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Crescent Journal of Medical and Biological Sciences
Vol. 7, No. 2, April 2020, 243–248
eISSN 2148-9696

Echocardiographic Assessment of Right Atrial Volume Index in Acute Inferior Myocardial Infarction Patients

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Abstract

Objectives: Acute myocardial infarction can cause the right ventricle (RV) dysfunction. The echocardiography (ECHO) can provide the first clue to RV involvement in patients with inferior MI. In addition, the echocardiographic assessment of RV function can help in the early diagnosis and management of these patients in whom ECG cannot be diagnosed for RV involvement. Consequently, the current study measured the right atrium (RA) volume index instead of conventional RV echocardiographic parameters in order to evaluate the RV function in patients with poor RV echo windows.

Materials and Methods: To this end, 116 patients with inferior myocardial infarction (MI) (66 with isolated inferior and 50 with inferoRV MI) were included after 24-72 hours after MI. Furthermore, RV systolic function parameters were measured, including tricuspid annular plane systolic excursion (TAPSE), fractional area change, and peak systolic velocity of the tricuspid annulus at tissue Doppler imaging (TDI) mode (RVSm). Finally, monoplane Simpson's and biplane area length methods were used to measure RA volume index in these patients.

Results: Based on the results, the RA volume index was high in both inferior and inferoRV MI patients but was significantly higher in inferoRV MI. Patients with inferoRV MI more likely had RAEF≤35%, high E/E', and high right ventricular end-diastolic diameter (RVEDD) compared to isolated inferior MI. The correlation between RAVI in both groups was very significant with E/E' and RVEDD.

Conclusions: RA volume index is a good parameter for demonstrating RV dysfunction in patients with inferior and inferoRV MI.

Keywords: Inferior myocardial infarction, Echocardiography, Right atrial volume index, Right ventricle dysfunction

Introduction

Acute inferior myocardial infarction (MI) can cause systolic and diastolic dysfunction in both right ventricle (RV) and left ventricle (LV) (1). Primary percutaneous coronary intervention (PCI) is a streamline therapy in most patients with ST-segment elevation MI given recent improvements in PCI techniques (2).

In-hospital morbidity and mortality have increased after inferior STEMI and those with concomitant RV involvement (3,4). Despite multiple studies about the right atrium (RA) volume index measurement in chronic systolic heart failure patients and its role in predicting the outcome of these patients, there is no similar study in acute MI patients. Besides, the important prognostic role of RV involvement in inferior MI in predicting the outcome, on the one hand, and the challenging evaluation of RV systolic function by conventional echocardiography methods due to special RV anatomy and position in the chest, on the other hand, prompted us to evaluate RA volume index for the first time in acute inferior MI patients. It is believed that RA volume index measurement may open up for easier and earlier evaluation of RV systolic function in acute inferior MI. RV systolic dysfunction is associated with poor long-term prognosis (5,6). Despite some degree involvement of RV in roughly 50% of patients with inferior MI, only a third of them simultaneously demonstrates the ECG changes of RV MI. Unlike the LV, the anatomical position and form of RV make it difficult for conventional methods to evaluate its function. Thus, echocardiography was used to study RV function although the precise echocardiographic assessment of RV systolic function is challenging (7).

Recent reports have shown the role of RA volume index in determining RV systolic dysfunction and predicting low functional capacity and adverse outcomes among heart failure patients (8-11). There are very few studies regarding right atrial function in acute MI. Considering the possible RV dysfunction in inferior MI, it is possible that RA volume index measurement could be helpful in predicting the outcomes in patients with inferior MI. In

Received 16 November 2018, **Accepted** 11 April 2019, **Available online** 28 April 2019

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the past, the RA received little attention when assessing the impact of inferior MI on RV. Contrarily, the focus has recently shifted toward the RA because the RA size has diagnostic and prognostic significance in hypertension and heart failure patients under examination. The RA has triple important act in the cardiac cycle including its reservoir, conduit, and pump functions.

Due to the rapid recovery of RV ischemia, high RA volume index, despite normal conventional RV echocardiographic parameters (e.g., tricuspid annular plane systolic excursion [TAPSE], fractional area change, and RVSm) can be a footprint of transient RV dysfunction or ischemia that can be missed if the RA volume index is not measured. Therefore, normal conventional RV parameters cannot alone rule out RV ischemia and dysfunction in inferior MI patients thus high RA volume index raises our clinical suspicion that these patients have some degree of transient RV ischemia and high right ventricular end-diastolic diameter (RVEDD), which can have prognostic importance in such patients. The ability to visualize the RA allows a quantitative, highly reproducible assessment of the RA volume that can be indexed to the body surface area. A recent study reported that RA reservoir and conduit functions were impaired in patients with inferior and RV MI compared to those with inferior MI (12).

Accordingly, the present study evaluated the RA volume index in inferior and inferoRV MI and its correlation with RV indices.

Moreover, the measurement of RA volume index by monoplane Simpson's method with 2D echo is considered as a novel method that no other study has so far used for these patients. Thus, the current study investigated the correlation of RA volume index with RV function parameters in patients with inferior and inferoRV MI.

Materials and Methods

In this study, 116 patients were recruited, who suffered from inferior MI (66 cases with inferior MI and 50 cases with both inferoRV MI on the basis of ECG) and were admitted to Tertiary Referral Heart Center, Tabriz, Iran between October 2015 and October 2016. The exclusion criteria were non-inferior MI patients who referred after 72 hours following MI, left ventricle ejection fraction <40%, atrial fibrillation, and any supraventricular arrhythmias, coexisting moderate to severe tricuspid regurgitation (TR) and moderate to severe pulmonary hypertension (PH), concurrent cor pulmonale or chronic obstructive pulmonary disease, or previous MI.

The methods of evaluation by echocardiography were two-dimensional (2D), color-flow and spectral Doppler, and tissue Doppler imaging (TDI) using a GE Vingmed Vivid 7 system (GE Vingmed Ultrasound, Horten, Norway). All images were analyzed by an experienced echocardiographer who was blinded to the study. The global systolic function of the RV function was assessed as TAPSE, RV fractional area change (FAC), and RVSm. TAPSE is referred to as tricuspid annular displacement, which reflects longitudinal shortening and movement of the RV. TAPSE is measured in the apical four-chamber view by placing an M-MODE cursor on the lateral annulus and measuring the peak distance travelled by this reference point during the systole. Additionally, RV FAC is the percent change in RV area from diastole to systole and reflects the systolic function of RV inflow, as well as the apical portions of the RV and is measured in apical four-chamber view by manually tracing the end-diastolic and -systolic areas of the RV (cm^2). In addition, RV FAC is calculated as FAC= (End diastolic RV area -End systolic RV area/-End systolic RV area)*100. The RVEDD was measured at the level of the tricuspid annulus in the RV focused view.

Further, pulsed Doppler echocardiography was performed to evaluate the diastolic filling velocities of both ventricles. The RV diastolic function was evaluated by pulsed Doppler of the tricuspid inflow in RV modified view for better alignment on TR jet and tissue Doppler of the lateral tricuspid annulus (Figures 1A and 1B). Thus, the peak early diastolic filling velocity (E-wave) and peak late diastolic (A-wave) filling velocities were recorded. Furthermore, the TDI of the tricuspid annulus was required in apical the four-chamber view. Moreover, the peak systolic (S wave), early diastolic velocity (E'), and late diastolic velocity (A') of the tricuspid annulus were measured by placing pulsed Doppler on the lateral tricuspid annulus at the TDI mode.

The percent change in RA volume from diastole to systole is RA EF that was measured in RV focused view by manually tracing the contour of RA at its largest and smallest volumes. RAEF formula is as follows:

RAEF = the largest RA volume - the smallest RA volume/ the largest RA volume * 100

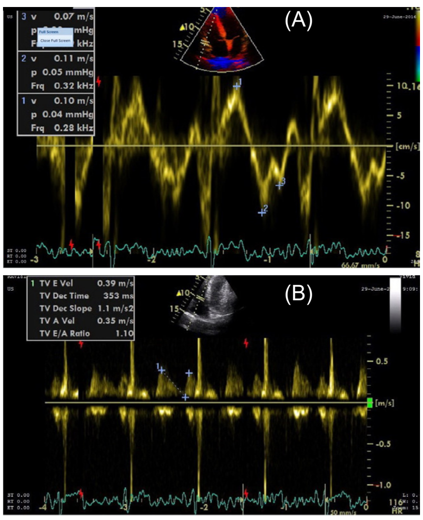

Figure 1. (A) Tissue Doppler Assessment of RV Systolic Function. (B) Assessment of TV Inflow With Pulse Doppler.

The RA volume index was calculated twice using the single-plane Simpson's method (Figures 2A and 2B) in the apical four-chamber view and biplane area length (Figures 3A and 3B) in the apical four-chamber and RV inflow views, and then indexed to body surface area.

Statistical Analysis

All the data were analyzed by using SPSS 16. The results were expressed as the MD ± SD or percentage. Similarly, continuous variables were compared within each group using Student's *t* test whereas the categorical variables were compared using Chi-square statistics or Fisher exact test when appropriate. Finally, Pearson correlation was used to define possible correlations with RA volume index and *P* values of less than 0.05 were considered statistically significant.

Results

One hundred and sixteen patients were studied, including 92 males and 24 females within the age range of 61.75 ± 11.37 encompassing 66 with inferior (56.9%) and 50 with inferoRV MI (43.1%). Forty-six cases (53.4%) with the right coronary artery (RCA) as culprit lesion, 13 cases with left circumference (LCX) as culprit lesion and both RCA and LCX in three cases and the remaining patients (54 cases) received fibrinolytic or medical treatment.

Echocardiographic Findings

Fifty-one patients (44%) had left ventricle ejection fraction (LVEF) 40%-44%, 43 patients (37.1%) had LVEF 45%-49%, and 22 patients (19%) had LVEF >50%. LV diastolic dysfunction (LVDD) was grade I, II, and III or IV in 74 (63.8%), 37 (31.9%) and five (4.3%) patients, respectively. The mean E/E' was 6.25+-0.61.

The mean RA volume index in inferior MI patients was 30.03 ± 6.64 and 30.55 ± 6.62 by monoplane and biplane area length methods, respectively. Additionally, the mean RA volume index in inferoRV MI patients was 43.00 ± 16.02 by the monoplane method and 41.63 ± 15.57 cc/m^2 by the biplane area length method. In addition, the mean RA volume index in all MI patients was 35.62 ± 13.26 cc/m^2 and 35.32 ± 12.59 cc/m^2 by monoplane Simpson's and biplane methods. Further, 73 (62.9%), 49 (42.2%), and 22 patients (19%) had RV TAPSE ≤16 mm, RV FAC ≤35%, and RVSm ≤9.5 cm/s, respectively. The right atrial ejection fraction (RAEF) was ≤35% in 22 patients (19%) while >35% in 94 patients (81%). The mean RVEDD was 36.13 ± 5.41 mm as well.

Demographic and echocardiographic findings between inferior and inferoRV MI patients are demonstrated in Table 1. As shown, patients with inferoRV MI compared to inferior MIs had significantly more cases with RV TAPSE <16 mm, FAC ≤35%, RVSm ≤9.5 cm/s, RAEF ≤35%, higher RA volume index values, high E/E', and high RVEDD.

Among patients with inferoRV MI, the mean RA volume index was 41.80 ± 16.49 cc/m^2 and 28.98 ± 9.27 cc/m^2 in cases with TAPSE ≤16 mm and TAPSE >16 mm by the monoplane method ($P < 0.001$), as well as 40.91 ± 15.78 cc/m^2 and 27.03 ± 8.84 cc/m^2 by the biplane method, respectively ($P < 0.001$).

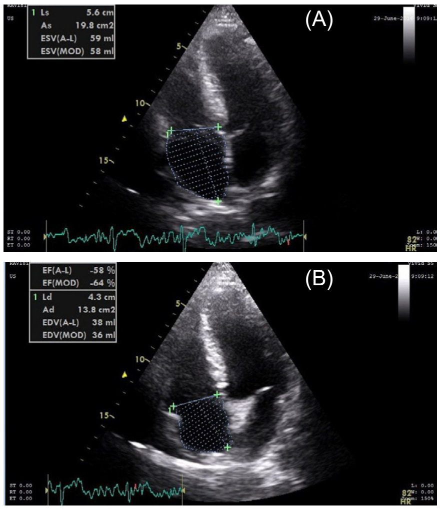

Figure 2. (A , B) RA Volume Index Measurement With Monoplane Simpson Method in Systole and Diastole.

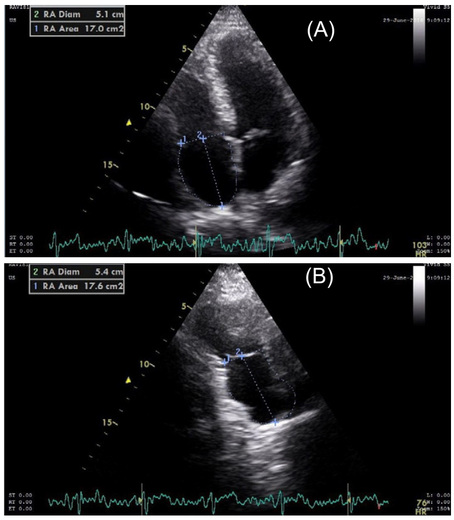

Figure 3. (A, B) RA Volume Index Measurement in Biplane Area Length Method RV Focused View.

Furthermore, the mean RAVIs in inferoRV MI cases with FAC≤35 and >35 were 39.14 ± 16.55 cc/m^2 and 27.85 ± 7.24 cc/m^2 according to the monoplane method, along with 38.6 ± 15.77 cc/m^2 and 27.71 ± 6.64 cc/m^2 according to the biplane method, respectively ($P < 0.001$).

Moreover, patients with RVSm ≤9.5 and >9.5 cm/s had the mean RAVIs of 40.65 ± 16.67 cc/m^2 and 27.57 ± 7.18 cc/m^2 based on the monoplane method, as well as 39.51 ± 16.03 cc/m^2 and 27.79 ± 6.69 cc/m^2 based on the biplane method, respectively ($P < 0.001$ for both).

As regards the patients with RAEF ≤35% and >35%, the mean RAVIs were 46.20 ± 16.96 cc/m^2 and 29.60 ± 9.85 cc/

Table 1. Demographic and Echocardiographic Findings Between Patients With Inferior MI With and Without RV MI

		Inferior MI	Inferior and RV MI	*P* Value
Age		59.96±11.20	64.12±11.26	0.053
Gender	Male	50 (75.8%)	42 (84%)	0.27
	Female	16 (24.2%)	8 (16%)	
Primary PCI		36 (54.5%)	26 (52%)	0.78
LVEF	40-44%	26 (39.4%)	25 (50%)	0.09
	45-49%	23 (34.8%)	20 (40%)	
	50%≤	17 (25.8%)	5 (10%)	
LVDD	Grade I	48 (72.7%)	26 (52%)	0.050
	Grade II	15 (22.7%)	22 (44%)	
	Grade III or IV	3 (4.6%)	2 (4%)	
RV TAPSE <16		5 (7.6%)	38 (76%)	<0.001
FAC ≤35		7 (10.6%)	42 (84%)	<0.001
RVSm ≤9.5		4 (6.1%)	40 (80%)	<0.001
RAEF ≤35%		17 (25.8%)	30 (60%)	<0.001
RAVI	Monoplane	30.03±6.64	43.00±16.02	<0.001
	Biplane	30.55±6.62	41.63±15.57	<0.001
E/E′		4.81±1.74	8.16±1.36	0.007
RVEDD		33.86±3.69	39.14±5.87	<0.001

Note. PCI: Primary Percutaneous coronary intervention; LVEF: Left Ventricular Ejection Fraction; LVDD: Left ventricular end diastolic dimension; RV TAPSE: Right ventricular tricuspid annular plane systolic excursion; FAC: Fractional area change; RV: Right Ventricular; RAFE: RA Ejection fraction; RVEDD: Right ventricular end diastolic dimension; RAVI: Right atrium volume index; RVSm: Peak systolic velocity of tricuspid annulus at TDI mode.

m^2, as well as 45.94 ± 15.39 cc/m^2 and 29.28 ± 9.35 cc/m^2 based on monoplane and biplane methods, respectively (P < 0.001 for both).

Among patients with isolated inferior MI, those with RVFAC ≤35 and >35 had a mean monoplane RAVI of 30.05 ± 5.47 and 26.26 ± 6.76 (P = 0.48) and biplane RAVI of 33.32 ± 7.22 and 27.57 ± 6.61 (P = 0.89). Additionally, 16 out of 66 patients with isolated inferior MI (66 patients) had abnormal RV systolic function by conventional echocardiographic methods while RA volume index increased in all these patients.

There was a significant, strong positive correlation between RA volume indices measured by monoplane and biplane methods (r = 0.956, P < 0.001). In addition, a significant, positive correlation was observed between RVEDD and RA volume indices (monoplane method, r = 0.732, P < 0.001; biplane method, r = 0.734, P < 0.001). However, no significant, positive correlation was found between E/E' with RA volume index (monoplane method, r = 0.201, P = 0.03; biplane, r = 0.192, P = 0.03)

Table 1 presents demographic and echocardiographic findings between patients with inferior MI with and without RV MI.

Discussion

This study evaluated the RV function by conventional echocardiographic methods, mainly the RA volume index in patients with isolated inferior MI and inferoRV MI patients. Based on the results, the mean RA volume index was 35 cc/m^2, which is higher than the normal values reported (13) in healthy subjects (25 ± 7 cc/m^2 for men and 21 ± 5 cc/m^2 for women). Darahim reported a cut-off value of 29 mL/m^2 in predicting the adverse outcome in chronic heart failure (11).

Other parameters such as TAPSE, RVFAC, and RVSm were also used to evaluate the RV function (14). RV dysfunction secondary to LV dysfunction usually initiates due to pressure overload, which is translated into the tricuspid valve and leads to RV and RA dilatation (15). The anatomical position and shape of RV make it difficult for the conventional methods of echocardiography to evaluate its function. Accordingly, precise assessment of RV systolic function is challenging.

RV systolic function evaluation by conventional echocardiographic parameters such as RV FAC can be difficult, especially when the echo window is poor and the correlation between the observers is also poor compared with the other indices. TAPSE is another index of RV systolic function. TAPSE ≤16 mm indicates RV systolic dysfunction according to the American Society of Echocardiography (ASE) guidelines (13). However, this method has some limitations in that measurement is restricted to the longitudinal function of the RV free wall and the functional status of LV may have an influence on it (16,17).

RVSm was found as an independent parameter for RVMI diagnosis in inferior MI (18). Previous studies reported a correlation between RA volume index and RVFAC, RVSm, and reduced LVEF in heart failure patients (8, 10, 11). Piros et al found correlations between RA volumes and LVEF in healthy subjects (19).

As known, silent or overt RV ischemia, concomitant with LV ischemia is very important, thus its early diagnosis is highly essential and has a prognostic role. Conventional parameters may not show RV dysfunction or ischemia due to the rapid recovery of RV ischemia. Further, despite normal TAPSE, RV FAC, RVSm, high RA volume index accurately in such patients can be considered as a footprint of transient RV dysfunction or ischemia that could be missed if RA volume index is not measured. As a result, a high RA volume index in inferior MI patients can be a clue for transient high RVEDP and RV systolic or diastolic dysfunction that could be missed easily if not measuring the RA volume index.

RA volume index was first measured by monoplane Simpson's method in this study and the results showed a significant correlation with the biplane area length method, indicating that both of them may yield similar results. Two groups of patients were included in this study, encompassing those with ECG findings of inferoRV MI and those with isolated inferior MI based on the ECG. Echocardiographic findings revealed a higher RA volume index and reduced TAPSE, RVSm, and RV FAC in the first group. As know, near 50% of the isolated inferior MIs have some degrees of RV systolic impairment but in our study, despite increased RA volume index in all patients, only less than 10% of them had some degrees of RV systolic dysfunction by conventional methods of echocardiography and nearly 20%-25% of inferoRV MIs had normal conventional parameters in spite of increased RA volume index in all inferoRV MI patients.

It is explained that RV ischemia has a fast recovery and the evaluation of RV systolic function by routine methods leads to the ignorance of RV systolic dysfunction, thus RA volume index can be a more sensitive parameter for indicating high RVEDP and RV systolic and diastolic function compared to the other parameters. In addition, it is known that diagnosing RV infarction is very important in acute inferior MI and inferoRV MI patients due to hemodynamic compromise and poor prognosis.

Previous studies reported that concomitant RV MI in inferior MI leads to increased mortality and morbidity (4, 20). It was demonstrated that RV dysfunction is associated with poor long-term outcomes (5, 6). However, due to anatomical position and form of RV, as well as technical challenges in the echocardiographic evaluation of RV function, RA volume index could be a better and sensitive parameter in determining RV dysfunction in inferior MI patients compared to conventional methods.

In this study, all patients in the isolated inferior MI group had a higher RA volume index while abnormal RV systolic function was not observed in all isolated inferior MI patients by conventional echo parameters. In fact, it could be concluded that the RA volume index becomes normal later than RV and due to a fast recovery of RV ischemia.

In other words, in cases with isolated inferior MI and normal RV by conventional echocardiography, additional parameters such as RA volume index should be defined and the evaluation of RV function and information from all available acoustic windows is necessary for the complete RV assessment.

Currently, no study is available regarding evaluating the correlations between RA volume index and RV dysfunction parameters in MI patients. The findings of this study demonstrated that patients with TAPSE ≤16, RVFAC ≤35%, and RVSm ≤9.5 cm/s had higher RA volume indexes. Further, there was a significant correlation between the RA volume index and RVEDD. In sum, the RA volume index is considered as a better and sensitive parameter for determining RV dysfunction in inferior MI patients and can be used to predict and indicate RV involvement.

The findings further represented a significant positive correlation between E/E’ with RA volume index while not showing any correlation with the tricuspid E/E ratio in heart failure patients (8). It was suggested that the RA volume index may reflect the chronicity of RV diastolic function over time, but our findings contradict these findings.

Moreover, it was found that patients with inferoRV MI had significantly more cases with RV TAPSE ≤16, FAC≤35, RVSm ≤9.5, RAEF ≤35%, higher RA volume index, high E/E’, and RVEDD compared to those with isolated inferior MI. Similarly, Nourian et al (12) reported impaired RA function in patients with inferoRV MI compared to those with only inferior MI.

Study Limitations

In this study, we only evaluated the correlation between RV function parameters and RA volume index in inferior MI patients. The measurement of RVFAC can be difficult when the echo window is poor. In addition, the measurement of indices of RV and RA was poor due to their anatomical place. Our study was conducted during a short-time interval (72 hours) for our RA volume index measurements. Furthermore, the outcome was not evaluated, which is considered as a limitation. The relatively small sample of the study population is another limitation of this study.

Conclusions

In general, RA volume index, measured by monoplane and biplane area length methods, is a good parameter for demonstrating RV dysfunction in patients with inferior and inferoRV MI and becomes normal later than the RV dysfunction. RA volume index also showed higher values in patients with inferoRV MI, indicating more severe dysfunction. Finally, it is a better and more sensitive method for determining RV dysfunction in inferior MI patients compared to conventional methods.

Conflict of Interests

The authors declare that they have no conflict of interests.

Ethical Issues

This study was approved by the Ethics Committee of Tabriz University of Medical Sciences, Tabriz, Iran (IR.TBZMED.REC.1395.1220). Informed consent was obtained from all the participants before inclusion in the study.

Financial Support

There was no financial disclosure in this study.

Acknowledgments

The authors would like to thank all patients who kindly collaborated on this research project.

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