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The Role of Doppler Imaging in the Assessment of Right Ventricular Function: a Case-control Study of Acute Inferior Wall Infarction

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ABSTRACT

Background: Right ventricular infarction (RVI) develops in 30-50% of patients with inferior wall infarction (IWI). The rates of mortality, morbidity, and complications in these patients are greater than in the patients without RVI. We compared the tissue Doppler imaging (TDI) indices between a group of patients with IWI and RVI, with a similar group of patients who had IWI alone to investigate the application of TDI indices in the evaluation and detection of right ventricular function. **Material and Methods**: We studied 49 patients with first acute IWI in two groups. Group 1 (N=24) were patients with IWI and RVI while group 2 consisted of patients with IWI alone (N=25), based on standard electrocardiogram criteria. The peak systolic (Sm), peak early (Em) and late (Am) diastolic velocities, and Em/Am ratio were obtained from the apical four chamber view, at the lateral side of the tricuspid annulus. We measured trans-tricuspid early (ET) and peak (AT) filling velocity, ET/AT ratio, right ventricular end diastolic diameter (RVEDD), and tricuspid annular plane systolic excursion (TAPSE) by M-mode TDI projected at the long axis of parasternal view. **Results**: The RVEDD and E/Em ratio were increased, while the TAPSE was significantly decreased in the patients with RVI as compared to those without RVI (4.7± 0.6 vs. 3.1±0.2 cm; $p < 0.005$, 5.6±2.21 Vs 4.5±1.2; $p<0.006$ and 1.7±0.4 vs. 2.3±0.5 cm; $p <0.0001$, respectively). However, the other statistically measured parameters were not significantly different between these groups. **Conclusion**: The measurement of RVEDD, E/Em ratio, and TAPSE, as right ventricular myocardial systolic and diastolic parameters by pulse wave TDI could be used to objectively assess the status of RV condition in patients with first acute IWI.

Keywords: Tissue Doppler imaging, Inferior wall myocardial infarction, Systole, Diastole, Echocardiography, Right ventricular function.

1. INTRODUCTION

Right ventricular infarction (RVI) develops subsequent to inferior wall infarction (IWI) in approximately 30–50% of the patients, and may lead to an increase in mortality or major complications (1, 2). The presence of RVI raises the risks of shock, arrhythmia, and death in the patients with IWI (1). The proximal occlusion of the dominant right coronary artery (RCA) is usually responsible for right ventricular (RV) infarction in patients with IWI with a relative risk of 3.0 (3). Diagnostic techniques, such as electrocardiography (ECG) and echocardiography are used for the initial evaluation of RV function in these patients (4). The evaluation of RV function during systole and diastole plays an important role in determining the prognosis and clinical outcomes of these patients (5).

Tissue Doppler imaging (TDI) has evolved as a technique that measures myocardial velocities and as an indicator of global right and left ventricular function (5, 6). It can also measure the movements of the myocardial walls during systolic and diastolic periods (7). Studies have recommended the use of TDI for the assessment of the RV function through the analysis of the tricuspid annular motion and systolic annular velocity (8, 9), systolic and diastolic time intervals (8, 10), and the RV strain and strain rate (11). Although there are preliminary data on the role of TDI in the investigation of RVI in patients with IWI (8, 12), there are few studies that have addressed the assessment of RV function in these patients, using TDI during systolic and diastolic phases.

2. AIM

The aim of this study was to compare the TDI indices in patients with IWI, with or without RVI, and to investigate the beneficial effects of such an assessment. The investigation can raise the objectivity and sensitivity of RV function assessment in patients with acute IWI (13).

3. MATERIALS AND METHODS

Subjects: We clinically evaluated 57 patients with acute IWI who had been referred to Mazandaran Heart Center, Sari, Iran, over a six month period (February-August 2015). These patients had suffered their first acute IWI and presented with significant ST-segment elevation on their ECG test.

Inclusion criteria: The inclusion criteria were, a) having characteristic chest pain, b) ≥1 mm ST-segment elevation in two out of three inferior leads (II, III, aVF), c) a rise of double the normal amount of blood troponin-I and creatine kinase-MB (CKMB) levels, d) and taking prescribed thrombolytic medications (14).

Exclusion criteria: The exclusion criteria were a) refusal to consent, b) having a history of previous MI or heart failure, c) previous abnormal function in left or right ventricles, d) documented significant valvular disease (e.g., stenosis or moderate regurgitation), e) pulmonary hypertension, f) atrial fibrillation (AF), g) paced rhythm cardiomyopathy, h) chronic obstructive pulmonary disease (COPD), i) a history of coronary artery bypass grafting (CABG), and j) left and/or right bundle branch block. Based on the inclusion and exclusion criteria, 49 patients with IWI were recruited into the study. Twenty-five patients had IWI without RVI, and the other 24 had been diagnosed with combined IWI and RVI. The diagnosis of combined IWI and RVI was made based on a ST-segment elevation of more than 0.1 mV in V3R and V4R in addition to leads II, III, and aVF in an ECG taken within six hours of the symptoms onset (15).

Echocardiography: For transthoracic echocardiography, M-mode, 2D color Doppler and TDI, we used a Vivid S5 echocardiographic unit (General Electric, Boston, MA, USA) in supine and left lateral decubitus positions, according to the American Society of Echocardiography guidelines (16). We adjusted the pulsed wave Doppler program by filtering for high-frequency signals. Concerning the mitral annular segments, two predefined consecutive cardiac cycles were used to achieve color-coded tissue Doppler images that were tested for customized image visualization, processing, and analysis, using a software package on a personal computer.

Myocardial velocity: For the measurements of myocardial velocities from the apical four-chamber view, the sample volume of 2 mm was placed at the lateral and medial mitral valve annulus at the junction of interventricular septum. We recorded the velocity profiles of peak systolic velocity at lateral mitral valve annulus (Sm), or SmRV or S'RV or Sa, peak early diastolic velocity at lateral mitral valve annulus (Em) or E'RV, and peak late diastolic velocity at lateral mitral valve annulus (Am) or A'RV waves (17).

Right ventricular assessment: For the RV assessment by TDI, the sample volume was placed 1 cm above the tricuspid annulus at the RV free wall in the apical four-chamber view. The mean systolic tricuspid annular velocity, and both early and late tricuspid diastolic velocities were measured in centimeters per second. The RV dimension was estimated at the end-diastole from a right ventricle-focused apical 4-chamber view. This demonstrated the maximum diameter of the RV, while the crux and apex of the heart were in the view (18). The tricuspid annular plane systolic excursion (TAPSE) was examined by placing an M-mode cursor through the lateral tricuspid annulus in an apical 4-chamber view, measuring the extent of longitudinal motion of the annulus at peak systole (18).

Institutional approval: The Ethics Committee of Mazandaran University of Medical Sciences approved the conduction of this study. Upon the initial interview, the objectives and design of the study were described to the participants and an informed written consent was obtained from each. Patients were also assured that the data would remain strictly confidential. Baseline characteristic and clinical data were collected prospectively from the enrolled patients. These data included age, gender, history of diabetes mellitus (DM), hypertension, hyperlipidemia, and smoking.

Statistical analysis: Mean ± standard deviation (SD) was used to describe the continuous variables with a normal distribution assessed by Kolmogorov-Smirnov test. The independent samples T-test analyzed the differences for the mean continuous data between the two study groups. The qualitative data were compared using the Chi-squared test.

4. RESULTS

Fifty-seven patients with a first, acute IWI were admitted consecutively to the hospital during the study period. Two patients were excluded because they had a history of heart failure, three subjects were excluded because of a previous infarction, and three were excluded because they had AF dysrhythmia. Thus, 49 patients were included in the study, i.e., 30 men (61.2%) and 19 women (38.8%). The mean age ± SD of all patients with IWI was 56.2±11.6 years, with the age range being between 31-

Variables	Inferior Wall Infarction		P-value
	With RVMI (n=24)	No RVMI (n=25)	
Age	56.84 ±11.30 (58)	55.54 ±12.08 (53)	0.52
Male	11(45.8)	19(76.8)	0.42
DM	10(41.7)	8(32)	0.27
Hypertension	11(45.8)	11(52)	0.65
Hyperlipidemia	10(41.7)	8(32)	0.15
Smoking	12(50)	12(48)	0.35

Table 1. Basic and clinical characteristics of patients with IWI and without RVI.. . Measures of P-value were obtained through independent sample T-test.. Data are shown as mean ± standard deviation (median) or number (percent).. IWI: Inferior wall myocardial infarction. RVI: Right ventricular myocardial infarction. DM: Diabetics mellitus

Variables (unit)	Inferior Wall Infarction		P-value
	With RVI (n=24)	No RVI (n=25)	
Trans-tricuspid early rapid filling velocity (ET)	45.23±10.82 (46.5)	42.56±10.02 (44)	0.31
Trans-tricuspid peak atrial filling velocity (AT)	43.02±13.27 (43)	50.75±22.13 (45)	0.25
Em(cm/s)	9.02±3.55 (8.45)	9.94±3.22 (9.11)	0.25
Am(cm/s)	13.45±5.24 (13.3)	13.65±3.03 (13.8)	0.75
Sm(cm/s) or SmRV	10.63±3.62 (9.7)	12.19±2.79 (11.6)	0.06
TAPSE (cm)	1.78±0.45 (1.7)	2.35±0.51 (2.3)	<0.0001*
RVEDD (cm)	3.44±0.35 (3.5)	3.19±0.28 (3.2)	0.009*
E/A	1.12±0.44 (1.11)	0.95±0.39 (0.9)	0.11
E/Em ratio	5.60±2.23 (5.4)	4.51±1.28 (4.34)	0.04*

Table 2. Tissue Doppler imaging indices in patients with IWI, with or without RVI.. . * P-value lower than 0.05 was considered significant level. Measures of P-value were obtained through independent sample T-test. Data are shown as mean ± standard deviation (median).. IWI: inferior wall infarction. RVI: right ventricle infarction. Sm: Peak systolic velocity at lateral mitral valve annulus. Em: Peak early diastolic velocity at lateral mitral valve annulus. Am: Peak late diastolic velocity at lateral mitral valve annulus. TAPSE: Tricuspid annular plane systolic excursion. RVEDD: Right ventricular end diastolic diameter. Trans-tricuspid early rapid filling velocity (ET). Trans-tricuspid peak atrial filling velocity (AT).

83 years. Twenty-four patients (49%) had the first RV infarction (men=36.7%; women=68.4%). As noted in Table 1, there were no significant differences in terms of gender, age, history of diabetes, hypertension, and hyperlipidemia between the two groups of patients ($p<0.05$).

The results indicated that the indices of TAPSE, RVEDD, and E/Em ratio were significantly different between the two groups of IWI patients, with and without RVI. Other echocardiographic parameters were not significantly different between the two groups. A comparison of the TDI and conventional echo indices in the study patients have been presented in Table 2. As shown in Table 2, the TAPSE index of 24.26% was decreased in patients with both IWI and RVI in comparison with patients who had IWI alone. The percentage of change in RVEDD and E/Em ratio indices in patients with combined IWI and RVI were also higher than those with IWI alone (19.47% vs 7.26% , respectively).

5. DISCUSSION

Acute myocardial infarction and its complications have been one of the main causes of mortality despite considerable advances made in the clinical management of these patients (2). In several studies, TDI was used for the detection of RV dysfunction with high sensitivity and specificity (19, 20). Echocardiographic findings of RV systolic and diastolic function in patients with IWI alone versus those with combined RVI and IWI showed that the RVEDD, E/Em ratio indices were remarkably higher and the TAPSE value was significantly lower in patients with coexisting IWI and RVI. Also, there were systolic and diastolic dysfunction in patients with combined IWI and RVI. Other statistically measured parameters between the two groups were not significantly different.

TAPSE is an independent predictor of mortality in patients with IWI (21). Traditionally, TAPSE <16 cm has been associated with RV systolic dysfunction (21, 22). In a prospective cohort study of 31 patients, annular movement and velocities along with the TAPSE index were measured by TDI (23). These data were collected before and after thrombolytic therapy and angiography. The results showed that TAPSE, tricuspid systolic velocity (Sa), and peak early and late diastolic velocity (E′ and A′) were significantly higher in the patients without RVI than in those with RVI, before treatment with thrombolytic medications (21.6 ± 2.1 mm vs. 16.2 ± 2.0 mm, 136.1 ± 8.8 mm/s vs. 110.0 ± 12.6 mm/s, 133.0 ± 8.6 mm/s vs. 91.3 ± 14.1 mm/s, and 146.4 ± 13.1 mm/s vs. 132.1 ± 10.6 mm/s, respectively). Furthermore, the comparison of the TDI indices before and after the thrombolytic therapy revealed a significant difference in TAPSE and Sa in patients with combined RVI and IWI. The TAPSE and systolic velocity increased significantly after thrombolysis compared to pre-thrombolysis (113.0 ± 12.7 mm/s vs. 17.6 ± 1.8 mm), respectively. The diastolic velocities did not change significantly after thrombolysis in patients with RVI. We believe that measuring the tricuspid annular movement and velocity measurement by TDI might have contributed to the RV dysfunction in patients with IWI. Our study findings were consistent with those reported by the above study, since the authors demonstrated that the TAPSE also significantly decreased in patients with combined IWI and RVI, unlike in those with IWI alone. Moreover, several studies concluded that TAPSE is useful in predicting proximal RCA stenosis and may be used to assess the RV function in the first episode of acute IWI (12, 21, 24). Dokainish et al. (9) found significant differences in the RV end-diastolic dimension indices between patients with combined IWI and RVI than in those with IWI alone. These researchers suggested that RV diastolic dimension, TD imaging of tricuspid annular systolic velocity, early diastolic velocity, and systolic annular velocity to be the univariate predictors of RVI. We also noted a considerable increase in right ventricular end diastolic diameter in patients with combined IWI and RVI compared with those who had IWI alone. It appears that the RVEDD index could be considered as an important diagnostic element in the evaluation of RV function in patients with IWI. In another study (5) the mean of the RV diameter was reported as being 27.1 + 1.9 mm vs. 25.5 + 1.7 mm in patients with concurrent IWI and RVI versus those with isolated IWI. The difference in the above mentioned indices between the two arms of the study was not significant. The reported RV diameter in that study differs from the RV end diastolic size in our study. The difference may arise from differences between the populations in the two studies. In our study, the E/Em ratio in patients with combined IWI and RVI was significantly higher than in that record-

ed for the IWI patients. Mukhaini et al. (1) studied 35 patients with first IWI and categorized them into those with or without RVI, based on the standard ECG criteria only. This study demonstrated that the Sm, Em, and Em/Am ratio were significantly reduced in the patients with combined IWI and RVI as compared with those without RVI. Differences between the Sm, Em, and Em/Am ratio between the IWI patients, with RVI were 2.9 cm/sec, 3.7 cm/sec, and 0.25, respectively (1). Another study (14) was conducted in a population of 76 patients with their first episode of acute IWI, significant RCA involvement and their echocardiographic examinations done before revascularization. The patients with proximal RCA had a remarkably lower Sm before revascularization in comparison with that reported for patients after reperfusion (10.44 ± 2.61 cm/s vs. 12.11 ± 2.94 cm/s). The results of that study identified the tricuspid annular plane systolic excursion and Sm as the most independent predictors for proximal RCA lesions. In our study, the Sm parameter in the patients with RVMI was similar to that study's findings. We also found a 1.56 cm/s reduction in the Sm index among patients with combined IWI and RVI compared to those with IWI alone. However, the differences between the two groups were not significant.

6. CONCLUSION

The myocardial infarction associated with right coronary artery is a clinically important condition because it can lead to high mortality. Tricuspid annular movement and velocity measurements by TDI can contribute to the accurate diagnosis of RV involvement in patients with IWI. Measuring the right ventricular end diastolic diameter, tricuspid annular plane systolic excursion, and E/Em ratio could be considered as a useful approach to the evaluation of the RV function in patients with IWI. We suggest that diagnostic studies should be designed to evaluate the predictable role of these TDI indices for the detection of subsequent RVI in patients suffering from an initial IWI. Moreover, more well-design studies can develop to compare occluded arterial segments and type of coronary dominant among patients with acute inferior wall infarction with RVI and IWI alone.

- **Conflicts of interest**: none declared.
- **Author's contributions**: All authors had significant contributions to all aspects of this research project.

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