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# Right ventricular dysfunction and associated factors in patients after coronary artery bypass grafting

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Original Article


## Abstract

**BACKGROUND:** Coronary artery bypass grafting (CABG) surgery is widely accepted as a revascularization method for coronary artery disease (CAD). Despite survival benefit and improvement in quality of life, CABG may impose major morbidities and significant complications. Right ventricle (RV) dysfunction is an important complication that may affect patient's longevity and functional capacity. The aim of this study was to evaluate the relationship between RV dysfunction and some invisible parameters like inferior vena cava (IVC) size with physical capacity.

**METHODS:** In this prospective study, 61 eligible CABG candidates were enrolled and RV function was assessed by echocardiographic parameters before CABG and one week and six months after the procedure, using tricuspid annular plane systolic excursion (TAPSE), Tei Index (TI), peak systolic movement (Sm) (cm/s), and IVC size. Functional capacity was assessed by six-minute walk test (6-MWT) 6 months after CABG.

**RESULTS:** 58 patients who did not have any perioperative RV dysfunction were remained until the end of study; mean age was 58.2 ± 7.9 years with 68.9% being men, and 3 patients died after CABG. Preoperatively, septal motion, RV indices, and IVC size were normal in all patients. The frequency of RV dysfunction according to abnormal TAPSE index, TI, and peak Sm one week after surgery was 81.0%, 79.0%, and 62.0%, respectively, and 6 months after surgery was 49.0%, 49.0%, and 37.0%, respectively. Mean walked distance in 6-MWT was significantly less in patients with RV dysfunction, older age, and higher number of involved vessels (P < 0.001).

**CONCLUSION:** The significant reduction in RV function and impairment of exercise capacity after CABG in this study suggests cardiologists to pay more attention to RV assessment in follow-up visits of patients undergoing GABG.


**Keywords:** Coronary Artery Bypass Surgery, Right Ventricle, Inferior Vena Cava

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## Introduction

Cardiovascular diseases (CVDs) are the leading cause of mortality in most countries with increasing prevalence around the world,[1] mostly coronary heart disease (CHD).[2] Coronary artery bypass grafting (CABG) is one of two main revascularization strategies.[3]

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This procedure is widely used for many patients around the world[4] and has significant post-surgical complications that may end in death or serious morbidity.[5] One of the most important complications of CABG is right ventricle (RV) dysfunction.[6] RV function has been considered a significant determinant of post-CABG outcome and is associated with high mortality and morbidity.[7] Therefore, diagnosis and management of RV dysfunction after CABG is crucial for maintenance of hemodynamic stability and organ function in early post-operation period and prognostic for later phase.[8]

Although depressed RV function is a recognized echocardiographic finding after CABG, the mechanism and clinical significance of this phenomenon is poorly understood.[9] Cardiopulmonary bypass (CPB), perioperative myocardial ischemia, intra-operative cardiac damage, cardioplegia, and pericardial disruption or adhesion are the most proposed mechanisms.[10,11] RV dysfunction in early and late post-operation periods after CABG has been reported by many investigators and in addition it has been emphasized that RV dysfunction lasts at least 12-18 months after the procedure.[12,13] Some reports have proposed that RV dysfunction recovers after 6 months[14] and long-term RV dysfunction is mainly associated with preoperative RV dysfunction, rather than CABG.[15] Moreover, some researchers have suggested that it does not affect the exercise performance and is not clinically significant.[16]

Depressed RV function significantly affects cardiac re-hospitalization and patients' mortality[17] and morbidity. Determination of RV dysfunction after CABG and its predictors is clinically important. Controversy in published studies necessitates evaluating this underestimated derangement after CABG. The current study aimed to determine the frequency of patients with RV dysfunction within one week and 6 months after CABG and effective factors.

## Materials and Methods

In this prospective study, 61 eligible CABG candidates at Dr. Heshmat Hospital in Rasht, Iran, were enrolled by simple sampling method. Patients who did not have these factors were included in the study: suffering recent myocardial infarction (MI), previous CABG, atrial fibrillation (AF), significant valvular heart disease (VHD), pulmonary hypertension (PH), history of severe pulmonary disease, pulmonary embolism (PE), left bundle branch block (LBBB) in electrocardiogram (ECG), abnormal septal motion(ASM) in echocardiography, periprocedural MI, RV dysfunction before surgery according to echocardiographic findings [tricuspid annular plane systolic excursion (TAPSE) < 1.6 cm, Tei Index (TI) > 55%, peak systolic movement (Sm) < 10 cm/s, inferior vena cava (IVC) size > 21 mm],[18] and poor acoustic window. The study was approved by the Ethics Committee of Guilan University of Medical Sciences, Rasht, Iran (IR.GUMS.REC.1394.86).

MI associated with CABG is defined by increased cardiac biomarker levels to 5 times the 99$^{th}$ percentile of the reference range during the first 72 hours after surgery, in addition to one of the following criteria: 1) new pathologic Q waves or new LBBB, 2) new graft or coronary artery occlusion, confirmed by angiographic examination, or 3) new loss of viable myocardium or regional wall motion abnormality, confirmed by imaging.[19]

Demographic characteristics, including age, gender, diabetes mellitus (DM), hypertension (HTN), smoking, and body mass index (BMI) were recorded. Patients were diagnosed as DM, when fasting blood sugar (FBS) was ≥ 126 mg/dl or random blood sugar was > 200 mg/dl with symptoms, and were diagnosed as hypertensive, when systolic and diastolic blood pressures were greater than 140 mmHg and 90 mmHg, respectively, or when they were on antihypertensive medication. Patients were considered overweight according to BMI > 25 kg/m$^2$ and were considered obese when BMI was > 30 kg/m$^2$. The number of grafts, right coronary artery (RCA) and RV branch lesions and their revascularization, number of diseased arteries, left ventricular ejection fraction (LVEF), pump time, hypothermia, cardioplegia, and pericardial closure were recorded, as well.

Two-dimensional (2D) echocardiography and tissue Doppler imaging (TDI) were performed for all patients before CABG, one week, and six months after the procedure (with Vivid 3 device, GE healthcare model, Germany) by an expert cardiologist. The function of RV was assessed by TAPSE, peak Sm velocity, and TI, based on the protocol explained in previous studies.[20] In addition, IVC size and respiratory variation were measured by M-mode method in subcostal view. ASM was visually speculated by M-mode method from parasternal and apical views. Functional capacity was assessed by the six-minute walk test (6-MWT) 6 months after surgery.

All patients underwent general anesthesia with similar protocol, including induction of anesthesia with 3 mg/kg/h propofol and 0.5 to 1.0 mg/kg/min remifentanil infusion. CABG with CPB was performed using ascending aortic cannulation and a two-stage venous cannulation in the right atrium. Antegrade cold cardioplegia and moderate hypothermia (approximately 32 °C) were used in all patients and total revascularization was done. In 17 patients, partial pericardial closure was performed.

Normal distribution assumption was checked by skewness and Kurtosis criteria (lower than 1) and Kolmogorov-Smirnov test (K-S test). Continuous and categorical variables were expressed as mean and standard deviation (SD) and frequency and percentage, respectively. McNemar's test was used for comparing the frequency of RV dysfunction between first and second period. Paired t-test was used to compare the mean of RV function indices before surgery and one week after surgery and also one week and 6 months after surgery. Logistic regression test was used to assess the influence of the independent variables on RV dysfunction. To compare the mean distance paced in 6-MWT in patients with and without RV dysfunction based on three indices, independent t-test was used. Linear regression analysis was used to determine the effective factors on 6-MWT. Repeated measures analysis of variance (ANOVA) was used to determine the effect of time for different variables. Data were analyzed using SPSS software (version 19, SPSS Inc., Chicago, IL, USA). P-values < 0.050 were considered statistically significant.

## Results

Among 61 patients undergoing CABG who participated in this study, 3 patients were excluded from the study due to cerebrovascular accident (CVA), bleeding after surgery, and inferior wall rupture due to MI. All three indices of RV function, IVC size, and SM were normal before surgery. Baseline characteristics of patients are presented in table 1.

In the first follow-up after surgery (one week after surgery), the frequency of patients with abnormal TAPSE index, TI, and peak Sm were 81.0%, 79.3%, and 62.0%, respectively. The size of IVC and SM was normal in all patients.

**Table 1.** Baseline demographic characteristics of patients (n = 61)

| Characteristic | Amount [n (%)] |
|---|---|
| Male gender | 42 (68.9) |
| DM | 28 (45.9) |
| HTN | 41 (67.2) |
| Smoking | 18 (29.5) |
| Angiographic result | |
| SVD | 3 (5.0) |
| 2VD | 11 (18.3) |
| 3VD | 46 (76.7) |
| Graft number | |
| 1 | 1 (1.7) |
| 2 | 7 (11.7) |
| 3 | 29 (48.3) |
| 4 | 21 (35.0) |
| 5 | 2 (3.3) |
| RCA disease | 54 (88.5) |
| RV branch disease | 14 (23.0) |
| RCA graft | 44 (73.3) |
| Pericardial closure | 17 (27.9) |
| | **Mean ± SD** |
| Age (year) | 58.2 ± 7.9 |
| LVEF (%) | 38.2 ± 22.7 |
| Pump time (minutes) | 60.3 ± 27.4 |

DM: Diabetes mellitus; HTN: Hypertension; SVD: Single vessel disease; 2VD: Two vessel disease; 3VD: Three vessel disease; RCA: Right coronary artery; RV: Right ventricle; SD: Standard deviation; LVEF: Left ventricular ejection fraction

In the second follow-up (6 months after surgery), the number of cases with RV dysfunction decreased based on all three indices: TAPSE < 1.6 cm was observed in 49.0% of patients, TI > 55% in 49.0%, and peak Sm < 10 cm/s in 37.0% of patients. The size of IVC and SM was reported normal in all patients (Table 2).

**Table 2.** Frequency of right ventricle (RV) dysfunction according to echocardiographic indices at baseline, one week, and 6 months after surgery

| Variable | Frequency [n (%)] | | |
|---|---|---|---|
| | Baseline (n = 61) | One week after CABG (n = 60)* | 6 months after CABG (n = 59)** |
| Abnormal TAPSE | 0 | 48 (80.0) | 28 (47.4) |
| Abnormal peak systolic movement | 0 | 36 (58.0) | 21 (35.5) |
| Abnormal Tei index | 0 | 46 (76.6) | 28 (47.4) |
| Abnormal IVC | 0 | 0 | 0 |
| Abnormal septal motion | 0 | 60 (100) | 59 (100) |

* One patient died one week after surgery; ** One patient lost to follow up

CABG: Coronary artery bypass grafting; TAPSE: Tricuspid annular plane systolic excursion; IVC: Inferior vena cava

**Table 3.** Comparison of the mean of right ventricle (RV) function indices during the study period

| Variable | Amount | | | | |
|---|---|---|---|---|---|
| | Before | | One week after CABG | | 6 months after CABG |
| | Mean ± SD | P* | Mean ± SD | P** | Mean ± SD |
| TAPSE (cm) | 2.50 ± 0.30 | 0.001 | 1.30 ± 0.20 | 0.001 | 1.50 ± 0.20 |
| Peak systolic movement (cm/s) | 13.60 ± 2.20 | 0.001 | 9.10 ± 1.30 | 0.001 | 9.90 ± 1.50 |
| Tei index | 30.70 ± 7.50 | 0.001 | 64.90 ± 11.80 | 0.002 | 57.30 ± 15.10 |
| IVC size (cm) | 1.11 ± 0.21 | 0.002 | 1.16 ± 0.25 | 0.001 | 1.19 ± 0.23 |

* Comparison of the mean of right ventricle (RV) function indices between before surgery and one week after surgery using paired t-test; ** Comparison of the mean of RV function indices between one week after surgery and 6 months after surgery using paired t-test

CABG: Coronary artery bypass grafting; SD: Standard deviation; TAPSE: Tricuspid annular plane systolic excursion; IVC: Inferior vena cava

Paired comparison was conducted to compare the mean RV function indices before surgery and one week after surgery and also one week and six months after surgery, using paired t-test. As shown in table 3, the mean of TAPSE significantly decreased from 2.25 ± 0.30 cm before surgery to 1.30 ± 0.20 cm one week after surgery (P < 0.001), and then significantly increased to 1.50 ± 0.20 cm six months after surgery (P < 0.001).

The mean TI increased from 30.7 ± 7.5 percent before surgery to 64.9 ± 11.8 percent one week after surgery (P < 0.001) and decreased to 57.3 ± 15.1 percent six months after surgery (P < 0.002). The mean of peak Sm index decreased from 13.6 ± 2.2 cm/s to 9.1 ± 1.3 cm/s one week after surgery (P < 0.001) and then significantly increased to 9.1 ± 1.3 cm/s six months after surgery (P < 0.001). The result of repeated measures ANOVA showed that the mean of RV function indices was significantly different during the time of study: TAPSE (P = 0.001), TI (P = 0.001), peak Sm (P = 0.001), and IVC (P = 0.001).

To determine the effective factors on RV dysfunction after 6 months, we conducted logistic regression analysis. Independent variables were demographic variables, angiography results, DM, and HTN. Dependent variables were RV function indices as binominal (normal or abnormal). Logistic regression analysis for TAPSE index showed that only age was significant effective factor [odds ratio (OR) = 0.88, 95% confidence interval (CI): 0.78-0.98, P = 0.020]. For TI, two factors including age and DM were effective [(OR = 0.87, 95% CI: 0.70-0.97, P = 0.010) and (OR = 6.70, 95% CI: 0.45-14.30, P = 0.030), respectively]. There were no significant effective factors on peak Sm index in 6 months after surgery. IVC size was normal during study period but the mean of IVC size significantly increased. Hence, we used linear regression analysis to determine effective factors on IVC size in second follow-up. The result of linear regression analysis showed that only history of HTN was significant effective factor (b = 0.1, β = 0.2, 95% CI: 0.01-0.28, P = 0.040).

6-MWT was conducted for all study patients 6 month after surgery. The mean of 6-MWT result was 326 ± 50 m (minimum = 255 m, maximum = 450 m). As shown in table 4, mean distance paced in 6-MWT in patients with RV dysfunction according to RV function indices was significantly lower than those without RV dysfunction (P < 0.001).

**Table 4.** Comparison of mean distance paced in six-minute walk test (6-MWT) in study patients with/without right ventricle (RV) dysfunction based on three indices

| Variable | Mean ± SD | P* |
|---|---|---|
| TAPSE < 1.6 (cm) | 298.89 ± 42.80 | 0.001 |
| TAPSE > 1.6 (cm) | 351.21 ± 46.30 | |
| Tei index > 55% | 301.67 ± 43.10 | 0.001 |
| Tei index < 55% | 348.62 ± 48.80 | |
| Peak systolic movement < 10 (cm/s) | 296.43 ± 37.60 | 0.001 |
| Peak systolic movement > 10 (cm/s) | 343.71 ± 50.90 | |

* Independent t-test

SD: Standard deviation; TAPSE: Tricuspid annular plane systolic excursion

Based on linear regression analysis, age (b = -3.1, β = -0.5, P = 0.001), number of involved vessels (b = -33.5, β = -0.3, P = 0.006), graft number (b = -20.3, β = -0.3, P = 0.010), RV dysfunction based on TAPSE six months after surgery (b = 52.3, β = 0.5, P = 0.001), peak Sm six months after surgery (b = 47.2, β = 0.4, P = 0.010), and TI six months after surgery (b = 46.9, β = 0.3, P = 0.001) were significant effective factors on 6-MWT. Results of multiple regression analysis are shown in table 5. As showed in this table, older age, higher number of involved vessels, and severity of RV dysfunction according to TABSE, TI, and peak Sm deteriorated 6-MWT.

**Table 5.** Predictive factors for six-minute walk test (6MWT) by multiple linear regression analysis

| Variable | b | SE | 95% CI | P* |
|---|---|---|---|---|
| Age | -2.9 | 0.67 | -4.30-1.60 | 0.001 |
| Number of involved vessels | -34.9 | 8.80 | -52.60-17.90 | 0.001 |
| TI | -1.3 | 0.33 | -1.90-0.63 | 0.001 |

* Multiple regression analysis
TI: Tei index; SE: Standard error; CI: Confidence interval

## Discussion

This study evaluated changes in RV function and IVC size after CABG that have been considered by some investigators. The findings indicated that in patients with normal RV indices preoperatively, one week (abnormal TAPSE 81.0%, TI 79.0%, and peak Sm 62.0%) and 6 months after surgery (abnormal TAPSE 49.0%, TI 49.0%, and peak Sm 37.0%), all indices showed significant decrement. Mean distance paced in 6-MWT in patients was significantly less in patients with RV dysfunction, older age, multivessel disease, and higher graft number.

Similarly, previous studies evaluated the echocardiographic indices of RV dysfunction in patients after CABG, but the results were controversial. RV function had significant influence on patients' outcome in several studies.[21] Ojaghi et al. evaluated echocardiographic indices in 30 Iranian patients and have reported reduced TAPSE and peak Sm velocity one week after CABG that remained after one month, while TI increased significantly.[20] In our study, RV dysfunction remained even up to 6 months postoperatively. Alam et al. have also evaluated RV function by tricuspid annular velocity and demonstrated reduced function 1 and 3 month(s) after CABG.[13] Hedman et al. demonstrated that RV function remained depressed one year after CABG and suggested permanent changes in the majority of patients after CABG,[16] findings that are contrary to our results. Alam et al.[13] reported that RV dysfunction partially recovered after 1 year, and Pegg et al. reported complete recovery after 6 months.[14]

One noticeable observation in our experience was the distance paced in 6-MWT that decreased in patients with RV dysfunction, while Hedman et al. reported improved exercise performance 3 months after CABG, despite decreased RV function.[16] These discrepancies in the results of the studies can be attributable to the differences in demographic characteristics of patients, as older age and other parameters as higher number of involved vessels and grafts that had deleterious effect on 6-MWT result.

There is an increased risk of coronary artery disease (CAD) in subjects with risk factors including HTN, obesity, dyslipidemia, and smoking.[22,23] We considered these risks in the present study and the results showed that patients undergoing CABG had a high prevalence of HTN and DM and were smoker and overweight (67.2%, 45.9%, 29.5%, and 68.0%, respectively). More analysis proved that two of the indices (TAPSE and peak Sm) were not associated with major risk factors, while TI one week after surgery was more impaired in patients with DM.

Off-pump coronary artery bypass (CAB) represents an acceptable alternative to conventional on-pump surgery[24] and has been reported to be associated with reduced oxidative stress[25] and less pro-inflammatory cytokine expression compared to conventional CABG.[26] On cellular level, systemic inflammatory response due to the release of pro-inflammatory cytokines is a recognized feature of CPB.[27] Diller et al. reported a non-significant trend that off-pump surgery might be associated with less RV damage.[12] Larger studies may be required to investigate whether off-pump CABG is associated with less RV damage compared to on-pump surgery.

The present study had several strengths, including assessment of all three indices of 2D echocardiography, IVC size, and exercise test together that could give a bright view to researchers and physicians to speculate the effects of CABG on all RV parameters. Limitation of this study is lack of control group. Moreover, although the sample size was calculated based on previous studies, only 58 patients completed the 6-month follow-up who were selected from one center that decreased the credibility of the results. Multicenter studies with larger sample size can add to our knowledge.

In conclusion, there was a significant reduction in RV function, increase in IVC size, and impairment of exercise test in patients with RV dysfunction six months after CABG. Peak Sm index one week after surgery was associated with its value prior to surgery and number of diseased arteries, and TI one week after surgery was affected by history of DM and TI before surgery and was more impaired in older patients, while deteriorated 6-MWT was observed in patients with RV dysfunction, older age, higher numbers of involved vessels, and higher grafts.

## Conclusion

The significant reduction in RV function and impairment of exercise capacity after CABG in this study suggest cardiologists to pay more attention to RV assessment in follow-up visits of patients undergoing GABG.

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## Conflict of Interests

Authors have no conflict of interests.

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