Heart Surgery Forum 2024; 27(4): E381–E390 https://journal.hsforum.com/
doi: 10.59958/hsf.6881

Article

Appraised Value of 3D Echocardiography Combined with the Triglyceride–Glucose Index to Evaluate the Long-Term Prognosis of Patients after Percutaneous Coronary Intervention

Xuan Luo[1], Yaoyao Deng[1,*], Lijuan Gu[1]

[1]Department of Ultrasound, Jingmen Central Hospital, 448000 Jingmen, Hubei, China
*Correspondence: dengyaoyao11589@163.com (Yaoyao Deng)
Submitted: 27 September 2023 Revised: 21 February 2024 Accepted: 27 March 2024 Published: 10 April 2024

Abstract

Objective: This study analyzed three-dimensional echocardiography (3DE) combined with the triglyceride–glucose (TYG) index to evaluate the long-term prognosis of patients after percutaneous coronary intervention (PCI). **Methods**: The clinical data of 102 patients who were treated with PCI after admission to our hospital from January 2020 to December 2020 were retrospectively analyzed. All the patients were followed up for 24 months to evaluate their long-term prognosis. The occurrence of cardiovascular and cerebrovascular events in all the patients was recorded. Cardiovascular and cerebrovascular events refer to a series of diseases or conditions of the heart and the cerebrovascular system, including sudden cardiac death. Patients with cardiovascular events were assigned to the exposed group, while those without cardiovascular events were included in the nonexposed group. The left ventricular end-diastolic volume (LVEDV), left ventricular end-systolic volume (LVESV), left ventricular mass index (LVMI), left ventricular remodeling index (LVRI), left ventricular ejection fraction (LVEF), standard deviation of time to peak of left ventricular 16 segments (Tmsv16-SD), maximum time difference (Tmsv16-Dif), and difference between the 3DE index and the TYG index were collected. Logistic regression analysis was performed on the indicators with differences to analyze the influencing factors of the long-term prognosis of patients after PCI. The receiver operating characteristic (ROC) curve was drawn. The sensitivity, specificity, area under the curve (AUC), and Youden index were calculated. The best predictive cutoff value was determined. The predictive value of the 3DE index and the TYG index, either alone or in combination, was observed for long-term prognosis after PCI. The relationship between the 3DE index and the TYG index was explored. **Result**: The 2-year follow-up results showed that 22 patients experienced cardiovascular events, and they were included in the exposed group, accounting for 21.57%. The remaining 80 patients without cardiovascular events were included in the nonexposed group, accounting for 78.43%. A significant difference was found in creatinine (Cr), high-density lipoprotein cholesterol (HDL-C), LVEDV, LVESV, LVMI, LVRI, LVEF, Tmsv16-SD, Tmsv16-Dif, and the TYG index between the exposed group and nonexposed group ($p < 0.05$). Cr, HDL-C, LVEDV, LVESV, LVMI, Tmsv16-SD, Tmsv16-Dif, and the TYG index in the exposed group were higher than those in the nonexposed group ($p < 0.05$). The exposed group also had lower LVRI and LVEF than the nonexposed group ($p < 0.05$). Logistic regression analysis of the indicators with differences showed that Cr, HDL-C, LVEDV, LVESV, LVMI, LVRI, LVEF, Tmsv16-SD, Tmsv16-Dif, and the TYG index were the major factors that affect the long-term prognosis of patients after PCI, with odds ratio values >1. Correlation analysis showed that the TYG index was positively correlated with LVEDV, LVESV, LVMI, Tmsv16-SD, Tmsv16-Dif, and the TYG index (r = 0.565, 0.678, 0.696, 0.702, 0.788, 0.804, $p < 0.05$). Moreover, it was negatively correlated with LVRI and LVEF (r = –0.580, –0.674, $p < 0.05$). The sensitivity and specificity of the 3DE index combined with the TYG index in predicting long-term prognosis after PCI were 0.818 and 0.950, respectively, which were significantly higher than those of the 3DE index or the TYG index alone. The Youden index was 0.768, the AUC value was 0.922, and the optimal threshold was 36.64. **Conclusion**: The 3DE index and the TYG index were influencing factors for the long-term prognosis of patients after PCI, and a correlation existed between the 3DE index and the TYG index. The 3DE index combined with the TYG index can improve the predictive efficiency of the long-term prognosis of patients after PCI.

Keywords

3D echocardiography; triglyceride–glucose index; percutaneous coronary intervention; long-term prognosis

Introduction

Coronary heart disease (CHD) belongs to a class of cardiovascular diseases with high clinical incidence. It refers to the accumulation of plaque in the coronary arteries, causing the lumen to acquire a state of stenosis or occlusion, affecting blood flow to the heart, and leading to myocardial hypoxia or necrosis of the disease [1]. Under the influence of various factors, such as fatigue and emotional fluctuations, CHD is prone to serious complications that can endanger the life of patients [2]. Percutaneous coronary intervention (PCI) is one of the primary therapeutic measures for patients with coronary artery disease; it promotes hemodynamic restoration by unblocking stenotic or occluded coronary arteries, restoring myocardial blood perfusion [3]. PCI is not only less invasive, but it can also be as effective as desired [4]. However, PCI treatment has some drawbacks; for example, the occurrence of postoperative cardiovascular events results in poor prognosis for patients and the burden of undergoing a second surgery [5]. Therefore, the prevention and treatment of PCI prognosis have gradually become a popular topic of clinical concern. Among various techniques, three-dimensional echocardiography (3DE) can truly provide the 3D structure of the heart, and it has been widely used in the clinical assessment of the left ventricular volume and function in patients with coronary artery disease [6]. In accordance with a relevant study [7], the recovery of cardiac function can be evaluated via the 3DE measurement index after PCI, proving its considerable value for the prognostic assessment of patients. The triglyceride–glucose (TYG) index belongs to the synthetic index of triglyceride related to blood glucose in the fasting state; it is an effective evaluation index of insulin resistance and exhibits a good predictive effect on the occurrence of cardiovascular and cerebrovascular diseases, coronary artery calcification disease, and asymptomatic coronary heart disease [8]. A related study found that the TYG index is closely related to the prognosis of patients who underwent PCI [9]. However, the value of 3DE combined with the TYG index in assessing long-term prognosis after PCI has rarely been reported clinically. Therefore, the clinical data of 102 patients who underwent PCI in our hospital from January 2020 to December 2020 were retrospectively analyzed to investigate the value of 3DE combined with the TYG index in the long-term prognosis after PCI of such patients. This study also aims to provide a reference for the assessment of patients post-PCI.

Subjects and Methods

Research Subjects

The clinical data of 102 patients (60 males and 42 females) who underwent PCI in our hospital from January 2020 to December 2020 were retrospectively analyzed. The mean age of the patients was (59.32 $\pm$ 2.86) years, ranging from 55 years to 65 years. This study obtained ethical approval from the institutional review board, and all the patients provided informed consent.

Inclusion criteria: (1) Patients diagnosed with stable angina pectoris in accordance with the latest guidelines and expert consensus [10]. (2) The stenosis rate of diseased vessels was at least 75% in accordance with coronary angiography. (3) PCI was performed and complete revascularization was achieved in our hospital. (4) Patients with complete long-term follow-up and clinical data. Exclusion criteria: (1) Patients with congenital heart disease, cardiomyopathy, or rheumatic heart disease. (2) Patients with other organ diseases, such as diseases of the liver and kidney. (3) Patients with endocrine system or coagulation system diseases. (4) Patients with severe diseases, such as malignant tumors. (5) Patients with cardiac pacemakers. (6) Patients who underwent urgent PCI for acute coronary syndrome.

Methods

Therapeutic Methods

All the patients received symptomatic treatments, such as oxygen inhalation, nutritional support, antiplatelet aggregation, and anticoagulation; antihypertensive, hypoglycemic, and hypolipidemic treatments; and oral statins after admission. In accordance with the specific conditions of the patients, PCI was performed after 12 h of treatment. The major PCI procedure was as follows. Multilocation coronary angiography was performed through the right femoral artery to determine whether the patients were eligible for PCI. After determining whether the patients met the criteria for treatment, a balloon pre-dilated stent or a direct stent was implanted depending on the angiographic findings. The right femoral artery was selected as the puncture route and punctured using the Seldinger method. Then, a 6F sheath was inserted with 6000–8000 U of low-molecular-weight heparin (0.4 mL; Qilu Pharmaceutical Co., Ltd.; 5000 IU; SFDA approval no.: H20030429, Jinan, Shandong, China), and whether a pacemaker should be placed was determined in accordance with the actual situation of the patients. The sheath was removed 4 h after surgery, and a localized pressure bandage was applied for 30 min. The sheath was wrapped with sterile gauze and bandage and could be removed after 24 h. Postoperatively, patients continued to receive various symptomatic treatments, such as statins, anticoagulation, oxygen inhalation, and antiplatelet aggregation.

3DE Examination

Instrument. A Philips EPIQ 7C echocardiography device (Philips Corporation, 20193062262, Amsterdam, Holland) with a 3D ultrasound heart model system and an X5-1 probe was selected, with a probe frequency of 3.5 Hz to 5.0 Hz.

Examination methods. The electrocardiography (ECG) device was connected, the ultrasonic probe was placed in the apical position, and the angle of the probe was adjusted

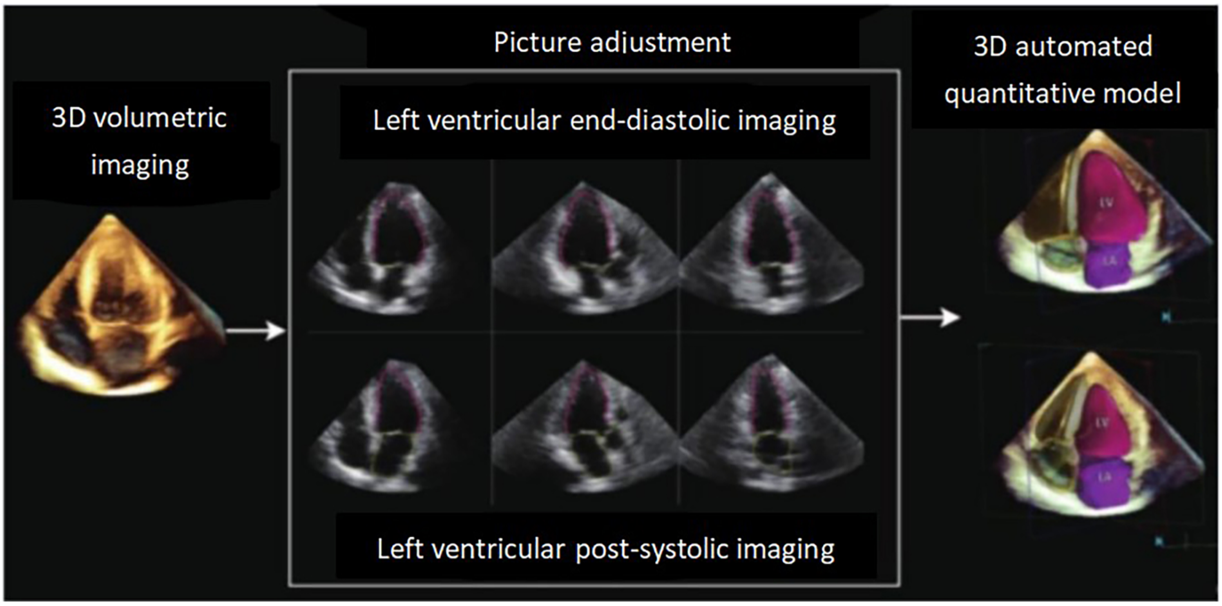

Fig. 1. Evaluation of cardiac function after percutaneous coronary intervention (PCI) by using the three-dimensional echocardiography (3DE) technique.

to ensure that the apical four-chamber and two-chamber images could be clearly displayed. The depth, gain, focus, and fan angle of an image were adjusted to ensure the most ideal display in the left ventricle. When the ECG was stable, it was changed to the heart model, and the fan angle and depth were adjusted to ensure that the volume frame rate was at least 18 Hz. The patients were instructed to start holding their breath at the end of expiration. Four consecutive cardiac cycles were collected, and at least three 3DE dataset acquisition effort were made. In-machine analysis was performed on the obtained 3DE measurement data. The images obtained in the heart model mode were selected and the heart model key was pressed to automatically reconstruct the 3D cardiac cavity contour of the left ventricle. Each segment with poor automatic reconstruction was manually adjusted. QLAB 4.2 quantitative analysis software (Philips Corporation, 20172702464, Amsterdam, Holland) was used to select five sampling points of the left ventricular endocardium at the level of the mitral valve in the two-chamber view and at the apex in the four-chamber view. The left ventricular end-diastolic volume (LVEDV), left ventricular end-systolic volume (LVESV), left ventricular mass index (LVMI), left ventricular remodeling index (LVRI), left ventricular ejection fraction (LVEF), standard deviation of time to peak of left ventricular 16 segments (Tmsv16-SD), and maximum time difference (Tmsv16-Dif) were automatically outputted in the software, as shown in Fig. 1.

LVEF, LVEDV, LVESV, and other indicators were automatically calculated on the basis of the 3DE dataset with a high frame rate for CHD patients. The 3D contours of the heart obtained via automatic reconstruction were observed with the naked eyes, and the inaccurate segments were manually adjusted during local automatic delineation. Then, the 3D color model of the left ventricular chamber was generated again, and the values of LVEF, LVEDV, and LVESV were recorded.

Biochemical Detection

Before and after PCI operation, 5 mL of fasting serum samples were collected from all the patients, centrifuged, and separated to obtain sera, which were stored at –20 °C until detection. The serum samples were taken out during the test, and the indicators were determined using a BS-200 automatic biochemical analyzer (Shenzhen Mindray Medical Co., 20192220392, Shenzhen, Guangdong, China). The primary measurement indicators included fasting plasma glucose (FPG), triglyceride (TG), creatinine (Cr), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and urea nitrogen (BUN). The TYG index was calculated, and the specific calculation formula was as follows: TYG index = In [the product of the fasting serum triglycerides and fasting blood glucose values/2] (the potential threshold for TYG was 9.05–9.09, and higher than 9.09 was used as a prognostic threshold for identifying individuals at risk of diabetic nephropathy).

The 3DE and laboratory test data of all the patients were collected after surgery.

Follow-up

After PCI, patients were followed up for 24 months to evaluate their long-term prognosis comprehensively. Follow-up in written form was conducted in detail to record

Table 1. Occurrence of cardiovascular events after PCI (n = 102).

Cardiovascular events and their occurrence time points (month)	Number of cases (n)	Proportion (%)
Heart failure (8, 11, 13, 17, 18, and 22)	6	5.88
Angina pectoris recurrence (6, 9, 11, 14, 15, 18, 20, 21, and 24)	9	8.82
Stent thrombosis (12, 16, 19, and 23)	4	3.92
Target-vessel revascularization (13 and 17)	2	1.96
Death from cardiac causes (21)	1	0.98

Table 2. Comparison of basic data between the exposed and nonexposed groups.

Projects	Number of cases	Exposed group (n = 22)	Nonexposed group (n = 80)	χ^2/t	*p*
Gender					
Male	60	14 (63.64)	46 (57.50)	0.268	0.605
Female	42	8 (36.36)	34 (42.50)		
Age (years)		59.10 ± 2.94	59.68 ± 3.12	0.781	0.436
Body mass index (kg/m^2)		21.68 ± 2.40	22.10 ± 2.58	0.686	0.494
Smoking history					
Yes	28	5 (22.73)	23 (28.75)	0.314	0.575
None	74	17 (76.27)	57 (71.25)		
Drinking history					
Yes	20	4 (18.18)	16 (20.00)	0.036	0.849
None	82	18 (81.82)	64 (80.00)		
Family history of heart disease					
Yes	6	1 (4.55)	5 (6.25)	0.091	0.763
None	96	21 (95.45)	75 (93.75)		
History of renal insufficiency					
Yes	5	1 (4.55)	4 (5.00)	0.008	0.930
None	97	21 (95.45)	76 (95.00)		
Anticoagulants					
One kind of	56	12 (54.55)	44 (55.00)	0.001	0.970
Two kinds of	46	10 (45.45)	36 (45.00)		
Basic diseases					
Hypertension	25	4 (18.18)	21 (26.25)	0.607	0.436
Diabetes	20	3 (13.64)	17 (21.25)	0.910	0.340
Hyperlipidemia	18	3 (13.64)	15 (18.75)	0.504	0.478
Cardiac function classification					
Level III	44	9 (40.91)	35 (43.75)	0.057	0.812
Level IV	58	13 (59.09)	45 (56.25)		
Lesion site					
Left main coronary artery	40	8 (36.36)	32 (40.00)	0.096	0.757
Three coronary lesions	62	14 (63.64)	48 (60.00)		
Interventional path					
Transradial artery	84	19 (86.4)	65 (81.25)	0.311	0.577
Transfemoral artery	18	3 (13.64)	15 (18.75)		
TIMI grade					
Level 2	11	3 (13.64)	8 (10.00)	0.237	0.626
Level 3	91	19 (86.4)	72 (90.00)		
Complete revascularization					
Yes	94	20 (90.90)	74 (92.5)	0.060	0.806
No	8	2 (9.09)	6 (7.50)		
Postoperative monitoring days (range) complication		2.17 ± 0.73	2.31 ± 0.68	0.842	0.402
None	82	18 (81.82)	64 (80.00)		
Major complications (bleeding/vascular injury)	7	1 (4.55)	6 (7.50)	0.224	0.610
Secondary complications (renal insufficiency)	13	3 (13.64)	10 (12.50)		

Table 3. Comparison of the 3DE index, TYG index, and laboratory indicators between the exposed group and the nonexposed group.

Project		Exposed group (n = 22)	Nonexposed group (n = 80)	*t*	*p*
Cr (µmol/L)	Preoperative	124.85 ± 10.32	118.90 ± 10.78	2.313	0.023
	Postoperative	114.21 ± 9.12	112.45 ± 8.78	0.824	0.412
HDL-C (mmol/L)	Preoperative	1.10 ± 0.12	0.99 ± 0.15	3.168	0.002
	Postoperative	1.24 ± 0.17	1.38 ± 0.20	2.996	0.003
LDL-C (mmol/L)	Preoperative	3.15 ± 0.42	3.10 ± 0.36	0.556	0.579
	Postoperative	2.31 ± 0.29	2.27 ± 0.19	0.773	0.441
BUN (mmol/L)	Preoperative	5.70 ± 1.06	5.36 ± 1.14	1.257	0.212
	Postoperative	6.02 ± 0.98	5.97 ± 0.93	0.221	0.826
LVEDV (mL)	Preoperative	110.25 ± 11.25	102.54 ± 10.88	2.922	0.004
	Postoperative	106.41 ± 10.27	98.02 ± 9.37	3.643	0.000
LVESV (mL)	Preoperative	74.76 ± 7.42	70.32 ± 6.50	2.751	0.007
	Postoperative	68.31 ± 6.48	62.45 ± 5.32	4.360	0.000
LVMI (g/m^2)	Preoperative	98.65 ± 5.60	95.42 ± 5.14	2.561	0.012
	Postoperative	82.56 ± 4.21	78.34 ± 3.88	4.436	0.000
LVRI	Preoperative	1.70 ± 0.32	2.04 ± 0.46	3.252	0.002
	Postoperative	2.42 ± 0.40	2.73 ± 0.45	2.927	0.004
LVEF (%)	Preoperative	47.20 ± 6.88	51.82 ± 6.95	2.767	0.007
	Postoperative	53.73 ± 7.81	58.41 ± 7.69	2.520	0.013
Tmsv16-SD (ms)	Preoperative	8.78 ± 1.20	7.82 ± 1.32	3.078	0.003
	Postoperative	7.45 ± 1.05	6.98 ± 0.88	2.126	0.036
Tmsv16-Dif (ms)	Preoperative	38.65 ± 4.70	36.14 ± 4.32	2.368	0.020
	Postoperative	35.87 ± 3.94	32.32 ± 3.27	4.310	0.000
TYG Index	Preoperative	9.58 ± 1.58	8.60 ± 1.62	2.526	0.013
	Postoperative	8.24 ± 1.21	7.69 ± 1.04	2.119	0.037

Cr, creatinine; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; BUN, Blood urea nitrogen; LVEDV, left ventricular end-diastolic volume; LVESV, left ventricular end-systolic volume; LVMI, left ventricular mass index; LVRI, left ventricular remodeling index; LVEF, left ventricular ejection fraction; Tmsv16-SD, standard deviation of time to peak of left ventricular 16 segments; Tmsv16-Dif, maximum time difference; TYG, triglyceride–glucose.

the occurrence of cardiovascular events in all the patients. These cardiovascular events mostly included heart failure, angina recurrence, stent thrombosis, target vessel revascularization (reoperation of any target vessel part), and cardiac death.

The definition of cardiovascular events was described in detail as follows. Heart failure was defined as a clinical situation in which patients needed to undergo a new heart failure treatment or adjust the original treatment because of cardiac function decline. Angina recurrence referred to the recurrence of angina symptoms after PCI that required medical intervention. Stent thrombosis was a confirmed stent-related thrombotic event. Target vessel revascularization referred to any re-interventional or surgical operation required for the target vessel part that was initially treated with PCI. Cardiac death meant that the cause of death was directly related to a heart disease.

Observation Indexes

The differences of the 3DE and TYG indexes between the exposed group and the nonexposed group were observed, and logistic regression analysis was performed to analyze the influencing factors of long-term prognosis after PCI. The receiver operating characteristic (ROC) curve was drawn to analyze the predictive value of the 3DE index and the TYG index either alone or in combination for long-term prognosis after PCI, and the relationship between the 3DE index and the TYG index was analyzed.

Statistical Methods

SPSS 23.0 statistical software (IBM SPSS statistics, Chicago, IL, USA) was used to analyze the data. The count data were expressed as percentage and detected via χ^2 test. The measurement data were expressed as (± s) and detected via *t*-test. Pearson correlation analysis was used to screen out the indicators with statistically significant differences between the two groups. The test standard was α = 0.05, and binary logistic regression analysis was performed. *p*

Table 4. Multivariate analysis of prognostic factors after PCI.

Influencing factors	β value	SE	p	Wald value	OR value	95% CI
Cr	0.545	0.784	0.012	6.254	1.442	−1.0125–1.7832
HDL-C	0.570	0.720	0.025	6.126	1.638	−1.1282–2.0576
LVEDV	0.628	0.843	0.010	11.788	1.650	−1.1130–1.8845
LVESV	0.690	0.887	0.005	15.422	1.715	−1.1368–1.8520
LVMI	0.542	0.565	0.014	4.015	1.840	−1.0684–1.9250
LVRI	1.288	0.424	0.008	8.747	1.590	−1.1230–1.8996
LVEF	0.969	0.613	0.014	9.214	1.632	−1.0521–2.1325
Tmsv16-SD	0.661	0.702	0.008	9.356	1.688	−1.0776–2.1425
Tmsv16-Dif	0.783	0.798	0.002	12.248	1.650	−1.0698–1.8052
TYG index	0.695	0.733	0.006	6.089	1.696	−1.1320–1.8990

SE, standard error; OR, odds ratio.

Table 5. Correlation analysis between the TYG index and the 3DE index.

Indicators	TYG Index	
	r	p
LVEDV	0.420	0.035
LVESV	0.458	0.029
LVMI	0.410	0.020
LVRI	−0.492	0.018
LVEF	−0.450	0.022
Tmsv16-SD	0.502	0.018
Tmsv16-Dif	0.518	0.009
TYG index	0.534	0.004

< 0.05 was considered statistically significant. The ROC curve was used to calculate the sensitivity, specificity, area under the curve (AUC), and the Youden index, and to determine the best predictive cutoff value. The predictive value of the 3DE index and the TYG index either alone or in combination for long-term prognosis after PCI was analyzed.

Result

Prognosis Situation after PCI

Regular postoperative follow-up was performed once a month for 2 years. No patient was lost during the follow-up period, and only one patient died of heart disease at the 21st month. The follow-up results showed that 22 patients had cardiovascular events within 2 years after surgery, accounting for 21.57% (22/102). They were included in the exposed group. The specific types of cardiovascular events are listed in Table 1. The remaining 80 patients had no cardiovascular events within 2 years after surgery, accounting for 78.43% (80/102). They were included in the nonexposed group.

Comparison of Basic Information between the Exposed Group and the Non-Exposed Group

No significant difference was observed in gender, age, body mass index, smoking history, drinking history, family history of heart disease, history of renal insufficiency, anticoagulant drugs, underlying diseases, cardiac function classification, lesion location, interventional route, coronary blood flow grade (Thrombolysis in Myocardial Infarction [TIMI] Study Group grade), complete revascularization, postoperative monitoring days, and complications between the exposed group and the nonexposed group ($p >$ 0.05), as indicated in Table 2.

Comparison of the 3DE, TYG, and Laboratory Indexes between the Exposed Group and the Nonexposed Group

No significant difference was found in the levels of LDL-C and BUN between the exposed group and the non-exposed group before and after surgery ($p > 0.05$), but a significant difference was observed in Cr, HDL-C, LVEDV, LVESV, LVMI, LVRI, LVEF, Tmsv16-SD, Tmsv16-Dif, and the TYG index ($p < 0.05$). The Cr, HDL-C, LVEDV, LVESV, LVMI, Tmsv16-SD, Tmsv16-Dif, and the TYG index of the exposed group were higher than those of the non-exposed group before and after surgery ($p < 0.05$), while LVRI and LVEF in the exposed group were lower than those in the non-exposed group ($p < 0.05$), as indicated in Table 3.

Multivariate Analysis of Prognostic Factors after PCI

The logistic regression analysis of the indicators with differences showed that Cr, HDL-C, LVEDV, LVESV, LVMI, LVRI, LVEF, Tmsv16-SD, Tmsv16-Dif, and the TYG index were the major factors that affect the long-term prognosis of patients after PCI, with odds ratio (OR) values >1. The details are provided in Table 4.

Table 6. **Predictive value of the 3DE index and the TYG index either alone or in combination for long-term prognosis after PCI.**

Characteristics	AUC values	Sensitivity	Specificity	Youden index	Optimal threshold values
LVEDV	0.688	0.545	0.763	0.308	111.78
LVESV	0.731	0.545	0.925	0.470	76.26
LVMI	0.865	0.727	0.888	0.615	96.11
LVRI	0.724	0.513	0.909	0.422	2.00
LVEF	0.666	0.863	0.455	0.317	45.25
Tmsv16-SD	0.776	0.818	0.725	0.543	8.16
Tmsv16-Dif	0.657	0.682	0.625	0.307	30.00
TYG index	0.770	0.864	0.625	0.489	8.21
3DE index combined with TYG index	0.922	0.818	0.950	0.768	36.64

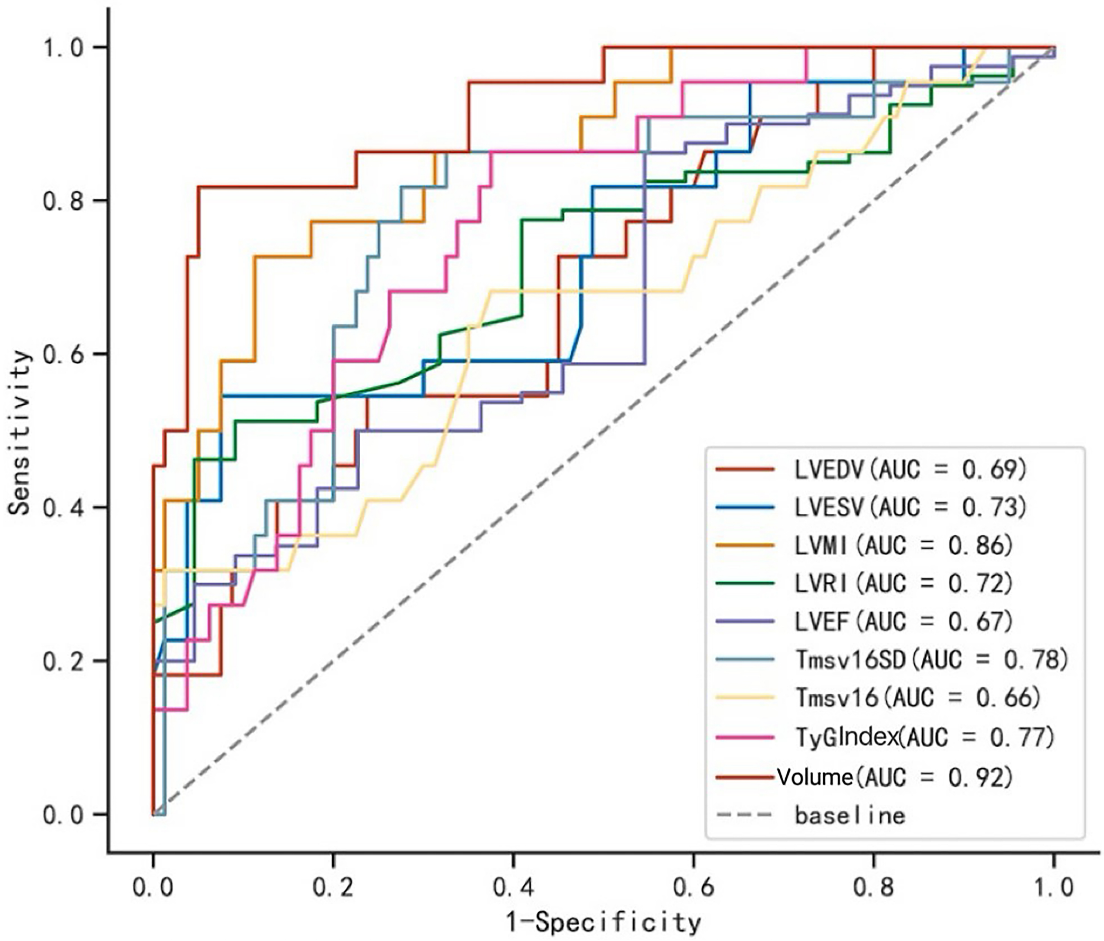

Fig. 2. ROC curves of the 3DE index and the TYG index either alone or in combination for predicting long-term prognosis in patients after PCI. ROC, Receiver Operating Characteristic; AUC, Area Under Curve.

Correlation Analysis between the TYG Index and the 3DE Index

The correlation analysis showed that the TYG index was positively correlated with LVEDV, LVESV, LVMI, Tmsv16-SD, Tmsv16-Dif, and the TYG index ($p < 0.05$), but negatively correlated with LVRI and LVEF ($p < 0.05$). Table 5 presents the details.

Prognostic Value of the 3DE Index and the TYG Index either Alone or in Combination for Long-Term Prognosis after PCI

The sensitivity and specificity of the 3DE index combined with the TYG index in predicting long-term prognosis after PCI were 0.818 and 0.950, respectively, which were significantly higher than those of the 3DE index or the TYG index alone. The Youden index was 0.768, the AUC value was 0.922, and the optimal threshold was 36.64, as shown in Table 6 and Fig. 2.

Discussion

CHD is the second most common cardiovascular disease in China; with a rapid onset, which takes less than 1 h from onset to death, and heavy burden of resuscitation and treatment, CHD seriously affects people's health [11–13]. PCI is the primary treatment method for this disease, and its effect on CHD has been fully confirmed by clinical studies [14,15]. In the diagnosis and treatment stages, the case data accumulated from past clinical work showed a significance in evaluating the prognosis of patients with coronary artery disease after PCI by using 3DE combined with the TYG index. Therefore, the current study sorted out and analyzed the clinical data of patients after PCI in 2020 for the retrospective study, aiming to summarize the experience, determine the rule, and guide clinical practice. However, some patients may suffer from cardiovascular events after PCI, which may affect their prognosis [16]. Patients are typically followed up for 3–6 months after PCI to observe the efficacy and condition of adverse drug reactions. However, our hospital conducted follow-up for 2 years to reconfirm the prognosis and the practice of bad lifestyle habits through physical examination, laboratory tests, and assessment of cardiac function. Long-term follow-up observation is beneficial for the recovery of patients with coronary artery disease and the development of disease prognosis. This study showed that 22 patients (21.57%) experienced cardiovascular events during the 2-year follow-up after PCI, and this finding was consistent with the results of one clinical report [17]. A variety of imaging techniques can be used to evaluate the efficacy and prognosis of patients after surgery, such as coronary angiography; however, this examination exhibits the disadvantages of invasiveness and high cost [18,19]. Therefore, more reasonable and scientific evaluation methods for prognosis must be explored.

3DE can detect the heart from all directions, obtaining a wide range of full-volume 3D structure database of the heart without the help of geometric shape assumptions, including the true 3D shape of the left ventricular chamber; it can evaluate the postoperative cardiac function recovery of patients in accordance with the size, shape, and function of the heart chamber [20–22]. LVEDV, LVESV, LVMI, LVRI, and LVEF can reflect ventricular remodeling, volume, and systolic function. This study found that LVEDV, LVESV, and LVMI in the exposed group were higher than those in the nonexposed group ($p < 0.05$), whereas LVRI and LVEF in the exposed group were lower than those in the nonexposed group ($p < 0.05$), suggesting that the evaluation of ventricular remodeling, volume, and systolic function via 3DE after PCI can help the clinical judgment of the long-term prognosis of patients. Under normal physiological conditions, the ventricle maintains rapid, neat, and regular synchronous systolic pumping. If a patient has CHD, then a lack of synchronization of the ventricular wall motion may occur. Left ventricular systolic synchrony can be evaluated by analyzing Tmsv16-SD, Tmsv16-Dif, and other indicators [23–25]. Tmsv16-SD and Tmsv16-Dif in the exposed group were higher than those in the nonexposed group ($p < 0.05$), suggesting that wall motion indexes related to 3DE can effectively evaluate the long-term prognosis of patients who underwent PCI.

The TYG index was first proposed in 2008. It is a new type of synthetic index related to glucose and triglyceride. The TYG index is convenient to use for detection and easy to calculate; it does not require multiple blood drawings and complex laboratory equipment, and thus, it has broad application prospects in clinical practice [26,27]. The TYG index can reflect the status of insulin resistance, and it has a good predictive value for cardiovascular diseases [28]. A relevant study showed that the TYG index has high sensitivity and specificity, and a high level of the TYG index is associated with symptomatic CHD [29]. After adjusting for various confounding factors, Peters *et al*. [30] found that the TYG index is one of the major factors for the poor prognosis of CHD patients with diabetes. The TYG index of the exposed group was higher than that of the nonexposed group ($p < 0.05$), suggesting that a high level of the TYG index may be related to the poor prognosis of patients after PCI.

The innovation of the current study is that it observes the influencing factors of the long-term prognosis of patients after PCI and analyzes the relationship between the 3DE index and the TYG index. It further confirmed the value of the 3DE index combined with the TYG index in judging the long-term prognosis of patients after PCI. The sensitivity and specificity of the combination of the 3DE index and the TYG index for the prediction of long-term prognosis after PCI were 0.818 and 0.950, respectively, which were significantly higher than those of the 3DE index or the TYG index alone, suggesting that the combination of the two indexes achieved higher prediction efficiency. In addition, this study found that Cr and HDL-C were also the major factors that affect the long-term prognosis of patients after PCI. This result is similar to that of a previous study [31], indicating that high levels of Cr and HDL-C can lead to poor prognosis after PCI.

The current study also has several limitations. (1) A single-center sample study is actually conducted. A comprehensive assessment of a multicenter study will be added to the detailed information of patients to increase the external validity of the study. (2) The dynamic monitoring of the 3DE and TYG indexes cannot be collected completely because this study is retrospective. The work lacks a comprehensive mastery of assessment of the patients during prognosis and is affected by the follow-up of the treatment. (3) Several characteristic information, such as underlying diseases, history of drinking and smoking, and anticoagulant drugs used in the postoperative period, is not considered in this study. Therefore, subsequent studies should give more attention to the exclusion criteria and explore more objective clinical data. (4) This study only includes samples from 2020, and the smaller sample size does not exclude the possibility of a Class II error. Thus, the sample size should be expanded to increase the confidence of this study.

Conclusion

In conclusion, the 3DE index and the TYG index were identified as influencing factors for the long-term prognosis of patients after PCI, and a correlation existed between the two indexes. The combination of 3DE and the TYG index could improve the predictive efficiency of the long-term prognosis of patients after PCI. The role of 3DE combined with the TYG index in evaluating long-term prognosis after PCI should be fully confirmed by multicenter and long-term follow-up studies with larger samples in the future.

Availability of Data and Materials

Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

Author Contributions

XL designed and supervised the entire work. YD and LG performed the experiments and contributed equally to this work. XL and LG prepared and wrote the paper. XL, YD and LG analysed the data and prepared the figures. 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

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Jingmen Central Hospital Medical Ethics Committee (approval number: 2024–02–010). All patients signed informed consent forms.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Zhu Y, Liu K, Chen M, Liu Y, Gao A, Hu C, *et al*. Triglyceride-glucose index is associated with in-stent restenosis in patients with acute coronary syndrome after percutaneous coronary intervention with drug-eluting stents. Cardiovascular Diabetology. 2021; 20: 137.

[2] Luo E, Wang D, Yan G, Qiao Y, Liu B, Hou J, *et al*. High triglyceride-glucose index is associated with poor prognosis in patients with acute ST-elevation myocardial infarction after percutaneous coronary intervention. Cardiovascular Diabetology. 2019; 18: 150.

[3] Zhao X, Wang Y, Chen R, Li J, Zhou J, Liu C, *et al*. Triglyceride glucose index combined with plaque characteristics as a novel biomarker for cardiovascular outcomes after percutaneous coronary intervention in ST-elevated myocardial infarction patients: an intravascular optical coherence tomography study. Cardiovascular Diabetology. 2021; 20: 131.

[4] Ma X, Dong L, Shao Q, Cheng Y, Lv S, Sun Y, *et al*. Triglyceride glucose index for predicting cardiovascular outcomes after percutaneous coronary intervention in patients with type 2 diabetes mellitus and acute coronary syndrome. Cardiovascular Diabetology. 2020; 19: 31.

[5] Li J, Ren L, Chang C, Luo L. Triglyceride-Glukose Index Predicts Adverse Events in Patients with Acute Coronary Syndrome: A Meta-Analysis of Cohort Studies. Hormone and Metabolic Research = Hormon- Und Stoffwechselforschung = Hormones et Metabolisme. 2021; 53: 594–601.

[6] Özkalaycı F, Karagöz A, Karabay CY, Tanboga İH, Türkyılmaz E, Saygı M, *et al*. Prognostic value of triglyceride/glucose index in patients with ST-segment elevation myocardial infarction. Biomarkers in Medicine. 2022; 16: 613–622.

[7] Mao Q, Zhou D, Li Y, Wang Y, Xu SC, Zhao XH. The Triglyceride-Glucose Index Predicts Coronary Artery Disease Severity and Cardiovascular Outcomes in Patients with Non-ST-Segment Elevation Acute Coronary Syndrome. Disease Markers. 2019; 2019: 6891537.

[8] Huang R, Lin Y, Ye X, Zhong X, Xie P, Li M, *et al*. Triglyceride-glucose index in the development of heart failure and left ventricular dysfunction: analysis of the ARIC study. European Journal of Preventive Cardiology. 2022; 29: 1531–1541.

[9] Gao S, Ma W, Huang S, Lin X, Yu M. Impact of triglyceride-glucose index on long-term cardiovascular outcomes in patients with myocardial infarction with nonobstructive coronary arteries. Nutrition, Metabolism, and Cardiovascular Diseases: NMCD. 2021; 31: 3184–3192.

[10] Farmakis D, Andrikopoulos G, Giamouzis G, Giannakoulas G, Poulimenos L, Skalidis E, *et al*. Practical Recommendations for the Diagnosis and Medical Management of Stable Angina: An Expert Panel Consensus. Journal of Cardiovascular Pharmacology. 2019; 74: 308–314.

[11] Mirshafiei H, Darroudi S, Ghayour-Mobarhan M, Esmaeili H, AkbariRad M, Mouhebati M, *et al*. Altered triglyceride glucose index and fasted serum triglyceride high-density lipopro-

tein cholesterol ratio predict incidence of cardiovascular disease in the Mashhad cohort study. BioFactors (Oxford, England). 2022; 48: 643–650.
[12] Baydar O, Kilic A, Okcuoglu J, Apaydin Z, Can MM. The Triglyceride-Glucose Index, a Predictor of Insulin Resistance, Is Associated with Subclinical Atherosclerosis. Angiology. 2021; 72: 994–1000.
[13] Cetin Sanlialp S, Nar G, Nar R. Relationship between circulating serum omentin-1 levels and nascent metabolic syndrome in patients with hypertension. Journal of Investigative Medicine: the Official Publication of the American Federation for Clinical Research. 2022; 70: 780–785.
[14] Biswas AK, Haque T, Banik D, Choudhury SR, Khan SR, Malik FTN. Identification of significant coronary artery disease in patients with non-ST segment elevation acute coronary syndrome by myocardial strain analyses using three dimensional speckle tracking echocardiography. Echocardiography (Mount Kisco, N.Y.). 2018; 35: 1988–1996.
[15] Fei M, Li M, Ran H, Sheng Z, Dong J, Zhang P. Four-dimensional quantification on left atrial volume-strain in coronary heart disease patients without regional wall motion abnormalities: Correlation with the severity of coronary stenosis. Echocardiography (Mount Kisco, N.Y.). 2022; 39: 758–767.
[16] Berbarie RF, Dib E, Ahmad M. Stress echocardiography using real-time three-dimensional imaging. Echocardiography (Mount Kisco, N.Y.). 2018; 35: 1196–1203.
[17] Hidayet Ş, Yağmur J, Karaca Y, Bayramoğlu A, Yolbaş S, Hidayet E, *et al*. Assessment of left atrial volume and function in patients with Sjögren's syndrome using three-dimensional echocardiography. Echocardiography (Mount Kisco, N.Y.). 2020; 37: 715–721.
[18] Nguyen VP, Qin A, Kirkpatrick JN. Three-dimensional echocardiography of mechanical circulatory support devices. Echocardiography (Mount Kisco, N.Y.). 2018; 35: 2071–2078.
[19] Inciardi RM, Galderisi M, Nistri S, Santoro C, Cicoira M, Rossi A. Echocardiographic advances in hypertrophic cardiomyopathy: Three-dimensional and strain imaging echocardiography. Echocardiography (Mount Kisco, N.Y.). 2018; 35: 716–726.
[20] Kemaloğlu Öz T, Fiore C, Gürol T, Şener T, Soylu Ö, Dağdeviren B, *et al*. Usefulness of live/real time three/four-dimensional transesophageal echocardiography in the percutaneous closure of an iatrogenic aorto-right ventricular fistula. Echocardiography (Mount Kisco, N.Y.). 2018; 35: 410–412.
[21] Murray CSG, Salama AY, Akdogan RE, Harb S, Nahar T, Nanda NC. Assessment of tricuspid valve by two- and three-dimensional echocardiography with special reference to percutaneous repair and prosthetic valve implantation procedures. Echocardiography (Mount Kisco, N.Y.). 2018; 35: 1419–1438.
[22] Nemes A, Kormányos Á, Domsik P, Kalapos A, Ambrus N, Lengyel C. Normal reference values of three-dimensional speckle-tracking echocardiography-derived right atrial volumes and volume-based functional properties in healthy adults (Insights from the MAGYAR-Healthy Study). Journal of Clinical Ultrasound: JCU. 2020; 48: 263–268.
[23] Dibbendhu K, Sinha SK, Pradyot T, Razi M, Puneet A, Shishir S, *et al*. Three Dimensional Echocardiography in Non ST Elevation Acute Coronary Syndrome in North India(3D-EINSTEIN)-A Single Centre Prospective Study. Journal of the Practice of Cardiovascular Sciences. 2019; 5: 94–101.
[24] Ostenfeld E, Werther-Evaldsson A, Engblom H, Ingvarsson A, Roijer A, Meurling C, *et al*. Discriminatory ability of right atrial volumes with two- and three-dimensional echocardiography to detect elevated right atrial pressure in pulmonary hypertension. Clinical Physiology and Functional Imaging. 2018; 38: 192–199.
[25] Grin L, Laish-Farkash A, Shenhav S, Piltz X, Ganelin L, Rabinovich M, *et al*. Safety of nifedipine in threatened preterm labor: Investigation by three-dimensional echocardiography. Echocardiography (Mount Kisco, N.Y.). 2018; 35: 1164–1170.
[26] Hani ME. Added value of three-dimensional transesophageal echocardiography in management of mitral paravalvular leaks. Echocardiography. 2020; 37: 954–964.
[27] Tandon R, Arisha MJ, Nanda NC, Kumar S, Wander GS, Sriralluri S, *et al*. Incremental benefit of three-dimensional transthoracic echocardiography in the assessment of left atrial appendage aneurysm leading to severe extrinsic compression of a coronary artery. Echocardiography (Mount Kisco, N.Y.). 2018; 35: 685–691.
[28] Lv Q, Li M, Li H, Wu C, Dong N, Li Y, *et al*. Assessment of biventricular function by three-dimensional speckle-tracking echocardiography in clinically well pediatric heart transplantation patients. Echocardiography (Mount Kisco, N.Y.). 2020; 37: 2107–2115.
[29] Ramsdell G, Davies S, Ailawadi G, Singh KE. An unusual appearance of a large mitral valve cleft within a prolapsing segment diagnosed by three-dimensional transesophageal echocardiography. Echocardiography (Mount Kisco, N.Y.). 2018; 35: 2124–2126.
[30] Peters AC, Gong FF, Rigolin VH. Three-dimensional echocardiography for the assessment of the tricuspid valve. Echocardiography (Mount Kisco, N.Y.). 2020; 37: 758–768.
[31] Ekmekci C, Cabuk AK. Comparison of left ventricular subclinical systolic dysfunction between hemodialysis patients and renal transplant recipients using real time three-dimensional echocardiography. Echocardiography (Mount Kisco, N.Y.). 2022; 39: 708–716.