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LEADING ARTICLE

Evaluation of the effect of elective percutaneous coronary intervention as a treatment method for right ventricular function

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Abstract

Objective

This study aimed to evaluate the early effects of successful elective percutaneous coronary intervention (PCI) of the right coronary artery (RCA) on right ventricular (RV) systolic and diastolic functions.

Materials and methods

Thirty consecutive patients with stable coronary artery disease (CAD) and significant RCA lesion, who underwent elective PCI, were included in this study. For all patients, echocardiographic parameters were assessed at baseline and within 24 hours after PCI to evaluate RV systolic and diastolic functions. Pulsed wave tissue Doppler imaging (PW TDI) was done using tricuspid inflow velocities at lateral angle of the tricuspid valve annulus, including Sa, Ea, and Aa wave peak velocities (in cm/sec) and Ea/Aa ratio of tricuspid annular velocities.

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Results

We found statistically significant early improvement of RV longitudinal systolic and diastolic functions within 24 hours after successful PCI documented by a significant increase in Sa, Ea waves, and Ea/Aa ratio at lateral angle of the tricuspid valve annulus compared with baseline values (P<0.001), while this early improvement was not detected by conventional echocardiographic parameters including right ventricular end-diastolic dimension (RVEDd), RVEDd/left ventricular end-diastolic dimension (LVEDd), RV wall motion abnormalities, and transtricuspid Doppler measurements.

Conclusion

Both RV systolic and diastolic functions improved within hours after PCI of the RCA in patients with stable CAD. PW TDI velocities at the lateral tricuspid valve annulus were the earliest index of early improvements in RV functions following successful elective PCI in such patients.

Keywords

Percutaneous coronary intervention, echocardiography, coronary artery disease, tissue Doppler imaging

Introduction

The physiological importance of the right ventricle (RV) has been underestimated. The RV was considered as a conduit whereas its contractile performance was thought to be haemodynamically unimportant [1,2]. It should be considered that RV dysfunction may affect left ventricular (LV) function, not only by limiting LV preload, but also by adverse interaction via the intraventricular septum and the pericardium (ventricular interdependence) [3–9]. Clinicians usually rely on noninvasive imaging methods for assessment of RV function. Assessment of the RV by two-dimensional echocardiography (2D Echo) is difficult due to its complex anatomy [10]. Recently, alternative techniques have been proposed, including tissue Doppler imaging (TDI) techniques, three dimensional echocardiography, and magnetic resonance imaging (MRI) [11–17]. Systolic myocardial velocity (Sa) at the lateral tricuspid annulus is a measure of RV longitudinal systolic function and is correlated with measurements of RV ejection fraction. A reduction in Sa velocity can be detected within 15 seconds of the onset of ischaemia, and regional reductions in Sa are correlated with regional wall-motion abnormalities. The potential of tissue Doppler–derived measurements in identifying ischaemia has been established in different experimental and clinical settings [18–19]. The present study was designed to evaluate the early effects of successful elective PCI of the RCA on RV systolic and diastolic functions in patients with stable coronary artery disease (CAD).

Materials and methods

In our study, we recruited 30 patients with stable CAD who were scheduled for elective PCI of the RCA in the Benha University Hospital from July 2014 to February 2015. We included patients with angiographically documented isolated stenosis >70% diameter in the RCA by visual assessment, and documented ischaemia. We enrolled patients with stable angina and the evidence of a positive stress test. We excluded patients over 75 years old; with significant left coronary artery lesions, left bundle branch block, any rhythm rather than sinus rhythm, valvular heart disease, cardiomyopathy, chronic obstructive pulmonary disease, or pulmonary hypertension. We classified RCA lesions according to the site into proximal RCA lesions defined as lesion in the portion of the artery prior to the origin of the acute marginal (AM) branch, while any lesion just beyond the AM branch defined as non-proximal RCA lesions aimed to define the immediate effect of proximal RCA revascularization versus distal RCA on RV functions. Successful revascularisation was defined as a residual stenosis of <30% in luminal diameter with TIMI grade 3 flow [20]. Patients with unsuccessful PCI were excluded from the study. Direct stenting or stenting after successful angioplasty was performed in all the participants according to published guidelines [20]. All patients received heparin to a target activated thrombin time level of 200–300 sec and clopidogrel in standard doses. All participants provided written informed consent.

For all patients, echocardiography examinations using a Vivid-S5 (GE) device, equipped with PW-DTI, were done one day before and 24 hours after successful PCI, according to the last *American Society of Echocardiography* guidelines for RV assessment [21]. All echocardiographers were blinded to patients' angiography status. There were used:

M-mode echocardiography to assess LVEDd in mm.

2D echocardiography to assess RVEDd**,** RVEDd/LVEDd ratio and left ventricular ejection fraction (LVEF, %) using modified Simpson's rule also used to study RV wall motion abnormalities (RVWMA) in the form of hypokinesia, akinesia, and dyskinesia in the apical, midzonal, or in the basal portions of the RV free wall.

Doppler transtricuspid flow velocities, including peak early diastolic velocity (Ea) and peak atrial diastolic velocity (Aa) in cm/s, and E/A ratio.

Pulsed-wave tissue Doppler imaging (PW TDI) at lateral angle of the tricuspid valve annulus, including peak systolic (Sa) velocity, peak early (Ea) and peak late (Aa) diastolic velocities in cm/s, and Ea /Aa ratio [21].

2.1. Statistical analysis

The data collected were tabulated and analysed by using SPSS (statistical package for social science) version 17.0 on IBM compatible computer. Descriptive statistics like percentage (%), mean (x), and standard deviation (SD) were used; the Mann-Whitney test (nonparametric test) was used in the comparison of improvement of RV functions; the *P* value of less than 0.05 was considered statistically significant [22].

Results

A total of 30 patients who had successful PCI of the RCA were considered for the study analysis. Baseline characteristics of participants showed insignificant differences and are summarised in Table 1. There was a non-significant improvement in conventional 2D Echo and M-mode measurements at baseline and 1 day after the intervention, including RVEDd, LVEDd, RVEDd/LVEDd, LVEF, and RV wall motion abnormalities (*P*=0.26, 0.3, 0.32, 0.4, respectively). The study showed a non-significant improvement in conventional Doppler measurements at baseline and 1 day after the intervention, including transtricuspid mean E-wave, mean A-wave, and mean E/A ratio, (*P*=0.83, 0.67, 0.32, respectively, Table 2). There was a highly significant improvement in PW TDI measurements, including mean Sa (10.37±4.12 vs. 11.67±3.99 cm/s at baseline and 1day after the intervention, *P*<0.001), mean Ea (8.53±2.79 vs. 9.57±3.01 cm/s, *P*<0.001), and mean Ea/Aa ratio (0.77±0.43 vs. 0.93±0.25cm/s, *P*=0.03). There was an unexpected non-significant improvement in mean Aa (14.63±5.59 vs. 14.37±5.54 cm/s, *P*=0.11, Table 3, Figure 1). A subgroup analysis showed that 23 patients (76.7%) had proximal RCA lesions while 7 patients (23.3%) had non-proximal RCA lesions. Patients, who had PCI done to proximal RCA lesions, showed a significant improvement in RV systolic and early diastolic functions in com-

Table 1. **Baseline characteristics of patients**

Demographic results:	Study population (n = 30)
Mean age, years	57.43±7.54*
Male, (%)	24 (80%)
Hypertensive patients, (%)	21 (70%)
Diabetic patients, (%)	12 (40%)
Smokers, (%)	22 (73.3%)
Patients with positive family history, (%)	6 (20%)
Angiographic results:	
Proximal RCA lesions compromise RV branch, (%)	23 (76.7%)
Non-proximal RCA lesion, (%)	7 (23.3%)

*Means ± standard deviation, RCA – right coronary artery, RV – right ventricle

Table 3**. TDI myocardial velocities at lateral angle of the tricuspid valve annulus before and after successful PCI***

Method	Index	Pre-PCI	Post-PCI	*P*
Tissue Doppler Imaging (cm/sec)	Sa *	10.37±4.12	11.67 ± 3.99	<0.001
	Ea *	8.53 ± 2.79	9.57 ± 3.01	<0.001
	Aa *	14.63 ± 5.59	14.37 ± 5.54	0.11
	Ea/Aa ratio*	0.77 ± 0.43	0.93 ± 0.25	0.03

*Means ± standard deviation

Table 2. **Conventional echocardiographic indices before and after successful PCI**

Method	Index	Pre-PCI	Post-PCI	P
2-D echocardiography	LVEDd*	4.80±0.81	4.80±0.81	–
	RVEDd*	2.23±0.63	2.27±0.58	0.3
	RVEDd/LVEDd*	0.477±0.49	0.478±0.48	0.32
	RV WMA Hypokinesia Apical Basal Normal wall motion	 6 (20%) 3 (10%) 3 (10%) 24 (80%)	 6 (20%) 3 (10%) 3 (10%) 24 (80%)	–
M-mode echocardiography	LVEF (%)*	61.67±9.46	61.53 ± 9.49	0.4
Doppler echocardiography	E tricuspid	49.6 ± 10.57	49.33 ± 10.92	0.83
	A tricuspid	72.5 ± 22.79	71.5 ± 20.82	0.67
	E/A tricuspid	0.97 ± 0.32	1.0 ± 0.26	0.32

*Means ± standard deviation, RV WMA – right ventricle wall motion abnormality

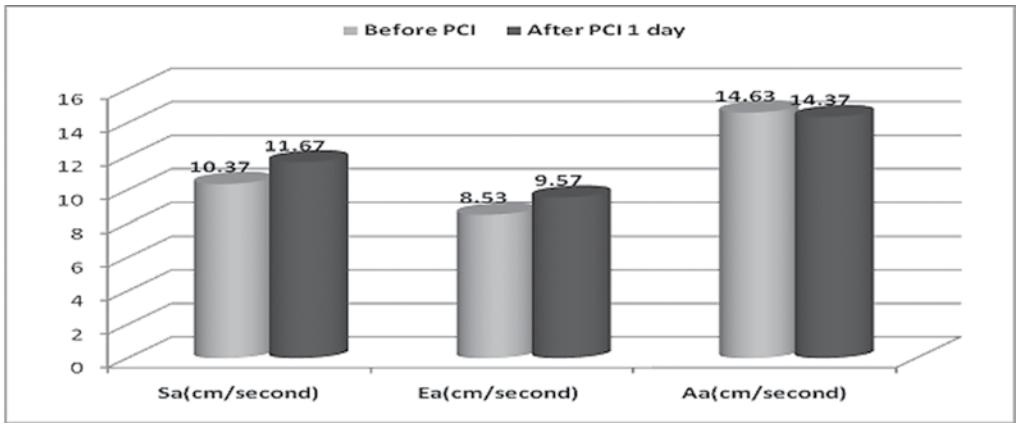

Figure 1. TDI myocardial velocities at lateral angle of the tricuspid valve annulus before and after successful PCI

Table 4. **Improvement of TDI myocardial velocities at lateral angle of the tricuspid valve annulus of proximal RCA lesions and non-proximal RCA lesions**

	Improvement (After – Before)		Mann-Whitney U test	*P*
	Proximal RCA lesions No = 23	Non-proximal RCA lesions No = 7		
Sa (cm/second) *	1.50±0.67	0.75±0.89	2.07	0.04
Ea (cm/second) *	1.23±0.43	0.50±1.19	1.74	0.03

*Means ± standard deviation, RCA – right coronary artery

parison with patients who had PCI done to distal RCA lesions (*P*=0.04 and 0.03, respectively, Table 4). Socio-demographic factors like age, gender, diabetes, hypertension, smoking, dyslipidaemia, or positive family history showed to have statistically non-significant effect on improvement of RV functions in such patients, except for age. Patients <50 years old (13.3 %) had a statistically significant improvement in RV systolic function (Sa) and non-significant improvement in early diastolic function (Ea) (*P* = 0.62). compared with patients ⩾50 but <75 years old (*P* = 0.03).

Discussion

In our study of 30 patients with isolated RCA lesions, a highly significant improvement of RV systolic myocardial velocity at lateral angle of the tricuspid valve annulus was found 1 day after the intervention as compared to baseline (*P* <0.001). Our results coincided with the results of the studies conducted by Diller *et al*. and Rashid *et al*., which included 24 and 25 patients with chronic CAD, respectively. Not all of their patients had isolated RCA lesions. The results of both studies showed a significant improvement in Sa velocity (*P*<0.05 and <0.001, respectively) [23–24].

In our study, there was also a significant improvement in early diastolic myocardial velocity (Ea) (*P*<0.001). And again, our results coincided with the results obtained by Diller *et al*. and Rashid *et al*., which showed a significant improvement in early diastolic velocities (*P*<0.05 and <0.001, respectively) [23–24]. Unexpected non-significant changes were observed in our results of late diastolic myocardial velocities (Aa) (*P* = 0.11). This observation did not coincide with the results of Diller *et al*. Their results showed a significant improvement of both early and late diastolic myocardial velocities after PCI. This could be due to a longer period of follow-up (6 weeks) versus one day in our study [23].

In our study, there was a significant increase in Ea/Aa ratio at lateral angle of the tricuspid valve annulus, *P*=0.03), mainly due to a significant increase in Ea velocity. While the results of Rashid *et al*. showed a non-significant increase in Ea/Aa ratio (*P*>0.05), because their results showed a limited improvement in both Ea and Aa values [24]. The unique feature of our study was that all of our patients had right coronary interventions, so TDI measurements in our study represented hence more effect on RV function. On the other hand, Rashid *et al*. and Diller *et al.* included patients with single vessel disease (right coronary artery (RCA), left anterior descending (LAD) coronary artery, or left circumflex (LCX) coronary artery) and two-vessel disease. So, their results showed less effect on RV function and controversial improvement in TDI measurements at lateral angle of the tricuspid valve annulus. The improvement of RV early diastolic myocardial velocity (Ea) was more evident than RV late myocardial diastolic velocity (Aa) and myocardial Ea/Aa ratio. This may be because early myo-

cardial relaxation is an active and energy dependent process that requires energy for Ca++ mobilization by Ca++ ATPase pump of the sarcoplasmic reticulum. With the occurrence of ischaemia, the relaxation is impaired due to decreased production of ATP leading to delayed and slowed relaxation, but this process improves rapidly after revascularization [25–26].

Proximal RCA occlusion of the right ventricular branch in patients with CAD would suggest more of right ventricular involvement [27]. In our study, patients who had PCI done to proximal RCA lesions showed a significant improvement in RV systolic and diastolic functions in comparison with patients who had PCI done to non-proximal RCA lesions (P=0.04 and 0.03, respectively). Our results confirmed that correction of ischaemia after successful PCI proximal to the right ventricular branch origin could predict and could correlate with more rapid improvement in RV systolic and diastolic functions, confirmed by PW TDI. Our results correlated with the results of the study conducted by Gopalan *et al.* and published in the Indian Heart Journal in 2013. There were found statistically significant differences in RV functions assessed by tricuspid annular plane systolic excursion (TAPSE), myocardial performance index (MPI), and TDI in RV free wall among patients who had proximal RCA lesions versus patients who had distal lesions after inferior wall ST segment elevation myocardial infarction (STEMI) [28].

A limitation of the current study could have been a relatively small number of patients evaluated. Moreover, since the functional improvement of RV following PCI of the RCA may increase over time, a short follow-up of myocardial performance could have been another limitation of this study. The final shortcoming may have been the fact that we did not consider a clinical improvement along with the echocardiographic parameters. To our knowledge, this study is, however, the first to cover a wide range of echocardiographic indices for RV functional assessment of post-elective PCI of the RCA in patients with stable CAD.

Conflict of interest: None declared

Conclusion

From all of the above, we can conclude that elective PCI of the RCA causes a very early improvement in RV systolic and diastolic functions. TDI allows sensitive detection of a very early improvement of RV myocardial function after successful elective PCI of the RCA.

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