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ORIGINAL RESEARCH

Comparison and Optimization of Cardiovascular Risk Scores in Predicting the 4-Year Outcome of Patients with Obstructive Coronary Arteries Disease

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Objective: How well cardiovascular risk models perform in selected atherosclerosis patients for predicting outcomes is unknown. We sought to compare the performance of cardiovascular risk models (Framingham, Globorisk, SCORE2 & SCORE2-OP, and an updated new model) in predicting the 4-year outcome of patients with obstructive coronary artery disease (CAD).

Methods: Patients with suspected CAD who underwent coronary computed tomography angiography (CCTA) were recruited. Obstructive CAD was defined from CCTA as ≥ 50% stenosis. Computed tomography images, the scores of the cardiovascular risk models, and 4-year composite endpoints were assessed. Whether the patients underwent revascularization within 60 days after CCTA was also recorded. Multivariate regression analysis and receiver operating characteristics (ROC) curve analysis were performed.

Results: A total of 95 patients (mean age: 69.5 ± 10.33 years; 69 males) with obstructive CAD were included in this study. After the ROC analysis, the Framingham, Globorisk, SCORE2 & SCORE2-OP risk score showed prediction values with AUC 0.628 (95% CI: 0.532–0.725), 0.647 (95% CI: 0.542–0.742), 0.684 (95% CI: 0.581–0.776), respectively. Multivariate regression analysis showed that, among the three risk models, only SCORE2 & SCORE2-OP risk score was associated with composite endpoints (hazard ratio: 1.050; 95% CI: 1.021–1.079; $p = 0.001$) after adjusting for confounding factors. The AUC of the new risk model by combing SCORE2 & SCORE2-OP risk score with revascularization and the number of obstructive vessels in predicting composite endpoints reached 0.898 (95% CI: 0.819–0.951).

Conclusion: The SCORE2 & SCORE2-OP risk score combined with the number of obstructive vessels and revascularization is predictive for adverse outcomes in patients with obstructive CAD.

Keywords: coronary computed tomography, obstructive coronary artery disease, cardiovascular risk factors, prediction model

Introduction

Coronary artery disease (CAD) remains the leading cause of death in the world.[1] Serious clinical trials[2–4] demonstrated that patients with obstructive CAD had a higher likelihood to develop fatal or non-fatal cardiovascular events, compared to those with non-obstructive CAD. It is important to accurately stratify the risk of future cardiovascular events in CAD patients.

Although several risk scores, such as Framingham risk score,[5] Globorisk risk score,[6] and SCORE2 & SCORE2-OP risk score[7] have been proposed for predicting the 10-year risk of fatal or non-fatal cardiovascular events, these risk scores were based on asymptomatic community cohort. In particular, the SCORE2 & SCORE2-OP risk score can also be utilized in patients with type 2 diabetes mellitus or established atherosclerotic cardiovascular disease. The known risk factors for cardiovascular disease such as age, sex, lipid levels, blood pressure, and smoking, are covered by the SCORE2

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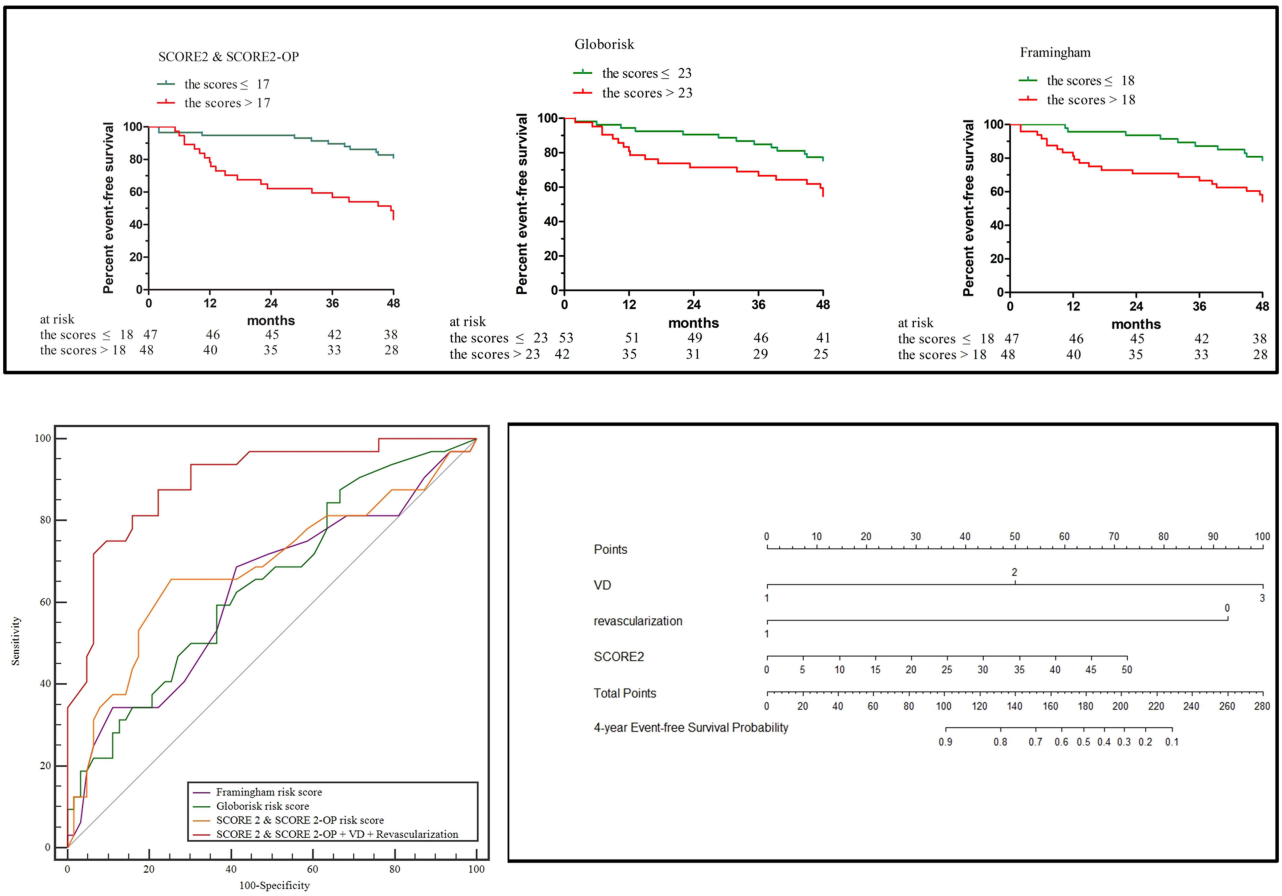
Graphical Abstract



& SCORE2-OP risk prediction. A competing risk model is also used to adjust the risk for the likelihood of future fatal and nonfatal events based on additional risk factors, including diabetes mellitus, renal function, familial hypercholesterolemia, and established atherosclerotic cardiovascular disease. However, the usefulness of these risk scores in predicting the risk of developing cardiovascular events in patients with obstructive CAD is unknown.

The purpose of this study is to determine the efficiency of the Framingham risk score, Globorisk risk score, and SCORE2 & SCORE2-OP risk score in predicting cardiovascular events in patients with obstructive CAD and to compare them to the new optimized SCORE2 & SCORE2-OP risk prediction model.

Methods

Patients

Patients with suspected CAD by clinicians due to stable chest pain or angina-equivalent symptoms were consecutively recruited in this study. All patients underwent coronary computed tomography angiography (CCTA). The exclusion criteria were as follows: (1) history of CAD, myocardial infarction (MI), or acute coronary syndrome; (2) history of percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) treatment; (3) had <50% luminal stenosis in all epicardial coronary arteries; (4) allergy to iodine contrast; and (5) moderate or severe renal dysfunction (GFR < 45 mL/min/1.73m^2). The present study complies with the Declaration of Helsinki. The study protocol was approved by our institutional medical ethics committee and each participant provided a written consent form.

Baseline Data Collection

The baseline data of the patients were collected from the medical records. The baseline data included age, sex, current smoking (tobacco products used within the last month), systolic blood pressure (SBP), antihypertensive medication use, total cholesterol, high-density lipoprotein (HLD), diabetes mellitus, and chronic kidney disease. Diabetes mellitus was considered to be present if diabetes mellitus was self-reported or if using anti-diabetic medication. The time of suffering diabetes mellitus and evidence of target organ damage in diabetes mellitus were collected. Chronic kidney disease (CKD) was considered to be present if CKD was diagnosed by nephrologists. The Framingham risk score, the Globorisk risk score, and the SCORE2 & SCORE2-OP risk score were calculated using the published criteria.[5–7] The time interval between baseline data collection and coronary CTA examination was within 2 weeks.

Coronary CTA

The CCTA was performed on a dual-source CT scanner (SOMATOM Force, Siemens Healthcare, Siemens, Germany). A clinically routine protocol was used for CCTA with the following imaging parameters: tube voltage between 70 kVp and 100 kVp based on body mass index (BMI), 280 mAs per rotation, beam collimation 192 mm × 0.6 mm, pitch 3.2, 0.25 s/rot. The acquired images were reconstructed with a slice thickness of 0.75 mm. The iodine contrast agent (Iomeron 400 mg/mL, iomeprol injection, Bracco Shanghai, China) was injected into an antecubital vein with a dose of 1.5 mL/kg and a flow rate of 5 mL/s followed by 50 mL of saline solution with the same flow rate. The image acquisition was initiated using the bolus tracking method with a region of interest placed at the ascending aorta and the attenuation threshold was set as 100 Hounsfield units.

CCTA Image Analysis

All the CCTA imaging data were analyzed by 2 experienced (>5 years' experience in cardiovascular imaging) radiologists using an offline workstation (Syngo.via, Siemens Healthcare, Forchheim, Germany) blinded to clinical data and the follow-up information with consensus. The disagreement between these 2 radiologists was addressed by a senior radiologist (>10 years' experience in cardiovascular imaging). The coronary artery was segmented based on the American Heart Association 15-segment coronary artery classification criteria.[8] The luminal stenosis of each coronary artery segment >1.5 mm diameter was measured on the images of curved reconstruction. The luminal stenosis of the coronary artery was graded as the following categories: none stenosis (0% lumen diameter stenosis); mild stenosis (1% to 49%); moderate stenosis (50% to 69%), severe stenosis (70% to 99%), and occlusion (100%). Obstructive CAD was defined when there was ≥50% stenosis in any coronary artery segment.

Follow-Up and Outcome Data

All the patients were followed-up by phone at 6-month intervals after baseline examination until the date of occurrence of outcome or for a total of 4 years. The composite endpoints included death from any cause, hospitalization for myocardial infarction (MI), or stroke. During the follow-up, the information of patients undergoing revascularization (PCI or CABG) within 60 days after CCTA was also recorded.

Statistical Analysis

Continuous data were presented as mean and standard deviation and the categorical data were presented as counts and percentages. The obstructive CAD patients were divided into three groups: one-vessel disease (1-VD) group, ≥50% stenosis in 1 major vessel / its' branch; two-vessel disease (2-VD) group, ≥50% stenosis in 2 major vessels / their branches; and three-vessel disease and/or left main stem stenosis (3-VD) group, ≥50% stenosis in 3 major vessels /their branches or ≥50% in left main stenosis. Clinical characteristics at baseline were compared between patients with and without composite endpoints using an independent *t*-test, Mann–Whitney *U*-test, Chi-square test, or Fisher's exact test when appropriate. For assessing the predictive value of different risk scores for composite endpoints, univariable Cox regression was used. Multivariate Cox regression analysis was also conducted by adjusting for confounding factors which were determined in univariate analysis when p value < 0.1. The survival curves were generated using the Kaplan-

Meier method, and the differences between curves were assessed by using the Log rank test. Receiver operating characteristics (ROC) curves were utilized to calculate the area under the curve (AUC) of CV risk models in predicting composite endpoints.

A two-sided p-value of less than 0.05 was considered statistically significant. The statistical analyses were performed with IBM SPSS 20.0, the R4.2.1 software, MedCalc, and GraphPad Prism 5.

Results

Clinical Characteristics

From March 2017 to July 2018, 849 consecutive patients who were suspected of CAD and underwent coronary CTA were recruited. Of the 849 patients, 754 were excluded due to the following reasons: 18 patients underwent PCI or CABG before CCTA; 39 patients with a history of CAD or MI or stroke; 15 patients were suspected of acute coronary syndrome; 682 patients had <50% luminal stenosis in all epicardial coronary arteries (Figure 1). Of the remaining 95 patients, the mean age was 69.5 (69.5 ± 10.33, years old) and 69 are male (72.6%). The clinical characteristics of this study population are detailed in Table 1. The prevalence of CKD, the number of vessel diseases, and revascularization in patients with composite endpoints were significantly greater than that in patients without (all $p < 0.05$). No significant differences were found in other variables between the two patient groups (all $p > 0.05$). Of all 95 patients, 35 patients received revascularization (1 CABG and 34 PCIs), 4 of whom underwent incomplete revascularization and 2 patients occurred composite endpoints. Of 32 patients with composite endpoints, 3 (9.4%) received revascularization, whereas 50.8% of patients without composite endpoints received revascularization ($p < 0.001$).

Different Risk Scores Predict Composite Endpoints

The median follow-up time of this study population was 41.2 months (range: 2–64, months). A total of 32 (33.7%) patients suffered from the composite endpoints within 4 years including 18 deaths, 8 Mis, and 6 strokes. Univariate Cox regression analyses showed that SCORE 2 and SCORE 2-OP risk score (HR, 1.050; 95% CI, 1.021–1.079; $p = 0.001$), Globorisk risk score (HR, 1.024; 95% CI, 1.007–1.041; $p = 0.007$), and Framingham risk score (HR, 1.095; 95% CI, 1.010–1.187; $p = 0.028$) were predictive for composite endpoints (all $p < 0.05$) (Table 2). Among the three risk scores, only SCORE2 & SCORE2-OP risk score

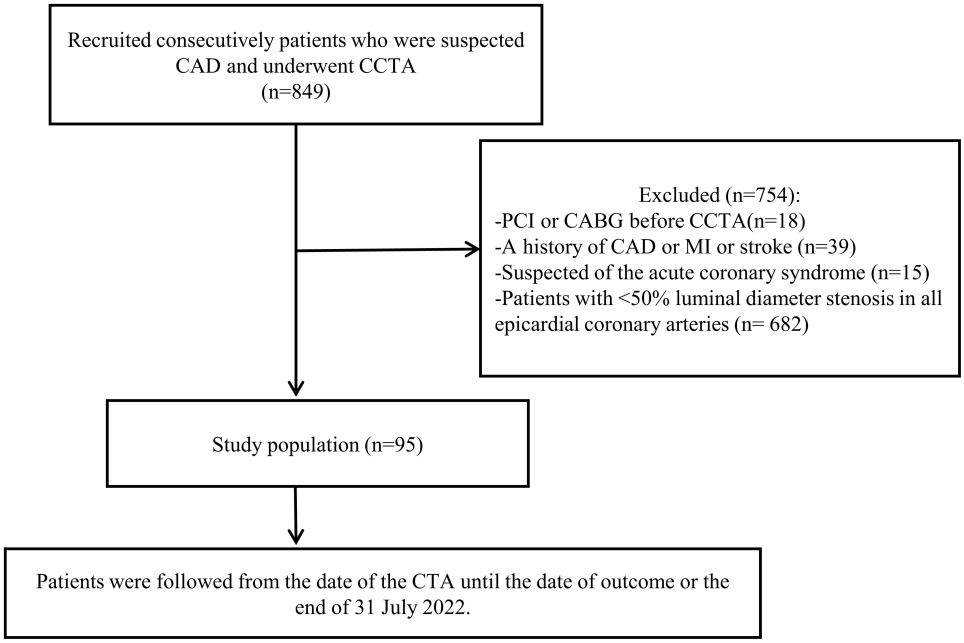


Figure 1 Study population flow chart.

Table 1 Clinical Characteristics of the Study Population (n = 95)

	Patients with Composite Endpoints (n=32)	Patients Without Composite Endpoints (n=63)	*P*
Age, years	72 ± 10	68 ± 10	0.087
Sex, male	23 (71.9)	46 (73.0)	0.906
BMI, Kg/m^2	24.0 ± 2.9	24.0 ± 2.9	0.874
Current smoking	21 (52.8)	33 (54.0)	0.218
Hypertension	23 (71.9)	43 (68.3)	0.717
SBP, mmHg	136.9 ± 17.5	134.9 ± 20.3	0.636
DBP, mmHg	75.1 ± 10.4	76.5 ± 13.7	0.726
Hyperlipidemia	6 (18.8)	17 (27.0)	0.376
HDL, mmol/L	1.2 ± 0.3	1.3 ± 0.3	0.249
LDL, mmol/L	2.1 ± 0.5	2.3 ± 0.8	0.616
Total Cholesterol, mmol/L	4.2 ± 1.1	4.3 ± 0.9	0.334
Triglycerides, mmol/L	1.7 ± 0.6	2.1 ± 2.1	0.828
CKD	6 (8.7)	2 (3.2)	0.010*
Diabetes mellitus			0.058
No	16 (50.0)	49 (77.8)	
< 10 years	8 (25.0)	7 (11.1)	
≥10 years	4 (12.5)	4 (6.3)	
Severe TOD	4 (12.5)	3 (4.8)	
No. of vessel diseases			<0.001**
1-VD	2 (6.3)	30 (47.6)	
2-VD	11 (34.4)	16 (25.4)	
3-VD	19 (59.3)	17 (28.0)	
Revascularization	3 (9.4)	32 (50.8)	<0.001**

Notes: Composite endpoints were defined as death, myocardial infarction, and stroke. Data are *n* (%) or mean ± standard deviation. *$p < 0.05$; **$p < 0.01$.

Abbreviations: BMI, body mass index; SBP, systolic blood pressure; HLD, high-density lipoprotein; TOD, target organ damage; CKD, chronic kidney disease.

Table 2 Univariate Cox Regression of Risk Factors for the Composite Endpoints

	Composite Endpoints		*P*
	Hazard Ratio (HR)	95% CI	
SCORE 2 & SCORE 2-OP risk score	1.050	1.021–1.079	0.001
Globorisk risk score	1.024	1.007–1.041	0.007
Framingham risk score	1.095	1.010–1.187	0.028
CKD	0.240	0.098–0.588	0.002
No. of vessel diseases			
1-VD	Reference	Reference	-
2-VD	7.415	1.643–33.465	0.009
3-VD	12.038	2.799–51.768	0.001
Revascularization	7.116	2.165–23.387	0.001

Abbreviations: HR, Hazard Ratio; CI, confidence interval; SCORE2, Systematic Coronary Risk Estimation 2; SCORE2-OP, Systematic Coronary Risk Estimation 2-Older Persons; CKD, chronic kidney disease; VD, vessel disease.

remained significant in association with composite endpoints (HR, 1.036; 95% CI, 1.008–1.064; $p = 0.011$) after adjusting for confounding factors (Table 3). The Log rank test in Kaplan-Meier estimated the SCORE2 & SCORE2-OP risk score, Globorisk risk score, and Framingham risk score and showed significant associations with the time to event (all $p < 0.05$) (Figure 2).

Table 3 Multivariate Cox Regression of CV Risk Models for the Event-Free Survival

	Model 1		Model 2		Model 3	
	HR (95% CI)	***P***	**HR (95% CI)**	***P***	**HR (95% CI)**	***P***
SCORE 2 & SCORE 2-OP risk score	1.036 (1.008–1.064)	0.011*				
Globorisk risk score			1.017 (0.997–1.037)	0.106		
Framingham risk score					1.069 (0.969–1.178)	0.183
CKD			1.233 (0.357–1.037)	0.740	1.429 (0.445–4.591)	0.549
No. of vessel diseases						
1-VD	Reference		Reference		Reference	
2-VD	6.688 (1.481–30.207)	0.014*	6.811 (1.507–30.783)	0.013*	6.922 (1.531–31.302)	0.012*
3-VD	16.434 (3.769–71.667)	<0.001**	17.085 (3.764–77.557)	<0.001**	16.730 (3.689–75.876)	<0.001**
Revascularization	0.111 (0.033–0.371)	<0.001**	0.105 (0.031–0.354)	<0.001**	0.106 (0.031–0.356)	<0.001**

Notes: Model 1: SCORE 2 & SCORE 2-OP, adjusted for revascularization and the number of obstructive vessels; Model 2: Globorisk, adjusted for chronic kidney disease, revascularization, and the number of obstructive vessels; Model 3: Framingham, adjusted for chronic kidney disease, revascularization, and the number of obstructive vessels; Abbreviations as Table 2; *$p < 0.05$, **$p < 0.01$.

ROC Analysis

In predicting composite endpoints, SCORE2 & SCORE2-OP risk score showed the highest AUC (0.684, 95% CI: 0.581–0.776) and its optimal cut-off value was 17 with a sensitivity of 65.62% and specificity of 74.60%), followed by Globorisk risk score (AUC: 0.647, 95% CI: 0.542–0.742) and its optimal cut-off value was 23 with a sensitivity of 59.38% and specificity of 63.49%), and Framingham risk score (AUC: 0.628, 95% CI: 0.532–0.725) and its optimal cut-off value was 18 with a sensitivity of 68.75% and specificity of 58.73%. The AUC of combining SCORE2 & SCORE2-OP with VD and revascularization reached 0.898 (95% CI: 0.819–9510) (Figure 3). The nomogram of combining SCORE2 & SCORE2-OP risk score, VD, and revascularization was presented in Figure 4.

Discussion

This study compared three cardiovascular risk models and proposed a new risk model for predicting the 4-year outcome of patients with obstructive CAD. We found that, after adjusting for confounding factors, only SCORE2 & SCORE2-OP risk score showed a significant association with composite endpoints. We also found that combining SCORE2 & SCORE2-OP risk score with revascularization and the number of vessel diseases could significantly improve the predictive value for clinical outcomes. Our findings suggest that adding revascularization and the number of vessel diseases into the risk score of SCORE2 & SCORE2-OP will be valuable for stratifying the risk of developing adverse outcomes in patients with obstructive CAD.

In the present study, among three risk scores, only SCORE2 & SCORE2-OP risk score was found to have independent predictive value for 4-year composite endpoints of obstructive CAD. SCORE2 & SCORE2-OP risk score, consisting of SCORE2 (participants aged 40-to-69 years) and SCORE2-OP (participants aged 70-to-89 years), is calculated by age, sex, smoking, SBP, and total cholesterol. The SCORE2 & SCORE2-OP risk score is also classified into low, moderate, high, and very high categories depending on the status of other risk factors, such as renal function, the timing of diabetes mellitus, target organ damage due to diabetes mellitus, and family history. When calculating the Globorisk risk score, variables of age, sex, smoking, SBP, total cholesterol, and diabetes mellitus were taken into account. Compared to the Globorisk risk score, the Framingham risk score additionally includes HLD and antihypertensive medication usage. Although a slight difference in the model between Globorisk and Framingham risk scores, these two risk scores showed a fair level of concordance in predicting CVD risk in the selected study subjects, such as type-2 diabetic subjects.[9] Our study also showed that these two risk scores had similar performance (Framingham risk score: AUC = 0.628; Globorisk risk score: AUC = 0.647) in predicting composite endpoints in patients with obstructive CAD. One study demonstrated that the Framingham risk score's AUC for predicting future cardiovascular events was 0.64 at a mean follow-up of 11.2 years.[10] It is well-established that CKD and diabetes mellitus could increase the atherosclerotic cardiovascular disease risk.[11] Therefore, the slightly higher predictive value for the adverse outcome of SCORE2 &

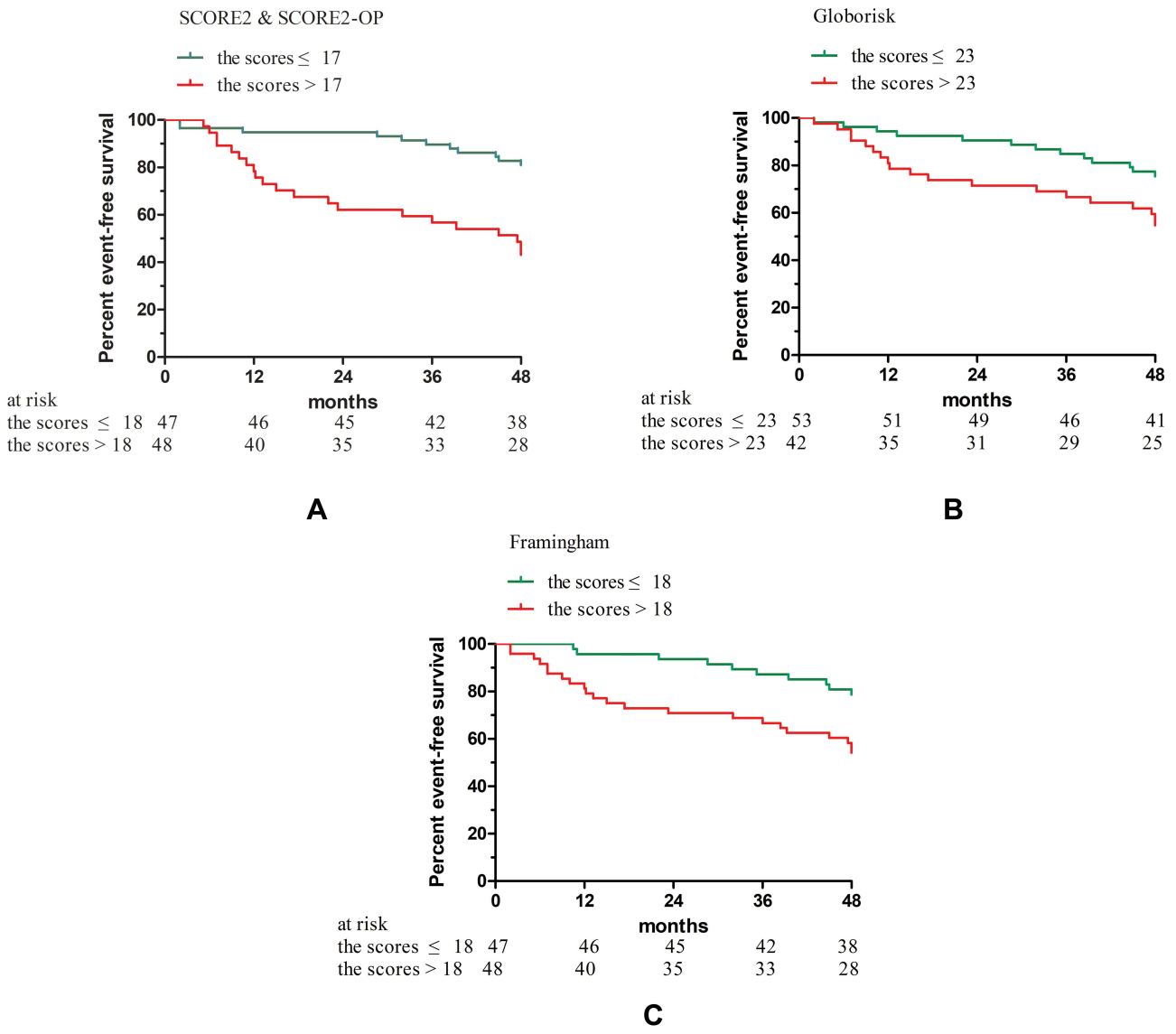


Figure 2 Kaplan-Meier plot for 4-year event-free survival stratified according to the SCORE2 &SCORE2-OP risk score (**A**), the Globorisk risk score (**B**), and the Framingham risk score (**C**) in 95 obstructive patients (all $p < 0.05$).

SCORE2-OP risk score might be due to the addition of renal function and diabetes mellitus in the risk model compared to the Globorisk risk score and the Framingham risk score.

To improve the predictive value of SCORE2 & SCORE2-OP risk score, a new risk model was proposed combing SCORE2 & SCORE2-OP risk score with the number of obstructive vessels and revascularization performed in this present study. We found that the new risk score had a stronger predictive value for composite endpoints in patients with obstructive CAD compared to the risk score of SCORE2 & SCORE2-OP (0.898 vs 0.684). In the present study, we found that the number of epicardial obstructive vessels was independently associated with composite endpoints. Such association has been reported in studies by Martin et al[12] and Min et al.[13] In the present study, 36.8% (35/95) of patients underwent revascularization during follow-up and revascularization tends to be an independent predictor for composite endpoints. Previous studies[14,15] demonstrated that patients with CAD would benefit more from revascularization than medical therapy. Another study[16] demonstrated that patients with multivessel disease who underwent complete revascularization as opposed to incomplete revascularization had a higher survival rate from adverse cardiovascular events. In

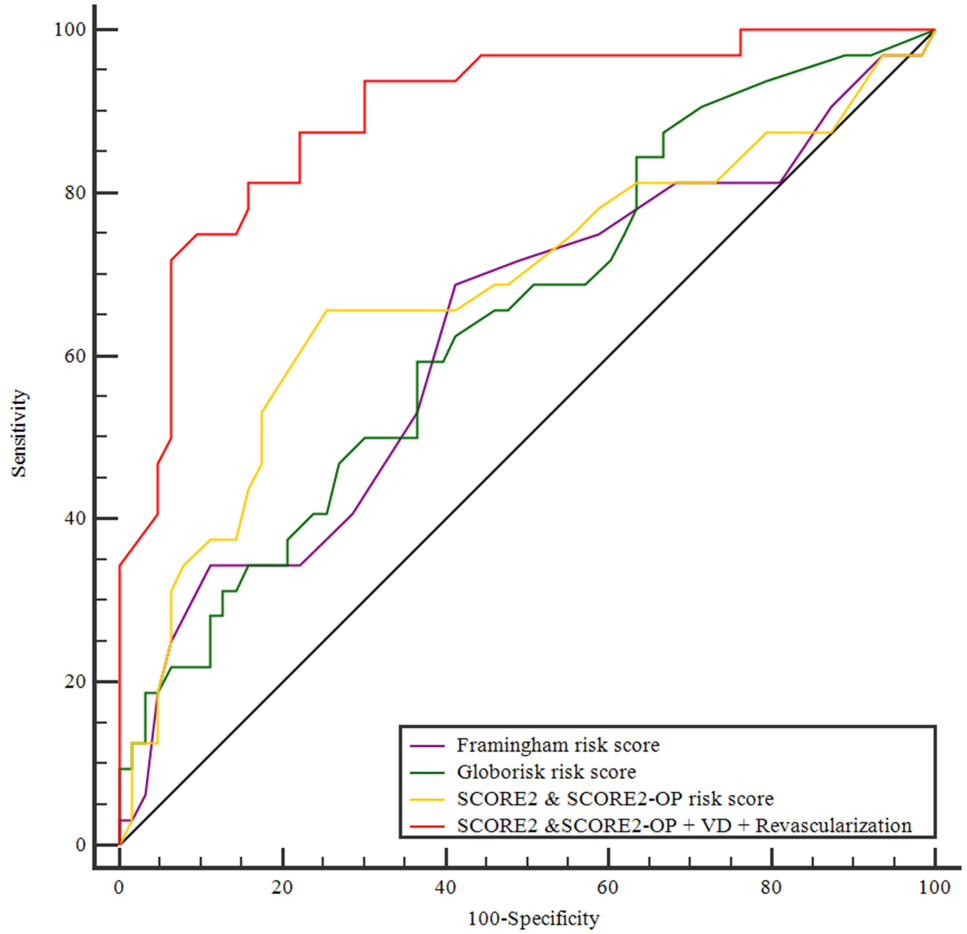


Figure 3 Receive-operator curves for event-free survival assessed by Framingham risk score (AUC: 0.628), Globorisk risk score (AUC: 0.647), SCORE2 &SCORE2-OP risk score (AUC: 0.684), model 1 = SCORE2 &SCORE2-OP risk score + VD + Revascularization (AUC: 0.898).

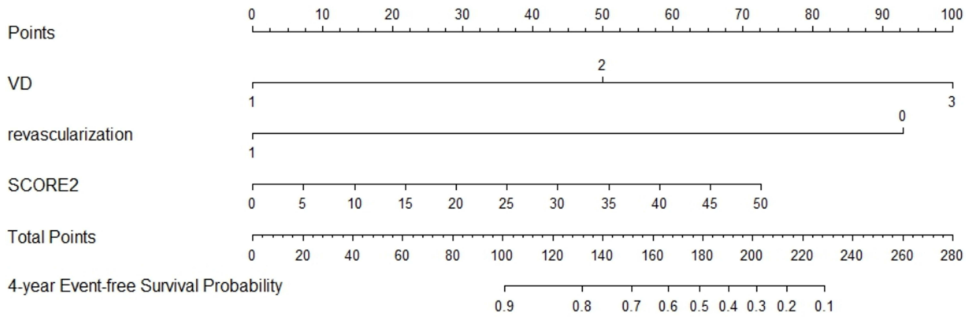


Figure 4 Predicting 4-year event-free survival model 1 nomogram. Model 1 is based on revascularization, the number of obstructive vessels, and the SCORE2 & SCORE2-OP risk score. A total score is equal to adding every single score, and project to the lower total point scale, we could determine the corresponding predicted probability of event-free survival.

the present study, a new risk model including the factors of the number of obstructive vessels and revascularization was more in accordance with the clinical workflow. This new risk model needs validation in future multicenter studies.

Our study has some limitations. First, only the characteristic of the number of obstructive vessels was used for proposing the risk score. To further improve the risk score, future studies including more coronary plaque characteristics, such as coronary plaque types and plaque scores, are warranted. Second, in the present study, the characteristics of moderate or severe CKD, a history of atherosclerotic cardiovascular disease, and familial hypercholesterolemia were not

acquired which will affect the risk stratification of SCORE2 & SCORE2-OP risk score.[7] Third, this is a single-center study which may introduce selection bias in patients. Furthermore, although our single-center cohort study enables an accurate evaluation of each patient's outcome, results might not generalize to other regions. Our findings need to be further validated by multi-center studies. Fourth, all study patients were followed up by phone, which presented challenges such as a high loss to follow-up rate from not being able to respondents on the phone.

Conclusion

The SCORE2 & SCORE2-OP risk score combined with the number of obstructive vessels and revascularization is predictive for adverse outcomes in patients with obstructive CAD.

Data Sharing Statement

The datasets are available by contacting the corresponding author (zuomengren1@163.com).

Ethics Statement

The study protocol was conducted by Deyang People's Hospital and was approved by the institutional review board and each participant provided a written consent form.

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Disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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