conflict of interest.

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