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Evaluation of the prevalence and predictors of right ventricular diastolic dysfunction in patients undergoing coronary artery bypass surgery

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Original Article

Abstract

BACKGROUND: With the increase in the number of coronary artery bypass grafting (CABG) surgeries, the concern about complications after it has also increased. RV diastolic dysfunction (RVDD) is one of the post-CABG complications, and in this study, we intend to investigate its frequency and predictors.

METHODS: In this cross-sectional study, eighty CABG candidate adult patients were included. A history of previous heart surgery or arrhythmia were the main exclusion criteria. After recording demographic and clinical information, echocardiography of the right ventricle (RV) was performed the day before the surgery and seven days later. The functional parameters were obtained according to the Guidelines for the Echocardiographic Assessment of the Right Heart in Adults.

RESULTS: Eighty patients with an average age of 60.25 ± 8.93 years participated in the study. Most patients were male (72.5%). Thirteen patients had RVDD before CABG (30.8% grade I and 69.2% grade II). All these 13 patients had RVDD grade II after surgery (P=0.046). Among 67 patients with normal RV function before CABG, RV function was normal in only 20 patients (29.9%) after CABG. The incidence of grade I and grade II post-CABG RVDD (post-coronary artery bypass grafting right ventricle diastolic dysfunction) was 11.9% and 58.2%, respectively (P<0.001). Univariate logistic regression analysis showed that there was no association between pre-CABG variables, neither demographic nor echocardiographic, and the occurrence of RVDD after CABG.

CONCLUSION: CABG surgery is associated with a high incidence of RVDD, which cannot be predicted before surgery. The short-term and long-term consequences of this complication are still unknown.

Keywords: Coronary Artery Bypass; Echocardiography; Patients; Arrhythmias, Cardiac

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Introduction

Cardiovascular diseases (CVD) are considered to be the most dominant disease by 2020 in terms of mortality, morbidity, and economic costs[1], and it is estimated that about 20 million people will die because of CVD in 2030[2]. Currently, coronary artery diseases (CAD) are the leading cause of death in people over 35 years old in Iran[3].

CADs are the most common heart disease in adults, and despite recent advances in the field of

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coronary angioplasty, coronary artery bypass grafting (CABG) is still the most common treatment method for blood supply to the ischemic heart muscle[4,5]. Approximately 35-50 thousand patients undergo CABG in Iran annually[6].

In any case, CABG is a major surgery that can have several complications. For example, although the mechanism and consequences of this phenomenon are not exactly known, post-CABG right ventricular diastolic dysfunction (PC-RVDD) is a known finding that occurs regardless of the use of the cardiopulmonary pump, the duration of the aortic clamp, and the method used for cardioplegia or myocardial protection[7-9].

Diastolic dysfunction is defined as a disorder in the relaxation of the heart myocardium and a decrease in its mechanical capacity. This leads to an increase in the filling pressure, and while the ejection fraction remains normal, the stroke volume decreases. In recent years, it has been seen that diastolic dysfunction plays a crucial role in the mortality and morbidity of heart patients[9,10]. On the other hand, diastolic dysfunction has been associated with post-CABG atrial fibrillation in some reports [11,12].

Although post-CABG right ventricular systolic dysfunction is well established, PC-RVDD is less studied, and its predictors and consequences, especially short-term outcomes such as duration of connection to mechanical ventilation, readmission to the intensive care unit, and overall length of stay, are still unclear [12-14]. In this study, we intend to compare the pre- and post-CABG right ventricular diastolic function parameters and to identify the association between CAD risk factors and other potential predictors with PC-RVDD.

Methods

This cross-sectional study was conducted at Dr. Heshmat heart hospital in Rasht and approved by the local ethics committee of Guilan University of Medical Sciences (Ethical code: IR.GUMS.REC.1400.034) The study was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Written informed consent was obtained from all participants.

All patients were sampled using the available sampling method. To determine the sample size, a proportional formula was used to analyze with Repeated Measures Designs using Gpower 3.1 software. By determining the effect size of 0.26, the statistical power of 0.95, the error level of 0.05, and the correlation of 0.30 between the sizes, the minimum sample size of 70 was obtained. In this study, the number of participating patients was 80.

Exclusion criteria were age younger than 18 years, any brady/tachyarrhythmia prior to CABG, previous history of any cardiac surgery, severe valvular insufficiency or stenosis, mild and moderate pulmonary valve stenosis, mean pulmonary artery pressure greater than 25 mmHg, pulmonary disease, history of pulmonary thromboembolism (PTE), conduction disorders or pacemaker-implanted patients, and thyroid diseases. After obtaining informed consent, the demographic (age, gender), current smoking, and clinical information (history of underlying diseases, characteristics of coronary artery disease, etc.) of the patients were recorded. RV parameters were measured before and seven days after CABG using RV-focused view, end of expiration, and averaging 3 consecutive beats using the Philips Affiniti 50 Ultrasound Machine (Philips Healthcare, Andover, MA, USA). Parameters related to RV diastolic function were obtained according to the Guidelines for the Echocardiographic Assessment of the Right Heart in Adults.[15].

Diastolic performance parameters including E and A waves (peak early and late diastolic flow velocity through the tricuspid valve), E' wave (peak velocity of the tricuspid's lateral annulus in the first phase of diastole), DT (E wave deceleration time) and right atrium size were evaluated and recorded (Figures 1 and 2). Subsequently, RV diastolic function was classified from Normal to third-degree dysfunction as follows:

Normal function: Trans-Tricuspid E/A: 0.8-2.1, Tricuspid E/E'<6, RA size: Normal

Grade I dysfunction: Trans-Tricuspid E/A <0.8, Tricuspid E/E'<6, RA size: Normal or Dilated

Grade II dysfunction: Trans-Tricuspid E/A 0.8-2.1, 1 Tricuspid E/E'>6, RA size: Dilated

Grade III dysfunction: Trans-Tricuspid E/A> 2.1, Tricuspid E/E'>6, RA size: Dilated, deceleration time < 120 ms

Other right and left ventricle functional parameters such as Tricuspid Annular Plane Systolic Excursion (TAPSE), right ventricular peak systolic

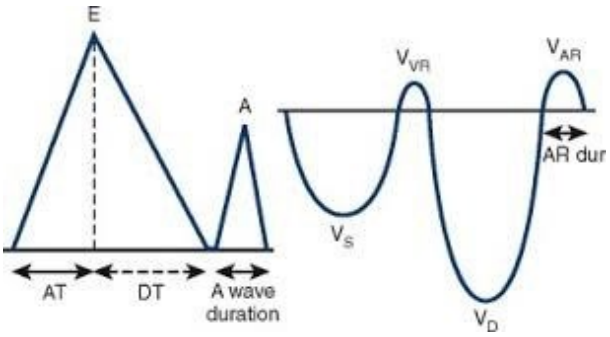

Figure 1. The E and A waves and duration DT

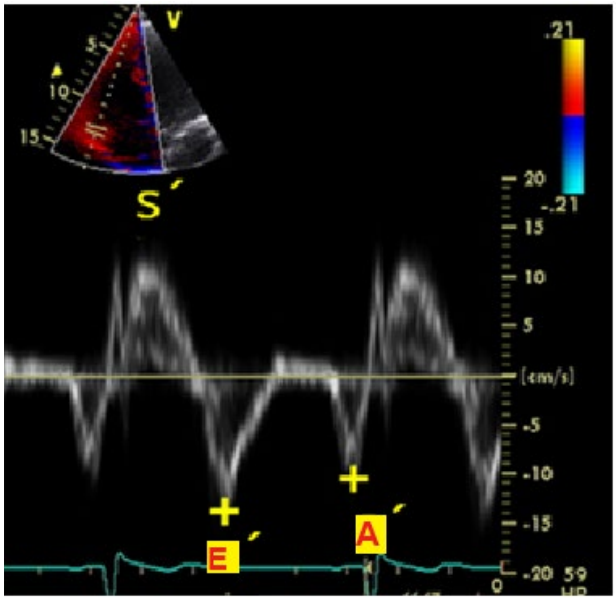

Figure 2. The S' and E' Waves

myocardial velocity (RVSM), pulmonary artery systolic pressure (PASP) and ejection fraction (using Simpson's biplane method(were also obtained according to echocardiography guidelines[15,16]

Statistical analysis

Data were analyzed using IBM SPSS 22.0 (IBM, Armonk, NY, USA). To check normality, the Shapiro–Wilk test and the descriptive method of the curvature and skewness indices (Kurtosis and Skewness) were used. Descriptive statistics are presented as mean ± standard deviation (SD) for continuous variables and as number and percentage for categorical variables. Univariate logistic regression was used to find the association between pre-CABG variables and the occurrence of RVDD after CABG. To analyze the post-CABG changes in echocardiographic parameters, a paired samples test was used for quantitative variables. A P-value of less than 0.05 was considered statistically significant.

Results

Eighty patients with an average age of 60.25 ± 8.93 years participated in the study. Table 1 shows that most patients were male, with hypertension being the most common CAD risk factor. Also, triple vessel disease (3VD) was the most common form of CAD.

Pre-CABG RVDD

Univariate logistic regression analysis did not show an association between pre-CABG variables and the occurrence of pre-RVDD (Table 2). In other words, the incidence of pre-RVDD was independent of age, sex, underlying diseases, or primary echocardiographic parameters.

Pre-Post CABG RVDD Change

Initial assessment of the patients showed that 13

Table 1. Baseline characteristics of the patients

Characteristics	Mean+SD / n (%)
Total number	80
Age (years)	60.25+8.93
Gender	
Male	58 (72.5%)
Female	22 (27.5%)
Past medical history	
Smoking	18 (22.5%)
Dyslipidemia	16 (20%)
HTN	43 (53.8%)
DM	34 (42.5%)
Coronary artery disease	
2VD	4 (5%)
3VD	63 (78.8%)
LM+2VD	2 (2.5%)
LM+3VD	11 (13.8%)

HTN: Hypertension; DM: Diabetes mellitus; VD: vessel disease; LM: left main; SD: Standard deviation

patients had RVDD before CABG (30.8% grade I and 69.2% grade II). All these 13 patients had RVDD grade II after surgery, which was statistically significant (P=0.046). On the other hand, RV function was normal in 67 patients before CABG. Of these, RV function was normal in only 20 patients (29.9%) after CABG. The incidence of grade I and grade II PC-RVDD was 11.9% and 58.2%, respectively (P<0.001) (Table 3).

Post-CABG changes of echocardiographic parameters

After surgery, a significant decrease in TAPSE and EF, as well as a significant increase in PASP and E/E', was observed (P<0.05). Although the mean E/A also increased, these changes were not statistically significant (P>0.05). These findings indicate increased pulmonary artery pressure and

Table 2. Univariate logistic regression analyses for Pre-CABG predictors of Post-CABG RVDD

Pre-CABG Variables	Normal/grade-I /grade-II RVDD OR	0.95% CI	P.value
Age>60	1.51	0.94-2.41	0.440
Gender (Male)	0.80	0.49-1.30	0.706
Number of involved vessels	0.99	0.9 - 2.5	0.999
Current smoking	1.02	0.76-1.37	0.963
Dyslipidemia	0.43	0.29-0.64	0.224
HTN	1.13	0.79-1.52	0.811
DM	1.11	0.78-1.59	0.846
E/A	1	0.69-1.45	0.996
E/E/	0.80	0.57-1.12	0.508
DT	1	0.70-1.43	0.456
PASP	1.08	0.87-1.33	0.101
TAPSE	0.98	0.68-1.40	0.832
RVSM	0.90	0.62-1.31	0.266
LVDD	2.11	0.88-1.5	0.160
EF	0.95	0.76-1.18	0.192

CABG: coronary artery bypass grafting; HTN: hypertension; DM: Diabetes mellitus; E/A: (peak early(E) and late(A) diastolic flow velocity through the tricuspid valve), E' wave (peak velocity of the tricuspid's lateral annulus in the first phase of diastole; DT: Deceleration time; PASP: Pulmonary arterial systolic pressure; TAPSE: Tricuspid Annular Plane Systolic Excursion; RVSM:Right ventricular peak systolic myocardial velocity ; LVDD: left ventricular diastolic dysfunction; EF: Ejection fraction; RVDD: Right ventricular diastolic dysfunction; CI: Confidence interval; OR: Odds ratio

Table 3. RVDD Grade Cross-tabulation

			RVDD-Grade Post CABG Normal	GI	GII	Total
RVDD-Grade Pre CABG	**Normal**	Count	20	8	39	67
		% of Total	25.0%	10.0%	48.8%	83.8%
	Grade-I	Count	0	0	4	4
		% of Total	0.0%	0.0%	5.0%	5.0%
	Grade-II	Count	0	0	9	9
		% of Total	0.0%	0.0%	11.3%	11.3%
Total		Count	20	8	52	80
		% of Total	25.0%	10.0%	65.0%	100.0%

RVDD: Right ventricular diastolic dysfunction; CABG: coronary artery bypass grafting

Table 4. Post-CABG changes of echocardiographic parameters

Parameter	Pre-CABG	Post-CABG	P.value*
TAPSE	21.84 ± 3.75	11.83± 2.51	0.009
EF	47.47 ± 9.12	43.48 ± 9.41	<0.001
PASP	18.63 ± 5.38	19.67 ± 4.86	0.012
RVSM	14.41 ± 2.88	9.95 ± 1.45	<0.001
E/A	1.09 ± 0.24	1.26 ± 0.89	0.121
E/E/	4.35 ± 1.26	6.58 ± 2.18	<0.001

* paired t-tests

TAPSE: Tricuspid Annular Plane Systolic Excursion; EF: Ejection fraction; PASP: Pulmonary arterial systolic pressure; RVSM: Right ventricular peak systolic myocardial velocity; E/A: (peak early (E) and late (A) diastolic flow velocity through the tricuspid valve), E' wave (peak velocity of the tricuspid's lateral annulus in the first phase of diastole; CABG: Coronary artery bypass grafting

deterioration of RV systolic and diastolic parameters (Table 4).

Post-CABG right valvular dysfunction

Before CABG, the frequency of mild and moderate tricuspid regurgitation (TR) was 46.3% and 2.5%, respectively, while after CABG, these frequencies were 61.3% and 3.8%, respectively (P<0.001). In other words, the TR grade significantly increased after surgery.

Finally, before CABG, the frequency of trivial and mild pulmonary regurgitation (PR) was 22.5% and 8.8%, respectively, while after CABG, these frequencies were 20% and 11.3%, respectively (P<0.001). In other words, the PR grade significantly increased after surgery. Moderate to severe PR was not seen in any of the cases.

Discussion

With the increased life expectancy in recent years, the prevalence of cardiovascular diseases has grown, resulting in an increase in the number of CABG surgeries[5,17].

This study included both patients with and without RVDD before CABG surgery. The results showed that in both groups, systolic and diastolic performance parameters of the right ventricle deteriorated after CABG, as a significant percentage of patients had de novo RVDD grade II, and all patients with pre-CABG RVDD had RVDD grade II after CABG. Another noteworthy finding was the deterioration of right valvular function after CABG. Unfortunately, in our study, no variable could predict the occurrence of RVDD after CABG. The aforementioned, along with the unknown outcomes of post-CABG RVDD, can make the patient's management more challenging.

Fazlinejad and colleagues[18] compared the right ventricular systolic and diastolic function between the day before CABG and five days later in 36 patients. Similar to our study, they also found that TAPSE was reduced significantly after CABG. Both the RV systolic and diastolic function parameters declined in their study after CABG. Additionally, off-pump CABG couldn't prevent RVDD in their study. In another study by Ojaghi et al.,[19] RV function was evaluated before CABG and thereafter one week, as well as one month after. They found that TAPSE and systolic and diastolic tricuspid annular velocities (Sm) decreased significantly, which remained stable after one month. Also, the RV myocardial performance index (MPI), which is the sum of the isovolumic contraction and the isovolumic relaxation time divided by ejection time, increased significantly. The MPI, also known as the Tei-index, shows global ventricular function, and its increase indicates diastolic dysfunction or pulmonary artery hypertension[20].

Therefore, the overall findings of Ojaghi's study indicate both RV diastolic and systolic dysfunction after CABG, which is consistent with our study. In their study, lower LVEF, 3-VD, and longer cardiopulmonary bypass (CPB) duration were associated with more severe systolic dysfunction in terms of peak systolic velocity. However, they did not evaluate the relationship of these predictors with diastolic function. Singh and colleagues[21] also showed that RV function deteriorates after cardiac surgery (CABG or valvular surgery), which was independent of the type and approach of surgery.

RV dysfunction has also been observed after other cardiac surgeries. For example, in the study by Sakata et al.,[22] patients who underwent left heart annuloplasty were included. The results showed that after surgery,

RV systolic function parameters, including TAPSE, RV global longitudinal strain (RVGLS), and RV fractional area change (RVFAC), deteriorated. These parameters improved over a year but did not reach the initial value. In addition, the disturbance of the diastolic function parameter, E/E', was much higher in the group that simultaneously underwent tricuspid annuloplasty than in the group without tricuspid annuloplasty.

Although the outcomes of PC-RVDD are unknown, Sumin et al.,[23] found that preexisting RVDD was associated with a higher incidence of post-CABG heart failure (PC-HF) (OR=4.82; P=0.015), and the Et/At ratio was the best predictor of PC-HF. This warns that PC-RVDD may also have severe adverse consequences that should be considered in future studies.

Conclusion

CABG is associated with a high prevalence of PC-RVDD and right heart valvular dysfunction. These complications cannot be predicted before surgery, either by demographic variables or by echocardiographic parameters. Although some studies show that RV function parameters improve somewhat after CABG, the short-term and long-term consequences of these complications are still unclear.

Limitations

This study was conducted in a single center with a relatively small sample size. Furthermore, we did not evaluate the outcomes of PC-RVDD. However, since we observed a high prevalence of PC-RVDD, it is necessary to investigate the consequences in a larger sample size in future studies.

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Conflict of interest

The authors report no conflicts of interest.

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Author's Contributions

MRA: Conceptualization, Methodology, Project administration, Supervision, Writing - Review & Editing. JA: Data curation, Investigation, Resources, Software, Visualization, Writing - Review & Editing. JK: Data curation, Investigation, Resources, Validation, Writing - Original Draft. MEG: Formal analysis, Methodology, Writing - Original Draft. HM: Conceptualization, Project administration, Supervision, Validation, Writing - Review & Editing.

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