

Assessment of the effect of off-pump coronary artery bypass (OPCAB) surgery on right ventricle function using strain and strain rate imaging

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Background: Right ventricle function significantly decreases after coronary artery bypass surgery; as one of the likely causes, such a condition is attributed to the use of cardiopulmonary pump (CPB). Because nowadays there is a tendency toward increasing use of off-pump coronary artery bypass (OPCAB) surgery, this study was conducted to evaluate the right ventricle function after this type of surgery using strain and strain rate imaging (SRI) echocardiography.

Methods: This study was conducted on 30 patients, candidate for elective OPCAB surgery, between 2011 and 2012. Standard echocardiography was performed before the surgery and the right ventricle function was examined using strain and SRI echocardiography. Then patient underwent surgery, 6 days and 3 months after surgery they underwent echocardiography again and the results obtained from the three stages were compared with each other.

Results: Participants included 30 patients (23 males and 7 females) with a mean age of 66 ± 11 years. Compared to the prior of the surgery, 6 days and 3 months after the surgery there was a significant decrease in tricuspid annular plane systolic excursion (TAPSE), tissue Doppler imaging (TDI) at the lateral annulus of tricuspid valve, and strain and SRI of right ventricle. However, the values obtained 3 months after surgery were significantly higher than those obtained after 6 days. In other words, the right ventricle function 6 days after the surgery had dropped, however some of the values recovered 3 months after the surgery.

Conclusions: The findings of this study are consistent with other studies in this field and showed that after coronary artery surgery a decline occurs in right ventricular function. However, more detailed quantitative strain and SRI parameters which were measured in our study showed that at the early days after the OPCAB surgery there is a decline in the right ventricle function which is relatively reversible at longer intervals (3 months after surgery).

Keywords: Right ventricle function; off-pump coronary artery bypass surgery (OPCAB surgery); off-pump coronary artery bypass surgery (OPCAB); strain and strain rate imaging echocardiography (strain and SRI echocardiography)

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Introduction

Reduced right ventricular function is a common finding in coronary artery bypass graft surgery (CABG) which can cause heart failure and increase mortality after surgery (1-4). Although the underlying mechanism is not clear, such a condition is attributed to different causes such as intraoperative ischemia, intraoperative myocardial damage, and the use of cardiopulmonary pump (CPB) (5,6). Several studies have shown that intraoperative right ventricle dysfunction can last up to 6 months after the surgery (7-9). Some other studies have reported that the echocardiographic right ventricular dysfunction can last up to even 1 year after CABG (2,10); nevertheless, due to improved levels of exercise stress test, some studies have considered a minor clinical value for such disorders (2).

On the other hand, nowadays, off-pump coronary artery bypass surgery (OPCAB) or beating heart is accepted as a procedure that allows the surgeon to perform CABG on a beating heart without aortic cannulation and clamp (11,12) and it has been proved as a safe and effective way whose long-term patients survival rate do not differ with that of on-pump CABG (13). Although CPB, which is one of the possible causes of reduced right ventricular function, is not used in this type of surgery, several studies have reported declined right ventricular function after this type of surgery; the rate of decline immediately after surgery was similar to that of on-pump technique (3).

Echocardiographic assessment of left ventricular function is simple, however due to the complex anatomy of the right ventricle; it is difficult to evaluate its performance by echocardiography. Therefore, different methods have been used to assess right ventricular function of which it can be named tricuspid annular motion or TAM measurement, which is actually an estimate of ejection fraction, tricuspid annular velocity or TAV, and tissue Doppler imaging or TDI (10). However, the procedure of strain and strain rate imaging (SRI), which is an exact method for assessment of right ventricular function, has been used rarely (14). Accordingly, this study aimed to evaluate the right ventricular function in patients undergoing OPCAB surgery using strain and SRI.

Materials and methods

This study was conducted on 30 patients, candidate for elective OPCAB surgery, in Modarres Hospital, between 2011 and 2012. The main criterion for the inclusion was

the electiveness of the surgery. Exclusion criteria were: the absence of sinus rhythm, emergency cardiac surgery or repeated CABG, the presence of tricuspid regurgitation or the need to repair it, myocardial infarction in right ventricle, and severe mitral or tricuspid valve disease. The study received ethical approval from the ethics committee of Shahid Beheshti University of Medical Sciences.

After explaining the aims of the study to patients and obtaining their written informed consent, the researchers performed standard echocardiography including different views of parasternal, long axis parasternal, apical, and apical 4 chambers, short axis apical 2 and 3 chambers. Right ventricular function of patients was examined by strain and SRI echocardiography and the following items were determined through echocardiography: tricuspid annular plane systolic excursion (TAPSE), strain and SRI of right ventricle and tissue Doppler imaging or TDI at lateral annulus of tricuspid valve. Then patients underwent OPCAB. Echocardiography was performed again 6 days and 3 months after surgery and the results obtained from the three stages were compared with each other. All of the echocardiographic measurements in our study were done by an experienced echocardiographer. To assess intraobserver variability, one experienced echocardiographer measured the strain data, with the second set of measurements performed 2 weeks later.

SPSS 18 software was used for data analysis. In order to describe the variables we used mean and standard deviation, and to compare the values obtained before surgery, 6 days and 3 months after the surgery we used repeated measures ANOVA test and its non-parametric equivalent i.e., Friedman test. To compare pairs of means we used paired *t*-test and its non-parametric equivalent i.e., Wilcoxon signed-rank test. P value <0.05 was considered as the significant level.

Results

Participants included 30 patients (23 males and 7 females) with a mean age of 66 ± 11 years (ranged from 49 to 83 years). *Table 1* and *Figures 1-4* show the comparison between echocardiography items before surgery, 6 days after surgery and 3 months after surgery. As it can be observed, in all cases there is a difference between measurements ($P < 0.001$), so that the measured values of 6 days and 3 months after surgery are significantly lower than preoperative values; the values obtained 3 months after surgery are also significantly higher than those obtained 6 days after the surgery. In other

Table 1 Comparison of right ventricle echocardiographic measurements prior to OPCAB, 6 days after OPCAB, and 3 months after OPCAB

Measurement	Prior to OPCAB	6 days after OPCAB	3 months after OPCAB	P value
TAPSE	1.97±0.24	1.24±0.20	1.37±0.24	<0.001*
TDI	0.13±0.03	0.08±0.01	0.12±0.17	<0.001**
SRI 1	-1.42±0.64	-0.85±0.42	-0.98±0.39	<0.001**
SRI 2	-1.52±0.81	-0.88±0.46	-1.03±0.53	<0.001**
SR 1	-19.63±7.04	-13.35±4.97	-14.58±5.00	<0.001*
SR 2	-24.55±8.05	-11.91±4.63	-14.92±5.06	<0.001*
Mean SRI 1 & 2	-1.47±0.54	-0.86±0.34	-1.00±0.34	<0.001*
Mean SR 1 & 2	-22.09±5.89	-12.63±3.27	-14.75±3.61	<0.001*

*, repeated measures ANOVA; ** Friedman test. TAPSE, tricuspid annular plane systolic excursion; TDI, tissue Doppler index; SRI 1, right ventricle free wall (RVFW) basal strain rate imaging; SRI 2, RVFW mid strain rate imaging; SR 1, RVFW basal strain rate; SR 2, RVFW mid strain rate; mean SRI 1 & 2, the mean of RVFW basal strain rate imaging and RVFW mid strain rate imaging; mean SR 1 & 2, the mean of RVFW basal strain rate and RVFW mid strain rate.

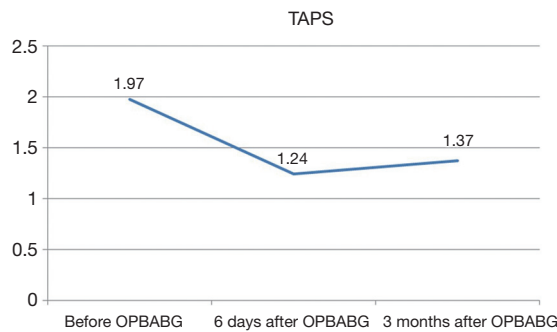


Figure 1 Comparison of tricuspid annular plane systolic excursion (TAPSE) prior to, 6 days, and 3 months after OPCAB.

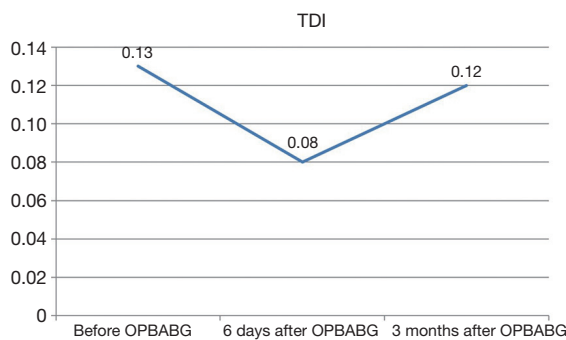


Figure 2 Comparison of tissue Doppler index (TDI) prior to, 6 days, and 3 months after OPCAB.

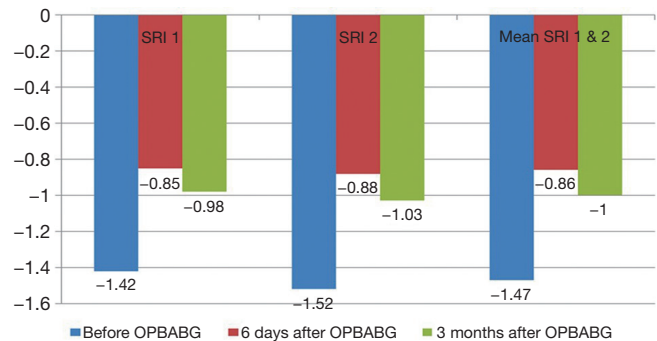


Figure 3 Comparison of right ventricle free wall (RVFW) basal, mid, and mean strain rate imaging prior to, 6 days, and 3 months after OPCAB. SRI 1, RVFW basal strain rate imaging; SRI 2, RVFW mid strain rate imaging; mean SRI 1 & 2, the mean of RVFW basal strain rate imaging and RVFW mid strain rate imaging.

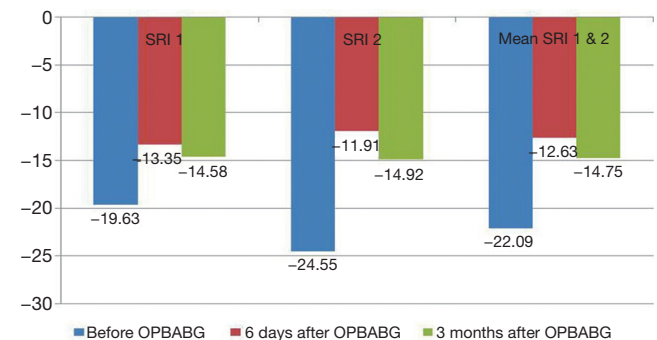


Figure 4 Comparison of right ventricle free wall (RVFW) basal, mid, and mean strain rate prior to, 6 days, and 3 months after OPCAB. SR 1, RVFW basal strain rate; SR 2, RVFW mid strain rate; mean SR 1 & 2, the mean of RVFW basal strain rate and RVFW mid strain rate.

words, right ventricular function had deteriorated 6 days after surgery, but the amount of the loss was compensated 3 months after surgery. According to this point that all measurements were performed by one experienced echocardiographer, the intraobserver variability was 0.90 (range, 0.79–0.97).

Discussion

The findings of this study are consistent with other studies in this field, and showed that after coronary artery surgery a decline occurs in right ventricular function. However, more detailed quantitative strain and SRI parameters which were measured in our study showed that at the early days after the OPCAB surgery there was a decline in the right ventricle function which was relatively reversible at longer intervals (3 months after surgery).

CABG, as the common method of coronary artery bypass, is performed using CPB on the stopped heart. The main advantage of this method is convenient and easy access to coronary artery which facilitates accurate anastomosis in an environment with good vision and without moving (15). On the other hand, in the off-pump CABG the surgery is operated on the beating heart without the use of a pump; it does not have complications associated with the use of the pump and is a less invasive approach which has become popular in recent years (16). Several studies have been conducted about the superiority of this method and each study has given special consideration to a separate specific parameter.

Right ventricular dysfunction after cardiac surgery is a well-known phenomenon that can be observed immediately after cardiac surgery. Both contraction and filling of the right ventricular are impaired after CABG, however, the mechanism of this phenomenon is not yet known exactly. Right ventricular dysfunction is observed in all patients who undergo heart surgery, regardless of the use of CPB, the time of aortic clamping, the methods used for cardioplegia, and myocardial preservation (10). Although most studies have reported intraoperative and post-operative right ventricular dysfunction, but long-term results are not known. Although some studies have shown the recovery of ventricular function during the first 6 months after surgery (8), some other studies reported that the recovery of right ventricular function lasts up to 1 year after CABG (2,10).

Michaux *et al.* examined the effect of coronary artery bypass on right ventricular function in two groups of on-pump and off-pump surgery and reported that after the

surgery, overall systolic function of right ventricle remained the same in the two groups, however, the diastolic function were reduced similarly in both groups and there was no significant difference between the two groups in terms of right ventricular echocardiographic findings. Accordingly, they stated that the effect of off-pump surgery on right ventricular systolic and diastolic functions was similar to those of on-pump procedures (3). Pegg *et al.* also examined the impact of on-pump and off-pump surgery methods on early and late right ventricular function. In their study, 60 patients with normal left ventricular function were randomly divided into two groups of on-pump and off-pump surgery and were examined 6 days after surgery and 6 months after surgery using cardiac magnetic resonance imaging. Right ventricular stroke volume index was reduced immediately after surgery in both groups and there was no difference between the two groups, however, after 6 months, all indices of right ventricular function in both groups got back to their preoperative levels. As a result, they found that although the changes in RV function happened after both types of surgery and with the same levels, in the long run these changes are reversible (8). Roshanali *et al.* studied right ventricular function after conventional CABG using TDI; they reported that right ventricular dysfunction after cardiac surgery remains up to a year after the operation (10).

As it was shown, various studies on right ventricular function after surgery with or without pump have resulted in different findings. Although right ventricular dysfunction after surgery is proven, the level and the duration of dysfunction in the postoperative period are still controversial. One of the reasons that can be cited in this context is the method of examining and measuring right ventricular function. Because different studies have used different methods to assess right ventricular function, hence different results have been obtained. The use of MRI is the best technique in this field; however, due to its high cost and lack of facilities in many health centers, it cannot be used as a conventional method for the evaluation of right ventricular function (17). Therefore, echocardiography, which is a noninvasive, inexpensive, and available method, is used for this purpose. However, assessing right ventricular function by echocardiography is not as easy as to assess left ventricular function. Nowadays, TDI and strain and SRI are used to assess right ventricular function (10,17). Since SRI shows clearer quantitative values and more objective parameters, especially when clinical status shows intangible results, it could indicate a more precise examination of right

ventricle (18). Hence, in the present study to investigate the postoperative right ventricular function we used the strain and SRI, in addition to TAPS and TDI.

Consistent with previous studies, our results also indicated that the TAPS, TDI and strain and SRI of right ventricle had a significant decline 6 days after surgery, which was recovered slightly during 3 months after surgery. The level of recovery 3 months after surgery in comparison to 6 days after surgery was significant, which indicated the reversible nature of right ventricular function after cardiac surgery. However, the rate of dysfunction 3 months after the surgery was still significant, compared with its preoperative level. Rates of recovery to the initial state of each of these parameters were varied in such a way that the rate of recovery on the TDI was sharper and higher. Our study showed that there was more decline in right ventricle free wall (RVFW) strain rate (SR) and SRI in the middle (mid), compared to the base (basal). In addition to measuring these two parts, we algebraically calculated the mean of SR and SRI for both the middle and the base; consistent with other changes, they also showed reduced right ventricular function 6 days and 3 months after surgery. Although in most studies, many of the examined indicators are in line with each other, however, our study showed that the level of recovery of the right ventricle may vary based on different indicators. Therefore, it is recommended to conduct further studies to find the best and most appropriate indicators to assess and follow the right ventricle function. Our study was a single center study and was relatively unique in its time; strain echocardiography is a non-invasive modality; however, we enrolled only the patients who were fully consent after comprehensive explanation of the study for them. So, it was inevitable that a part of our candidate patients were not included in the study. On the other hand, off-pump cardiac surgery is less performed than on-pump cardiac surgery. This study could be as a pilot study and new window for future large and multicenter studies which will reveal more detailed results. Moreover, valuable clinical and systematic reviews could be published from results of various centers. It is recommended for future large sample-size studies to have long duration follow-up.

The small sample size, short time of the study, and lack of a comparison with patients who underwent on-pump surgery are the limitations of this study, however, it seems that our study to be one of the few studies on right ventricular function after cardiac surgery using the strain and SRI. Hence, it is recommended to conduct further broader, multi-center studies, to determine appropriate

indicators to measure and follow the right ventricle function.

Conclusions

The present findings are consistent with other studies in this area and showed that a decline occurs in right ventricular function after the coronary artery surgeries. However, more detailed quantitative strain and SRI parameters which were measured in our study showed that at the early days after the OPCAB surgery there is a decline in right ventricle function which is relatively reversible at longer intervals (3 months after surgery). Hence, it is recommended to conduct longer studies to evaluate right ventricular function after this type of surgery.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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