

Research Article

Evaluation of the effect of coronary artery bypass grafting on the right ventricular function using speckle tracking echocardiography

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Abstract

Purpose: This was a prospective study conducted at Benha University hospital and National Heart Institute on one hundred patients underwent coronary artery bypass grafting (CABG) to evaluate the effect of CABG on the right ventricular (RV) function using speckle tracking echocardiography (STE).

Methods: All cases were subjected to detailed medical history, full physical examination, 12 leads electrocardiogram (ECG), routine laboratory tests including (complete blood picture, liver functions, renal functions and lipid profile) and echocardiography either conventional echocardiography or STE, all parameters obtained before and within 2 weeks after surgery.

Results: By conventional echocardiography there was statistically significant decrease in peak right ventricle systolic velocity (RVSV) from (12.76 ± 1.72) to (7.33 ± 1.71) and tricuspid annular plane systolic excursion (TAPSE) from (22.8 ± 3.99) to (13.77 ± 4.63) among the studied patients after CABG. While there was significant increase in right ventricle fractional area change (RVFAC) from (44.69 ± 3.25) to (49.01 ± 3.36) . On the other hand, there was non-significant change in right ventricle end diastolic diameter (RVEDD) at mid-cavity from (26.37 ± 2.72) to (26.53 ± 2.72) and basal segment from (36.05 ± 2.98) to (36.29 ± 3.04) , right ventricle stroke volume (RVSV) from (65.44 ± 7.02) to (65.85 ± 6.86) and right myocardial performance index (RMPI) from (0.491 ± 0.088) to (0.498 ± 0.086) .

By STE There was statistically significant decrease in right ventricle global longitudinal strain (RVGLS) from (-20.63) to (-14.1) after CABG. There was statistically significant decrease in right ventricle free wall longitudinal strain [apical decreased from (-23.73) to (-13.7) , mid-cavity decreased from (-25.76) to (-11.53) , basal decreased from (-20.39) to (-10.13) and lateral wall declined from (-23.01) to (-9.13)]. There was statistically significant decrease in interventricular septum longitudinal strain [apical decreased from (-19.77) to (-10.06) , mid-cavity decreased from (-17.81) to (-10.87) and basal decreased from (-15.89) to (-11.13)]. There was statistically significant increase in RV circumferential strain of lateral free wall from (-12.04) to (-16.21) , while there was non-significant change in RV circumferential strain of septum from (-19.77 ± 4.86) to (-20.37 ± 5.14) .

Conclusion: Distorted RV geometry after CABG can lead to altered deformation parameters, in other words longitudinal functional parameters may underestimate RV function and the decrease in RVGLS was compensated by increase in circumferential strain of lateral free wall of RV without change in RVSV or RMPI. Therefore changes in deformation parameters should always be interpreted in relation to change in geometry.

More Information

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Keywords: Coronary artery bypass grafting; Longitudinal strain; Right ventricle; Circumferential strain



Introduction

Coronary artery disease (CAD) is the leading cause of death globally resulting in over 7 million deaths. This increased from 5.2 million deaths in 1990. It may affect individuals at any age but becomes dramatically more common at progressively older ages, with approximately a tripling with each decade of life. Males are affected more often than females [1].

Treatment of CAD with CABG has been associated with better outcome and longer survival than percutaneous coronary intervention (PCI) using either drug eluting or bare metal stents [2]. Extensive literature search reveals that on pump CABG causes more complete revascularization as compared to off pump CABG, on pump patients tend to have significantly higher frequencies of complete revascularization as compared to patients treated via Off pump method [3]. Incomplete revascularization has traditionally been associated with increased mortality, evidence for that was the study done by Jones & Weintraub, [4], and showed that incomplete revascularization lead to decreased patient survival and associated with high incidence of recurrent angina. Therefore off pump patients have higher rates of repeat revascularizations as compared to on pump patients [3].

Speckle tracking echocardiography (STE) is a new diagnostic modality that enabling the assessment of deformation in the longitudinal, circumferential and radial planes and shows good correlation in different studies [5].

Analysis of myocardial strain by tissue Doppler is restricted along the axis parallel to the ultrasound beam and is thus limited by this angle dependence. By analyzing speckle motion, (STE) offers the opportunity to assess myocardial tissue velocity, strain and strain rate independently of cardiac translation and beam angle. STE is simple to perform, it requires only one cardiac cycle, The software only requires harmonic and high frame rate imaging [6].

Quantative evaluation of RV function and changes in its cavity area from end diastole to end systole can be evaluated echocardiographically [7].

Aim of the work

The aim of this study was to evaluate the effect of CABG on the RV function using speckle tracking echocardiography.

Subjects and Methods

Study design and population

This was a prospective study conducted at Benha University hospital and National Heart Institute from 6/2/2019 to 14/11/2019 on one hundred patients underwent CABG after obtained informed consents to assess global and regional right ventricle function using conventional echocardiography and STE, all parameters obtained before and within 2 weeks after surgery. The ethics committee of the hospital approved the protocol.

Exclusion criteria were included patients refusal, presence of valvular disease, severe myocarditis, significant arrhythmia, uncompleted reperfusion therapy, previous pacemaker implantation, very poor image quality and patients on drugs that affect RV function.

All cases were subjected to detailed medical history (including name, age, sex, history of (hypertension, diabetes mellitus (DM), smoking, dyslipidemia, previous myocardial infarction (MI)), full physical examination, 12 leads ECG, routine laboratory tests including (complete blood picture, liver functions, renal functions and lipid profile) and echocardiography either conventional echocardiography or STE.

Conventional echocardiography

All 2 dimensional (2D) and tissue doppler imaging (TDI) measurements obtained using vivid 7 dimensions ultrasound frame work (GE health care, USA, WI). TAPSE was measured using M mode at lateral tricuspid annulus in apical 4 chamber view. Modified apical 4 chamber view focused on RV used to measure RV area by tracing the RV endocardium during systole and diastole to calculate RVFAC. RV inflow dimensions (basal and mid cavity of RV) measured in apical 4 chamber view and subcostal view as well. Pulsed wave doppler used to measure RVS' in subcostal 4 chamber view by placing TDI sample volume at lateral tricuspid annulus. RVSV measured by calculated volumes (end systolic volume (ESV) and end diastolic volume (EDV)) and heart rate (HR).

Speckle tracking echocardiography

An imaging modality that analyzes the movement of heart muscles by use of normally found speckle pattern in the heart when exposed to ultrasound beam and is considered a noninvasive tool of identification of vectors and velocity, each region of the myocardium has a unique speckle pattern that allows the region to be traced from one frame to the next. After that this can be tracked cadre to cadre and finally translated into angle-independent images. That new modality provides quantitative and qualitative information about myocardial segments deformation and motion.

Dynamic 2D ultrasound images of 3 cardiac cycles obtained at frame rates of greater than 60 Hz obtained and examined using altered programming with Echo PAC work station (general health care) to assess the following; Longitudinal strain of RV to analyze the free wall and interventricular septum deformation and motion (both in apical, mid cavity, basal segments) in apical 4 chamber view, RVGLS measured by averaging values measured at RV free wall and septum, also circumferential strain of RV to analyze the RV lateral free wall (anterolateral and inferolateral segments) and interventricular septum (anterior and inferior segments).

Statistical analysis

Data analysis was performed using the software SPSS (Statistical Package for the Social Sciences) version 20.



Quantitative variables were described by their means and standard deviations. Categorical variables were described by their absolute frequencies. Kolmogorov-Smirnov (distribution-type) and Levene (homogeneity of variances) tests were used to confirm suppositions for use in parametric tests. Paired sample t test was used to compare change in one group at two points of time. The level statistical significance was set at 5% ($p < 0.05$).

Results

In this study, male represented 61% of the studied patients while female patients were 39%. Age of them ranged from 38 to 78 years with mean 57.02 years (Table 1).

Regarding risk factors for ischemic heart disease (IHD), 60% had hypertension, 57% were diabetic, 62% were smokers and 59% had dyslipidemia. Only 18% reported past history of MI (Table 2).

Twenty one percent of the studied patients had left internal mammary artery (LIMA) graft to left anterior disending (LAD) artery, 31% had both LIMA graft to LAD and saphenous vein graft(SVG) to obtuse marginal artery (OM) and 48% had LIMA graft to LAD, SVG to OM, and SVG to right coronary artery (RCA) (Table 3).

By conventional echocardiography there was statistically significant decrease in RVS' from (12.76 ± 1.72) to (7.33 ± 1.71) and TAPSE from (22.8 ± 3.99) to (13.77 ± 4.63) among the studied patients after CABG. While there was significant increase in RVFAC from (44.69 ± 3.25) to (49.01 ± 3.36). On the other hand, there was non-significant change in RVEDD at mid-cavity from (26.37 ± 2.72) to (26.53 ± 2.72) and basal segment from (36.05 ± 2.98) to (36.29 ± 3.04), RVSV from (65.44 ± 7.02) to (65.85 ± 6.86) or RMPI from (0.491 ± 0.088) to (0.498 ± 0.086) (Table 4).

By STE There was statistically significant decrease in RVGLS from (-20.63 to -14.1) after CABG. There was statistically significant decrease in right ventricle free wall longitudinal strain [apical decreased from (-23.73 to -13.7), mid-cavity decreased from (-25.76 to -11.53), basal decreased from (-20.39 to -10.13) and lateral wall declined from (-23.01 to -9.13)]. There was statistically significant decrease in interventricular septum longitudinal strain [apical decreased from (-19.77 to -10.06), mid-cavity decreased from (-17.81 to -10.87) and basal decreased from (-15.89 to -11.13)]. There was statistically significant increase in RV circumferential strain of lateral free wall from (-12.04 to -16.21), while there is non-significant change in RV circumferential strain of septum from (-19.77 ± 4.86) to (-20.37 ± 5.14) (Table 5).

Discussion

RV dysfunction commonly developed and reported in >25% of patients after cardiac surgery. Either intraoperative or post-operative RV dysfunction highly associated with post-operative mortality [8].

Table 1: Distribution of the studied patients according to demographic characteristics.

Demographic data	N = 100	%
Gender		
Male	61	61
Female	39	39
Age (years)		
Mean \pm SD	57.02 \pm 8.3	
Range	38 – 78	

Table 2: Distribution of the studied patients according to risk factors for coronary artery disease.

Risk factors	N = 100	%
Hypertension	60	60
Diabetes mellitus	57	57
Smoking	62	62
Dyslipidemia	59	59
Previous MI	18	18

Table 3: Distribution of the studied patients according to performed graft.

Graft	N = 100	%
LIMA to LAD	21	21
LIMA to LAD, SVG to OM	31	31
LIMA to LAD, SVG to OM, SVG to RCA	48	48

Table 4: Conventional echocardiography parameters among the studied patients before and after CABG.

Parameters	Before CABG	After CABG	P [#]
	Mean \pm SD	Mean \pm SD	
RVEDD basal (mm)	36.05 \pm 2.98	36.29 \pm 3.04	0.051
RVEDD midcavity (mm)	26.37 \pm 2.72	26.53 \pm 2.72	0.063
RVS (mm/s)	12.76 \pm 1.72	7.33 \pm 1.71	< 0.001*
RVSV (ml)	65.44 \pm 7.02	65.58 \pm 6.86	0.341
RVFAC (%)	44.69 \pm 3.25	49.01 \pm 3.36	< 0.001*
TAPSE (mm)	22.8 \pm 3.99	13.77 \pm 4.63	< 0.001*
RMPI	0.491 \pm 0.088	0.498 \pm 0.086	0.583

RVEDD; Right Ventricle End Diastolic Diameter; RVS'Peak: Right Ventricle Systolic Velocity; RVSV: Right Ventricle Stroke Volume; RVFAC: Right Ventricle Fractional Area Change; TAPSE: Tricuspid Annular Plane Systolic Excursion; RMPI: Right Myocardial Performance Index; CABG: Coronary Artery Bypass Graft; #p for paired sample t test. *denote significant.

Table 5: Speckle tracking echocardiography parameters among the studied patient before and after CABG.

Parameters	Pre CABG	Post CABG	P [#]
	Mean \pm SD	Mean \pm SD	
RVGLS (%)	-20.63 \pm 2.53	-14.1 \pm 3.25	< 0.001*
RV free wall longitudinal strain (%)			
Apical	-23.73 \pm 2.21	-13.7 \pm 1.96	< 0.001*
Mid	-25.76 \pm 3.08	-11.53 \pm 3.41	< 0.001*
Basal	-20.39 \pm 4.41	-10.13 \pm 2.74	< 0.001*
Lateral wall	-23.01 \pm 3.74	-9.13 \pm 1.99	< 0.001*
Interventricular septum longitudinal strain (%)			
Apical	-19.77 \pm 5.38	-10.06 \pm 4.54	< 0.001*
Mid	-17.81 \pm 3.69	-10.87 \pm 3.94	< 0.001*
Basal	-15.89 \pm 3.14	-11.13 \pm 3.9	< 0.001*
RV circumferential strain (%)			
Lateral free wall	-12.04 \pm 1.91	-16.21 \pm 2.75	< 0.001*
Septum	-19.77 \pm 4.86	-20.37 \pm 5.14	0.213

RVGLS: Right Ventricle Global Longitudinal Strain; CABG: Coronary Artery Bypass Graft; #p for paired sample t test. *denote significant

In this study, male represented 61% of the studied patients while female patients are 39%, age of them ranged from 38 to 78 years with mean 57.02 years.

Also we are in line with El-Adawy, et al. [9], who studied fifty consecutive patients with IHD of them (34 (68%) male and 16 (32%) female). The mean age of the study population was 52.92 ± 9.97 years [9].

A total of 4,024 patients performed CABG included in the study by Varma, et al. [10], their mean age was 57 ± 9.6 years. The incidence of female patients undergoing surgery was the minority of cases (12.6%) [10].

Also in harmony with us among fifty patients were included in the Korshin, et al, [11], study, the gender distribution revealed more male than female patients [11].

Although among twenty-four patients undergoing elective CABG were enrolled by Bitcon and Tousignant, There were 18 male and three female patients which similar to our results. Mean (SD) age was higher than our study as the mean value was 70 year [12].

In this study, 21% of the studied patients had LIMA graft to LAD artery, 31% had both LIMA graft to LAD artery and SVG to OM artery and 48% had LIMA graft to LAD artery, SVG to OM artery, and SVG to RCA artery.

Similarly, in study by Gozdzik, et al. [14], 69 patients undergoing elective CABG were included. 55 of them had three-vessel disease. The most of patients received three grafts and in all LIMA graft to the LAD artery was used [14].

El-Adawy, et al. [9], reported that, the most common diseased coronary vessel was LAD in (49%) of patients followed by (34%) had RCA & (17%) had OM [9].

In this study, regarding the risk factors for IHD, 60% had hypertension, 57% were diabetics, 62% were smokers and 59% had dyslipidemia. Only 18% reported past history of MI.

This was in agreement with Varma, et al. [10], study in which the patients at the time of CABG surgery showed that hypertension was the commonest risk factors [10].

Also, we are in line with El-Adawy, et al. [9], who studied fifty patients with IHD. 32% of them were diabetic, 40% were hypertensive, 10% were smoker and 30% of patients were complaining of dyslipidemia [9].

In this study, by conventional echocardiography there was statistically significant decrease in RVS' from (12.76 ± 1.72) to (7.33 ± 1.71) and TAPSE from (22.8 ± 3.99) to (13.77 ± 4.63) among the studied patients after CABG. While there was significant increase in RVFAC from (44.69 ± 3.25) to (49.01 ± 3.36). On the other hand, there was non-significant change in right ventricle end diastolic diameter (RVEDD) measured at mid-cavity and basal segment, RVSV or RMPI after CABG.

The possible reason of deformation of RV geometry, reduction of TAPSE and RVS' after open heart surgery was still unclear. Changed contraction pattern of the interventricular septum, pericardiotomy mechanical effects, or postoperative adhesions of the right ventricle may be causative factors. Some theories were proposed to explain this dysfunction as pericardial opening, injury to the right atrium during cannulation, incomplete myocardial protection, and adhesions between the RV and nearby mediastinal structures [15,16], right ventricular ejection fraction (RVEF) is unchanged and cardiac output (COP) is not reduced [17].

In agreement with our study, 50 patients underwent CABG were included in a study by Korshin, et al. [11], who found significant reduction in TAPSE after surgery [11].

A second study done by Unsworth, et al. [18], who examined a group of 34 patients undergoing conventional on pump & robotic CABG, They found significant reduction in TAPSE after CABG. But in contrast to us, they found that a significant reduction in RVSV only in patients undergoing conventional on-pump CABG [18].

In concordance with our results, Hashemi, et al. [19], found that, TAPSE decreased significantly when matching the values from before to after CABG (23.9 ± 4.46 vs 14.6 ± 3.67 , $p < 0.001$). In contrast to us, Hashemi, et al. [19], found that, RVS' also decreased after CABG (11.9 ± 2.40 vs 8.5 ± 1.93 , $p < 0.001$) [19].

Another study by Rösner, et al. [17], indicated that post-CABG tricuspid TAPSE was markedly reduced, but there was unchanged RVFAC [17].

Moreover, Joshi, et al. [20], noted that after CABG, although there was a reduction in TAPSE, there was reduction of RVSV assessed by echocardiography with an improvement in RV function assessed by RMPI [20].

Also, after off-pump CABG, Khani, et al. [21], reported that the reduction in TAPSE not belonged to the cardiopulmonary bypass itself [21].

Our results were in line with Unsworth, et al. [22] who conducted echocardiography in 33 patients before and after elective CABG, TAPSE estimates decline significantly after the surgery by 58%, ($p < 0.0001$) [22].

Also, among forty six patients who were accepted for CABG were included in a study by Hashemi, et al. [19], on the impact of CABG on RV function, TAPSE reduced substantially after CABG ($p < 0.001$), On contrary, RMPI improved significantly ($p < 0.001$) with significant decline in RVS' was also observed following CABG ($p < 0.001$) [19].

In disagreement with our study, among twenty-four patients undergoing elective CABG were enrolled by Bitcon, et al. [12], there was significant change in post chest closure

values of RVFAC comparing to pre-pericardiotomy. On the other hand, there was a significant reduction in postoperative value of TAPSE & RVSV [12].

In contrast to our study, Larrazet, et al. [23], found that RVFAC remained unchanged despite there was a decline in RVSV after CABG [23].

In this study, by STE there was statistically significant decrease in RVGLS from (-20.63 to -14.1) after CABG. There is statistically significant decrease in RV free wall longitudinal strain [apical decreased from (-23.73 to -13.7), mid-cavity decreased from (-25.76 to -11.53), basal decreased from (-20.39 to -10.13) and lateral wall declined from (-23.01 to -9.13)]. There is statistically significant decrease in interventricular septum longitudinal strain [apical decreased from (-19.77 to -10.06), mid-cavity decreased from (-17.81 to -10.87) and basal decreased from (-15.89 to -11.13)]. There was statistically significant increase in RV circumferential strain of lateral free wall from (-12.04 to -16.21) while there was non-significant change in RV circumferential strain of septum from (-19.77 ± 4.86) to (-20.37 ± 5.14).

Our results were in agreement with previous study after cardiac surgery, there was decline in the longitudinal contraction of the RV lateral free wall [17].

Similarly, Gozdzik, et al. [14], enrolled 69 patients scheduled for CABG, they observed a significant decrease in the RVGLS post operatively [14].

In line with our results, as shown by Rong, et al. [24], RV free wall global longitudinal strain decreased significantly post operatively ($p < 0.05$ for all). With no significant change in post-operative interventricular septal deformation ($p = 0.23$) [24].

Similar finding was observed by Rong, et al. [24], who showed a significant reduction in RVGLS ($p < 0.001$) [24].

Similar to our results, among twenty-four patients undergoing elective CABG were enrolled by Bitcon, et al. [12], there was a significant decrease in in RV free wall strain [12].

While some studies have reported deterioration in global RV function and reduced longitudinal RV movement [25], other studies using other modalities for assessment of RV function had reported preserved global RV function despite a post-surgical reduction in RV longitudinal function [26].

Maffessanti, et al. [16], and Lindqvist, et al. [27], studies observed that no significant changes in the interventricular septum postoperative. The mechanism of these controversial findings is vague and may be due to a paradoxical movement of the septum after CABG, as well as cardiac injury due to ischemia [16,27].

Conclusion

In conclusion, this study revealed high prevalence of

most of the cardiovascular risk factors especially diabetes, hypertension and dyslipidemia in patients underwent CABG. By conventional echocardiography, TAPSE and RVSV were significantly decreased while RVFAC was significantly increased than its initial value in all patients after CABG. By STE, Global, free wall and interventricular septum longitudinal strain of RV were decreased significantly while circumferential strain of the RV lateral wall increased significantly. Distorted right ventricle geometry after CABG can lead to altered deformation parameters, in other words longitudinal functional parameters may underestimate RV function and the decrease in RVGLS was compensated by increase in circumferential strain of lateral free wall of RV without change in RVSV or RMPI. Therefore changes in deformation parameters should always be interpreted in relation to change in geometry.

Limitations

The influence of RV dysfunction on post-operative morbidity and mortality is not estimated. This study not evaluated intraoperative RV function rather than only after 2 weeks postoperatively. Also, as a cross sectional study we couldn't determine effects of risk factors for coronary artery disease on outcome following CABG. The lack of other independent diagnostic modalities as magnetic resonance imaging, Radial strain of RV not evaluated. The effect of the treatment on the prevalence of risk factors and on the RV function are not studied. Additionally, limited follow-up period beside the low sample size were the most important study limitations.

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