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Coronary artery bypass grafting in octogenarians: a nomogram for predicting all-cause mortality

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Abstract

Background The benefits and risks of coronary artery bypass grafting (CABG) in octogenarians remain unclear. This study aimed to identify the predictors of increased risk of all-cause mortality in octogenarian patients after CABG.

Methods We retrospectively analyzed the data of 1636 octogenarians who underwent isolated elective on-pump CABG between 2007 and 2016. The primary endpoint was mortality from any cause. The Kaplan–Meier curve was generated for mortality. A univariate Cox regression was performed for preprocedural and procedural variables. The Akaike information criterion (AIC) using the Cox proportional hazard model was applied to determine the strongest predictors. We designed a nomogram based on the selected variables to calculate the mortality risk after one, five, and ten years. The bootstrap resampling based on the C-index was performed to validate the final model. Calibration plots were created at different time points.

Results The mean age of the patients was 82.03 years (SD = 1.74), and 74% were male. In a median follow-up of 9.2 (95% CI 9.0,9.5) years, 626 (38.2%) patients died. After the selection of best predictors based on AIC, the multivariable Cox regression showed that ejection fraction < 40 (HR 1.41, 95% CI 1.21–1.65, $P < 0.001$), two-vessel disease (HR: 0.59, 95% CI 0.40–0.89, $P = 0.012$), peripheral vascular disease (HR 1.52, 95% CI 1.05–2.21, $P = 0.027$), and valvular heart disease (HR 1.45, 95% CI 1.24–1.69, $P < 0.001$) were the significant predictors of all-cause mortality.

Conclusion Octogenarians who undergo CABG have a high mortality risk, influenced by several preprocedural and procedural risk factors. The proposed nomogram can be considered for optimizing the management of this vulnerable age group.

Clinical registration number IR.TUMS.THC.REC.1400.081.

Keywords Coronary artery bypass, Octogenarians, Risk factors, Nomograms, Mortality

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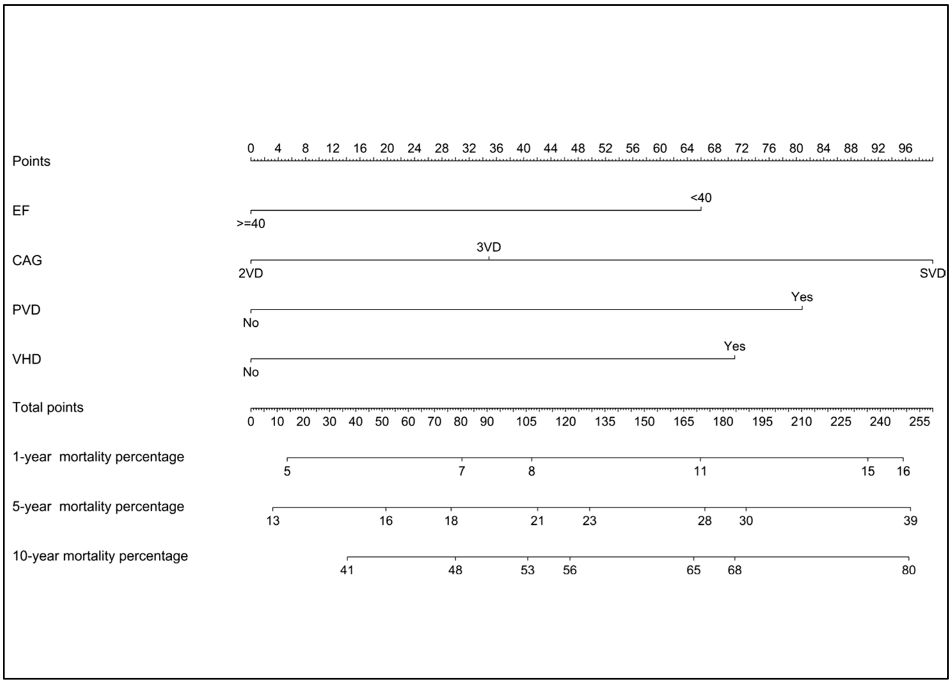
Graphical abstract

Coronary Artery Bypass Grafting in Octogenarians: A Nomogram for All-cause Mortality Prediction

Summary

1636 consecutive octogenarians who underwent elective isolated CABG between 2007 and 2016 at Tehran Heart Center and were followed up for a median of 9.2 years

Ejection fraction<40, number of diseased vessels in coronary angiography, peripheral vascular disease, and valvular heart disease were the most important predictors of mortality among octogenarians. These predictors were used to build a nomogram for one- five- and ten-year mortality prediction.



Legend: CABG = coronary artery bypass graft; EF = ejection fraction; CAG = cornary angiography; PVD = peripheral vascular disease; VHD: valvular heart disease

Introduction

Coronary artery disease (CAD) significantly contributes to global morbidity and mortality [1]. CAD has been reported as the leading cause of mortality and morbidity in the Iranian population of older adults [2]. Coronary artery bypass grafting (CABG) is the main revascularization method among the various therapeutic approaches for treating multiple coronary stenoses or severe lesions of the left main coronary artery. The Clinical application of CABG can potentially provide patients with better outcomes and prognoses and significantly improve their quality of life.

Iran is currently undergoing a notable acceleration in the aging of its population. By 2022, the proportion of individuals aged 60 and above exceeded 10% of the population. Advanced age has been consistently linked to a heightened risk of death and multiple adverse events after CABG [3]. Moreover, the prevalence of risk factors associated with cardiovascular diseases such as diabetes [4], hypertension [5], opium use [6], and obesity [7] has demonstrated an upward trend in Iran over recent decades, primarily attributed to socioeconomic and cultural shifts.

With the demographic shift towards an aging population and increasing life expectancy in developing countries, the incidence of CABG in older adult patients is on a noticeable rise [8]. Octogenarians are a rapidly expanding portion of the population that exhibit the highest incidence of coronary artery disease and an increased frequency of referrals to cardiothoracic surgeons for surgical revascularization [9].

Older patients, especially octogenarians, represent a unique population that can benefit from CABG but also face significant risks. Additional data are needed to determine the essential predictors of mortality in octogenarians. Therefore, this study aimed to identify the most critical mortality risk factors after CABG among individuals aged 80–89 years and propose a mortality prediction nomogram.

Materials and methods

Ethical statement

The ethics committee of Tehran University of Medical Sciences approved the study (IR.TUMS.THC.REC.1400.081). Written informed consent for the use of the data was obtained from all patients upon admission. The study was carried out according to the Helsinki Declaration.

Setting and population

We used the Adult Cardiac Surgery Databank of the Tehran Heart Center [10]. All consecutive patients aged 80–89 years who underwent elective isolated on-pump CABG at the Tehran Heart Center between March 2007 and March 2016 were identified and enrolled in our registry-based historical cohort study. Patients undergoing off-pump CABG were excluded to create a more homogeneous population and minimize the impact of procedural differences on the outcomes. In addition, we excluded patients undergoing urgent/emergent surgery because they are generally at a higher risk of postoperative complications and mortality compared to those undergoing elective procedures. Moreover, patients who lost to follow-up were excluded from the final analysis. Patient demographic, clinical, laboratory, angiographic, and angioplasty-related information was meticulously extracted from the databank of the Tehran Heart Center.

Variables

The demographic data included age, gender, and body mass index (BMI). The risk factors and comorbidities were ejection fraction (EF) < 40, diabetes mellitus (DM), dyslipidemia (DLP), hypertension (HTN), first-degree family history (FHx) of CAD, valvular heart disease (VHD), chronic obstructive pulmonary disease (COPD), peripheral vascular disease (PVD), previous cerebrovascular accidents or transient ischemic attacks (CVA/TIA), prior myocardial infarction (previous MI), number of disease vessel(s) in coronary artery angiography (CAG), glomerular filtration rate (GFR), and left main disease (LM). Valvular heart disease is any malfunction with a moderate or higher severity determined by transthoracic echocardiography in one or more heart valves: mitral, aortic, tricuspid, and pulmonary. Urgent/emergent surgery was performed within the initial week after cardiac catheterization due to the patient's critical condition. The data regarding the patients requiring intra-procedural blood transfusion or intra-aortic balloon pump (IABP) was also included. Mortality was defined as all-cause death occurring up to ten years following surgery. Postoperative complications included prolonged ventilation (defined as ventilation in a postsurgical intensive care unit for more than 24 h), CVA/TIA, and acute renal failure (ARF). The postoperative variables were not included in the predictive model.

Statistical analysis

Descriptive statistics for continuous variables are reported as the mean (standard deviation; SD) for normally distributed data. In contrast, median and interquartile range (IQR) boundaries are presented for non-normally distributed continuous data. Also, categorical variables are summarized by their frequency and percentage distributions. A Kaplan–Meier (KM) survival curve with the table at risk was plotted to provide an overall perspective. The Cox proportional hazards (Cox-PH) regression model was employed to identify predictors of all-cause mortality. Subsequently, the Akaike Information Criterion (AIC) was used to determine the best subset of predictors. Similar to our previous study [11], after confirmation of the PH assumption, a Cox-PH regression was initially fitted without any covariates (i.e., the null model). Then, its AIC was calculated. In a forward stepwise selection procedure, variables were introduced one at a time to the null model. At each step, the variable that resulted in the smallest increase in the AIC compared to the previous model was retained. The final model selection focused on identifying a parsimonious subset of predictors that met two criteria: (i) statistically significant effects on all-cause mortality, and (ii) a substantial contribution to model improvement as measured by a percentage reduction in AIC exceeding 0.15. A multivariable Cox PH regression with selected predictors was considered the final model. The results were presented as a hazard ratio (HR) with 95% Confidence Interval (CI). To facilitate clinical decision-making, a nomogram was developed to provide a user-friendly tool for predicting 1-, 5-, and 10-year mortality percentages. Calibration plots (predicted vs. observed values) were drawn to evaluate the prediction model and Harrell's C-index was used to estimate the overall model's discrimination ability. We calibrated and validated the model's performance with bootstrap resampling, at 1-, 5-, 7.5-, and 10 years. All statistical analyses were conducted in the R (version 4.4.0, R Foundation for Statistical Computing, Vienna, Austria, 2024) using the following packages: "rms" package (Harrell FE Jr. rms: Regression Modeling Strategies, ver. 5.1–2), "survival" package (Therneau TM. survival: Survival Analysis, ver. 2.42–6) [12].

Results

Our analysis included 1636 octogenarians undergoing elective on-pump CABG. The details of the study population are provided in Fig. 1. The mean age of the patients was 82.03 years (SD = 1.74), who were predominantly male (74.4%). The median follow-up of patients was 9.2 (95% CI 9.0,9.5) years. The mean hospital stay was 15 (12–20) days. The left internal mammary artery was the most common graft used in 1602 (98.5%) patients, followed by the saphenous vein graft used in the remainder of the patients (1.5%). Preprocedural variables that were predictors of all-cause mortality in the univariate analysis included age, ejection fraction < 40, diabetes, opium use, smoking, valvular heart disease, COPD, peripheral vascular disease, CVA/TIA, GFR, and two-vessel/three-vessel disease. Among the procedural predictors of mortality in univariate analysis are intra-procedural blood transfusion and IABP. Postoperative complications, including CVA/TIA (HR 3.10, 95% CI 1.66–5.80, $P < 0.001$) and ARF (HR 2.20, 95% CI 1.49–3.26, $P < 0.001$) were observed in 1.2% and 2.8% of patients, respectively. Moreover, 94 (5.7%) patients had prolonged ventilation (HR 2.50, 95% CI 1.91–3.27, $P < 0.001$). The preprocedural and procedural patient characteristics associated with mortality are summarized in Table 1.

The 30-day short-term mortality in our study was 37 (2.2%). The number of deceased patients at 1- 5- 10 years follow-up was 110 (6.7%), 291 (17.7%), and 626 (38.2%) respectively. The Kaplan–Meier curve of ten-year survival probability, number of events, and at-risk patients are illustrated in Fig. 2.

The best subset of predictors was selected based on AIC (Fig. 3). The selected variables were then applied in the Cox multivariable regression analysis as shown in Table 2. After the selection of best predictors based on AIC, the multivariable Cox regression showed that ejection fraction < 40 (HR 1.41, 95% CI 1.21–1.65, $P < 0.001$), two-vessel disease (HR 0.59, 95% CI 0.40–0.89, $P = 0.012$), peripheral vascular disease (HR 1.52, 95% CI 1.05–2.21, $P = 0.027$), and valvular heart disease (HR 1.45, 95% CI 1.24–1.69, $P < 0.001$) were the significant predictors of all-cause mortality. The overall model's C-index was 0.59 (95% CI 0.58–0.61), indicating modest predictive accuracy.

A nomogram was designed based on the best subset of predictors to predict the risk of all-cause mortality in the first, fifth, and tenth years after CABG, as shown in Fig. 4. For example, an octogenarian with PVD (81 points), EF < 40 (66 points), two-vessel disease (zero points), and VHD (71 points) have a total score of 218 suggesting approximately 14%, 34%, and 74% mortality at one, five, and ten-year after surgery respectively.

Calibration plots demonstrating the relation between the predicted and observed survival probability are presented in Supplementary Fig. S1. In addition, the model validation with bootstrap resampling is shown in Supplementary Fig. S2 indicating stable performance, with Harrell's C-index showing acceptable discrimination.

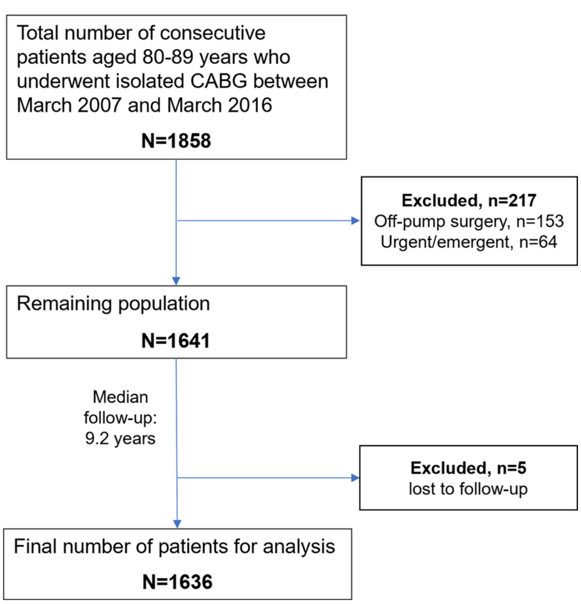


Fig. 1 Study population flow chart. CABG: coronary artery bypass graft

Discussion

The present study investigated the main predictors of all-cause mortality in octogenarian patients undergoing isolated CABG in a high-volume referral center with a total of 18,070 CABGs in the study period. We developed and validated a nomogram to predict mortality in these patients. Based on the AIC, the best predictors of one-, five- and ten-year mortality were identified: EF < 40, PVD, two-vessel disease, and VHD. We intentionally excluded opium use from the AIC and final modeling since opium use is a local health problem in Iran, attributed to its high prevalence, particularly among older individuals in our population. The worse outcome in patients with single-vessel disease (for instance left anterior descending artery) indicates the failure of the other two main supplying coronary arteries to compensate for the stenosis in one vessel. In other words, the involvement of only one vessel could cause substantial clinical symptoms that lead to CABG, and the dependence of heart muscle on one vessel forecasts poor prognosis. Likewise, a three-vessel disease, a total involvement of the myocardium blood-supplying system, could predict adverse outcomes

Table 1 Patient characteristics and univariate Cox regression

Variables	Overall, $N = 1,636$	Survived, $N = 985$	Deceased, $N = 651$	HR	95% CI	*P* value*
Demographics & Preprocedural						
Age	82.03 (1.74)	81.94 (1.66)	82.17 (1.84)	1.06	1.01, 1.11	0.009
Sex (male)	1,211 (74.0%)	728 (73.9%)	483 (74.2%)	0.99	0.83, 1.18	0.918
BMI	26.34 (3.88)	26.23 (3.76)	26.51 (4.05)	1.01	0.99, 1.03	0.221
EF < 40	482 (29.5%)	247 (25.1%)	235 (36.2%)	1.49	1.27, 1.74	< 0.001
Diabetes	530 (32.4%)	280 (28.4%)	250 (38.4%)	1.34	1.15, 1.57	< 0.001
Dyslipidemia	897 (54.8%)	551 (55.9%)	346 (53.1%)	0.86	0.74, 1.01	0.061
Hypertension	1,010 (61.8%)	597 (60.7%)	413 (63.4%)	1.12	0.95, 1.31	0.175
FH of CAD	420 (25.7%)	256 (26.0%)	164 (25.2%)	0.85	0.71, 1.02	0.079
Opium use	120 (7.3%)	54 (5.5%)	66 (10.2%)	1.69	1.31, 2.19	< 0.001
Smoking	376 (23.0%)	199 (20.2%)	177 (27.2%)	1.35	1.13, 1.60	< 0.001
VHD	518 (31.7%)	287 (29.1%)	231 (35.5%)	1.49	1.27, 1.75	< 0.001
COPD	74 (4.5%)	39 (4.0%)	35 (5.4%)	1.51	1.08, 2.13	0.017
PVD	45 (2.8%)	19 (1.9%)	26 (4.0%)	1.70	1.15, 2.52	0.008
CVA/TIA	108 (6.6%)	57 (5.8%)	51 (7.8%)	1.58	1.19, 2.11	0.002
GFR						
< 30	60 (3.7%)	29 (2.9%)	31 (4.8%)	Ref	–	–
30–59	967 (59.2%)	575 (58.4%)	392 (60.3%)	0.70	0.48, 1.00	0.052
≥ 60	607 (37.1%)	380 (38.6%)	227 (34.9%)	0.62	0.43, 0.90	0.013
Previous MI	683 (41.8%)	395 (40.2%)	288 (44.3%)	1.09	0.94, 1.27	0.267
CAG						
SVD	44 (2.7%)	20 (2.0%)	24 (3.7%)	Ref	–	–
2VD	309 (18.9%)	205 (20.9%)	104 (16.0%)	0.53	0.34, 0.82	0.005
3VD	1,278 (78.4%)	758 (77.1%)	520 (80.2%)	0.65	0.43, 0.98	0.042
LM disease	414 (25.4%)	244 (24.9%)	170 (26.1%)	1.10	0.93, 1.31	0.277
Procedural						
Graft number						
1	13 (0.8%)	9 (0.9%)	4 (0.6%)	—	—	
2	147 (9.0%)	78 (7.9%)	69 (10.6%)	1.51	0.55, 4.13	0.425
3	727 (44.4%)	435 (44.2%)	292 (44.9%)	1.21	0.45, 3.26	0.699
4 +	749 (45.8%)	463 (47.0%)	286 (43.9%)	1.07	0.40, 2.86	0.899
Graft						
Saphenous	25 (1.5%)	15 (1.5%)	10 (1.5%)	–	–	–
LIMA	1,602 (98.5%)	962 (98.5%)	640 (98.5%)	0.77	0.41, 1.45	0.421
IABP	40 (2.5%)	17 (1.7%)	23 (3.5%)	2.16	1.42, 3.27	< 0.001
Blood transfusion	1,037 (63.4%)	604 (61.3%)	433 (66.5%)	1.26	1.07, 1.48	0.005
Prolonged ventilation	94 (5.7%)	35 (3.6%)	59 (9.1%)	2.50	1.91, 3.27	< 0.001
Postoperative CVA/TIA	19 (1.2%)	9 (0.9%)	10 (1.5%)	3.10	1.66, 5.80	< 0.001
Postoperative ARF	45 (2.8%)	19 (1.9%)	26 (4.0%)	2.20	1.49, 3.26	< 0.001
Hospitalization days	15.0 (12.0, 20.0)	15.0 (12.0, 18.0)	16.0 (13.0, 22.0)	1.03	1.02, 1.03	< 0.001
Length of stay	8.0 (6.0, 10.0)	7.0 (6.0, 9.0)	8.0 (6.0, 12.0)	1.03	1.03, 1.04	< 0.001

The data are presented as the mean (SD), frequency (percentage), or median (IQR)

ARF acute renal failure, *BMI* body mass index, *CAD* coronary artery disease, *CAG* coronary artery angiography, *CHF* chronic heart failure, *CI* confidence interval, *COPD* chronic obstructive pulmonary disease, *CVA* cerebral vascular accident, *DM* diabetes mellitus, *EF* ejection fraction, *FH* family history, *GFR* glomerular filtration rate, *HR* hazard ratio, *HTN* hypertension, *IABP* intra-aortic balloon pump, *IQR* interquartile range, *LIMA* left internal mammary artery, *LM* left main, *MI* myocardial infarction, *OR* odds ratio, *PVD* peripheral vascular disease, *SD* standard deviation, *TIA* transient ischemic attack, *VD* vessel(s) diseased, *VHD* valvular heart disease

* *P* value < 0.05 was considered statistically significant

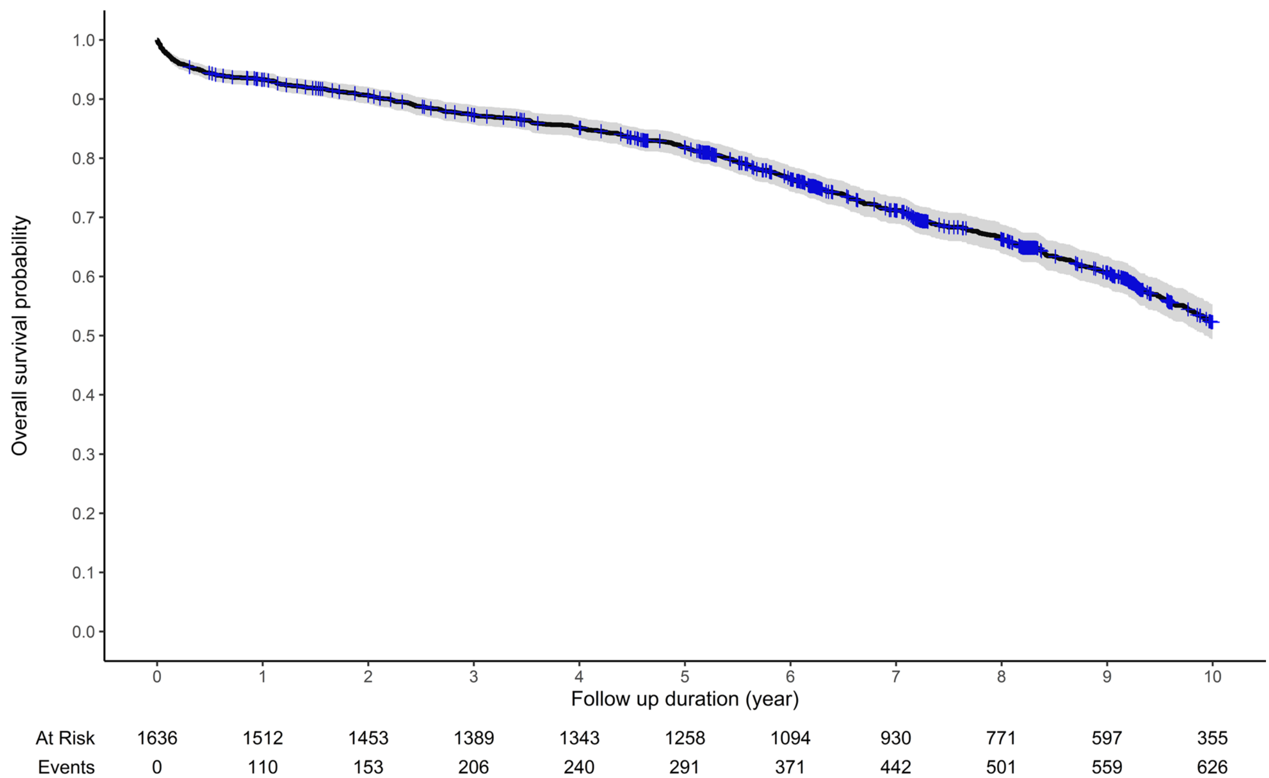


Fig. 2 The median follow-up duration was 9.2 years (95% CI 9.0–9.5), as obtained by the inverse Kaplan–Meier method. The Kaplan–Meier survival curve with the table of patients at risk highlighted survival probabilities over time, with censoring indicated by small blue lines

in octogenarians. Moreover, the severity of myocardial infarction caused by three diseased vessels might account for the poor outcomes in these patients. Although high-risk patients might benefit from off-pump CABG [13], we had to exclude such patients to lower the risk of selection bias since this population had worse preprocedural clinical conditions and underwent a completely different procedure (off-pump) performed only by a limited number of surgeons. The moderate C-index of the model could indicate the masked importance of the predictive value of older age in mortality prediction since we limited our investigation to octogenarians.

While debate continues about the utility and safety of CABG in octogenarians because of the high surgical risk in this age group, many highly skilled cardiac surgeons in the context of a developing world such as Iran believe that octogenarians who have medically manageable cardiac symptoms without critical coronary lesions or who are asymptomatic would not benefit from CABG. Moreover, many studies suggest that comorbidities such as CKD [14] or COPD [15] in older adults can worsen CABG outcomes and increase mortality risk. Therefore, mortality risk prediction could help surgeons make appropriate decisions in this vulnerable age group. Our nomogram could be a perfect clinical guide, especially in underdeveloped and developing countries with limited resources and high surgical costs.

On the other hand, a recent study by Choi showed that octogenarians benefit most from CABG and have a greater probability of survival [16]. The severity, progression, and prognosis of disease in octogenarians after CABG rely significantly on several conventional risk factors, many of which have been used in different scoring systems for mortality risk prediction, such as EuroSCORE [17], STS [18], and EuroSCORE II [19]. These predictive scoring systems require more baseline information and are complex and difficult to calculate quickly. Furthermore, they have not been designed to predict long-term mortality risk in patients after CABG. Therefore, we recommend a model that can be implanted rapidly and efficiently in clinical settings. Similar studies have investigated risk factors and provided nomograms; for example, in the Ziv-Baran study, older age, DM status, COPD status, chronic heart failure (CHF), chronic renal failure (CRF), old MI, EF $< =30\%$, preoperative IABP and peripheral vascular disease were significant predictors of mortality in their model [20]. The model proposed by Wu et al. to predict seven-year mortality after CABG, was comprised of age, body mass index (BMI), EF, hemodynamic stability, left main coronary artery disease,

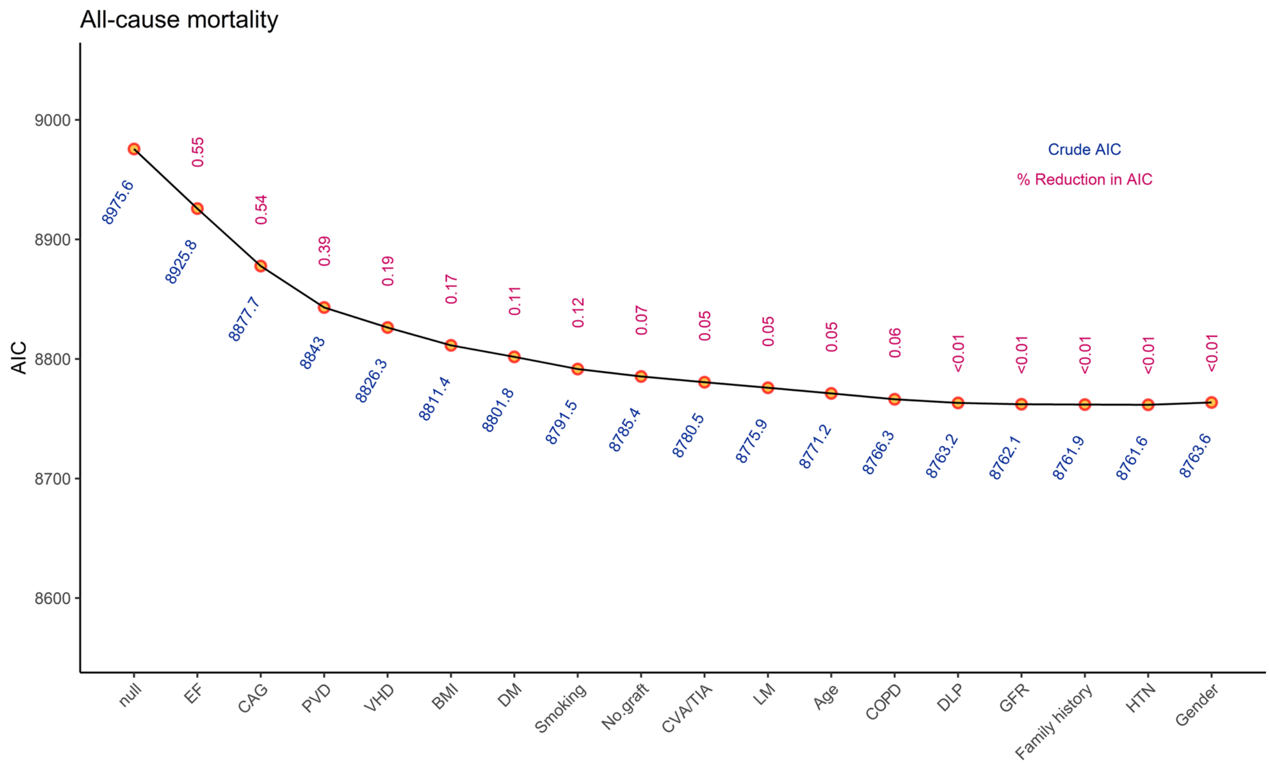


Fig. 3 Akaike information criterion (AIC). The best predictors were selected from the slope until the flattening point in the curve; CVA: cerebral vascular accident; TIA: transient ischemic attack; DM: diabetes mellitus; HTN: hypertension; DLP: dyslipidemia; COPD: chronic obstructive pulmonary disease; PVD: peripheral vascular disease; VHD: valvular heart disease; EF: ejection fraction; GFR: glomerular filtration rate; HTN: hypertension; LM: left main; BMI: body mass index; MI: myocardial infarction; DLP: dyslipidemia; CAG: coronary artery angiography (i.e. the number of the diseased vessel(s) in CAG)

Table 2 Multivariable Cox proportional hazard regression for the effect of the best subset of predictors on all-cause mortality

Characteristic	HR	95% CI	P-value
EF < 40	1.41	1.21, 1.65	< 0.001
CAG	–	–	0.029
SVD	–	–	–
2VD	0.59	0.40, 0.89	0.012
3VD	0.71	0.49, 1.03	0.075
PVD	1.52	1.05, 2.21	0.027
VHD	1.45	1.24, 1.69	< 0.001

Proportional hazard assumption: ($\chi^2_7 = 2.04, p = 0.842$)

C-Index: 0.59 (95% CI 0.58,0.61)

HR hazard ratio, *CI* confidence interval, *EF* ejection fraction, *CAG* coronary angiography, *SVD* single vessel disease, *PVD* peripheral vascular disease, *VHD* valvular heart disease

CVD, PVD, CHF, malignant ventricular arrhythmia, COPD, DM, CRF, and previous CABG [21]. Another model proposed by McKenzie et al. to predict eight-year mortality after CABG included age, BMI, COPD, DM, EF, gender, left main coronary artery disease, old MI, number of atherosclerotic vessels, previous CABG, PVD, CRF, the operative status of patients (elective/urgent, rescue, emergency) and white blood cell count [22]. In another similar study by Gardener et al., a multivariate risk model for mid-term mortality was evaluated, and essential noncardiac variables that predicted mid-term mortality included older age, partially or entirely dependent functional class, COPD, CVD, PVD, and serum Cr levels at 1.5 mg/dL or higher. In their study, important heart-related variables predicting mid-term mortality included preoperative digoxin use, preoperative diuretic use, prior cardiac surgery, Canadian Heart and Vascular Association class III or IV angina, prior MI, preoperative IABP, preoperative ST depression in ECG and New York Heart Association functional class III or IV, left main coronary artery stenosis of 50% or more, and LVEF less than 35% [23].

In the present study, sex was not an independent risk factor for mortality, and this association was not observed after controlling for race and other comorbidities. This finding is consistent with similar studies [24]; however, some studies have indicated that female sex is often associated with a greater risk of in-hospital and

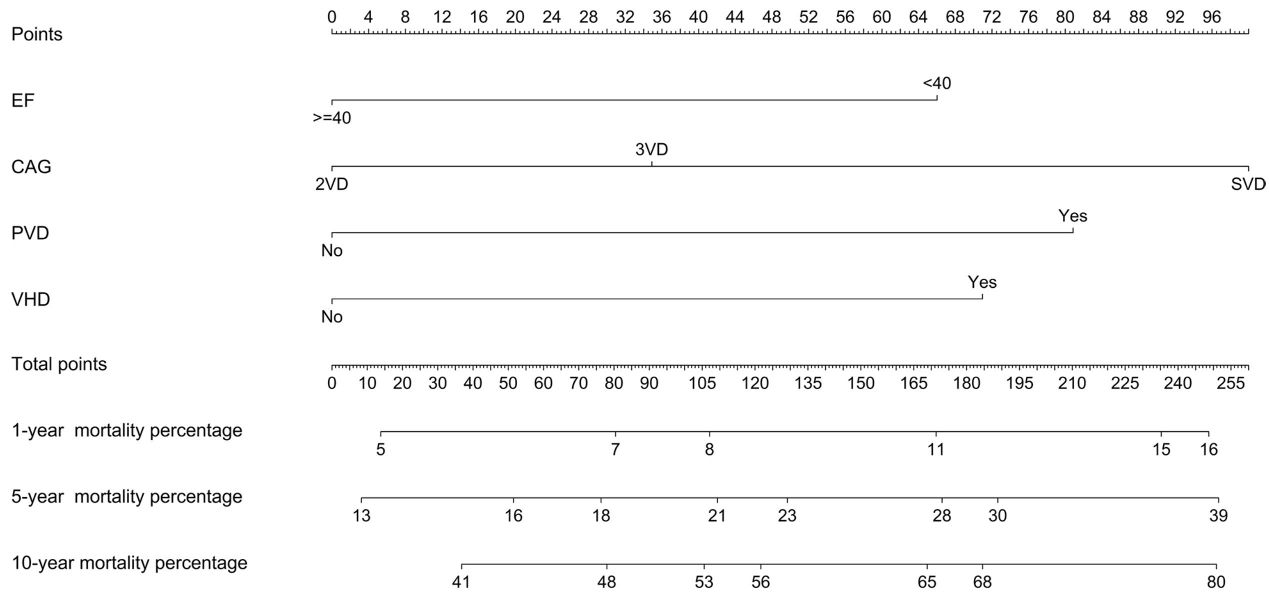


Fig. 4 Nomogram for predicting mortality within ten years after CABG. EF: ejection fraction; CAG: coronary angiography- number of the diseased vessel(s); PVD: peripheral vascular disease; VHD: valvular heart disease; *Instructions*: First, locate the relevant data points on the "points" scale at the top of the graph with a straight perpendicular line. After calculating the total score based on each predictor's point, a vertical line perpendicular to the total score scale starting from the achieved total point intercepting the mortality lines indicates death probability in the corresponding time after CABG. The higher the score is, the greater the mortality risk

short-term mortality [25]. In this regard, Lemaire showed that women had higher mortality than men in the same age group (OR = 1.25 95% CI 1.07–1.46) [26]. Conversely, our results showed that the older age of octogenarians, similar to gender, does not play a role in predicting the mortality rate and should not interfere with CABG. Therefore, patients' general condition and comorbidities should be evaluated for surgical compatibility rather than considering only advanced age.

Opium abuse is a significant health concern worldwide [27], especially in Iran which has the highest rate of opiate drug abuse with over 1.2 million addicts in need of treatment services [28]. Various studies indicated an association between opium use and an increased risk of coronary artery disease (CAD) [29, 30]. Although opium was a significant predictor of all-cause mortality, it was excluded from the variable selection and final model due to its unique status as a localized health issue within Iran. This decision was made to ensure the model's applicability and validity, as including a variable with such a specific regional influence could reduce the generalizability of the findings.

Older adults tend to have a more extended hospital stay, contributing to higher mortality and morbidity. Our study revealed that patients stayed in the hospital for 15.0 days (12.0, 20.0), almost twice as long as patients in industrialized countries. Longer hospital stays bring enormous costs for individuals and insurance companies and increase the risk of hospital-acquired infections, which are responsible for early rehospitalization and life-threatening complications [31].

We achieved a 30-day mortality of 2.2%, which is acceptable compared to similar studies reporting a mortality of 4.7% [32] to 16.8% [33]. Our study also indicates lower one-year mortality (6.7%) than similar studies in octogenarians with mortality rates ranging from 9.8% [16] to 19.3% [34]. In addition, we calculated 17.7% mortality at five years which is lower than the 23.4% [32] and 27% [35] mortality rates observed in other studies analyzing the outcomes in octogenarians. Similarly, the ten-year mortality in our study was lower than in the literature reporting 65% [32] and 69% [16].

CABG has been a safer treatment option in octogenarians compared to Percutaneous coronary intervention (PCI). As reported in a large cohort, octogenarians undergoing PCI have demonstrated higher in-hospital mortality rates compared with CABG (5.4% vs 4.8%, respectively) [36]. The one-year mortality rate reported by Abramik et al. [37] in octogenarians undergoing PCI was 13.0%. Another study found that 17.3% of octogenarians died within the first year after PCI [38].

Complications after CABG in our study included stroke in 1.2% and renal failure in 2.8% of the patients. Lemaire et al. studied 67,568 patients aged ≥ 70 years who underwent CABG. Octogenarians were more likely to develop cardiac complications than septuagenarians (OR = 1.20, 95% CI 1.12–1.23) and more likely to develop renal and respiratory complications ($P < 0001$ and $P < 0.0001$, respectively). These patients also had a greater chance of postoperative bleeding ($P < 0.0001$) and mortality ($P < 0.0001$) [26]. Moreover, another study that investigated postsurgical complications revealed that octogenarians, in comparison to septuagenarians, were more likely to receive a transfusion of blood products (52.80% vs. 36.88%, $P < 0.0001$), prolonged ventilation (> 24 h) (14.47% vs. 9.32%; $P = 0.0007$), and more often encountered acute renal failure (5.79% vs. 3.59%; $P = 0.02$), pneumonia (6.87% vs. 2.93%; $P < 0.0001$) and permanent stroke (3.07% vs. 1.32% $P = 0.0063$) [39].

Our study had the strength of using an extensive population-based database for CABG follow-ups in a referral center. However, there are also certain limitations to the study. First, data from patients who underwent isolated CABG surgery a decade ago were used. The quality of CABG, follow-up care, and outcomes have improved over time. Nevertheless, our available data on long-term mortality are the most recent. In addition, the medical treatment of patients was updated according to the most current guidelines during the study period. Second, the accuracy of this risk score should be tested in other populations. Third, the predictions of our statistical models are based on all-cause mortality predicted by risk factors present before CABG surgery. Some risk factors for overall long-term mortality (e.g., cancer) were unavailable. In addition, some risk factors may change over time (e.g., BMI), but only baseline values were available. Therefore, the accuracy of proportional models is limited.

Conclusion

We developed an accurate and easy-to-use nomogram to predict mortality up to ten years after CABG. The predictors included EF < 40, the number of diseased vessels in coronary angiography, PVD, and VHD. Estimating patient mortality can help surgeons make the best decisions considering the high surgical risk, especially for more vulnerable octogenarians.

Abbreviations

ARF	Acute renal failure
AIC	Akaike information criterion
BMI	Body mass index
CABG	Coronary artery bypass graft
CAD	Coronary artery disease
CAG	Coronary artery angiography
CHF	Chronic heart failure
CI	Confidence interval
COPD	Chronic obstructive pulmonary disease
Cr	Creatinine
CRF	Chronic renal failure
CVA	Cerebral vascular accident
CVD	Cardiovascular disease
DLP	Dyslipidemia
DM	Diabetes mellitus
ECG	Electrocardiogram
EF	Ejection fraction
FH	Family history
GFR	Glomerular filtration rate
HR	Hazard ratio
HTN	Hypertension
IQR	Interquartile range
LIMA	Left internal mammary artery
LM	Left main
MI	Myocardial infarction
OR	Odds ratio
PVD	Peripheral vascular disease
SD	Standard deviation
TIA	Transient ischemic attack
VD	Vessel(s) diseased
VHD	Valvular heart disease

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13019-024-03054-6.

Additional file1

Author contributions

Conceptualization: SD, SM, and JB; Data Curation, Formal Analysis: AJ and ZK; Investigation: AA and AH; Methodology: AJ, MS; Project Administration: SD and JB; Resources: ZK; Software: ZK; Supervision: SD, SM, and JB; Validation: JB, MS, and MSN; Visualization: AJ and ZK; Writing – Original Draft: MSN, ES, and MD; Writing – Review & Editing: MSN, ES, and MD;

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The ethics committee of Tehran University of Medical Sciences approved the study (IR.TUMS.THC.REC.1400.081). Written informed consent for the use of data was obtained from all patients upon admission. The study was carried out according to the Helsinki Declaration.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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