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Predicting outcomes in patients with low ejection fraction undergoing coronary artery bypass graft

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A R T I C L E I N F O

Keywords:
Left ventricular dysfunction
Coronary artery bypass grafting
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Survival analysis

A B S T R A C T

Introduction: Reduced left ventricular ejection fraction (LVEF) is a well-known predictor of adverse events after cardiac surgery. We aimed to assess the outcomes in patients with low LVEF undergoing coronary artery bypass graft.
Methods: In this retrospective cohort, we included all patients with left ventricular ejection fraction ≤ 40 who underwent coronary artery bypass grafting between March 2007 and March 2016 (with a median follow-up of nine years) at Tehran Heart Center. Demographics and clinical characteristics were extracted from the data registry. Akaike information criterion (AIC) was used. The univariate Cox regression was performed. We investigated the predictors of mortality and major adverse cardiac and cerebrovascular events (MACCE) using Cox multivariable regression.
Results: In total, 5,532 cases (79 % male) with a mean age of 65.58 were included in the study. The nine-year overall survival was calculated at 68 %, and more than half of the patients had MACCE (55 %). In adjusted multivariable Cox regression analysis, moderate to severe mitral valve regurgitation, glomerular filtration rate ≤ 60, mild right ventricular dysfunction, and valvular heart disease independently predicted higher mortality. The abovementioned predictors and peripheral vascular disease significantly increased MACCE.
Conclusion: Our study indicates the clinical significance of mitral regurgitation, valvular heart disease, and renal function in patients with low ejection fraction treated by coronary artery bypass grafting surgery. Identifying predictors of adverse events can help with clinical decision-making and risk stratification, ultimately improving patient outcomes.

1. Introduction

Reduced left ventricular ejection fraction (LVEF) (<30–40 %) is a well-known indicator of cardiac function. Cardiac surgery in patients with preoperative reduced LVEF results in higher complications and adverse events compared to normal EF [2], and coronary artery bypass graft (CABG) is not an exception [3]. CABG has been a viable revascularization treatment for coronary artery disease (CAD), displaying considerable clinical improvement and long-term survival. Compared to first-time primary cutaneous intervention (PCI), isolated CABG has demonstrated better survival and MACE patients with LVEF ≤ 35 [4]. Nearly one-third of patients who undergo CABG exhibit left ventricular

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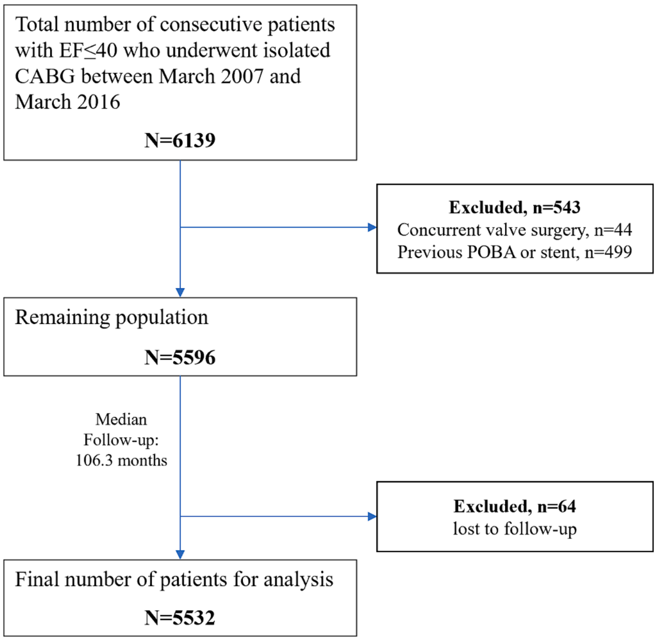

Fig. 1. Flow diagram of the study population selection.

systolic dysfunction with EF < 50 [5]. CABG candidates with lower ejection fraction exhibit a significantly greater risk of morbidity and mortality [6,7]. Similarly, reduced LVEF can predict an increased mortality risk and higher occurrence of adverse events after PCI [8].

Several risk factors have been associated with an increased risk of mortality in patients with low EF after CABG, such as cardiopulmonary bypass time, operation time, prolonged inotropic support, intensive care unit stay [9], hemodynamic instability before operation, and preoperative renal dysfunction [10]. Nevertheless, the predictors vary substantially in different populations and settings. For instance, advanced age, diabetes (DM), chronic obstructive pulmonary disease (COPD), and current smoking increased the risk of all-cause death and (MACCE) [11].

Data about predictors of CABG adverse outcomes in developing countries like Iran, especially in vulnerable patients with impaired LV function, seems insufficient; therefore, in the present study, we aimed to evaluate the predictors of all-cause mortality and MACCE in patients with low LVEF after CABG in Iranian population.

2. Materials and Methods

2.1. Study population

In the present retrospective cohort, we used the Tehran Heart Center database, a registry for all adult candidates for cardiac surgery. We included consecutive patients with low LVEF (≤40 %) who underwent

Table 1
Patients' characteristics.

Characteristic	Overall N = 5,532#	All-Cause Mortality		MACCE	
		Alive N = 3,953#	Deceased N = 1,579#	No N = 3,028#	Yes N = 2,504#
Age (*years*)	65.58 ± 9.98	64.12 ± 9.71	69.22 ± 9.71	64.24 ± 9.66	67.20 ± 10.12
Sex (*Female*)	1,162 (21.0 %)	792 (20.0 %)	370 (23.4 %)	588 (19.4 %)	574 (22.9 %)
BMI (kg/m^2)	26.72 ± 4.12	26.82 ± 4.09	26.47 ± 4.18	26.80 ± 4.08	26.63 ± 4.16
Hypertension	2,784 (50.4 %)	1,904 (48.2 %)	880 (55.8 %)	1,449 (47.9 %)	1,335 (53.4 %)
Diabetes	2,400 (43.4 %)	1,611 (40.8 %)	789 (50.0 %)	1,205 (39.8 %)	1,195 (47.7 %)
Dyslipidemia	3,211 (58.1 %)	2,294 (58.0 %)	917 (58.1 %)	1,715 (56.7 %)	1,496 (59.8 %)
FHx of CAD	1,912 (34.6 %)	1,418 (35.9 %)	494 (31.3 %)	1,042 (34.4 %)	870 (34.8 %)
Previuos MI	3,405 (61.8 %)	2,442 (62.0 %)	963 (61.4 %)	1,820 (60.3 %)	1,585 (63.6 %)
Cigarette Smoking	1,130 (20.5 %)	849 (21.5 %)	281 (17.9 %)	663 (21.9 %)	467 (18.7 %)
PVD	148 (2.7 %)	78 (2.0 %)	70 (4.5 %)	57 (1.9 %)	91 (3.7 %)
GFR ≥ 60 (ml/min)	3,831 (69.4 %)	2,991 (75.9 %)	840 (53.3 %)	2,337 (77.4 %)	1,494 (59.8 %)
CVA/TIA history	415 (7.5 %)	244 (6.2 %)	171 (10.8 %)	187 (6.2 %)	228 (9.1 %)
VHD	1,888 (34.6 %)	1,186 (30.4 %)	702 (45.0 %)	960 (32.1 %)	928 (37.6 %)
Chronic lung disease	245 (4.4 %)	143 (3.6 %)	102 (6.5 %)	109 (3.6 %)	136 (5.4 %)
Echocardiographic Features					
Mild RV systolic dysfunction	1,100 (20.1 %)	741 (18.9 %)	359 (22.9 %)	581 (19.4 %)	519 (20.9 %)
AI (moderate or severe)	186 (3.4 %)	110 (2.8 %)	76 (4.9 %)	93 (3.1 %)	93 (3.8 %)
MR (moderate or severe)	1,512 (27.9 %)	932 (24.1 %)	580 (37.5 %)	772 (26.0 %)	740 (30.3 %)
TR (moderate or severe)	467 (8.6 %)	255 (6.6 %)	212 (13.7 %)	219 (7.4 %)	248 (10.1 %)
Coronary Angiography Result					
Single vessel	153 (2.8 %)	121 (3.1 %)	32 (2.0 %)	92 (3.0 %)	61 (2.4 %)
Two vessels	1,018 (18.4 %)	780 (19.8 %)	238 (15.1 %)	602 (19.9 %)	416 (16.7 %)
Three vessels	4,349 (78.8 %)	3,046 (77.2 %)	1,303 (82.8 %)	2,331 (77.1 %)	2,018 (80.9 %)
LMCA involvement	1,101 (20.1 %)	742 (18.9 %)	359 (22.9 %)	582 (19.4 %)	519 (20.9 %)
Off-pump	509 (9.2 %)	351 (8.9 %)	158 (10.0 %)	309 (10.2 %)	200 (8.0 %)
Aortic clamp time (min)	42.41 (14.76)	42.19 (14.60)	42.98 (15.16)	41.95 (14.50)	42.96 (15.06)
Total ventilation hour	10.0 (7.5, 13.0)	9.0 (7.0, 12.0)	11.0 (8.0, 16.0)	9.0 (7.0, 12.0)	10.0 (8.0, 14.0)
Status of procedure (*Urgent&Emergent*)	252 (4.6 %)	172 (4.4 %)	80 (5.1 %)	99 (3.3 %)	153 (6.1 %)
LOS	7.0 (6.0, 9.0)	7.0 (6.0, 8.0)	8.0 (6.0, 11.0)	7.0 (6.0, 8.0)	7.0 (6.0, 10.0)
Reoperation for bleeding	117 (2.1 %)	98 (2.5 %)	19 (1.2 %)	86 (2.8 %)	31 (1.2 %)

Data are presented by frequency (%) or mean (SD); Abbreviations: MACCE: major adverse cardiac and cerebrovascular events, BMI: body mass index, TIA: transient ischemic attack, CVA: cerebral vascular accident, RV: right ventricle, FHx: family history, CAD: coronary artery disease, MI: myocardial infarction, AI: aortic insufficiency, MR: mitral regurgitation, TR: tricuspid regurgitation, PVD: peripheral vascular disease, VHD: valvular heart disease, LMCA: left main coronary artery, LOS: length of stay;

n (%); Mean ± SD; Median (IQR).

isolated CABG between March 2007 and March 2016. The patients were excluded within the following criteria: 1) concurrent valve surgery, 2) Previous balloon angioplasty or stenting of the coronary artery, and 3) completely lost to follow-up. The details about the study population have been demonstrated in Fig. 1. This study was approved by the ethics committee of the Tehran University of Medical Sciences with the code IR.TUMS.AEC.1403.019.

2.2. Risk factors and outcomes

Demographics included age, sex, body mass index (BMI), Diabetes (DM), hypertension (HTN), dyslipidemia, cigarette smoking, first-degree family history of CAD, previous MI, peripheral vascular disease (PVD), glomerular filtration rate (GFR), history of cerebrovascular accident (CVA) or TIA, valvular heart disease (VHD), and chronic lung disease (CLD). Preoperative risk factors included coronary angiography and echocardiography results. The angiography determined left main coronary artery disease (LMCA), and the findings were classified into three groups: single vessel, two vessels, and three vessels. Furthermore, echocardiography evaluated global EF, systolic dysfunction of the right ventricle (RV), LV diastolic dysfunction, aortic insufficiency (AI), tricuspid regurgitation (TR), and mitral regurgitation (MR) variables. Moreover, off-pump surgery and aortic clamp time were investigated. The primary outcome was considered all-cause mortality, and the secondary outcome was major adverse cardiac and cerebrovascular events (MACCE). MACCE was defined as one of the following events: all-cause death, acute coronary syndrome, stroke or transient ischemic attack (TIA), and revascularization. Total ventilation hour, status of the procedure (urgent and emergent), and reoperation for bleeding were also recorded.

2.3. Statistical Methods

We presented quantitative data using means and standard deviations for variables that followed a normal distribution and medians and interquartile ranges for the rest. Normality was assessed through histograms and descriptive statistics. Qualitative data were summarized using frequencies and percentages. We used the Akaike Information Criterion (AIC) to identify and select the most important risk factors of mortality and MACCE. For this purpose, after ensuring that proportional hazards (PH) are met, The Cox PH model was initially fitted without any risk factors (the null model), and its AIC was calculated. Next, the risk factors were attached one by one to the null model, the risk factors that had the least reduction in the AIC compared to the previous step were added to the model. This process continued until all the risk factors were added individually and the full model was reached. Then, the most important risk factors of mortality and MACCE include the variables that, in addition to having a significant effect, their percentage reduction of AIC is greater than 0.4. A multivariable Cox PH regression with selected risk factors as covariates were considered as the final model. Calibration and validity of the final model were evaluated using calibration plots at 1.5, 7.5, and 10-year time points and a 10-fold cross-validation based on Harrell's C-index, respectively. Statistical analyses were conducted using the R statistical language (version 4.3.2; R Core Team, 2023), using the packages *rms* (version 6.7.1) [12] *survminer* (version 0.4.9) [13], *survival* (version 3.5.7) [14,15], *ggplot2* (version 3.4.4) [16] and *SurvMetrics* (version 0.5.0) [17].

3. Results

3.1. Demographics and clinical features

A total of 5,532 individuals with a mean age of 65.58 years (standard deviation-SD = 9.98) were included in the study. Most of the participants were male (79.0 %). The average body mass index (BMI) was 26.72 (SD = 4.12). The median follow-up of patients was 106.3 months with a 95 % confidence interval (CI) of 104.6–108.1. Among the population, 43.4 % had diabetes, 50.4 % reported hypertension, 4.4 % chronic lung disease, 2.7 % peripheral vascular disease, and 34.6 % valvular heart disease. Demographic, clinical, and echocardiographic characteristics are shown in Table 1.

3.2. Predictive factors for mortality and MACCE

The overall five-year survival and MACCE were 84 % and 75 %, respectively. In a nine-year follow-up, these figures changed to 68 % and 55 %, respectively. The Kaplan-Meier curves for overall survival and MACCE are shown in Fig. 2. The univariate Cox regression analysis of the predictors is demonstrated in Table 2 . After calculating the AIC for each variable, the crude reduction of AIC was plotted (Fig. 3). In our final analysis, we included the first five variables to predict all-cause mortality and the first six to predict MACCE (based on AIC reduction). Using multivariable Cox regression analysis (Table 3), moderate to severe MR (HR = 1.45, 95 % CI: 1.16–1.70, P < 0.001), GFR < 60 (HR = 1.92, 95 % CI: 1.73–2.12, P < 0.001), mild RV systolic dysfunction (HR = 1.23, 95 % CI: 1.09–1.39, P < 0.001), valvular heart disease (HR = 1.37, 95 % CI: 1.15–1.64, P < 0.001), and length of stay (HR = 1.03, 95 % CI: 1.03–1.04, P = 0.001) were found to predict increased mortality among low EF patients after CABG (Table 3). The model's C-index for mortality prediction was 0.66 (95 % CI: 0.64–0.68). Moreover, moderate to severe MR (HR = 1.23, 95 % CI: 1.06–1.42, P = 0.005), GFR < 60 (HR = 1.57, 95 % CI: 1.44–1.70, P < 0.001), RV systolic dysfunction (HR = 1.12, 95 % CI: 1.01–1.23, P = 0.031), VHD (HR = 1.21, 95 % CI: 1.05–1.39, P = 0.007), and PVD (HR = 1.36, 95 % CI: 1.10–1.69, P =

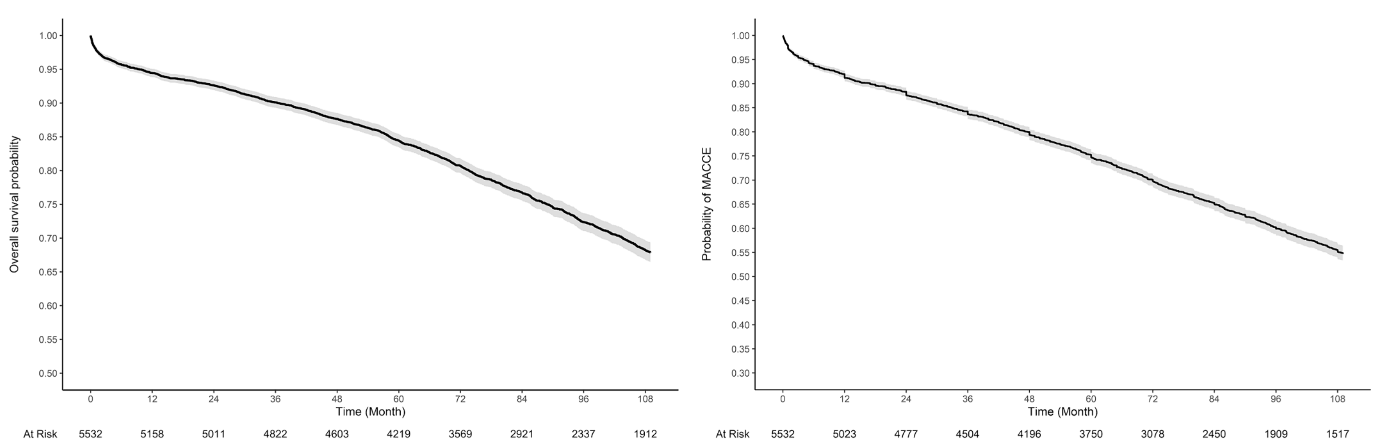

Fig. 2. Kaplan-Meier curve for survival (left) and major adverse cardiac and cerebrovascular events (right).

Table 2
Univariate Cox regression analysis.

Variables	All-Cause Mortality HR	95 % CI	P-value	MACCE HR	95 % CI	P-value
Age	1.04	1.04, 1.05	**<0.001**	1.03	1.02, 1.03	**<0.001**
Sex (Female)	0.84	0.75, 0.94	**0.003**	0.83	0.76, 0.91	**<0.001**
BMI	0.98	0.97, 0.99	**0.004**	0.99	0.98, 1.00	0.190
GFR (<60)	2.16	1.96, 2.39	**<0.001**	1.62	1.50, 1.76	**<0.001**
Hypertension	1.36	1.23, 1.50	**<0.001**	1.27	1.18, 1.38	**<0.001**
Diabetes	1.39	1.26, 1.53	**<0.001**	1.33	1.23, 1.44	**<0.001**
Cigarette smoking	0.89	0.78, 1.01	0.073	0.93	0.84, 1.03	0.175
FHx of CAD	0.77	0.69, 0.86	**<0.001**	0.90	0.83, 0.98	**0.011**
Dyslipidemia	0.96	0.87, 1.06	0.465	1.01	0.94, 1.10	0.727
Previous MI	0.89	0.81, 0.99	**0.030**	0.97	0.90, 1.06	0.517
PVD	1.81	1.42, 2.29	**<0.001**	1.46	1.18, 1.80	**<0.001**
LM	1.28	1.13, 1.44	**<0.001**	1.15	1.05, 1.27	**0.004**
VHD	1.94	1.75, 2.14	**<0.001**	1.46	1.35, 1.59	**<0.001**
CVA/TIA history	1.84	1.57, 2.16	**<0.001**	1.66	1.45, 1.91	**<0.001**
Chronic lung disease	1.67	1.37, 2.04	**<0.001**	1.38	1.16, 1.65	**<0.001**
AI (moderate or severe)	1.88	1.49, 2.37	**<0.001**	1.44	1.17, 1.77	**<0.001**
MR (moderate or severe)	1.98	1.78, 2.19	**<0.001**	1.49	1.37, 1.63	**<0.001**
TR (moderate or severe)	2.29	1.98, 2.65	**<0.001**	1.65	1.45, 1.88	**<0.001**
Mild RV systolic dysfunction	1.28	1.14, 1.44	**<0.001**	1.15	1.05, 1.27	**0.004**
Coronary angiography results						
Two vessels	1.09	0.76, 1.58	0.632	0.98	0.75, 1.28	0.893
Three vessels	1.48	1.04, 2.10	**0.030**	1.19	0.92, 1.54	0.174
LMCA involvement	1.28	1.13, 1.44	**<0.001**	1.15	1.05, 1.27	**0.004**
Off-pump	1.56	1.32, 1.85	**<0.001**	1.25	1.08, 1.44	**0.003**
Aortic clamp time	1.00	1.00, 1.01	0.165	1.00	1.00, 1.01	0.068
Reoperation for bleeding	0.77	0.49, 1.21	0.264	0.75	0.52, 1.06	0.106
LOS	1.04	1.03, 1.04	**<0.001**	1.03	1.03, 1.04	**<0.001**

HR: hazard ratio, CI: confidence interval, MACCE: major adverse cardiac and cerebrovascular events, FHx: family history, CAD: coronary artery disease, MI: myocardial infarction, AI: aortic insufficiency, MR: mitral regurgitation, TR: tricuspid regurgitation, RV: right ventricle, PVD: peripheral vascular disease, TIA: transient ischemic attack, VHD: valvular heart disease, BMI: body mass index, GFR: glomerular filtration rate, LMCA: left main coronary artery, LOS: length of stay;

0.005) increased the risk of MACCE (Table 3). The Cox model for MACCE demonstrated C-index = 0.67 (95 % CI: 0.65–0.70). Calibration plots were created to evaluate the agreement between predictions and observations, as shown in Supplementary Figures 1 & 2.

4. Discussion

We examined predictors associated with mortality MACCE in a cohort of patients with low ejection fraction (≤40 %) undergoing CABG. We found that GFR < 60, moderate to severe MR, mild RV systolic dysfunction, and VHD increase the mortality and MACCE risk. In addition, PVD was among the predictors of higher MACCE. These findings are consistent with the literature. Yoo et al. [18] assessed 476 patients with an LVEF ≤ 35 % who underwent CABG and demonstrated that ≥ moderate MR, lower eGFR, and LV wall thinning were independent predictors of death. Likewise, Hillis et al. showed that higher age and lower eGFR are strong predictors of mortality in reduced LVEF (≤35) [19], which was comparable to the results of a study by Brynjarsdottir et al. including advanced age, DM, chronic kidney disease (CKD), COPD, current smoking, NYHA classification III or IV, emergency procedure and longer skin-to-skin time [11]. In a similar study by DeRose et al., higher age, PVD, emergency operation, and chronic obstructive pulmonary disease were independent predictors of higher mortality in patients with LVEF ≤ 25 [20]. Moreover, Seese et al. [21] evaluated cardiac surgery outcomes in patients with LVEF ≤ 25. They found that simultaneous valve surgery, advanced age, CLD, PVD, and higher serum creatinine could predict five years of mortality. Similar in-hospital mortality predictors have been identified in a subgroup of patients with severely reduced LVEF (≤20), including older age, female sex, hepatic failure, renal failure on dialysis, congestive heart failure at admission, emergent operation, previous MI, and previous open heart operation [7]. However, Ergunes et al. found that smoking, prolonged inotropic support, and prolonged ventilatory support independently predicted higher midterm mortality in patients with EF ≤ 30 % [9].

Patients with mild systolic LV function have worse outcomes regarding major adverse events. For instance, Zhang et al. demonstrated older age, lower LVEF, CKD, New York Heart Association (NYHA) ≥ 3, intra-aortic balloon pump (IABP), and acute kidney injury as predictors of higher risk of mid-term heart failure and death [22]. Likewise, pre-existing right ventricular dysfunction has been associated with poor outcomes after left-sided valvular surgeries [23] and CABG [24], which is consistent with the results of our study.

Discrepancies between reported predictors in literature might arise from different cut-offs for low ejection fraction [25] and inconsistent composite outcomes. Some studies considered low EF ≤ 35 [26]; nevertheless, the EF ≤ 40 is used to define reduced LVEF [27]. Based on the existing literature, we considered EF ≤ 40 as reduced.

Our study's five-year mortality and MACCE were 15.1 % and 24.5 %, respectively. Yoo et al. calculated a five-year mortality of 27.9 % and 38.7 %. Generally, higher five-year mortality rates have been reported across the literature, varying significantly from 20 % to 40 % [4,28,29]. Moreover, Brynjarsdottir et al. reported 38 % five-year MACCE for patients with LVEF ≤ 35 [11]. Most studies have evaluated only mortality risk without investigating the adverse events. One of the strengths of the present study is the assessment of predictors of MACCE in vulnerable patients with reduced LVEF, which has clinical implications in CABG candidates.

4.1. Limitations

Our study has the advantages of a large sample, a comprehensive nine-year follow-up, and detailed clinical and echocardiographic parameters. However, the study has some limitations. First, this was a retrospective and single-center study. Moreover, the moderate C-index of 0.66 indicates the need to improve the prediction model in future studies. Second, the data regarding the initial outcome of the surgery including perioperative infarction indicated by cardiac markers was not available in our data registry, nor requested by surgeons. Additionally, in our analysis, we did not consider changes in medical treatment and the impact of surgery year on patients.

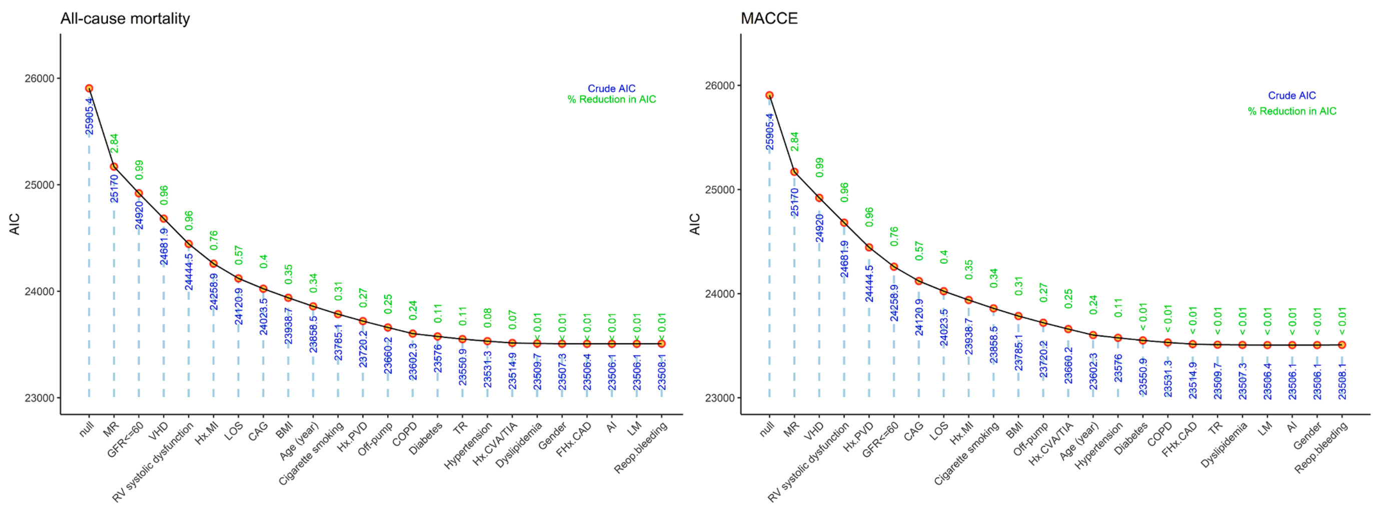

Fig. 3. Best subset of predictors for all-cause mortality (above) and major adverse cardiac and cerebrovascular events (below). MR: mitral regurgitation, GFR: glomerular filtration rate, VHD: valvular heart disease, PVD: peripheral vascular disease, CAG: coronary angiography, BMI: body mass index, CVA: cerebral vascular accident, TIA: transient ischemic attack, RV: right ventricle, TR: tricuspid regurgitation, COPD: chronic obstructive pulmonary disease, LM: left main coronary artery disease, AI: aortic insufficiency, FHx CAD: family history of coronary artery disease, LOS: length of stay;

Table 3
Multivariable Cox regression with selected predictors for all-cause mortality and MACCE.

	All-Cause Mortality[#]				MACCE[Ψ]			
Variables	**HR***	**95 % CI***	**P-value**	**VIF***	**HR***	**95 % CI***	**P-value**	**VIF***
MR (moderate or severe)	1.45	1.22, 1.74	**<0.001**	2.90	1.23	1.06, 1.42	**0.005**	2.70
GFR < 60	1.92	1.73, 2.12	**<0.001**	1.00	1.57	1.44, 1.70	**<0.001**	1.00
RV systolic dysfunction	1.23	1.09, 1.39	**<0.001**	1.00	1.12	1.01, 1.23	**0.031**	1.00
VHD	1.37	1.15, 1.64	**<0.001**	2.90	1.21	1.05, 1.39	**0.007**	2.70
LOS	1.03	1.03, 1.04	**0.001**	1.00	–	–	–	–
PVD	–	–	–	–	1.36	1.10, 1.69	**0.005**	1.00

RV: right ventricle, MR: mitral regurgitation, GFR: glomerular filtration rate, VHD: valvular heart disease.
[#] : Propositional Hazard assumption: ($\chi^2_5 = 6.3, p = 0.279$); C-index = 0.66, 95 % CI: 0.64–0.68.
[Ψ] *: Propositional Hazard assumption:* ($\chi^2_5 = 5.9, p = 0.316$)*; C-index = 0.67, 95 % CI: 0.65–0.70.*
[*] : HR: hazard ratio, CI: confidence interval, VIF = Variance Inflation Factor.

4.2. Conclusion

Our study indicates the clinical significance of MR, RV dysfunction, VHD, and renal function in patients with low ejection fraction treated by CABG. Our findings add to the literature on long-term outcomes in this high-risk population and give physicians a unique perspective on predictors that guide decision-makers. More extensive prospective studies are required to uncover the essential predictors of mortality and mace following CABG.

Ethics approval and consent to participate

This study was approved by the ethics committee of the Tehran University of Medical Sciences with the code IR.TUMS.AEC.1403.019. All participants were provided written informed consent at the start of the study. The study was carried out according to the Helsinki Declaration. We adhere to the statement of ethical publishing in the International Journal of Cardiology [1].

Authors' contributions

All authors contributed substantially to this work.

Consent for publication

Not applicable.

Availability of data and materials

The dataset of the present study is available upon reasonable request from the corresponding author.

Funding

None.

CRediT authorship contribution statement

Mohammad Sadeq Najafi: Writing – review & editing, Writing – original draft, Supervision, Project administration, Investigation. **Soroush Nematollahi:** Writing – review & editing, Writing – original draft, Investigation. **Ahmad Vakili-Basir:** Validation, Software, Formal analysis, Data curation. **Arash Jalali:** Supervision, Formal analysis, Data curation. **Arezoo Gholami:** Writing – original draft, Investigation. **Mohadese Dashtkoohi:** Writing – review & editing, Visualization, Resources. **Saeed Davoodi:** Validation, Supervision, Conceptualization. **Mina Pashang:** Resources, Project administration, Methodology. **Namvar Movahedi:** Methodology, Supervision, Validation. **Kyomars Abbasi:** Conceptualization, Methodology, Resources. **Soheil Mansourian:** Project administration, Software, Visualization. **Haleh Ashraf:** Supervision, Resources, Investigation, Conceptualization. **Seyed Hossein Ahmadi Tafti:** Supervision, Resources, Project administration, 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.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcha.2024.101412.

References

[1] L.G. Shewan, et al., A statement on ethical standards in publishing scientific articles in the international journal of cardiology family of journals, Int. J. Cardiol. 170 (3) (2014) 253–254.
[2] M. Pieri, et al., Outcome of cardiac surgery in patients with low preoperative ejection fraction, BMC Anesthesiol. 16 (1) (2016) 1–10.
[3] N.B. Robinson, et al., Coronary artery bypass grafting in low ejection fraction: state of the art, Curr. Opin. Cardiol. 36 (6) (2021) 740–747.
[4] L.Y. Sun, et al., Long-term outcomes in patients with severely reduced left ventricular ejection fraction undergoing percutaneous coronary intervention vs coronary artery bypass grafting, JAMA Cardiol. 5 (6) (2020) 631–641.
[5] L.Y. Sun, et al., Prevalence and long-term survival after coronary artery bypass grafting in women and men with heart failure and preserved versus reduced ejection fraction, J. Am. Heart Assoc. 7 (12) (2018).
[6] E.L. Alderman, et al., Results of coronary artery surgery in patients with poor left ventricular function (CASS), Circulation 68 (4) (1983) 785–795.
[7] V.K. Topkara, et al., Coronary artery bypass grafting in patients with low ejection fraction, Circulation 112 (9_supplement) (2005) (p. I-344-I-350).
[8] Y. Liu, et al., Association of ejection fraction with mortality and cardiovascular events in patients with coronary artery disease, ESC Heart Failure 9 (5) (2022) 3461–3468.
[9] K. Ergünes, et al., Coronary surgery in patients with low ejection fraction: mid-term results, Asian Cardiovasc. Thorac. Ann. 21 (2) (2013) 137–141.
[10] K. Vickneson, et al., Coronary artery bypass grafting in patients with low ejection fraction: what are the risk factors? J. Cardiovasc. Surg. (torino) 60 (3) (2019) 396–405.
[11] H.B. Brynjarsdottir, et al., Long-term outcome of surgical revascularization in patients with reduced left ventricular ejection fraction—a population-based cohort study, Interact. Cardiovasc. Thorac. Surg. 35 (3) (2022).
[12] rms: Regression Modeling Strategies. 2023.
[13] survminer: Drawing Survival Curves using `ggplot2'. 2021.
[14] Therneau, T.M., A Package for Survival Analysis in R. 2023.
[15] Therneau, T.M. and P.M. Grambsch, Modeling Survival Data: Extending the {C}ox Model. 2000: Springer.
[16] H. Wickham, ggplot2: Elegant Graphics for Data Analysis, Springer-Verlag, New York, 2016.
[17] Zhang, H., et al., SurvMetrics: Predictive Evaluation Metrics in Survival Analysis. 2022.
[18] J.S. Yoo, et al., Coronary artery bypass grafting in patients with left ventricular dysfunction: predictors of long-term survival and impact of surgical strategies, Int. J. Cardiol. 168 (6) (2013) 5316–5322.
[19] G.S. Hillis, et al., Outcome of patients with low ejection fraction undergoing coronary artery bypass grafting, Circulation 114 (1_supplement) (2006) (p. I-414-I-419).
[20] J.J. DeRose Jr, et al., Preoperative prediction of long-term survival after coronary artery bypass grafting in patients with low left ventricular ejection fraction, J. Thorac. Cardiovasc. Surg. 129 (2) (2005) 314–321.
[21] L. Seese, et al., Outcomes of conventional cardiac surgery in patients with severely reduced ejection fraction in the modern era, Ann. Thorac. Surg. 109 (5) (2020) 1409–1418.
[22] H. Zhang, et al., Mid-term outcomes of coronary artery bypass grafting in patients with mild left ventricular systolic dysfunction: a multicentre retrospective cohort study, Interact. Cardiovasc. Thorac. Surg. 32 (6) (2021) 855–863.
[23] A. Towheed, et al., Right ventricular dysfunction and short-term outcomes following left-sided valvular surgery: an echocardiographic study, J. Am. Heart Assoc. 10 (4) (2021) e016283.
[24] T. Davarpasand, et al., Impact of right ventricular systolic dysfunction on the outcome of coronary artery bypass graft surgery, Iranian Heart Journal 23 (2) (2022) 16–25.
[25] C.S.P. Lam, S.D. Solomon, classification of heart failure according to ejection fraction: JACC review topic of the week, J. Am. Coll. Cardiol. 77 (25) (2021) 3217–3225.
[26] E.J. Velazquez, et al., Coronary-artery bypass surgery in patients with left ventricular dysfunction, N. Engl. J. Med. 364 (17) (2011) 1607–1616.
[27] B. Bozkurt, et al., Universal definition and classification of heart failure: a report of the heart failure society of America, heart failure association of the European society of cardiology, Japanese heart failure society and writing committee of the universal definition of heart failure: endorsed by the Canadian heart failure society, heart failure association of India, cardiac society of Australia and New Zealand, and Chinese heart failure association, Eur. J. Heart Fail. 23 (3) (2021) 352–380.
[28] F. Bouchart, et al., Myocardial revascularization in patients with severe ischemic left ventricular dysfunction. long term follow-up in 141 patients, Eur. J. Cardiothorac. Surg. 20 (6) (2001) 1157–1162.
[29] J.A. Carr, et al., Long-term outcome after coronary artery bypass grafting in patients with severe left ventricular dysfunction, Ann. Thorac. Surg. 74 (5) (2002) 1531–1536.