CORONARY ARTERY BYPASS GRAFTING PORTENDS DECREASED RIGHT VENTRICULAR FUNCTION

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Abstract

Decreased right ventricular (RV) function is a frequently observed phenomenon after coronary artery bypass grafting (CABG) that often implicated poor long term prognosis. The aim of this study was to assess the existence of RV dysfunction 4 to 6 months after CABG using echocardiographic Assessment of tricuspid annular plane systolic motion (TAPSE) and RV free wall longitudinal strain (RVFWS) using speckle tracking.

During the period from October 2017 to October 2018, forty-seven consecutive patients undergoing CABG were enrolled in this prospective study. 2D transthoracic echocardiography was performed within one week before CABG as well as 4 to 6 months after surgery. All measurements were made by a single experienced investigator.

4-6 months after CABG right atrial (RA) and RV dimensions were significantly increased although the mean value stayed in reference margins. TAPSE was significantly reduced (p=0.0001) as well as RVFWS (p=0.015) which showed fewer negative results implicating decrement in RV function after surgery. Patients with abnormal postoperative RVFWS had insignificantly larger preoperative end-diastolic and end-systolic volume index as well as worse left ventricular (LV) function manifested with lower LV ejection fraction (LVEF), lower systolic volume index (SVI) and more positive LV global longitudinal strain. We could not find any significant difference among preoperative values of RA and RV dimension as well as TAPSE and PAPs between patients with normal *vs*. abnormal postoperative RVFWS.

Our study showed depressed RV function 4-6 months after CABG. We suggest that RV free wall strain could be obtained and should be applied along with other conventional markers in the assessment of RV function after CABG.

Keywords: coronary artery bypass grafting, echocardiography, tricuspid annular plane systolic motion, right ventricular strain, right ventricular function

Introduction

Decreased right ventricular (RV) function is a frequently observed phenomenon after coronary artery bypass grafting (CABG). Cardiac surgery with cardiopulmonary bypass, perioperative myocardial ischemia, pericardial disruption/adhesions, etc., has been hypothesized to be the reason for the phenomenon [1–6]. Previous studies have shown that the RV dysfunction occurs perioperatively and remains depressed 6 months after CABG. [7,8]. The most common methods used in these studies are the measurement of tricuspid annular plane systolic motion (TAPSE)—which itself provides an estimation of RV ejection fraction [9] and the measurement of tricuspid annular velocity (TAV). On the other hand, the measurement of RV strain has received less emphasis.

The goal of this study was to evaluate the efficiency of TAPSE and RV strain in detecting RV dysfunction 4 to 6 months after CABG. We also tried to find relationship between preoperative LV performance and RV function after CABG including measurements of RV free wall strain.

Methods

Study patients

During the period from October 2017 to September 2018, forty-seven consecutive patients undergoing CABG were enrolled in this prospective study. All procedures were done on-pump with cardiopulmonary bypass (CPB). In every case left internal thoracic artery (LITA) was used to bypass the left anterior descending artery (LAD). None of the patients had associated surgical procedures such as valve replacement or surgery of the ascending aorta. This study was approved by the Medical Ethics Committee of Medical School, University "St.Cyril&Methodius", Skopje, and all patients provided informed consent.

2-D echocardiographic parameters

Transthoracic 2D echocardiography was performed within one week before CABG as well as 4 to 6 months after surgery. Standard assessments of LV, RA and RV dimensions and function were performed in standard views using 2D echocardiography on commercially available equipment (Vivid 7; GE, USA) and analyzed with Echo PAC workstation (GE) according to the professional association recommendations [10,11]. Tricuspid annular plane systolic excursion (TAPSE) was obtained in an apical 4-chamber view and measured by placing the M-mode cursor through the tricuspid annulus and measuring the longitudinal excursion between end diastole and peak systole, abnormal cutoff defined as TAPSE <16 mm. Pulmonary artery systolic pressures (sPAP) was obtained by measurement of right ventricular systolic pressure (RVSP) and adding approximate value of right atrial pressure (RAP). RVSP was derived from peak tricuspid regurgitation velocity measured by CW Doppler across the tricuspid valve (<2.8 m/s is considered normal) and using the modified Bernoulli equation. RAP was estimated by the diameter of the inferior vena cava and its variability during sniff. The cutoff for pulmonary hypertension was PAPs ≥36 mmHg. RV myocardial longitudinal strain was assessed using speckle tracking with a frame rate > 50 Hz. RV end-diastolic endocardial border in 4-chamber view was manually tracked and RV free wall longitudinal strain (RVFWS) was calculated by averaging the values from the three segments of the RV free wall. The data were analyzed offline using workstation Echo Pac (GE). Current reference values for global RVFWS is < -20% (> 20% in absolute value).

Statistical analysis

Categorical parameters were summarized as percentages and continuous parameters as mean ±SD. Comparisons of preoperative vs. postoperative data were performed using a Wilcoxon Signed Rank test for related samples. Continuous variables were compared using nonparametric Mann-Whitney test for independent samples and categorical parameters were compared using Pearson's chi square test. Assessment of correlations was done using Pearson's correlation analysis. All data analysis was performed using SPSS version 25.0 (IBM SPSS, Inc., Chicago, Illinois) and p value ≤ 0.05 was considered significant.

Results

Patient characteristics

The baseline demographic and clinical characteristics of the patients as a whole, including coronary anatomy are shown in Table 1.

The mean age was 65.55±8.25 years; 74.5% of the patients were male and around 50% had diabetes and hypertension. Mean Euro SCORE was 2.17±0.60 and most of the patients had three vessel disease (80.9%). Distribution of *left main* (LM) disease was 40.4% and mean number of grafts per patient was 2.77±0.72. Ischemic time was 66.09±20.03 and bypass time 108.91±29.73.

Echocardiographic measurements of RA and RV dimensions 4-6 months after CABG showed significantly increased values in comparison to preoperative values, although the mean value stayed in reference margins (Table 2). After CABG, TAPSE was significantly reduced (p=0.0001) as well as was RVFWS (p=0.015) which showed less negative results implicating decrement in RV function after surgery (Table 2). On the other hand, PAPs showed insignificant increment after CABG, but still in the reference value (Table 2).

Table 1. Baseline characteristics in the study population as a whole

Parameter	**All patients n=47**
Age (years)	65.55±8.25
Gender (n/%) Male Female	 35/74.5 12/25.5
BMI (kg/m2)	27.40±4.38
Euro SCORE	2.17±0.60
Angina, stable (n/%)	26/55.3
Previous MI (n/%)	25/53.2
Previous PCI (n/%)	15/31.9
Urgent CABG (n/%)	14/29.8
Preoperative AF (n/%)	2/4.3
COPD (n/%)	8/17.0
PAD (n/%)	6/12.8
CKD (n/%)	9/19.1
Smoking (n/%)	17/36.2
Hypertension (n/%)	47/100
Dyslipidemia (n/%)	46/97.9
Diabetes mellitus (n/%)	23/48.9
SYNTAX score	31.53±6.58
Left main disease (n/%)	19/40.4
LAD proximal disease (n/%)	38/80.9
1 vessel disease (n/%)	-
2 vessel disease (n/%)	9/19.1
3 vessel disease (n/%)	38/80.9
Number of grafts	2.77±0.72
CPB time (min)	108.91±29.73
Ischemic time (min)	66.09±20.03

ACS=acute coronary syndrome; AF=atrial fibrillation; BMI= body mass index; CABG = coronary artery bypass graft surgery; CKD=chronic kidney disease; CPB=cardio pulmonary bypass; COPD= chronic obstructive pulmonary disease; LAD=Left anterior descending ; MI=myocardial infarction; PCI=percutaneous coronary intervention; PAD=peripheral artery disease; SYNTAX= SYNergy between percutaneous intervention with TAXus drug-eluting stents and cardiac surgery.

Table 2. Comparison of echocardiographic parameters of RV, RA dimension and function before and after CABG.

Parameter	Before CABG n=47	After CABG n=47	p
RA (mm)	34.85±4,97	37.02±7.14	0.048
RV (mm)	28.79±5.51	30.91±5.31	0.024
TAPSE (mm)	20.45±3.10	17.47±3.84	0.0001
PAPs (mmHg)	13.96±12.20	16.59±0.04	0.084
RVFWS (%)	-21.85±11.26	-18.74±5.72	0.015

CABG = coronary artery bypass graft surgery; RA=right atrial diameter; RV=right ventricular diameter; RVFWS= right ventricular free wall strain; PAPs= pulmonary artery systolic pressure; TAPSE= tricuspid annular plane systolic motion.

*p<0, 05 for comparison between groups is considered significant.

After CABG right ventricular free wall strain (RVFWS) was normal (-20%) in 19 patients out of 47 (40.9%). Patients with abnormal postoperative RVFWS had insignificantly larger preoperative end-diastolic and end-systolic volume index as well as worse LV function manifested with lower LV ejection fraction (LVEF), lower systolic volume index (SVI) and more positive LV global longitudinal strain (GLS%) (Table 3). We could not find any significant difference among preoperative values of RA and RV dimension as well as TAPSE and PAPs between patients with normal vs. abnormal postoperative RVFWS (Table 3). Although patients with abnormal postoperative RVFWS had higher Syntax score, longer cardio pulmonary bypass time (CPB) and higher postoperative values of troponin there was not significant difference in comparison to those with normal strain (Table 3).

Table 3. Comparison of angiographic, operative and echocardiographic parameters in patients divided according to the postoperative RVFWS value that showed differences although mostly insignificant.

Parameter	Normal RVFWS n=19	Abnormal RVFWS n=28	p
RVFWS before CABG (%)	-27.0±6.0	-18.5±12.6	0.011
Syntax score	30.4±5.1	32.2±7.4	0.358
CPB time (min)	108.4±25.9	109.2±32.5	0.934
hs-cTnI (ng/L)	3302.2±7146.9	6038.0±11548.5	0.384
RA before CABG (mm)	34.8±5.6	34.8±4.5	0.961
RV before CABG (mm)	27.5±4.4	29.6±6.0	0.199
TAPSE before CABG (mm)	20.1±2.4	20.6±3.5	0.540
PAPs before CABG (mmHg)	10.5±4.6	16.2±15.0	0.066
LAVI before CABG (ml/m2)	33.7±9.2	35.3±11.6	0.627
EDVI before CABG (ml/m2)	60.3±27.2	67.4±34.6	0.458
ESVI before CABG (ml/m2)	28.6±20.8	37.4±30.6	0.279
LVEF before CABG (%)	57.4±16.1	52.0±14.7	0.235
SVI before CABG (ml/m2)	39.4±10.0	37.2±10.0	0.468
LVGLS before CABG (%)	-15.4±4.2	-14.8±3.6	0.621

CPB=cardio pulmonary bypass; CABG = coronary artery bypass graft surgery; EDVI=end diastolic volume index; ESVI= end systolic volume index ; hs-cTnI = high-sensitivity cardiac troponin I; LVGLS= left ventricular global longitudinal strain; LAVI= left atrial volume index; LVEF= left ventricular ejection fraction; PAPs= pulmonary artery systolic pressure; RA=right atrial diameter; RV=right ventricular diameter; RVGLS= right ventricular global longitudinal strain; RVFWS= right ventricular free wall strain; SYNTAX= SYNergy between percutaneous intervention with TAXus drug-eluting stents and cardiac surgery; SVI= stroke volume index; TAPSE= tricuspid annular plane systolic motion.

*p<0, 05 for comparison between groups is considered significant.

Using Pearson's correlation analysis we found that greater RV dimension after CABG was significantly correlated with longer CPB time (r=0.341, p=0.019) and lower preoperative cardiac index (r=-0.314, p=0.031), while lower TAPSE after CABG was significantly positively correlated with lower preoperative MAPSE (r=0,458; p=0,001) and LVEF (r=0.287; p=0.05). RVFWS after CABG was positively correlated with higher Syntax score (r=0.280, p=0.057), and more frequent LM disease (r=0.325, p=0.026).

Discussion

Right ventricular (RV) dysfunction after cardiac surgery is a well-known phenomenon. RV dysfunction can be seen immediately after cardiac surgery as well as after one year follow up. The mechanism of this phenomenon is not well established, but there is evidence that abnormal RV ejection fraction is a strong predictor for long-term cardiac re-hospitalization and mortality in patients undergoing isolated CABG [12,13]. The changes in RV function that develop after CABG are found in all subjects irrespective of the duration of the cardiopulmonary bypass or aortic clamp time, or the methods used for cardioplegia, or type of surgery (on pump vs. off pump) [14–16]. The leading cause of post-operative decreased RV function has yet to be found; nonetheless, intraoperative ischemia, intraoperative myocardial damage, cardioplegia, and pericardial disruption have been suggested as probable causes [6,14,15,18].

There is no gold standard for assessing RV function by echocardiography. This is partly due to the complex anatomy of the right ventricle. Right ventricular systole comprises complex pattern of contractions of the RV myocardium along its long and short axes as well as rotation along its longitudinal axis. The method of recording the tricuspid annular plane systolic motion by either conventional 2-D or 2-D guided M-mode echocardiography, showed good correlation to RV ejection fraction calculated from radionuclide angiography and pulmonary artery catheter [9,17].

In our study, TAPSE decreased significantly 4 to 6 months after CABG. These data in our study are in agreement with those in other studies that report the perioperative occurrence of RV dysfunction and lingering dysfunction 6 to 12 months after CABG [7,8,19]. Another study, with a smaller number of patients at 1-year follow-up after CABG, also showed the persistence of depressed RV function [17].

Another emerging modality for evaluation of RV function is speckle tracking imaging. Correlation of RV strain and conventional echocardiographic measurements of RV function is well documented [20,21]. Using RV strain in the current study enabled us to see a significant loss in RV function 4 to 6 mounts after CABG. The reduction revealed by RV strain is perhaps more reliable and more probably is a true RV dysfunction: regional peak systolic values (RV strain) have a close correlation with intrinsic contractility. To our knowledge, despite the wide application of RV strain to the study of various RV diseases, this investigative technique is seldom used in the evaluation of post-CABG RV dysfunction. Roshanali et al. showed that one year after CABG, RV function measured via TAPSE and RV strain remained highly depressed. The results of this study suggest that RV strain should be applied as an alternative to TAPSE in the assessment of RV function, particularly when there are limitations in the application of TAPSE [19].

As for the relationship between preoperative LV performance and RV function after CABG measured with RV free wall strain, our study confirmed that patients with abnormal postoperative RVFWS had lower values of preoperative LVEF, larger end diastolic and end systolic volume index than patients with normal postoperative RVFWS. These differences although statistically insignificant, might be clinically significant and leads us to conclusion that patients with preoperative abnormality in LV systolic function tend to have greater postoperative decline in RV function.

TAPSE after CABG was positively correlated with MAPSE and LVEF before CABG. This finding was statistically significant and generates another hypothesis worth investigating.

Limitations

The major limitations in our study are that we used only conventional 2-D echocardiography and speckle tracking imaging to assess pre and postoperative RV function. Other technologies such as magnetic resonance imaging, positron emission tomography and radionuclide angiography might have yielded other results, but 2-D echocardiography is widely used method for quantifying perioperative LV function. This study has the advantage of being prospective and all consecutive patients that met inclusion criteria were enrolled in the study but we believe that their number is too small. Another disadvantage is that paired echocardiograms were done 6 months after surgery, time that might be too short for complete RV myocardial recovery after surgery. In our study all patients were done on pump with crystalloid cardioplegia and this might affect postoperative RV function in certain percent of patients.

Conclusion

Our study showed depressed RV function measured via TAPSE and RV strain 4-6 months after CABG. We suggest that RV strain be applied as an alternative to TAPSE in the assessment of RV function, particularly when there are limitations in the application of TAPSE. Positive correlation between TAPSE and parameters of LV function should be further investigated.

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