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Research article

# Two novel nomograms predict 30-day mortality after off-pump coronary artery bypass grafting☆

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ABSTRACT

*Background:* With the development of surgical techniques and medical equipment, the mortality rate of off-pump coronary artery bypass grafting (CABG) has been declining year by year, but there is a lack of convenient and accurate predictive models. This study aims to use two nomograms to predict 30-day mortality after off-pump CABG.

*Methods:* Patients with isolated off-pump CABG from January 2016 to January 2021 were consecutively enrolled. Potential predictive factors were first screened by lasso regression, and then predictive models were constructed by multivariate logistic regression. To earlier identify high-risk patients, two nomograms were constructed for predicting mortality risk before and after surgery.

*Results:* A total of 1840 patients met the inclusion and exclusion criteria. The 30-day mortality was 3.97 % (73/1840) in this cohort. Multivariate logistic analysis showed that age, BMI<18.5 $kg/m^2$, surgical time, creatinine, LVEF, history of previous stroke, and major adverse intraoperative events (including conversion to cardiopulmonary bypass or implantation of intra-aortic balloon pump) were independently associated with 30-day mortality. Model 1 contained preoperative and intraoperative variables, and the AUC was 0.836 ($p < 0.001$). The AUC of the K-fold validation was 0.819. Model 2 was only constructed by preoperative information. The AUC was 0.745 ($p < 0.001$). The AUC of the K-fold validation was 0.729. The predictive power of Model 1 was significantly higher than the SinoScore (DeLong's test $p < 0.001$).

*Conclusions:* The two novel nomograms could be conveniently and accurately used to predict the risk of 30-day mortality after isolated off-pump CABG.

## 1. Introduction

In-hospital mortality after off-pump coronary artery bypass grafting (CABG) has significantly decreased year by year. However, there is a lack of convenient and accurate predictive tools to predict 30-day mortality for these patients. The 30-day mortality rate after off-pump CABG is 1.7 %–14.4 % and is affected by perioperative complications, such as carotid artery stenosis, left ventricular

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dysfunction, history of previous stroke, renal dysfunction, and unstable hemodynamics [1–4].

Currently, scoring systems such as EuroScore [5], SinoScore [6], and ACEF II [7] are widely used clinical predictive models. But EuroSCORE and ACEF II are based on European patients and South Korean patients, respectively. These predictive models have been shown not to be applicable to Chinese patients [8]. In 2013, Hu and colleagues constructed the first 30-day mortality risk predictive model (SinoScore). It was based on 9564 Chinese patients who underwent coronary artery bypass grafting (CABG) similar to the SinoScore. This scoring system contains three types of risk factors: patient-related factors, cardiac factors, and operative-related factors [6]. However, the operative-related factors only included preoperative information. The SinoScore did not include various types of surgery such as emergency, or urgent surgery, or major adverse intraoperative events (MAIEs) such as conversion to cardiopulmonary bypass (CPB) or implantation of an intra-aortic balloon pump (IABP) [9].

It is well known that MAIEs significantly increase short-term mortality after off-pump CABG, such as malignant ventricular arrhythmias, bleeding, and unstable hemodynamics. Intraoperative information is needed to assess the risk of postoperative mortality. In view of these limitations, the SinoScore failed to fully assess the patient's preoperative risk.

In view of these limitations, we sought to develop a more accurate estimate of the link between MAIEs and preoperative risk factors which predict 30-day mortality, to construct a nomogram to predict 30-day mortality after off-pump CABG, in order to earlier identify high risk patients.

## 2. Methods

### 2.1. Patients

This study retrospectively enrolled consecutive patients who underwent isolated CABG from January 2016 to January 2021. All operations were performed by experienced surgeons. This study had been approved by the Ethics Committee of the Affiliated Hospital of Qingdao University, and the informed consent had been waived (QYFY WZLL 27399). The inclusion criteria were: (1) Patients aged >18 years old, (2) Patients undergoing isolated CABG. Exclusion criteria were as follows: (1) Planned cardiopulmonary bypass; (2) Minimally invasive CABG (Fig. 1).

### 2.2. Definitions

Laboratory tests and examinations of patients were completed within 7 days before surgery. Death: Followed up to 30 days after surgery, and by telephone after discharge. Major adverse intraoperative events were unplanned conversion to CPB (including on-pump beating and on-pump CABG) or implantation of an IABP during off-pump CABG.

### 2.3. Perioperative management

All patients were given anti-platelet medications (Aspirin, Clopidogrel, Indobuprofen, Tigrillo), nutritional supplements (Coenzyme Q10, Creatine Phosphate Sodium, Trimetazidine), and medical therapy (Isosorbide dinitrate, Nicorandil). All patients underwent median sternotomy. Heparin was administered at a dose of 1 mg/kg. In all patients, the left internal thoracic artery (LITA) was routinely anastomosed to the left anterior descending branch (LAD). When the LITA blood flow was inadequate, the great saphenous vein (GSV) was used for the LAD and other diseased coronary arteries. The LITA to LAD was the first anastomosis performed. All patients were routinely transferred to the cardiac intensive care unit after surgery.

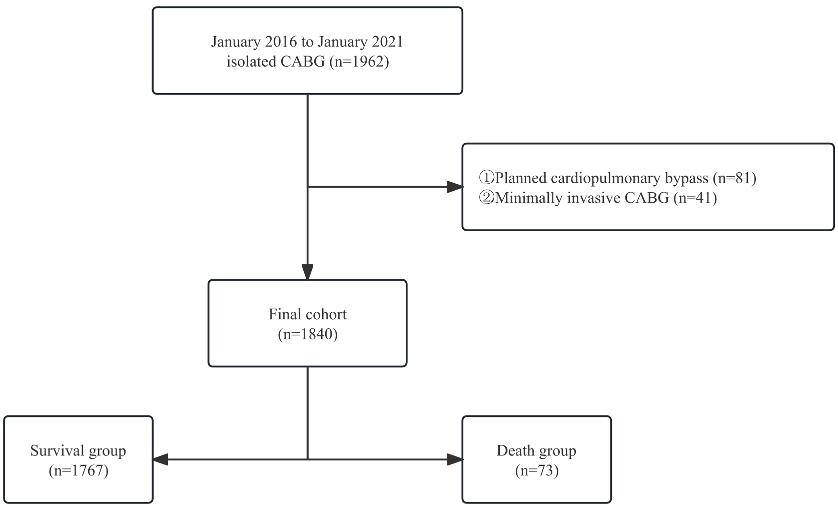


**Fig. 1.** The patient enrollment process.

### 2.4. Statistical analysis

Data with normal distribution were expressed as mean ± standard deviation (X ± S), and data with skewed distribution were expressed as median (25th, 75th percentile). Differences between the two groups were compared by Student's t-test or Mann–Whitney *U* test. Categorical variables were expressed as absolute values (percentage) and compared by the Pearson chi-square test or the Fisher exact test. Initially, potential predictive variables were screened by lasso regression (Supplement), and then the predictive variables were included in multivariate logistic regression for modeling. Logistic regression was performed using a stepwise backward method. The predictive power of the model was tested by the receiver operator characteristic curve (ROC), calibration curve, and decision curve analysis (DCA). Internal validation of the nomogram was performed by K-fold cross-validation (k = 4, times = 500), and the resampled area under the curve (AUC) was also calculated. The predictive power and clinical applicability of each model were analyzed respectively, and the importance of each index of the model was also analyzed. The two novel models constructed in this study were compared with the SinoScore by DeLong's test. To further explore the predictive ability of the two new models in older patients, the two models were revalidated in patients over 65 years of age. A two-tailed $p < 0.05$ was defined as statistically significant. Data

**Table 1**
Perioperative information of two groups.

| Variables | Overall (n = 1840) | Survival group (n = 1767) | Death group (n = 73) | p-Value |
|---|---|---|---|---|
| Age(year) | 63.9 (8.4) | 63.7 (8.4) | 67.3 (8.4) | <0.001 |
| Sex(male) | 1345 (73.1) | 1294 (73.2) | 51 (69.9) | 0.616 |
| Body mass index(Kg/m$^2$) | 25.6 (3.2) | 25.7 (3.2) | 24.8 (3.7) | 0.026 |
| BMI < 18.5 kg/m$^2$ | 25 (1.4) | 20 (1.1) | 5 (6.8) | <0.001 |
| Smoking | 799 (43.4) | 761 (43.1) | 38 (52.1) | 0.162 |
| Acute coronary syndrome | 319 (17.3) | 304 (17.2) | 15 (20.5) | 0.561 |
| Congestive heart failure | 115 (6.2) | 102 (5.8) | 13 (17.8) | <0.001 |
| Shock | 11 (0.6) | 10 (0.6) | 1 (1.4) | 0.36 |
| Coronary artery stent | 231 (12.6) | 223 (12.6) | 8 (11.0) | 0.811 |
| Atrial fibrillation | 40 (2.2) | 38 (2.2) | 2 (2.7) | 1 |
| Hypertensions | 1325 (72.0) | 1269 (71.8) | 56 (76.7) | 0.435 |
| Diabetes mellitus | 728 (39.6) | 702 (39.7) | 26 (35.6) | 0.561 |
| Stroke | 302 (16.4) | 282 (16.0) | 20 (27.4) | 0.015 |
| Peripheral vascular disease | 61 (3.3) | 57 (3.2) | 4 (5.5) | 0.471 |
| Chronic obstructive pulmonary disease | 36 (2.0) | 36 (2.0) | 0 (0.0) | 0.423 |
| Chronic kidney disease | 23 (1.2) | 20 (1.1) | 3 (4.1) | 0.088 |
| Albumin(g/L) | 45.8 (9.0) | 45.9 (9.0) | 44.0 (9.1) | 0.075 |
| Creatinine(umol/L) | 78.9 (40.0) | 78.3 (37.4) | 92.7 (80.4) | 0.003 |
| Cystatin C(mg/L) | 1.0 (0.4) | 1.0 (0.4) | 1.2 (0.9) | 0.001 |
| Triglyceride(mmol/L) | 1.8 (1.4) | 1.8 (1.4) | 1.6 (0.9) | 0.22 |
| Cholesterol(mmol/L) | 4.2 (1.3) | 4.2 (1.3) | 4.1 (1.4) | 0.476 |
| High-density lipoproteins(mmol/L) | 1.1 (0.3) | 1.1 (0.3) | 1.2 (0.3) | 0.611 |
| Low-density lipoproteins(mmol/L) | 2.6 (0.9) | 2.6 (0.9) | 2.5 (1.0) | 0.537 |
| Lipoprotein a(mg/L) | 212.6 [110.9, 414.8] | 212.0 [110.8, 421.0] | 226.0 [113.7, 383.0] | 0.967 |
| Apolipoprotein AI(g/L) | 1.2 (0.2) | 1.2 (0.2) | 1.2 (0.3) | 0.883 |
| Apolipoprotein B(g/L) | 0.9 (0.3) | 0.9 (0.3) | 0.8 (0.3) | 0.421 |
| Fasting blood glucose(mmol/L) | 6.3 (2.5) | 6.3 (2.5) | 6.3 (2.3) | 0.943 |
| Glycated albumin(%) | 14.7 (4.9) | 14.7 (4.9) | 14.3 (4.8) | 0.488 |
| Uric acid(umol/L) | 335.8 (94.1) | 335.1 (93.4) | 353.1 (109.0) | 0.109 |
| Hemoglobin(g/L) | 131.6 (17.1) | 131.7 (17.0) | 129.4 (20.0) | 0.274 |
| Platelet(10$^9$/L) | 219.6 (63.1) | 220.1 (62.8) | 208.4 (68.6) | 0.12 |
| High-sensitivity troponin I(ng/mL) | 0.0 [0.0, 0.0] | 0.0 [0.0, 0.0] | 0.0 [0.0, 0.1] | 0.015 |
| Ejection Fraction(%) | 56.6 (8.0) | 56.8 (7.7) | 51.2 (10.9) | <0.001 |
| Angiotensin converting enzyme inhibitor | 342 (18.6) | 325 (18.4) | 17 (23.3) | 0.368 |
| Angiotensin receptor blocker | 602 (32.7) | 583 (33.0) | 19 (26.0) | 0.264 |
| Beta receptor blocker | 1363 (74.1) | 1306 (73.9) | 57 (78.1) | 0.509 |
| Calcium channel blocker | 631 (34.3) | 607 (34.4) | 24 (32.9) | 0.893 |
| Statin | 1442 (78.4) | 1388 (78.6) | 54 (74.0) | 0.432 |
| Digoxin | 100 (5.4) | 95 (5.4) | 5 (6.8) | 0.779 |
| Diuretics | 697 (37.9) | 666 (37.7) | 31 (42.5) | 0.483 |
| Preoperative IABP | 136 (7.4) | 123 (7.0) | 13 (17.8) | 0.001 |
| Emergency surgery | 26 (1.4) | 22 (1.2) | 4 (5.5) | 0.012 |
| Left internal thoracic artery | 1640 (89.1) | 1581 (89.5) | 59 (80.8) | 0.033 |
| Incomplete revascularization | 43 (2.3) | 42 (2.4) | 1 (1.4) | 0.871 |
| Surgical time(min) | 271.2 (87.9) | 268.8 (84.4) | 328.0 (138.5) | <0.001 |
| Major adverse intraoperative events | 70 (3.8) | 49 (2.8) | 21 (28.8) | <0.001 |
| Conversion to cardiopulmonary bypass | 39 (2.1) | 27 (1.5) | 12 (16.4) | <0.001 |
| Intraoperative IABP | 44 (2.4) | 30 (1.7) | 14 (19.2) | <0.001 |

Abbreviations: BMI: Body mass index; PLT: platelet; HF: heart failure; COPD: chronic obstructive pulmonary disease; LVEF: left ventricular injection fraction; MAIES: major adverse intraoperative events; CPB: cardiopulmonary bypass; IABP: implantation of intra-aortic balloon pump; LITA: left anterior thoracic artery; LAD: left anterior descending branch; GSV: great saphenous vein.

analysis was performed using SPSS for Mac OS version 26 (SPSS Inc., Chicago, IL, USA) and R software (version 4.2.2).

## 3. Results

### 3.1. Patient characteristics

1962 patients who underwent isolated CABG were reviewed for inclusion into the study. According to the inclusion and exclusion criteria, a total of 1840 patients were finally included in the analysis. The average age was 63.8 years, 73.1 % were males, and the average BMI was 25.6 kg/$m^2$. The incidence of diabetes, hypertension, and stroke in the total cohort was 39.6 %, 72 %, and 16 %, respectively. Patients in the death group were significantly older, had higher serum creatinine levels, and a higher incidence of previous stroke. The incidence of heart failure, hypertension, and acute myocardial infarction in the death group was significantly higher than in the survival group. Patients in the death group had lower LVEF, BMI, and platelet counts (PLT) than the survival group. In addition, patients in the death group had longer operative times (328 ± 138.5min vs. 269.2 ± 86.7min, $p = 0.001$), and a higher incidence of MAIEs (21 (30 %) vs. 52 (2.9 %), $p < 0.001$) (Table 1).

#### 3.1.1. Predictors of mortality

Mortality was 3.97 % (73/1840) in this cohort. Lasso regression showed that factors related to postoperative mortality included: Age, BMI<18.5 kg/$m^2$, Smoking, heart failure (HF), History of previous stroke, chronic obstructive pulmonary disease (COPD), creatinine level, PLT, LVEF, preoperative IABP implantation, emergency surgery, surgical time, and major adverse intraoperative events. Logistic regression analysis showed that age, BMI<18.5 kg/$m^2$, surgical time, creatinine level, LVEF, history of previous stroke, and MAIEs were independent predictors of 30-day mortality after off-pump CABG.

### 3.2. Establishment and validation of predictive nomograms

Using the above 7 independent predictors, a nomogram was constructed to predict the risk of 30-day mortality after off-pump CABG (Table 2, Fig. 2A). The predictive value of Model 1 is shown in the red ROC curve (AUC = 0.836, $p < 0.001$) (Fig. 3). The red calibration curve shows that the predicted probability of Model 1 is consistent with the observed probability (Fig. 4). The y-axis indicates the net benefit; the x-axis indicates threshold probability. The grey line represents the assumption that all patients died. The black line represents the assumption that all patients survived. The red line, navy blue line, and yellow line represent the net benefit of Model 1, Model 2, and the SinoScore, respectively. Model 1 had a higher net benefit compared with Model 2 and the SinoScore (Fig. 5).

In order to earlier identify high-risk patients, this study only used preoperative patient data to construct the brief predictive model. Preoperative information was used to construct Model 2 (Table 3, Fig. 2B). The predictive value of Model 2 is shown in the navy-blue ROC curve (AUC = 0.745, $p < 0.001$) (Fig. 3). The navy-blue calibration curve shows that the predicted probability of Model 2 is consistent with the observed probability (Fig. 4). Model 2 had a higher net benefit compared the SinoScore. The net benefit of Model 2 and the SinoScore was largely the same (Fig. 5). Internal validation of the two nomograms was performed by K-fold cross-validation (k = 4, times = 500). K-fold cross-validation showed that the AUC of Model 1 is 0.819, and the AUC of Model 2 is 0.729.

The predictive value of the SinoScore is shown in the yellow ROC curve (AUC = 0.699, $p < 0.001$) (Fig. 3). The yellow calibration curve shows that the predicted probability of the SinoScore is consistent with the observed probability (Fig. 4). In addition, the predictive power of Model 1 is significantly higher than the SinoScore (DeLong's test $p < 0.001$), and the predictive power was not significant between Model 2 and the SinoScore (DeLong's test $p = 0.098$). In Model 1, the impact of MAIEs on patient mortality is higher than that of the other predictive factors, and in Model 2, the impact of LVEF is higher than that of other preoperative factors. The importance of each variable was displayed by radar maps (Fig. 6A and B), which show the levels of impact of predictive variables on 30-day mortality.

### 3.3. Subgroup analysis

To further test the predictive power of Model 1 and Model 2 in older patients, the ROC, calibration curve, and DCA test of each predictive model were performed in patients over 65 years of age. The AUC of Model 1 was 0.822, the AUC of Model 2 was 0.734, and the AUC of the SinoScore was 0.708. Similar to the total cohort, Model 1 still showed the best predictive power and the largest clinical net benefit. The predicted probability was consistent with the observed probability (Figs. 3–5).

**Table 2**
Multivariate logistic regression analysis (Including preoperative and intraoperative information).

| Variables | Adjusted OR | 95 % CI | P |
|---|---|---|---|
| Age | 1.055 | 1.022–1.088 | 0.001 |
| BMI<18.5 | 6.176 | 1.88–20.295 | 0.003 |
| Stroke | 2.145 | 1.199–3.839 | 0.01 |
| Creatinine | 1.006 | 1.002–1.009 | 0.001 |
| Ejection Fraction | 0.942 | 0.919–0.966 | <0.001 |
| Surgical Time | 1.003 | 1.001–1.005 | 0.013 |
| Major adverse intraoperative events | 9.496 | 4.733–19.049 | <0.001 |

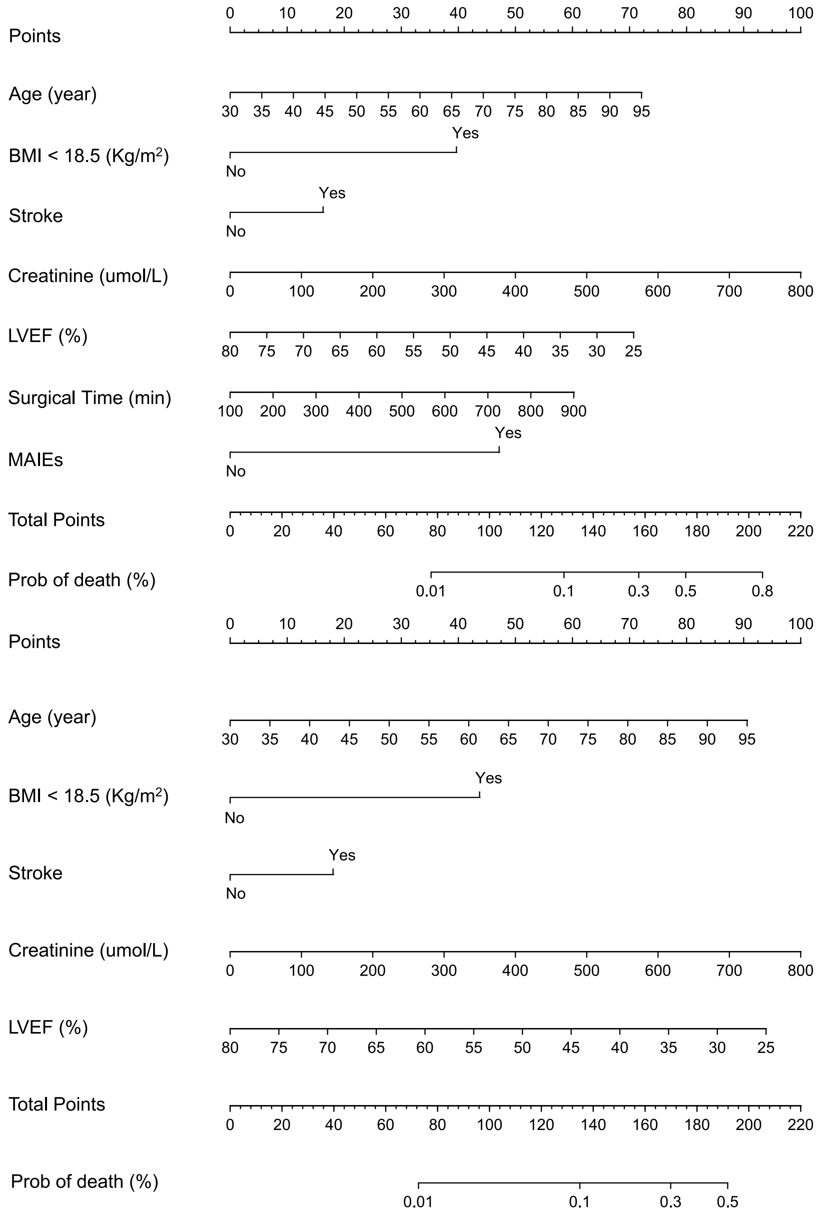


**Fig. 2.** Nomogram (Fig. 2A: Model 1; Fig. 2B: Model 2).Fig. 2A: Nomogram of predicted mortality at 30 days after isolated coronary artery bypass grafting, including preoperative and intraoperative variables. Fig. 2B: Nomogram of the 30-day predicted mortality after isolated coronary artery bypass grafting, using only preoperative variables.

### *3.4. Development of webserver for easy access*

An online version of our nomogram can be accessed at.

Model 1: https://cabgmortality.shinyapps.io/cabg_mortality/

Model 2: https://cabgmortality.shinyapps.io/pre-operation_CABG_mortality/

Clinicians can easily predict the 30-day mortality by inputting clinical features and reading output figures and tables generated by the webserver.

## 4. Discussion

This is the first study to construct a nomogram to predict 30-day mortality after off-pump CABG in Chinese patients. Model 1 is constructed by preoperative and intraoperative factors (including age, BMI<18.5 kg/m$^2$, creatinine, LVEF, history of previous stroke, surgical time, and MAIEs). Model 2, a brief nomogram, is only constructed using preoperative factors (age, BMI<18.5 kg/m$^2$,

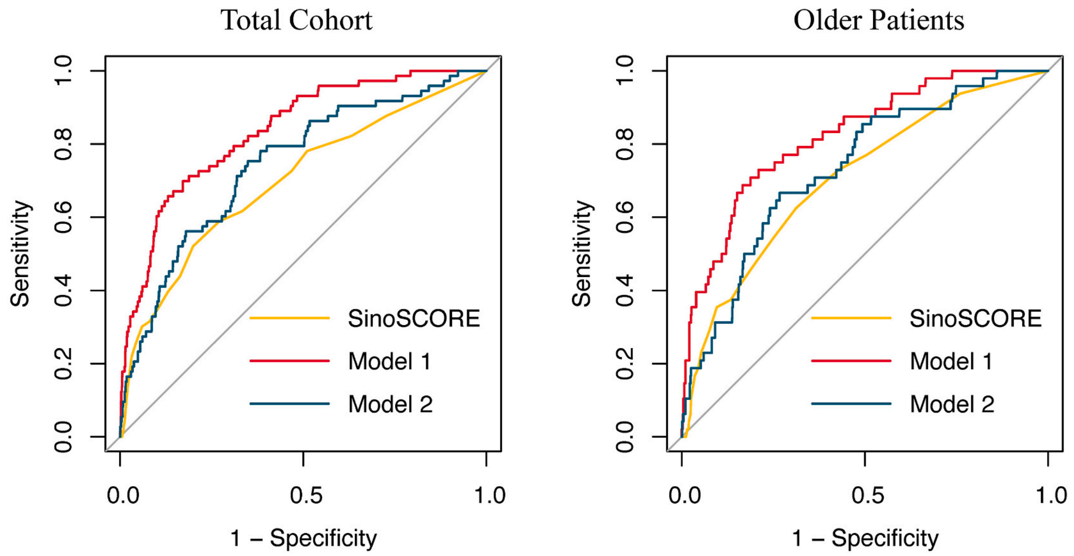


**Fig. 3.** ROC of each model and each cohort.

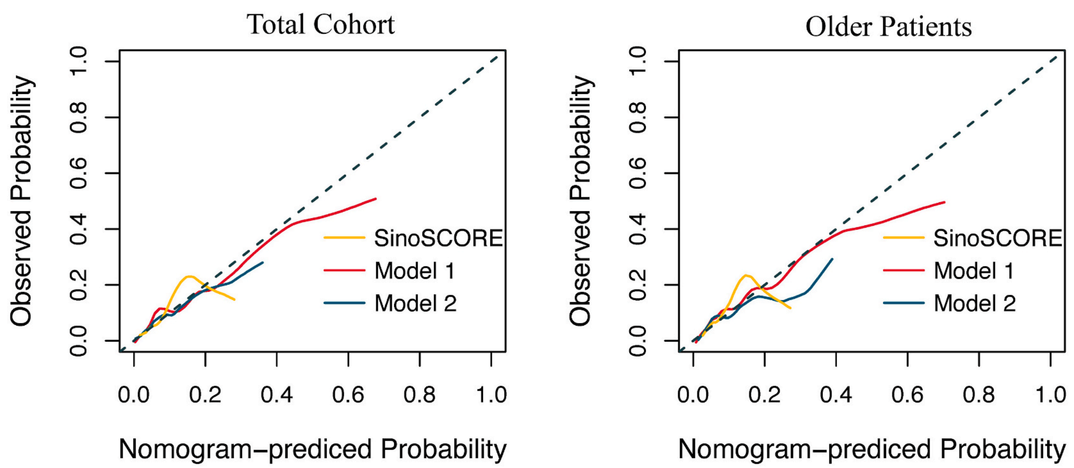


**Fig. 4.** Calibration curve of each model and each cohort. Calibration plots assess the accuracy and specificity of t each model and each cohort.

Creatinine, LVEF, history of previous stroke). The predictive value of Model 1 was significantly higher than Model 2 and the SinoScore. The predictive values of Model 2 and the SinoScore are equal.

The demographic information of the patients in this study such as sex, age, and BMI are similar to the cohort of the SinoScore. In the SinoScore, the average age was 62.1 years, and 77.3 % were male. The average BMI was 25.1, of which BMI>24 accounted for 62.6 %, BMI<18 accounted for 1.1 %, and 29.8 % had diabetes.

In this study, MAIEs included unplanned conversion to CPB or implantation of an IABP. The proportion of conversion to on-pump CBAG is 1.5 % in the survival group, while the proportion of conversion to CPB was 16.4 % in the mortality group. The incidence of CPB conversion is significantly higher in the mortality group than the survival group. Numerous studies have shown that intra-operative conversion to CPB is an independent risk factor for mortality [10–13]. A meta-analysis on off-pump CABG including 17 studies and 18,870 patients demonstrated that the mortality rate increased in patients undergoing off-pump CABG after conversion to CPB, and the OR of emergency conversion to CPB was 6.99 (95 % CI 5.18–9.45) [13]. In our cohort, the OR of intraoperative conversion to CPB was 12.68 (95 % CI 6.13–26.21). Intraoperative IABP implantation was an independent risk factor, 14 (0.8 %) in the survival group and 2 (2.7 %) in the mortality group. The study by Wu et al. demonstrated that intraoperative IABP implantation significantly reduced 30-day mortality after off-pump CABG [14]. It is noteworthy that Wu's cohort only included patients with planned IABP implantation. However, the IABP implantation in our cohort were all unplanned, usually to deal with hemodynamic instability.

Surgical time is an independent risk factor for cardiac surgery. Baik et al. showed that surgical time is not related to postoperative mortality. However, in Baik's study, patients who underwent emergency surgery and conversion to CPB were excluded [15]. It has

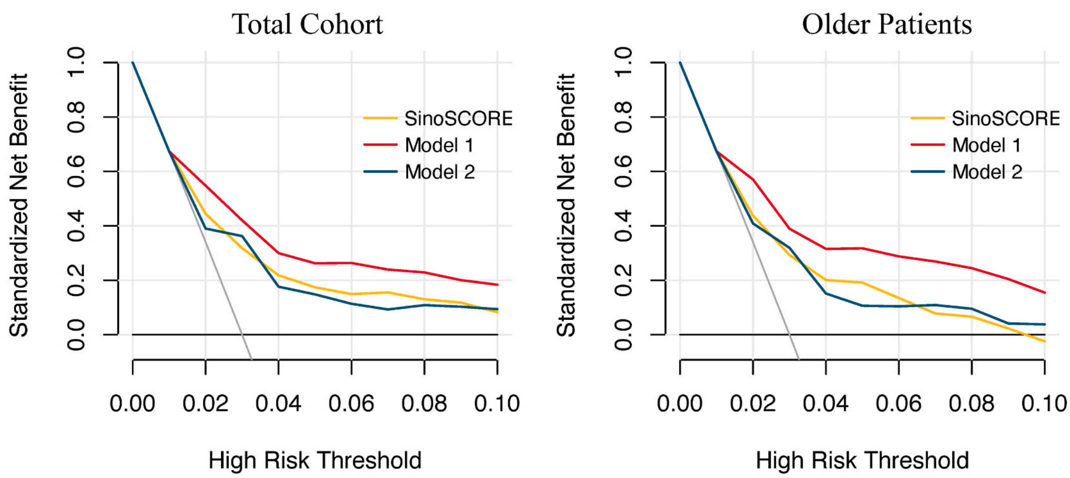


**Fig. 5.** DCA of each model and each cohort. The DCA curve of the nomogram for each model and each cohort. It revealed that the nomogram could obtain a greater net benefit strategy.

**Table 3**
Multivariate logistic regression analysis (Including preoperative information).

| Variables | Adjusted OR | 95 % CI | P |
|---|---|---|---|
| Age | 1.055 | 1.024–1.088 | 0.001 |
| BMI<18.5 | 5.394 | 1.83–15.894 | 0.002 |
| Stroke | 2.005 | 1.158–3.469 | 0.013 |
| Creatinine | 1.005 | 1.001–1.008 | 0.005 |
| Ejection Fraction | 0.936 | 0.914–0.959 | <0.001 |

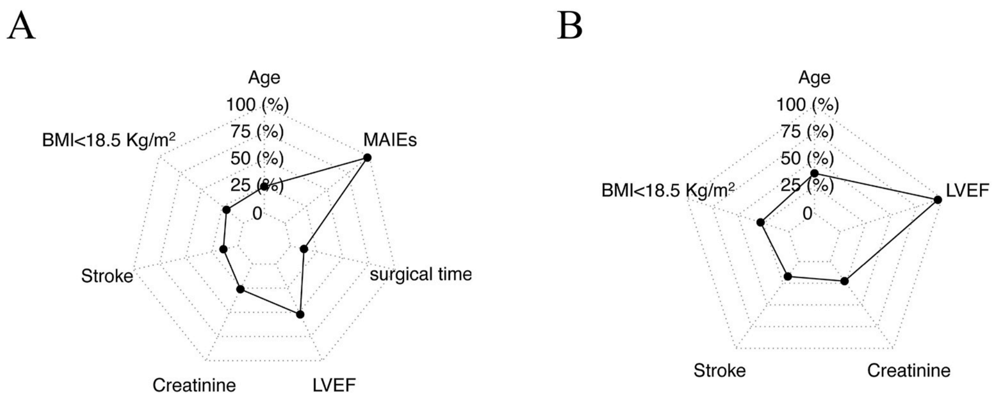


**Fig. 6.** Each predictor's contribution in the full model (A: Model 1; B: Model 2). The importance of each variables was displayed by Radar maps (Fig. 6) to visualize the levels of impact of predictive variables on 30-day mortality.

been well documented that patients with emergency surgery and conversion to CPB have longer surgical times and worse outcomes. Our study only excluded patients scheduled for on-pump CABG and minimally invasive CABG, retaining patients with emergency surgery and conversion to CPB, so the conclusions of this study are more applicable to all patients undergoing off-pump CABG. Therefore, the differences in inclusion criteria may have been responsible for the different outcomes between the two studies. Furthermore, Na Miao et al. also demonstrated that off-pump CABG conversion to on-pump CABG is significantly related to postoperative mortality [9].

To earlier identify high-risk patients for postoperative mortality, this study constructed a short predictive model that only included patients' preoperative information (age, BMI<18.5 kg/m$^2$, Creatinine, LVEF, history of previous stroke). This predictive model demonstrated a predictive value that was not inferior to the SinoScore. Age, history of previous stroke, creatinine, and BMI<18.5 kg/m$^2$ were independent risk factors for in-hospital mortality, while LVEF is a protective factor for early death. Model 2 in this study and the SinoScore both contain the patient's age, body mass index, renal and cardiac function. These four indicators are also important predictors in the SinoScore, and are important prognostic predictors for patients, except for BMI. The other three are also included in

EuroScore II and ACEF II [5,7].

Older patients are more likely to have multiple complications, thereby increasing the risk of postoperative mortality [16,17]. To further verify the predictive value of the two models in older patients, we tested the predictive value of Model 1 and Model 2 in patients over 65 years of age. Model 1 and Model 2 demonstrated good predictive power and greater clinical net benefit. In the overall population, the predictive power of the two novel models was fairly reliable.

The history of a previous stroke is a new predictive factor added in this study. Previous studies have shown that a history of previous stroke increases the risk of postoperative mortality, and other complications such as myocardial infarction, and perioperative stroke [18–21]. Patients with a history of stroke usually have underlying vascular conditions. These patients are more likely to develop postoperative delirium, poor cognitive recovery, and functional decline [22].

Creatinine is an independent predictor of postoperative mortality. van Straten et al. showed that patients with severe renal dysfunction before surgery have a worse prognosis after CABG [23]. Tolpin et al. reported that even subclinical elevations in serum creatinine levels increase postoperative mortality [24]. Compared with the SinoScore and ACEF II, the use of direct creatinine levels to predict postoperative mortality in our study is superior to creatinine >176 μmol/L (2 mg/dL). Several studies have found that left ventricular dysfunction will increase the risk of postoperative mortality [5,6,25].

Studies have demonstrated that being underweight is an independent predictor of early death after CABG [26]. A meta-analysis including 65 studies and a total of 865,774 participants found a U-shaped association in mortality across several BMI categories [27]. Compared with normal weight, underweight patients had increased mortality, while overweight, obese, and severely obese patients had reduced mortality. In our cohort, 18.5 was used as the cut-off in the BMI category. BMI<18.5 kg/m$^2$ (OR = 5.394, 95%CI (1.830, 15.894)) is a risk factor for 30-day mortality after surgery, which is consistent with the “obesity paradox”. Lower BMI may be related to sarcopenia or decreased muscle mass, both of which could significantly increase patient mortality [28,29]. Moreover, patients with lower BMI were less likely to be a target of secondary prevention therapies, such as a healthy diet, exercise, cholesterol control, or strict treatment for diabetes and hypertension [30].

Compared with our study, the advantage of the SinoScore is a larger sample size. The SinoScore also has some deficiencies. It does not include emergency surgery and does not consider the occurrence of sudden adverse events such as hemodynamic instability during off-pump CABG. In addition, this scoring system is complicated with too many variables, which makes it more difficult to use. MAIEs are very important predictive factors for postoperative mortality. MAIEs included unplanned conversion to CPB or an implanted IABP in Model 1, thus significantly improving the predictive power of this model.

### *4.1. Limitations*

This study has some limitations: (1) it is a retrospective, single-center study with potential recall bias. (2) this study only included patients undergoing isolated CABG, so the models of this study cannot be directly applied to guide risk assessment of postoperative mortality in patients undergoing re-do CABG or CABG with concomitant valve surgery. (3) this cardiac center routinely performs off-pump CABG, so centers that routinely perform on-pump bypass surgery should be cautious in using the two novel models. The two new models constructed in this study require further verification in larger sample sizes.

## 5. Conclusions

This study demonstrates that age, BMI<18.5 kg/m$^2$, surgical time, creatinine, LVEF, history of previous stroke, and major adverse intraoperative events (conversion to CPB or IABP implantation) are independent predictors of 30-day mortality after off-pump CABG. Both nomograms could predict the risk of 30-day mortality after isolated off-pump CABG and earlier identify high-risk patients.

## Ethics statement

This study followed the STrengthening the Reporting of OBservational studies inEpidemiology (STROBE) reporting guidelines and adhered to the Declaration of Helsinki. The study protocol was approved by the Ethics Committee of the Affiliated Hospital of Qingdao University, and informed consent was waived (QYFY WZLL 27399).

## Consent for publication

Not applicable.

## Funding

None.

## Data availability

Data will be made available on request.

## CRediT authorship contribution statement

**Yangyan Wei:** Writing – original draft, Conceptualization. **Xincheng Gu:** Writing – original draft, Conceptualization. **Shengpeng Hu:** Writing – original draft, Conceptualization. **Wenjie Zhu:** Writing – original draft, Conceptualization. **Kai Yang:** Writing – original draft, Conceptualization. **Zhengdong Hua:** Writing – original draft, Conceptualization.

## Declaration of competing interest

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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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e32641.

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