ORIGINAL RESEARCH

Right ventricular function in ST elevation myocardial infarction: Effect of reperfusion

Ozlem Karakurt MD
Ramazan Akdemir MD

Ministry of Health, Diskapi Yildirim Beyazit Research and Education Hospital, Department of Cardiology, Ankara, Turkey

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Abstract

Purpose: To investigate right ventricle function in successfully reperfused ST elevated myocardial infarction (STEMI) and to compare reperfusion strategies.

Methods: From January 2007 to August 2008, 33 patients with anterior myocardial infarction (MI) and 48 patients with non-anterior myocardial infarction were enrolled in this study. Patients were treated with thrombolytic therapy (TT) or primary percutaneous coronary intervention (PPCI) (Primary intervention: 16 and 25 patients (anterior and non-anterior consecutively), thrombolytic therapy: 17 and 23 patients (anterior and non-anterior consecutively)). Right ventricle (RV) function was analyzed using tissue Doppler investigation (TDI) after 72 hr of successful reperfusion.

Results: There was no difference in right ventricle function assessed by right ventricle TDI Tei index between the PPCI and TT group (0.39 ± 0.20 vs. 0.39 ± 0.17). RV TDI Tei index increased in anterior MI patients treated with either PPCI or TT compared with control group (0.39 ± 0.11 vs. 0.27 ± 0.16 , $P=0.015$ and 0.43 ± 0.18 vs. 0.27 ± 0.16 , $P=0.014$ respectively). RV TDI Tei index did not differ between non-anterior MI patients treated with either PPCI or TT and control group (0.38 ± 0.23 vs. 0.27 ± 0.16 , and 0.37 ± 0.16 vs. 0.27 ± 0.16 , respectively).

Conclusions: RV function deteriorated in STEMI compared with healthy controls. Contrary to the expectation, RV dysfunction was observed in anterior STEMI, but not in non anterior MI. There was no difference in RV function between the two treatment modalities.

Acute myocardial infarction (AMI) is still among the major causes of mortality and morbidity especially in the developed countries. There are two treatment modalities: primary percutaneous coronary intervention (PPCI) and thrombolytic therapy (TT). The Tei Index (Myocardial Performance Index) has become a valuable echocardiographic index for assessment of global systolic and diastolic function. TDI Tei index correlates with pulsed wave measurements.^{1,2} Tei index provides prognostic information in patients with dilated cardiomyopathy, cardiac amyloidosis, acute myocardial infarction congenital heart disease and primary pulmonary hypertension.³⁻¹¹ Increased Tei index is a strong predictor of mortality and morbidity after acute myocardial infarction.⁹⁻¹¹

Duan Y et al. demonstrated that RV TDI Tei index correlated well with the Tei index obtained by pulsed Doppler in fetuses. This demonstrated that RV TDI Tei index is a simple and valuable method of assessing RV global function even in seldom evaluated subjects such as fetuses.¹²

Even if the right ventricle has not faced ischemia it may be affected by left ventricle ischemia. In the GISSI-3 Echo Substudy, RV function deteriorated in acute MI patients and RV function recovery over time

was related to recovery of left ventricle ejection fraction (LV EF). As the LVEF recovery increases, improvement of RV function also increases.¹³ Our purpose was to investigate the presence of RV dysfunction, using RV TDI Tei Index, even when LV systolic function was preserved.

Methods

Patients

The study was approved by the Hospital's ethics committee and all patients gave informed written consent. The study was performed in our Cardiology Clinic from January 2007 to August 2008. Participants enrolled in the study were selected among patients admitted to the emergency department within the three hours of angina onset and hospitalized with a diagnosis of acute AMI for the first time. Inclusion criteria were defined as presence of Acute STEMI with 3 hours of angina onset and achievement of successful reperfusion. AMI was defined by the presence of typical chest pain, ST segment elevation on admission electrocardiograms compatible with MI, and increase of cardiac enzymes in the serum. Eleven female (mean age of: 52.7 ± 11.9 yr) and 70 male (mean age of: 54.8 ± 11.5 yr) patients were included in the study. Exclusion criteria were defined as following: presence of atrial fibrillation or flutter, bundle branch block or any other intraventricular conduction delay, patients who could not be reperfused with thrombolytic treatment and required rescue percutaneous coronary intervention (causing cross-over between groups), renal failure, previous myocardial infarction or coronary artery bypass graft surgery, congenital, pericardial disease, systolic left ventricular dysfunction at 24 hr echocardiographic evaluation and severe valvular heart disease.

Patients were treated by either primary percutaneous coronary angioplasty or thrombolytic therapy. The choice of treatment was decided according to the hospital's facilities at that moment and recommenda-

tions of the last ACC/ESC ST elevation MI guidelines. From the 81 patients matching the selection criteria, 41 patients were treated by primary percutaneous transluminal coronary angioplasty and stenting (16 and 25; anterior and non- anterior consecutively) and 40 were treated with thrombolytic agents (streptokinase) (17 and 23 patients; anterior and non-anterior consecutively). Low flow nasal oxygen, oral ASA (325 mg), clopidogrel (600 mg. loading dose and 75 mg./day maintenance dose), beta blocker (metoprolol succinate 25–50–100–200 mg/day according to the patient's blood pressure, heart rate and clinical status), angiotensin converting enzyme inhibitor (according to the blood pressure), unfractionated heparin, atorvastatin (80 mg) were administered to all patients. The control group consisted of 20 subjects whose clinical characteristics summarized in table 1.

Angiography and Primary Angioplasty Procedure

Before the procedure oral 600 mg. clopidogrel was given to all patients in the cardiac catheterization room. Procedures were performed using standard angioplasty technique with a 6 French (Fr) guiding catheter via the femoral artery. A bolus of 100 IU/kg heparin was administered intra-arterially after insertion of the vascular access.

Target lesions were initially treated with appropriate balloon predilation if necessary, followed by intra-coronary stenting. Bare metal stents were used for all patients. After stent implantation, heparin was administered.

Thrombolytic Treatment

Oral 75mg clopidogrel was given to all patients. Streptokinase was given intravenously 1,5 million Units about 60 minutes. Reperfusion after thrombolytic therapy was assessed by clinical criteria defined as complete relief of chest pain, 50% resolution of ST elevation, development of reperfusion arrhythmias, early CK, CK-MB peak.

TABLE 1. Clinical and echocardiographic characteristics of control and Stemi groups

Characteristics	Control (n=20)	STEMI (n=81)	P
Age (yr)	50±9	54±11	0.17
Sex (male/female)	17/3	70/11	0.86
Smoking (%)	16	66	0.87
Hypertension (%)	5	16	0.60
Diabetes Mellitus(%)	4	21	0.58
Familial coronary artery disease history(%)	6	23	0.88
Hyperlipidemia	4	8	0.21
LV end-diastolic diameter (cm)	5.2±0.30	5.3±0.47	0.24
LV end-systolic diameter (cm)	3.3±0.36	3.5±0.46	0.22
LA diameter (cm)	3.52±0.46	3.69±0.43	0.12
LV ejection fraction with Simpson (%)	61±5	59±9	0.54
RV enddiastolic diameter (cm)	3.13±0.36	3.26±0.56	0.3
Doppler Ea velocity (m/sec.)	14.4 (77-22.1)	12.3 (6.5-23.9)	0.011*
Doppler Aa velocity (m/sec.)	16.9±5.43	16.2±5.45	0.57
Doppler Sa velocity (m/sec.)	16.4±2.25	14.5±3.88	0.03*
a time	395±39.5	418±60.8	0.11
b time	312±29.5	298±50.6	0.24
Tei index	0.27±0.16	0.39±0.18	0.01*

*Statistically significant: $P<0.05$

Echocardiographic Evaluation

All patients underwent two dimensional transthoracic echocardiographic and Doppler study in the left lateral decubitus position from multiple windows. Echocardiographic evaluations were performed after 48–72 hr of acute myocardial infarction. A GE Vivid 3(Isreal) echocardiograph with a 2.5 MHz transducer was used. Echocardiographic measurements were performed according to recommendations of the American Society of echocardiography. Studies were stored on compact disks. The left ventricle volumes and ejection fraction were obtained by the modified biplane Simpson's method. Left atrial, left ventricular end diastolic and end systolic dimensions were measured from the parasternal long axis view. From the apical four-chamber view, the TDI cursor was placed on the right ventricular free wall, 1 cm apical to the tricuspid annulus. From TDI of the RV tricuspid annulus: systolic velocity (Sa), early diastolic velocity (Ea), and late diastolic velocity (Aa) were recorded. In the TDI images, Sa duration was measured as the ejection time

(ET), the time between the end of the Sa and the beginning of the Ea as isovolumetric relaxation time (IRT), and the time between the end of Aa and the beginning of Sa as isovolumetric contraction time (ICT); a time is the sum of IRT, ICT and ET, b time is equal to the ET. Right ventricular Tei index (MPI) was calculated as $(a-b)/b$ (Figure 1). In this study, a Doppler velocity range of -20 to 20 cm/s was selected.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences software (SPSS for Windows). Categorical data are presented as absolute values and percentages, whereas continuous data are summarized as mean value±SD. Chi-squared and Fisher's exact tests were used for comparison of categorical variables as appropriate. Comparison of continuous variables was performed by means of Student's t-test or Wilcoxon rank-sum test, as appropriate. P values <0.05 were considered statistically significant.

FIGURE 1. Estimation of RV Tei index (Myocardial Performance Index) with tissue doppler imaging. Tei index = (a-b)/b. (a=IRT+ICT+ET, b=ET).
Sa: systolic velocity, Ea: early diastolic velocity, Aa:late diastolic velocity

Results

Baseline clinical characteristics of MI patients and the control group are summarized in Table 1. There were no differences in age, sex, hypertension, diabetes, smoking, or familial coronary artery disease history between groups. On echocardiographic evaluation, results were similar between groups for left atrium diameter, left ventricular end diastolic and end systolic diameters, right ventricular end diastolic diameter, left ventricular ejection fraction, TDI Aa velocity, a and b time. Ea and Sa velocities were higher in the control group than in the MI patients. RV Tei index increased in MI patients more than in control subjects (0.39 ± 0.18 vs 0.27 ± 0.16 , $P=0.01$) (TABLE 1& Figure 2). When the PPCI and TT groups were compared, no differences were observed for Ea, Aa, Sa velocities, a, b time and RV Tei index (TABLE 4& Figure 2). But comparing PPCI group with the control group, we found that in the PPCI group, Sa and had diminished and Tei index had increased (TABLE 2 & Figure 2). In comparison with control subjects, MI patients

FIGURE 2. Comparison of RV Tei Index.
Group 1: STEMI patients treated with PPCI
Group 2: STEMI patients treated with TT
Group 3: Control group
Differences between group 1-3 and group 2-3, * $P<0.05$

treated with TT had lower Ea velocity, value and higher Tei index (TABLE 3).

On subgroup analysis, anterior MI and non anterior MI (MI localization except anterior region) subgroups displayed different RV function properties. Anterior MI patients treated with PPCI had lower Sa and higher Tei index values than control subjects (13.9 ± 3.1 vs. 16.4 ± 2.25 , $P=0.009$ and 0.40 ± 0.11 vs. 0.27 ± 0.16 , $P=0.015$ respectively). Also, anterior MI treated with TT had lower Ea and higher Tei index values than the control group (11.5 ± 3.0 vs. 14.4 ± 3.31 , $P=0.011$ and 0.43 ± 0.18 vs. 0.27 ± 0.16 , $P=0.014$ respectively). On the other hand, non-anterior MI treated with PPCI were different from the control group only at Sa and Ea values (14.4 ± 3.5 vs. 16.4 ± 2.25 , $P=0.03$ and 11.9 ± 3.4 vs. 14.4 ± 3.31 , $P=0.01$), but Tei index was not different (0.39 ± 0.23 vs. 0.27 ± 0.16). Non-anterior MI treated with TT had similar Tei index value as the control group (0.37 ± 0.16 vs. 0.27 ± 0.16), although Ea velocity was lower in the MI patients (11.9 ± 3.7 vs. 14.4 ± 3.31 , $P=0.03$ respectively).

TABLE 2. Echocardiographic characteristics of control group and STEMI treated with primary PCI GROUP

Characteristics	Control group (n=20)	STEMI treated with primary PCI group (n=41)	P
LV enddiastolic diameter (cm)	5.2±0.30	5.3±0.41	0.11
LV end systolic diameter (cm)	3.3±0.36	3.5±0.35	0.16
LA diameter (cm)	3.52±0.46	3.71±0.41	0.10
LV ejection fraction with Simpson (%)	61±5	60±8	0.86
RV enddiastolic diameter (cm)	3.13±0.36	3.24±0.56	0.41
Ea velocity (m/sec.)	14.4 ± 3.31	12.9± 3.45	0.109
Aa velocity(m/sec.)	16.9±5.43	15.2±5.63	0.25
Sa velocity (m/sec.)	16.4±2.25	14.2±3.35	0.011*
a time	395 (320-494)	414 (323-594)	0.21
b time	312±29.5	296±46.1	0.17
Tei index	0.27±0.16	0.39±0.20	0.023*

*Statistically significant: $P<0.05$

TABLE 3. Echocardiographic characteristics of control group and Stemi treated with thrombolytic therapy group

Characteristics	Control group (n=20)	STEMI treated with thrombolytic therapy group (n=40)	P
LV enddiastolic diameter (cm)	5.2±0.30	5.3±0.52	0.48
LV end systolic diameter (cm)	3.3±0.36	3.5±0.56	0.32
LA diameter (cm)	3.52±0.46	3.67±0.44	0.24
LV ejection fraction with Simpson (%)	61±5	58±10	0.35
RV enddiastolic diameter (cm)	3.13±0.36	3.24±0.55	0.25
Ea velocity (m/sec.)	14.4 ± 3.31	11.8± 3.47	0.007*
Aa velocity(m/sec.)	16.9±5.43	17.2±5.13	0.87
Sa velocity (m/sec.)	16.4±2.25	14.7±4.39	0.10
a time	395 (320-494)	422 (328-631)	0.14
b time	312±29.5	300±56.2	0.40
Tei index	0.27±0.16	0.39±0.17	0.013*

*Statistically significant: $P<0.05$

Discussion

In this study, we demonstrated that, in patients with anterior MI, irrespective of the treatment, RV Tei index increased and RV function deteriorated compared with normal subjects. No difference was observed in right ventricular function as assessed by RV TDI MPI between the two treatment methods. When we analyzed the STEMI group in terms of MI localization, in the non anterior group RV Tei index was no different from controls. In the LV Tei index analysis, in the anterior MI group, LV Tei index was higher than in the

non anterior MI group. As there was no difference for LV EF between anterior and non anterior MI groups, the increase in LV Tei index may be explained by impaired LV diastolic function. Thus, in successfully reperfused non anterior MI, RV function is preserved better than in the successfully reperfused anterior MI. Decreased LV diastolic function results in decreased RV function in anterior MI irrespective of the treatment method.

RV TDI measurements are used to diagnose many diseases and predict prognosis. Alam et al. demon-

TABLE 4. Echocardiographic characteristics of primary PCI and thrombolytic therapy group

Characteristics	STEMI treated with primary PCI group (n=41)	STEMI treated with thrombolytic therapy group (n=41)	P value
LV enddiastolic diameter (cm)	5.3±0.4	5.3±0.5	0.46
LV end systolic diameter (cm)	3.5±0.35	3.5±0.56	0.99
LA diameter (cm)	3.7±0.41	3.6±0.44	0.62
LV ejection fraction with Simpson (%)	60±8	58±10	0.35
RV enddiastolic diameter (cm)	3.24±0.56	3.28±0.55	0.72
Ea velocity (m/sec.)	12.9± 3.45	11.8±3.47	0.15
Aa velocity(m/sec.)	15.2±5.63	17.2±5.13	0.1
Sa velocity (m/sec.)	14.2±3.35	14.7±4.39	0.6
a time	404 (332-462)	388 (351-448)	0.56
b time	296±46.1	300±56.2	0.72
Tei index	0.39±0.20	0.39±0.17	0.95

*Statistically significant: $P < 0.05$

strated that, in patients with inferior myocardial infarction and lead V4R elevation, RV Sa was lower than in patients without V4R elevation as was RV Ea.¹⁴ Dokainish H et al. found that RV Sa could be used to determine RV infarction in inferior myocardial infarction and to predict cardiac death or heart failure at one year.¹⁵ In congenital heart disease, RV TDI parameters may be correlated with invasive hemodynamic indices and RV ejection fraction by magnetic resonance imaging. RV Sa was associated not only with RV function but also with LV systolic function. RV Sa was lower in patients with LV systolic heart failure than in healthy subjects.¹⁶ Strong linear correlation has been observed between RV Sa and RV fractional area change (RVFAC), which is a measure of RV systolic function.¹⁷ The two ventricles of the heart are not only interconnected anatomically, but they are also functionally dependent. During normal sinus rhythm, the tension generated by LV contraction and the increased left-to-right trans-septal pressure gradient that supports the interventricular septum during systole, contributes to RV systolic function. These mechanisms enhance the RV free wall and interventricular wall contraction.¹⁸

It is well recognised that RV dysfunction adversely affects LV diastolic properties via diastolic interactions composed by the interventricular septum (IVS) and amplified by elevated intrapericardial pressure. RV dilatation and elevated RV diastolic pressure shift the IVS toward the LV and impede LV diastole and vice versa in RV diastole. As a consequence, RV dilatation in the non compliant pericardium leads to elevation of intrapericardial pressure. This pericardial constraint, forming a vicious circle, results in biventricular diastolic failure.^{19,20}

Alteration in left ventricle function impairs RV function. Left ventricle function does not consist only of systolic function, even if left ventricle systolic function is normal, deterioration of left ventricular diastolic function results in RV dysfunction. In the GISSI-3 Echo Substudy, it was shown that RV function deteriorated in acute MI patients and RV function recovery, over time, was related to the left ventricle ejection fraction (LV EF) recovery. As the LVEF recovers, improvement of RV function also increases.¹³

Akdemir et al demonstrated that, in patients with acute anterior MI, TAPSE as an indicator of RV function was lower than in the control group in the ab-

sence of apparent systolic dysfunction. This was attributed to RV diastolic dysfunction.²¹

In conclusion, we demonstrated that, contrary to the expectation, anterior MI results in RV dysfunction when compared with non-anterior MI. This relationship is explained by the effect of LV diastolic dysfunction on RV function. As two chambers of the heart beat together, every stimulus effecting LV systolic or diastolic function will also have an impact on RV function. The effect of the RV should be remembered in anterior MI, perhaps more than in non-anterior MI.

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Correspondence to:

Özlem Karakurt, MD
Ministry of Health, Dışkapi Yıldırım Beyazıt Research and Education Hospital,
Department of Cardiology, Ankara, Turkey.
e-mail: ozlemkarakurt55@yahoo.com