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Echocardiographic evaluation of right ventricular functions after successful percutaneous recanalization of right coronary artery chronic total occlusions

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Abstract. – BACKGROUND: No data exist on regarding possible improvement will occur in right ventricular (RV) functions after successful recanalization of right coronary artery chronic total occlusions (RCA CTOs).

AIM: Our aim was to evaluate the revascularization induced changes in RV functions by novel echocardiographic techniques like tissue Doppler imaging (TDI) and two dimensional speckle tracking echocardiography (2DSTE).

PATIENTS AND METHODS: Forty-one consecutive successfully recanalized patients with RCA CTOs were included in our study. All included patients underwent standard echocardiography with TDI and 2DSTE to assess RV function before procedure and repeated after 24 hours and 1 month.

RESULTS: There were no significant changes in tricuspid annular plane systolic excursion, systolic myocardial velocities, and fractional area change values. However, RV global longitudinal strain and systolic strain rate values showed a significant increase at 24 hours after percutaneous coronary intervention compared to baseline (–23.6±4.1% vs. –19.7±3.9%, $p < 0.001$ and –1.55±0.18s^{-1} vs. –1.18±0.17s^{-1}, $p < 0.001$, respectively). Moreover, improvement of the RV functions in patients with RCA CTOs was further suggested by the higher RV isovolumic acceleration values at 1-month compared with baseline (2.29±0.62 vs. 2.05±0.5 m/s^2, $p = 0.014$).

CONCLUSIONS: TDI derived isovolumic acceleration and 2DSTE derived global longitudinal strain and systolic strain rate values showed improvement in RV functions after successful percutaneous recanalization of RCACTOs suggesting viability of RV in chronic ischemia.

Key Words:
Chronic total occlusion, Right ventricle, Two dimensional speckle tracking echocardiography.

Introduction

The prevalence of chronic total occlusions (CTOs) has been reported up to 15% to 30% among patients with suspected or known coronary artery disease[1]. Decision of revascularization mode (percutaneous coronary intervention (PCI) or coronary artery bypass grafting surgery) mainly depends on concomitant significant left main and/or multivessel coronary artery disease[2]. The main treatment targets are relief of symptoms, improvement in left ventricular (LV) functions and survival[3,4]. Some studies showed that opening of CTO is associated with significantly lower mortality than leaving CTO, though other reports did not confirm these observations[5-9]. However, no data exist on regarding possible improvement will occur in right ventricular (RV) functions after successful recanalization of right coronary artery (RCA) CTOs. Novel echocardiographic approaches like tissue Doppler imaging (TDI) and two-dimensional speckle-tracking echocardiography (2DSTE) improved the assessment of myocardial functions in both LV and RV, and may identify subtle changes in response to revascularization procedures[10-12]. Our aim was to assess whether TDI and/or 2DSTE could be considered as early methods for detecting improvement in RV functions in patients with RCA CTOs after successful revascularization.

Patients and Methods

Study Population

Between June 2011 and November 2012, consecutive 41 patients with successfully revascularized single vessel RCA CTOs were enrolled into this prospective registry. All patients had single

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vessel (RCA) coronary artery disease, stable angina pectoris and positive stress test – exercise test, or in some cases, myocardial perfusion scintigraphy. All patients had a proximal RCA occlusion compromising RV branch perfusion. Chronic total occlusion is defined by the Euro CTO Club as "a lesion with a TIMI grade 0 flow within the occluded segment and angiographic or clinical evidence or high likelihood of an occlusion duration ≥ 3 months"[13]. Angiographic success was defined by the same group as "a restoration of TIMI flow grade 3 in the target vessel after stent implantation and a residual stenosis < 15% by visual estimation"[14]. Following the successful RCA CTO recanalization, any serious complications were recorded, including no elevation of myocardial necrosis markers' levels in any patient. We excluded patients who had an anticipated noncompliance with dual antiplatelet treatment for at least 12 months, previous coronary artery bypass surgery, severe valvular disease or more than mild tricuspid regurgitation, non-sinus rhythm, pulmonary hypertension, lung disease, and other co-morbid systemic disease. The study was approved by the Institutional Ethics Committee and informed written consent was obtained from each patient.

Echocardiographic Assessment

Transthoracic echocardiography with a 3.4-MHz multifrequency transducer (Vivid 7, GE Medical Systems, Horten, Norway) was performed to all patients before the PCI, and it was repeated after 24 hours and 1-month. LV ejection fraction was estimated by modified Simpson's rule. Two-dimensional images were acquired from the four chamber view for offline analysis using the 2D strain (speckle-tracking) software (EchoPAC, GE Vingmed Ultrasound, Horten, Norway), as described previously[15]. The software is based on real-time tracking of natural acoustic markers, which allows the derivation of 2D strain and strain rate by comparing displacement of speckles in relation to one another throughout the cardiac cycle. To determine the RV global longitudinal strain (RVGLS) and systolic strain rate (SR), the endocardial border of the RV was traced manually and tracked by the software. Tricuspid annular plane systolic excursion (TAPSE) as a parameter for RV long axis function was assessed with M-Mode cursor positioned at the free wall angle of the tricuspid valve annulus. And also, the RV fractional area change (FAC) was measured from the 2D echocardiographic images from the same 3 cardiac cycles used for the speckle-tracking and TAPSE analysis. RV FAC was calculated as RV area difference (diastole-systole) normalized to RV area in diastole[16]. Pulsed tissue Doppler echocardiography at the apical four-chamber view was performed with the sample volume positioned at the RV free wall tricuspid annular junction. Systolic ($S^{'}$) myocardial velocity was obtained. The myocardial acceleration during isovolumic contraction (IVA) was calculated as the difference between the peak and baseline myocardial velocities divided by the time interval from the onset of the wave during isovolumic contraction to the time at peak velocity[17]. Measurements were made in three cardiac cycles, and the average values were used for statistical analysis.

Statistical Analysis

Results were presented as mean±SD, or frequency expressed as the number of patients (percentages). The absolute values of systolic strain and strain rate were used for analysis to facilitate presentation and interpretation. Intraclass correlation coefficients (ICC) and Bland and Altman analysis were used to assess intra and inter-observer reproducibility for measurements. The differences at the serial measurements of echocardiography were analyzed by repeated measures analysis of variance, followed by Bonferroni's multiple-comparison *t* test. Statistical analyses were performed using standard statistical software (SPSS version 16.0, SPSS Inc., Chicago, IL, USA). A p value < 0.05 was considered statistically significant.

Results

A total of 41 patients were enrolled into the study from June 2011 to November 2012. Table I shows the baseline characteristics of these patients eligible for the study. The pooled data from the 1-month follow-up echocardiographic examinations are presented in Table II. Although TAPSE, $S^{'}$ myocardial velocity, and FAC values improved slightly at 1-month follow-up, the data failed to reach statistical significance. In speckle tracking strain analysis, RVGLS and SR values showed a significant increase at 24 hours after PCI compared to baseline (–23.6±4.1% vs. –19.7±3.9%, $p < 0.001$ and –1.55±0.18s^{-1} vs. –1.18±0.17s^{-1}, $p < 0.001$, respectively). Figure 1 shows representative

Table I. Baseline characteristics of 41 patients with right coronary artery chronic total occlusions.

Age, y	59.6 ± 11.1
Male gender	33 (80%)
Diabetes mellitus	12 (29%)
Hypertension	28 (68%)
Hypercholesterolemia	30 (73%)
History of smoking	27 (66%)
Previous myocardial infarction	28 (68%)
Left ventricular ejection fraction	55.6 ± 9.2

Abbreviations: Value are mean ± SD or n (%).

strain and strain rate analyses of 2D images. And also, improvement of the RV functions in patients with RCA CTOs was further suggested by the higher RV IVA values at 1-month compared with baseline (2.29±0.6 vs. 2.05±0.5 m/s^2, $p = 0.014$). Intra-observer reproducibility for strain and SR was excellent (ICC = 0.91; 95% CI 0.81-95 and ICC = 0.88; 95% CI 0.73-95, respectively). Inter-observer reproducibility for strain and SR was also high (ICC = 0.80; 95% CI 0.60-86 and ICC = 0.73; 95% CI 0.61-80, respectively).

Discussion

The main finding of our study is the TDI derived IVA and speckle tracking derived strain and SR produced a similar picture with respect to improvement in RV contractility in patients with RCA CTOs undergoing successful PCI. Whereas, amelioration in TDI derived S' myocardial velocity, TAPSE, and FAC values failed to reach statistical significance. The Total Occlusion Study of Canada (TOSCA) reported that the restoration of coronary patency of nonacute occluded coronary arteries is associated with a small but significant improvement in regional and global LV function, especially in patients with recent occlusions and depressed LV function[9]. In the Occluded Artery Trial (OAT), 2201 stable patients with a persistently occluded infarct related artery after myocardial infarction were randomized to PCI or optimal medical treatment alone[8]. Overall, there was no difference in the primary endpoint of death, recurrent MI or heart failure. A lack of well-documented benefits from recanalization of CTO may result from unsufficient identification of patients that may benefit mostly. Better results from restoring patency of CTO are likely to be obtained in the group with demonstrated viability of myocardial area associated with this artery[9,18,19]. Our study enrolled patients with angina and positive stress test which indirectly confirmed viability of an area supplied by CTO artery (there were no stenoses in other coronary arteries). RV function is an important prognostic factor in a variety of cardiopulmonary diseases[20-22]. But its echocardiographic evaluation is often difficult because of the complex anatomy of RV[23]. Traditional echocardiographic parameters (TAPSE and FAC) and S' myocardial velocities by TDI only assess longitudinal RV shortening and do not take into account circumferential RV function[24]. In our work, we did not find any significant differences in TAPSE and S' myocardial velocity. The increase in systolic function is probably too small to be detected by TDI because it is angle dependent and influenced by cardiac translational motion and tethering[17]. Like S' myocardial velocity, TAPSE is angle dependent and also, the assumption that basal RV function reflects global function is another limitation[25]. Therefore, they do not have enough sensitivity to detect subtle differences in systolic function, even more in the RV. Despite S'

Table II. Comparison of echocardiographic findings of right ventricular function from. Baseline to 1 month follow-up (n = 41 patients).

Echocardiographic parameters	Baseline	Day 1	Month 1	*p* value
FAC (%)	42.2 ± 5.8	43.2 ± 6.8	44.5 ± 6.6	0.117
TAPSE (mm)	21.4 ± 4.6	22.4 ± 4.3	23.0 ± 4.6	0.095
S'(cm/s)	12.1 ± 2.6	12.5 ± 2.4	13.0 ± 2.7	0.097
IVA (m/s^2)	2.05 ± 0.5	2.14 ± 0.5	2.29 ± 0.6	0.012
RV global longitudinal strain (%)	−19.7 ± 3.9	−23.6 ± 4.1	−24.9 ± 4.3	<0.001
Right ventricle global longitudinal SR (s^{-1})	−1.18 ± 0.17	−1.55 ± 0.18	−1.63 ± 0.22	<0.001

Abbreviations: Value are mean ± SD. FAC = fractional area change; TAPSE = tricuspid annular plane systolic excursion; S' = peak myocardial systolic velocity at lateral tricuspid annulus; IVA = isovolumetric acceleration and SR = systolic strain rate.

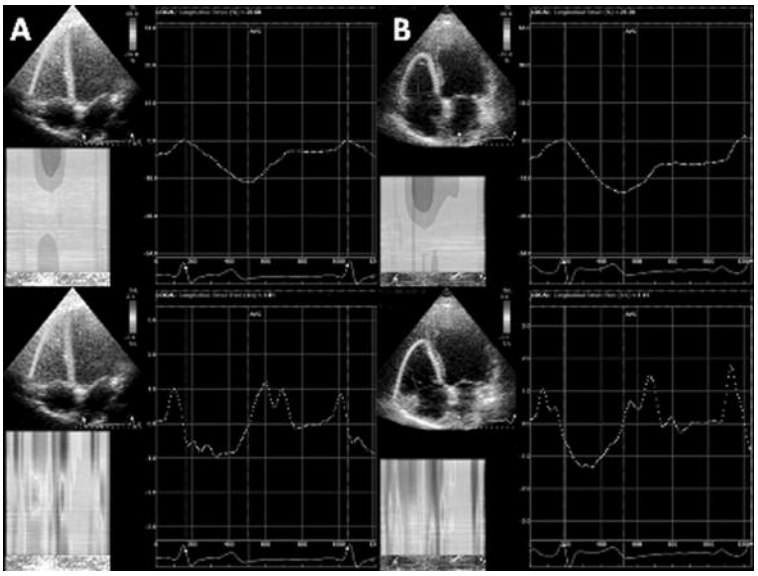

Figure 1. Example of a two-dimensional strain (above) and strain rate (below) measurement of the right ventricle (RV) in a patient with right coronary artery chronic total occlusions who underwent percutaneous coronary intervention (PCI); before (A) and after (B) successful PCI. Apical four-chamber view is shown. The dotted curve is the RV global longitudinal strain and strain rate. The mean RV global peak longitudinal strain and systolic strain rate before and 24 hour-after successful PCI were −20.16% vs −25.38%, and $-1.01s^{-1}$ vs $-1.41s^{-1}$, respectively.

myocardial velocity by TDI, RV IVA appeared to be the most consistent TDI variable for the evaluation of RV function measured by echocardiography[26]. Furthermore, speckle tracking imaging is a new method to analyze cardiac movement, based on its capability to follow a concrete myocardial region. Thus, it can follow it independently of the position or angle of the ultrasound beam. This method is neither angle nor user dependent, nor especially high frame rate, and it does not require any special equipment. 2DSTE-derived strain/SR has added value over TAPSE and RV FAC, because it identifies discrete and localized losses in contractility that is still insufficient to affect global systolic function and, thus, has potential diagnostic and prognostic implications[27]. Rather than the rough estimates of global RV function provided by TAPSE and RV FAC, 2DSTE helps us to determine the unmasking of subtle pathology, the quantification of myocardial function, and the detection of subtle changes over time[28]. Perhaps, our findings could reflect the greater sensitivity of the speckle-tracking technique to detect early subtle alterations in systolic function. Indeed, many of the studies have demonstrated sensitivity and specificity of the speckle tracking technique in the detection of LV function. Recently, this technique has also been used to assess RV function in pulmonary hypertension and RV diseases of different etiologies such as, RV infarction, arrhythmogenic RV dysplasia/cardiomyopathy[29-31]. Also, our results together with previous findings showed that the 2DSTE data were highly reproducible and had a small intra- and inter-observer variability. In fact, ischemic dysfunction is mostly reversible, and RV function usually recovers in the long term[32]. The term RV infarction is a misnomer, and that RV stunning with viability is more appropriate[33]. In our study, RV functions improved after successful RCA CTO revascularization. To best of our knowledge, there are no previous studies assessing RV functions in revascularized RCA CTO patients by 2DSTE derived strain analysis.

A limit of our study is the lack of a gold standard MRI technique for determination of global and regional RV contractility, since cardiac MRI could not be performed due to technical constraints. However, a recent comparative validation study[34], have demonstrated that RV speckle tracking strain is the most closely correlated parameter with cardiac MRI data, and was also the most reproducible echocardiographic parameter.

Moreover, the sample size could reduce the statistical power of our analyses.

Lack of long term follow-up period data, it is not proper to draw a firm conclusion on our findings. In evaluation of RV IVA, as with all tissue Doppler indices, the acquisition technique is important to document. In addition, IVA has been shown to vary with age and heart rate[17].

Despite its strong association with cardiac MRI RV ejection fraction, speckle-tracking measurement of strain was not feasible in a high proportion of RV segments. This may relate to its dependence on image quality, and to the thinness of the RV free wall.

Conclusions

TDI derived isovolumic acceleration and 2DSTE derived global longitudinal strain and systolic strain rate values showed improvement in RV functions after successful percutaneous recanalization of RCA CTOs suggesting viability of RV in chronic ischemia.

Disclosure of Interest

None.

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