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Original Article

Impact of Right Ventricular Systolic Dysfunction on the Outcome of Coronary Artery Bypass Graft Surgery

Tahereh Davarpasand[1], MD; Masoumeh Lotfi Tokaldani[2], MD; Afsaneh Sadeghian[3], MD; Arash Jalali[4], PhD; Hakimeh Sadeghian[5*], MD; Farbod Semnani[6], Amirhossein Ghaseminejad Raeini[6]

ABSTRACT

Background: We aimed to study the effects of right ventricular systolic dysfunction on the outcome of patients after coronary artery bypass graft surgery (CABG).

Methods: This study enrolled 106 patients (age=60.1±10.8 y, 58.5% male) who underwent pure CABG in Tehran Heart Center and had right ventricular systolic dysfunction (RVSD) with tricuspid annular plane systolic excursion (TAPSE)<16. As a control group, 424 patients (age=61.4±9.7 y, 55.7% male) with a history of isolated CABG and preoperative normal right ventricular systolic function (NRVSF) (TAPSE≥16) were selected. The median follow-up time was 12 months. Death, ICU stay, intubation time, hospital stay, postoperative blood transfusion, pleural effusion, and tamponade were considered adverse outcomes. TAPSE≤14 was considered more severe RVSD.

Results: In-hospital mortality was significantly higher in the RVSD group than in the NRVSF group (3.8% vs 0.7%; *P*=0.032). No significant effect of RVSD on ventilation time, hospital length of stay, ICU length of stay, postoperative blood transfusion, tamponade, and pleural effusion was found. The effect of RVSD on overall survival was not significant (*P*=0.096); however, there was a significantly higher rate of cardiac death in the RVSD group (*P*=0.017). Overall survival was better in the NRVSF group than in the group with more severe RVSD as a trend (*P*=0.076). The mean values of ventilation time, hospital length of stay, and ICU length of stay were significantly higher among patients with TAPSE≤14 than those with TAPSE≥16.

Conclusions: Preoperative RVSD was associated with increased in-hospital and cardiac mortality in patients undergoing pure CABG, and higher RVSD is a potent risk factor for adverse outcomes following CABG. ***(Iranian Heart Journal 2022; 23(2): 16-25)***

KEYWORDS: Coronary artery bypass, Dysfunction, Mortality, Outcome, Right ventricular systolic dysfunction

[1] Tehran Heart Center, Tehran University of Medical Sciences, Tehran, IR Iran.
[2] Research Department, Tehran Heart Center, Tehran University of Medical Sciences, Tehran, IR Iran.
[3] Pediatric Department, Bahar Hospital, Shahrood University of Medical Sciences, Shahrood, IR Iran.
[4] Tehran Heart Center, Cardiovascular Diseases Research Institute, Tehran University of Medical Sciences, Tehran, IR Iran.
[5] Echocardiography Department, Dr Shariati Hospital, Tehran University of Medical Sciences, Tehran, IR Iran.
[6] Student's Scientific Research Center, Tehran University of Medical Sciences, Tehran, IR Iran.

***Corresponding Author:** Hakimeh Sadeghian, MD; Echocardiography Department, Dr Shariati Hospital, Tehran University of Medical Sciences, Tehran, IR Iran.
Email: sadeghianhakimeh@yahoo.com **Tel:** +982188026910

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The role of right ventricular function in the outcome of patients with cardiovascular diseases has been a matter of investigation in recent years.[1-3] Right ventricular systolic dysfunction (RVSD) has been associated with increased cardiac surgery mortality[2] and may result in difficult weaning from cardiopulmonary bypass.[4] In both the Parsonnet and EuroSCORE models, pulmonary hypertension is an important risk factor for cardiac surgical complications, whereas RVSD is not involved in the risk stratification.[5,6] A few studies have reported the effects of RVSD on the outcome of coronary artery bypass grafting (CABG) or other cardiac surgeries.[4,7,8] Nonetheless, the direct effect of RVSD on postoperative mortality and morbidity and the correlation between the severity of RVSD and the outcome after CABG is still a matter of debate.

Therefore, the principal aim of this study was to evaluate the effects of RVSD on the in-hospital and midterm outcomes of patients undergoing isolated CABG. The second goal was to reassess the correlation between the severity of RVSD and the outcome in a subgroup analysis of patients with more severe RVSD and left ventricular ejection fraction (LVEF)<40%.

METHODS

In a retrospective design, from March 2014 through February 2017 a total of 106 consecutive patients who were referred to the Echocardiography Clinic in Tehran Heart Center, Tehran, Iran, and were diagnosed with RVSD before CABG were included. All the patients had undergone isolated CABG, and preoperative RVSD was evident in preoperative echocardiography. A total of 424 patients who had CABG with normal RV function and were referred to our clinic at the same period of time were included as the control group via the propensity score matching technique, described later in the statistics section.

Demographic, preprocedural, procedural, and postprocedural information was taken from the patients' medical records. Conventional echocardiography was performed for each patient by institutional expert echocardiography specialists, blinded to the study purposes prior to CABG and at follow-up evaluation. The study protocol was approved by our institutional review board.

Standard Echocardiography Study

Standard 2D and M-mode echocardiographic examinations were performed using a commercially available digital ultrasound machine (VIVID 7, Vingmed-General Electric, Horten, Norway), with a 3.5 MHz phased-array transducer. For the maximal optimization of the echocardiographic image, the left decubitus position was administered for the patients. LVEF was assessed via the biplane Simpson rule. Right ventricular systolic function was graded as normal (NRVSF) or dysfunctional (RVSD) according to Guidelines for the Echocardiographic Assessment of the Right Heart in Adults,[9] and tricuspid annular plane systolic excursion (TAPSE)<16 was considered to be RVSD. In a subgroup analysis, TAPSE≤14 was considered to represent more severe RVSD, and the variables were reassessed.

CABG

All the operations were performed through a median sternotomy by the institutional cardiac surgeons using mild hypothermia (32–34 ºC) either via cardiopulmonary bypass or off-pump surgery. Seeking complete revascularization during the operation, we did our best to graft all epicardial vessels with significant stenosis.

The median number of grafts was 3 (range=1–5), the mean cardiopulmonary bypass time was 70 (25%–75% percentile=58–93) minutes, and the mean aortic clamp time was 39 (30–52) minutes.

Definition of Outcomes

To investigate the possible effects of RVSD on the outcome of isolated CABG, we considered the following endpoints: in-hospital mortality, defined as death within 30 days of surgery; ventilation time during the procedure (min); hospital length of stay (d); intensive care unit (ICU) length of stay (h); postoperative blood transfusion; postoperative tamponade; and postoperative pleural effusion. Prolonged ICU length of stay was defined as a period exceeding 48 hours. Prolonged hospital length of stay was defined as a period exceeding 14 days. Mid-term all-cause mortality was defined as death for any reason at the time of follow-up, and cardiac mortality was defined as death due to cardiac events.

Statistical Analysis

Data were described using the mean with the standard deviation (SD) or the median with interquartile range (IQR) boundaries for continuous variables and also were presented through frequencies with percentages for categorical variables. Continuous variables were compared between the RVSF groups using the Student *t* or Mann–Whitney *U* test. The χ^2 or Fisher exact test was applied to compare categorical variables between the NRVSF and RVSD groups.

To control confounding factors, we applied a propensity score matching technique to account for nonrandom allocation in each group. A propensity score for the NRVSF group was performed using the multiple logistic regression method. The achieved score was the probability of being in the RVSD group. Important risk factors, consisting of age, sex, diabetes mellitus, hypertension, dyslipidemia, cigarette smoking, LVEF, family history of coronary artery disease, history of myocardial infarction, chronic kidney disease, chronic obstructive pulmonary disease, and cerebrovascular accidents, were considered in the propensity score. These variables were selected to deactivate their effects on postoperative outcomes. Propensity scores were used to match each patient with TAPSE<16 (RVSD) to 4 comparison patients with TAPSE≥16 (NRVSF) using a SAS Macro (SAS Institute Inc, Cary, NC). This matching procedure initially selects matched pairs identical to 8 decimal places of the propensity score. If no match was found in 8 decimal places, we considered match pairs at 7 decimal places, and so on.[10]

As a control group, 424 patients with a history of isolated CABG and preoperative NRVSF (TAPSE≥16) were involved.

The logistic regression model was then used to evaluate the effect of RVSDF versus NRVSF on in-hospital outcomes, including postoperative blood transfusion, tamponade, and pleural effusion. The estimated effect was reported as the odds ratio (OR) with the 95% confidence interval (CI). The effects of RVSD on ventilation time, ICU length of stay, and hospital length of stay were determined using the linear regression model. A Cox proportional hazard (PH) regression model was applied to assess the effects of RVSD on mortality, and a hazard ratio (HR) with a 95% CI was reported. The effect of RVSD on cardiac death, regarding noncardiac death as its competing event, was assessed in a competing risk setting. For this purpose, the Fine and Gray model[11] was applied, and the sub-distribution hazard ratio (SHR) with a 95% CI was reported. Intragroup correlations between the matched cases (1 RVSD to 4 NRVSF) were considered to estimate the robust standard error of the effect for the abovementioned models.

The SAS Software, version 9.1, for Windows (SAS Institute Inc, Cary, NC, USA) and Stata release 13 (StataCorp 2013, College Station, TX: StataCorp LP) were employed to conduct the propensity score matching and the statistical analyses, respectively. All *P* values were 2-tailed and were considered statistically significant at the level of 5%.

RESULTS

Baseline Characteristics

The baseline demographic, clinical, and echocardiographic findings of the study groups are summarized in Table 1. Mean TAPSE was 20.8±2.7 in the NRVSF group and 14.0±1.2 in the RVSD group ($P<0.001$). According to Table 1, there were no differences regarding the demographic and clinical characteristics between the groups. Patients in the RVSD group had a significantly higher frequency of moderate or severe tricuspid regurgitation in preoperative echocardiography.

Isolated CABG was done for all the patients without additional procedures. Six of these procedures were off-pump, and 5 procedures were emergent due to refractory chest pain or decompensated heart failure. For 16 patients (3.01%), intra-aortic balloon pumps were inserted after surgery. During ICU stay, intra-aortic balloon pumps were inserted for 8 patients (1.88%) in the NRVSF group and 8 patients (7.54%) in the RVSD group. In-hospital mortality in terms of mortality within 30 days of surgery occurred in 7 patients (1.32%). In-hospital mortality was significantly higher in the RVSD group than in the normal RV systolic function group (3.8% vs 0.7%; $P=0.032$).

Median follow-up was 12 months (25%–75% percentile=6.975–20.12 mon). Follow-up was successfully completed for 101 patients (94%). (Five patients were missed after hospital discharge.) During follow-up, all-cause mortality was reported in 21 patients (3.96%): 14 (3.3%) in the NRVSF group and 7 (6.7%) in the RVSD group. Cardiac mortality occurred in 13 patients (2.45%): 7 (1.7%) in the NRVSF group and 6 (5.7%) in the RVSD group.

The effect of RVSD on overall survival was not significant (HR, 2.14; 95% CI, 0.87 to 5.24; $P=0.096$); however, there was a significantly higher rate of cardiac death in the RVSD group (SHR, 3.6; 95% CI, 1.25 to 10.3; $P=0.017$) (Fig. 1). No significant effects of RVSD on ventilation time, ICU length of stay, postoperative blood transfusion, tamponade, and pleural effusion were found. There was only a trend ($P=0.08$) toward an increased hospital length of stay in the RVSD group (Table 2).

In further analysis, we reassessed and compared adverse outcomes in patients with more severe RVSD with TAPSE≤14 (Table 3). The results were slightly different. Although not at a significant level, overall survival was better in the NRVSF group than in the patients with more severe RVSD (SHR, 3.40; 95% CI, 0.87 to 13.19; $P=0.076$) (Fig. 2). There were 4 deaths among patients with TAPSE≤14: 3 cardiac deaths and 1 due to sepsis. The mean values of ventilation time, hospital length of stay, and ICU length of stay were significantly higher among patients with TAPSE≤14 than those with TAPSE≥16 (Table 3).

Table 4 presents comparisons of outcomes between 2 subgroups of 106 patients with RVSD: LVEF>40% and LVEF≤40%. The results showed no significant differences between the subgroups. The effect of LVEF≤40% on survival in patients with RVSD was not significant ($P=0.341$) (Fig. 3).

Table 1: Baseline demographic, clinical, and echocardiographic characteristics of the study groups

		NRVSF (n=424)	RVSD (n=106)	*P* value
Age (y)		61.4±9.7	60.1±10.8	0.748
Sex (male/female ratio)		236/188	62/44	0.599
Hypertension (n)		215 (50.7%)	57(53.8%)	0.572
Diabetes (n)		208 (49.1%)	46(43.3%)	0.297
Hyperlipidemia (n)		240 (56.6%)	55(51.9%)	0.382
Cigarette smoking (n)		63 (14.9%)	17(16%)	0.762
Family history		158 (37.3%)	32(30.2%)	0.174
Previous ST-elevation myocardial infarction (n)		204 (48.1%)	54(50.9%)	0.602
Cerebrovascular disease (n)		36 (8.5%)	11(10.4%)	0.541
Chronic renal failure (creatinine>2 mg/dL) (n)		7 (1.7%)	4(3.8%)	0.170
Chronic obstructive pulmonary disease (n)		35 (8.3%)	4(3.8%)	0.114
Moderate or severe tricuspid regurgitation		30(7.1%)	17(16.0%)	0.004
Coronary artery disease (n)				0.327
	Single vessel	23(5.4%)	3(2.8%)	
	Two vessels (n)	83(19.6%)	26(24.5%)	
	Three vessels (n)	318(75%)	77(72.6%)	
TAPSE		20.8±2.7	13.4±1.7	<0.001
Left ventricular ejection fraction		38.2±9.3%	37.8±9.8%	0.759
Left ventricular ejection fraction ≥40%		292(68.9)	73 (68.9)	0.999
Hb (mg/dL)		13.5±1.7	14.0±1.2	0.609
Cr (mg/dL)		0.86(0.71-1.01)	0.90(0.73-1.10)	0.125
Perfusion time (min)		70.0(58.0-93.0)	73.0(58.0-95.0)	0.485
Cross-clamp time (min)		39.0(31.0-52.0)	40.0(30.0-53.0)	0.894

RVSD, Right ventricular systolic dysfunction; NRVSF, Normal right ventricular systolic function; TAPSE, Tricuspid annular plane systolic excursion; Hb, Hemoglobin

Table 2: Comparison of in-hospital outcomes between patients with right ventricular systolic dysfunction and those with normal right ventricular systolic function

	NRVSF (n=424)	RVSD (n=106)	*P* value
Death	3 (0.7)	4(3.8%)	0.032
Ventilation time (min)	9.5(7.5-12.4)	10.7(8.0-14.2)	0.303
Hospital LOS (d)	7.0(6.0-9.0)	8.0(6.0-11.0)	0.083
ICU LOS (h)	43.7(23.0-70.0)	44(23.7-73.0)	0.160
Postoperative blood transfusion	197(46.5)	54(50.9)	0.367
Postoperative tamponade	7(1.7)	4(3.8)	0.149
Postoperative pleural effusion	13(3.1)	4(3.8)	0.414

RVSD, Right ventricular systolic dysfunction; NRVSF, Normal right ventricular systolic function; LOS, Length of stay; ICU, Intensive care unit

Table 3: Comparison of outcomes between 2 subgroups of studies patients; TAPSE≥16 and TAPSE<14

	NRVSF (TAPSE≥16)	RVSD (TAPSE<14)	*P* value
Ventilation time (min)	10.0(7.0-12.0)	11.0(8.0-14.0)	0.023
Hospital length of stay (d)	7.0(6.0-9.0)	8.0(6.0-13.0)	0.004
ICU length of stay (h)	44(23.0-70.0)	44.5(25.0-95.0)	0.017
Postoperative blood transfusion	197(46.5)	34(55.7)	0.081
Postoperative tamponade	7(1.7)	3(4.9)	0.052
Postoperative pleural effusion	13(3.1)	2(3.3)	0.869

TAPSE, Tricuspid annular plane systolic excursion; NRVSF, Normal right ventricular systolic function; RVSD, Right ventricular systolic dysfunction; ICU, Intensive care unit

Table 4: Comparison of outcomes between 2 subgroups of 106 patients with RVSD: LVEF>40% and LVEF≤40%

	EF>40%	EF≤40%	*P* value
Ventilation time (min)	10.5(8.0-16.5)	11.0(7.75-14.0)	0.625
Hospital length of stay (d)	7.0(6.0-11.5)	8.0(6.0-11.0)	0.597
ICU length of stay (h)	25.6(22.0-90.3)	46.5(25.1-72.5)	0.167
Postoperative blood transfusion	17(51.5)	37(50.7)	0.937
Postoperative tamponade	2(6.1)	2(2.7)	0.587
Postoperative pleural effusion	3(9.1)	1(1.4)	0.088

TAPSE, Tricuspid annular plane systolic excursion; NRVSF, Normal right ventricular systolic function; RVSD, Right ventricular systolic dysfunction; ICU, Intensive care unit

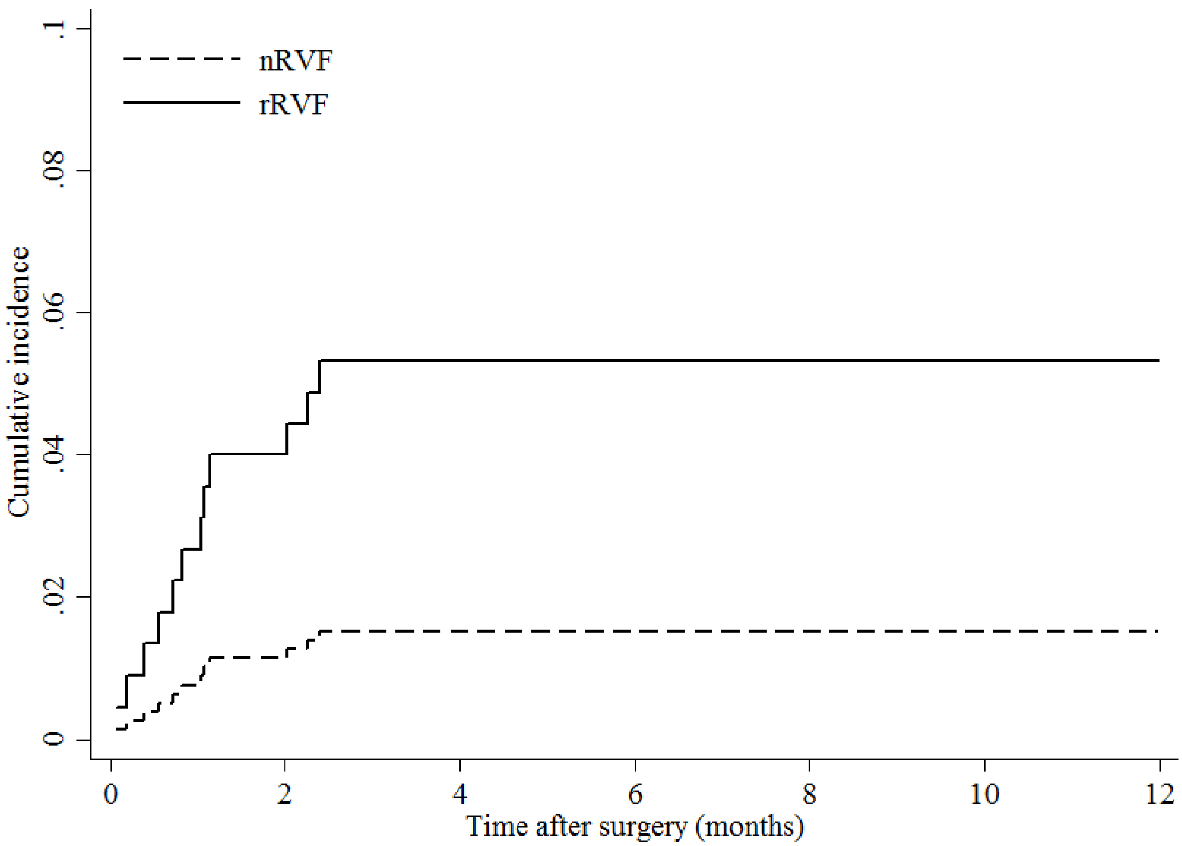

Figure 1: The graph depicts cardiac death in patients with right ventricular systolic dysfunction compared with patients with a normal right ventricular systolic function who underwent isolated coronary artery bypass graft.
nRVF, Normal right ventricular systolic function; rRVF, Reduced right ventricular systolic function

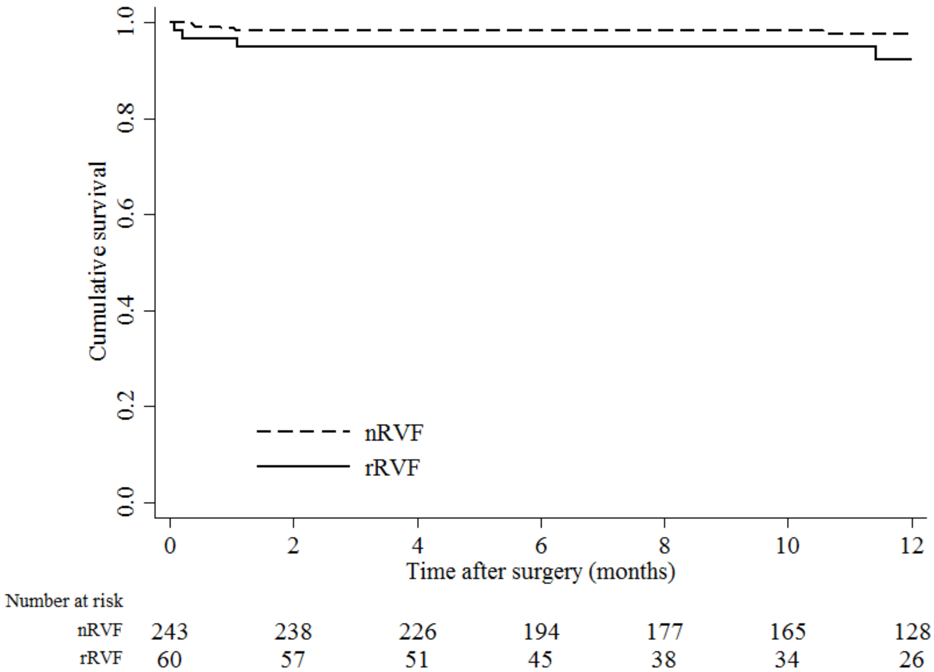

Figure 2: The image illustrates overall survival in patients with more severe right ventricular systolic dysfunction (TAPSE<14) compared with patients with a normal right ventricular systolic function who underwent isolated coronary artery bypass graft.

TAPSE, Tricuspid annular plane systolic excursion; nRVF, Normal right ventricular systolic function; rRVF, Reduced right ventricular systolic function

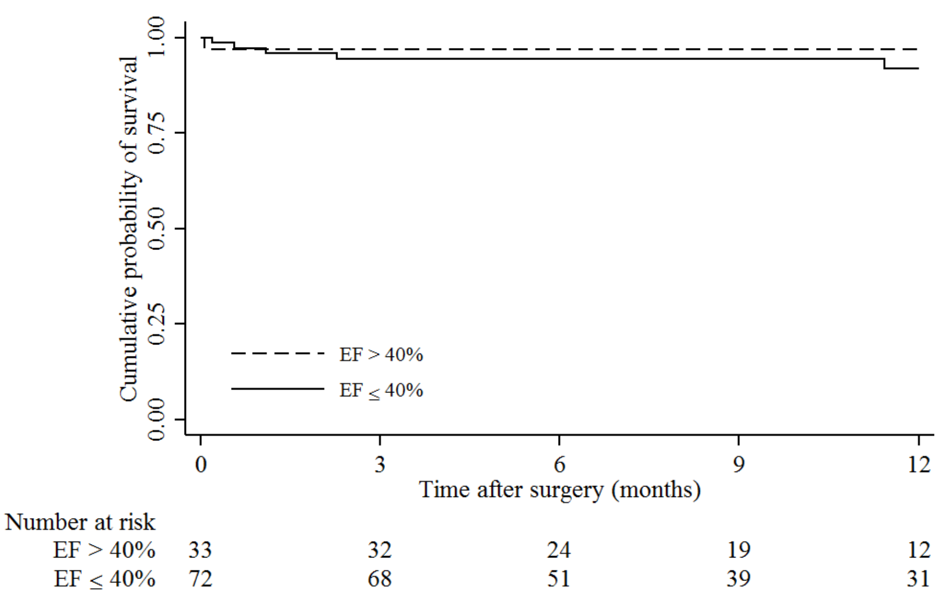

Figure 3: The image presents overall survival in patients in 2 groups of patients with right ventricular systolic dysfunction who underwent isolated coronary artery bypass graft: patients with left ventricular EF≤40% and those with EF>40%.

EF, Ejection fraction

DISCUSSION

The results of our study showed that patients with preoperative RVSD assessed by echocardiography undergoing isolated CABG had significantly higher cardiac in-hospital mortality and cardiac mortality within a 12-month follow-up. In addition, there was a significant relationship between more severe RVSD and intubation time, ICU length of stay, and hospital length of stay. The higher all-cause mortality rate in patients with TAPSE≤14 compared with those with TAPSE≥16 had a trend to be significant. There was no significant effect of LVEF≤40% on overall survival and adverse outcomes among patients with RVSD.

The impact of right ventricular function on the outcome of patients undergoing CABG has been mostly evaluated in patients with heart failure.[12] In the present study, we evaluated the effect of RVSF on overall patients undergoing isolated CABG. Javadi et al[7] reported that global RVEF and RV performance index as indicators of RVSF were not related to the incidence of postoperative pleural effusion, atrial fibrillation rhythm, myocardial infarction, pericardial effusion, infection, and readmission neither in patients with LVEF>40% nor in those with LVEF≤40%. In line with their study, the results of the present study did not show significant adverse effects for RVSD on postoperative ventilation time, tamponade, pleural effusion, ICU length of stay, and transfusion. Additionally, there were no adverse effects for RVSD as a trend on hospital length of stay, neither in normal LVEF nor in LVEF<40%. Nevertheless, in-hospital mortality was significantly higher in patients with RVSD, and cardiac mortality was also significantly higher in the RVSD group.

Maslow et al[8] studied the effects of RVSD on post-CABG outcomes in patients with severe LV systolic dysfunction (LVEF≤25%). They found that patients with RV fractional area change≤35% not only required greater duration of mechanical ventilation and longer intensive care unit and hospital stays but also had a smaller change in LVEF immediately after cardiopulmonary bypass compared with patients with RV fractional area change>35%. Pouleur et al[12] determined overall and cardiovascular deaths among 107 patients undergoing CABG with LVEF ≤35% by cardiac magnetic resonance imaging before CABG. They observed that RVSD (RVEF≤35% by cardiac magnetic resonance) strongly and independently predicted cardiovascular death in patients with coronary artery disease and low LVEF undergoing CABG. In the present study, we investigated the effects of RVSD (determined by echocardiography) on the outcome of patients with LVEF≤40% undergoing isolated CABG and did not find a significant effect.

We observed that ventilation time, hospital length of stay, and ICU length of stay were significantly higher in patients suffering from RVSD with TAPSE≤14 than in those with NRVSF. It has been documented that severe RV failure can cause systemic hypoperfusion[13] and result in longer ventilation time, hospital length of stay, and ICU length of stay.

In line with our study, Chowdhury et al[14] found that preoperative RV systolic dysfunction was associated with more short-term adverse outcomes and long-term mortality after CABG. Peyrou et al[15] showed that preoperative RV dysfunction elevated total and cardiovascular mortality caused by CABG in a 3-year period. Moreover, Ting et al[16] demonstrated that preoperative RV global longitudinal strain predicted more perioperative consumption of vasoactive inotropic agents.

CONCLUSIONS

Preoperative RVSD was associated with increased in-hospital and cardiac mortality during 12 months after isolated CABG among our study population. Further large studies are needed to determine the exact role of the degree of preoperative RVSD in the short and long-term outcomes of patients treated by CABG.

Declarations

This study was approved by the Ethics Committee of Tehran Heart Center. All the patients signed written informed consent before inclusion in the study.

Consent for Publication

We confirm that neither the manuscript submitted nor any part of it has been published or is being considered for publication elsewhere. Additionally, we confirm that the paper has been read and approved by all the authors. The authors also confirm that this manuscript represents useful information.

Availability of Data and Materials

The data sets generated and/or analyzed during the current study are not publicly available due to the confidentiality of patients' information but are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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Authors' Contributions

TD: core idea and echo supervision; HS: data collection, echo supervision, and final decision making; AJ: statistical analysis; ML: data collection, writing the manuscript, and figure design; AS: major contribution to the writing of the manuscript; FS: collaborating in submission and final approval of the version; AG: contribution to the writing of the manuscript and creating tables. All the authors have read and approved the final manuscript.

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