Cardiology and Cardiovascular Research
2020; 4(3): 111-118
http://www.sciencepublishinggroup.com/j/ccr
doi: 10.11648/j.ccr.20200403.16
ISSN: 2578-8906 (Print); ISSN: 2578-8914 (Online)

Assessment of Right Atrial Function in Patients with First Inferior Myocardial Infarction with & Without Right Ventricular Involvement by 2D Speckle Tracking Echocardiography

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To cite this article:
Mohamed Fahmy El-Noamany, Ghada Mahmoud Soltan, Naglaa Fahim Ahmed, Haitham Mohamed Omar El-Ahwal. Assessment of Right Atrial Function in Patients with First Inferior Myocardial Infarction with & Without Right Ventricular Involvement by 2D Speckle Tracking Echocardiography. *Cardiology and Cardiovascular Research*. Vol. 4, No. 3, 2020, pp. 111-118. doi: 10.11648/j.ccr.20200403.16

Received: May 23, 2020; **Accepted**: June 18, 2020; **Published**: July 23, 2020

Abstract: Background: The right atrium (RA), has received the least attention by researchers. Many reports demonstrated that, RA function may be impaired in the early stages of cardiac disease. The RA plays an important role in maintaining right ventricular (RV) output. RA functional changes have been evaluated in patients with coronary artery disease, but RA affection is not fully elucidated in patients with myocardial infarction (MI) Objective: To assess RA function by 2-Dimensional speckle tracking echocardiography (2D-STE) imaging in patients with acute first left ventricular (LV) inferior wall MI with and without RV involvement. Patients & methods:-Sixty patients with acute first inferior MI were included in this study; 30 patients had ECG signs of inferior MI without RV infarction (group II) and 30 patients had ECG signs of inferior MI with RV involvement (group III). Twenty five age and sex -matched healthy volunteers were included as a control group (group I). Assessment of RA function was done in all subjects using (2D-STE) for measurements of RA septal and free walls longitudinal strain and strain rate (SR). Results:-RA septal wall & global systolic strain were significantly reduced in group III (22.5±14.8% and 40.4±24.5%) compared to group I (37.5±16.3% and 60.4±22.4%) and group II (35.7±17.4% and 54.9±25.73%), (P<0.001), (P=0.008) respectively. RA septal wall and global early diastolic strain rate were also significantly reduced in group III (-0.77±0.46 s-1 and – 3.61±0.55 s-1) compared to group I (-1.38±0.74 s-1 and – 4.41±0.67 s-1) and group II (-1.07±0.76 s-1 and -3.73±0.76 s-1), (P=0.005), (P<0.001) respectively. Conclusion:-In patients with first LV inferior wall MI with RV involvement, RA functional parameters (RA septal and global strain and SR) were significantly impaired in comparison to healthy controls and patients with first LV inferior wall MI without RV affection. This result may illustrate the significant relation between RV & RA which is still under research.

Keywords: Right Atrium, Inferior MI, Strain, Strain Rate

1. Introduction

Myocardial infarction (MI) is a major cause of death and disability worldwide. Coronary atherosclerosis is achronic disease with stable and unstable periods. During unstable periods with activated inflammation in the vascular wall, patients may develop MI. MI may be a minor event in a lifelong chronic disease; it may even go undetected, but it may also be a major catastrophic event leading to sudden death or severe hemodynamic deterioration. A MI may be the first manifestation of coronary artery disease, or it may occur repeatedly in patients with established disease [2].

Right ventricular (RV) infarction may occur alone or in association with left ventricular (LV) inferior wall infarction.

ST-segment elevation in the right precordial lead, V4 R-V6R, is one of the most reliable ECG signs of acute RV infarction [3].

The right atrium (RA), has received the least attention by researchers. It has been demonstrated that RA function can be impaired in the early stages of cardiac disease [1].

The RA has three functions: reservoir, conduit, and contraction. Reservoir function is the reserving of blood at the time of right ventricular (RV) contraction, conduit function is the direct transferring of blood from the veins to the RV, and contraction function is the booster pumping of blood in late ventricular diastolic time [4].

Accordingly, the RA plays a significant role in maintaining RV output. RA function changes have been evaluated in patients with coronary artery disease, but RA function in patients with myocardial infarction (MI) has yet to be fully elucidated. It has been demonstrated that left atrial (LA) function can be affected by left ventricular myocardial infarction (LVMI), so it stands to reason that RA function may be affected by inferior myocardial infarction. [5, 6]

The RA interacts with the RV with altered RV systolic and diastolic function with an increased filling pressure. It can, therefore, be anticipated that some changes may occur in RA function. [10]

Strain is a measure of tissue deformation. As the ventricle contracts, muscle shortens in the longitudinal and circumferential dimensions (a negative strain) and thickens in the radial direction (a positive strain) [8].

Strain rate (SR) imaging allows the determination of velocity gradients between two points in space. The resulting contraction variable is independent of passive tethering effects from other regions, and therefore appears promising for quantification of regional myocardial function. [7]

Strain & strain rate techniques are used to assess myocardial movement and deformation. These methods have been frequently used to assess LV function; however, they have yet rarely been used to examine RA function [9], despite RA function is an important prognostic factor in patients with acute first inferior MI [3].

2. Patients and Methods

2.1. Study Population

The study excluded patients with inferior and anterior MI, previous STEMI, previous coronary artery bypass graft surgery, The presence of a pacemaker or defibrillator lead in the RV, atrial fibrillation, complete right or left bundle branch block, chronic obstructive pulmonary disease, pulmonary hypertension, pulmonary thromboembolic disease, signs of valvular heart disease, organic tricuspid or pulmonary valve disease, dilated cardiomyopathy, myocardial disease, and RV involving, for example, HOCM, amyloidosis, renal dysfunction, pregnancy, severe hypotension (systolic blood pressure <80 mmHg), pericardial disease and poor image quality. A total of 60 patients with first inferior MI with and without RVMI were included, in addition to 25 age-matched and sex-matched healthy volunteers as a control group.

A standard 12-lead ECG and a right precordial ECG (lead V4 R) were recorded immediately after arrival to the coronary care unit.

According to MI definition, 30 patients had ECG signs of inferior MI without RV infarction (group II), and 30 patients had ECG signs of inferior MI with RV infarction (group III). In all, 25 age-matched and sex-matched healthy volunteers were included as a control group (group I).

2.2. Echocardiography

Echocardiography was performed using a Vivid 9 (GE Vingmed, Horten, Norway) equipped with a harmonic M5S variable frequency (1.7–4 MHz) Phased-array transducer.

The conventional echocardiographic measurements were performed according to the recommendations of the American Society of Echocardiography [11]. Right atrial dimension was determined through the four-chamber view from the maximal medial to lateral dimension at end-ventricular systole (which corresponds to maximal atrial volume).

2.3. Assessment of RA Strain Rate and Strain

Border tracking of the RA was manually traced from the digitized 2D video clips recorded during breath holding and with good quality ECG signal which acquired and stored for off-line analysis using XStrain™ software with a frame rate between 40–80 fps. The "Zoom/ RES" feature on the echocardiographic machine was used to improve the accuracy of atrial measurements. A circular region of interest was traced on the endocardial cavity interface of the apical four chamber view at end.

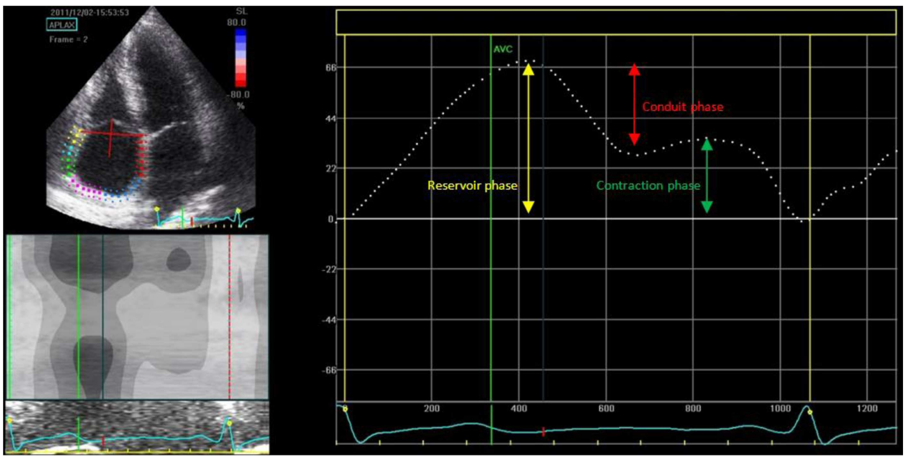

Figure 1. *The right atrial strain curve [16].*

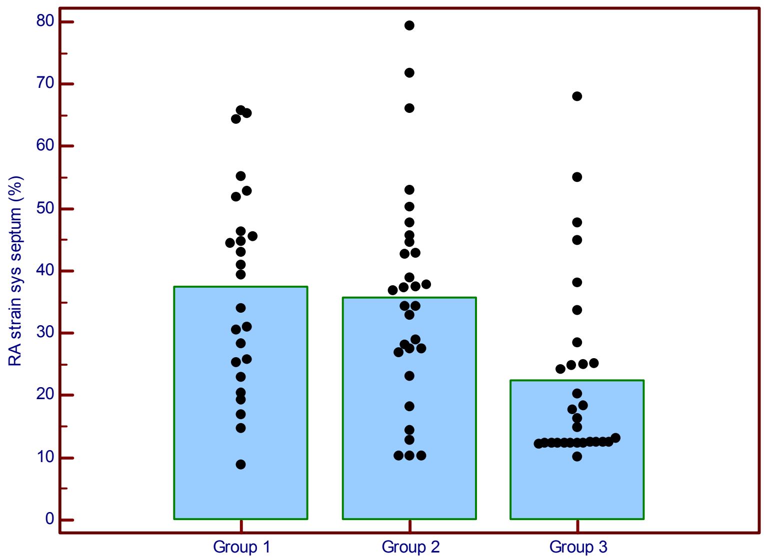

Figure 2. *Mean RA strain sys septum in the three study groups. Markers represent individual observations.*

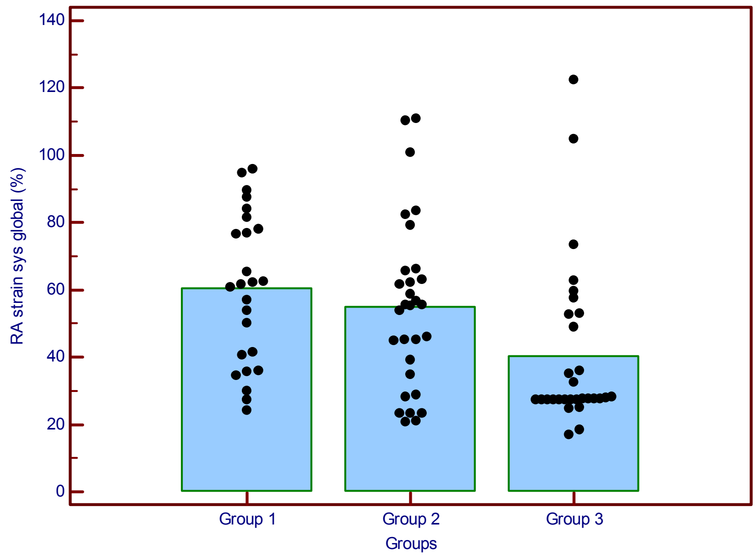

Figure 3. *Mean RA strain sys global in the three study groups. Markers represent individual observations.*

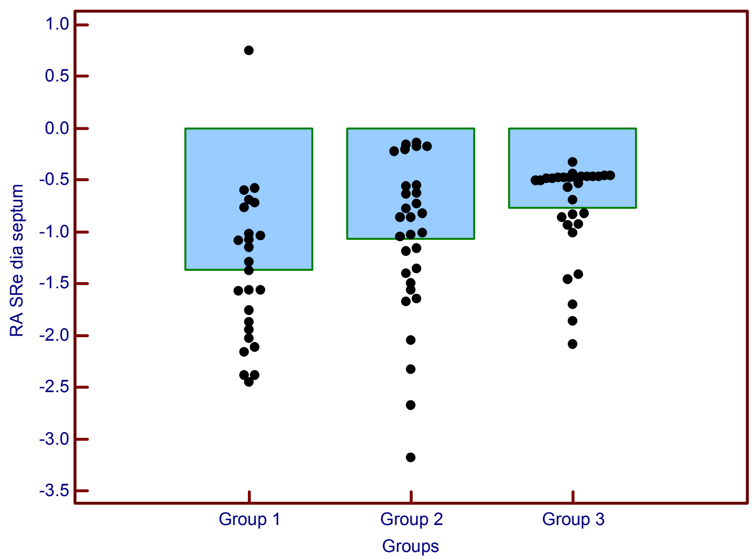

Figure 4. *Mean RA SRe dia septum in the three study groups. Markers represent individual observations.*

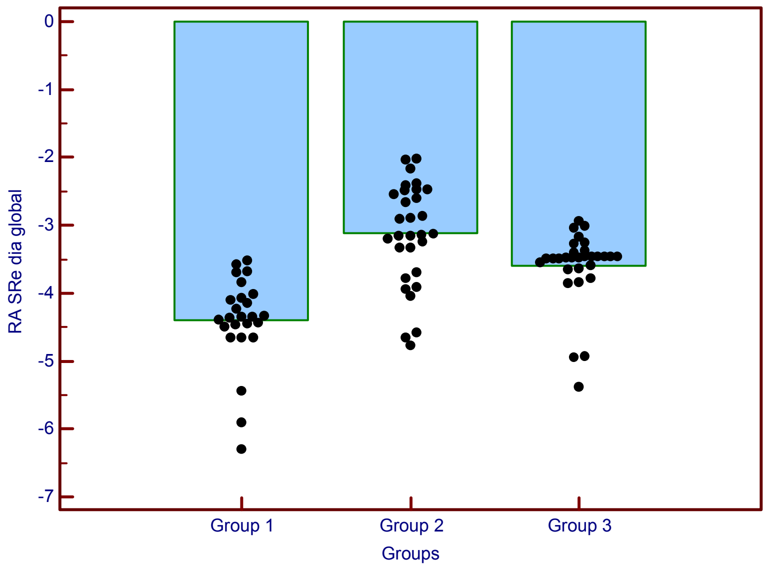

Figure 5. *Mean RA SRe dia global in the three study groups. Markers represent individual observations.*

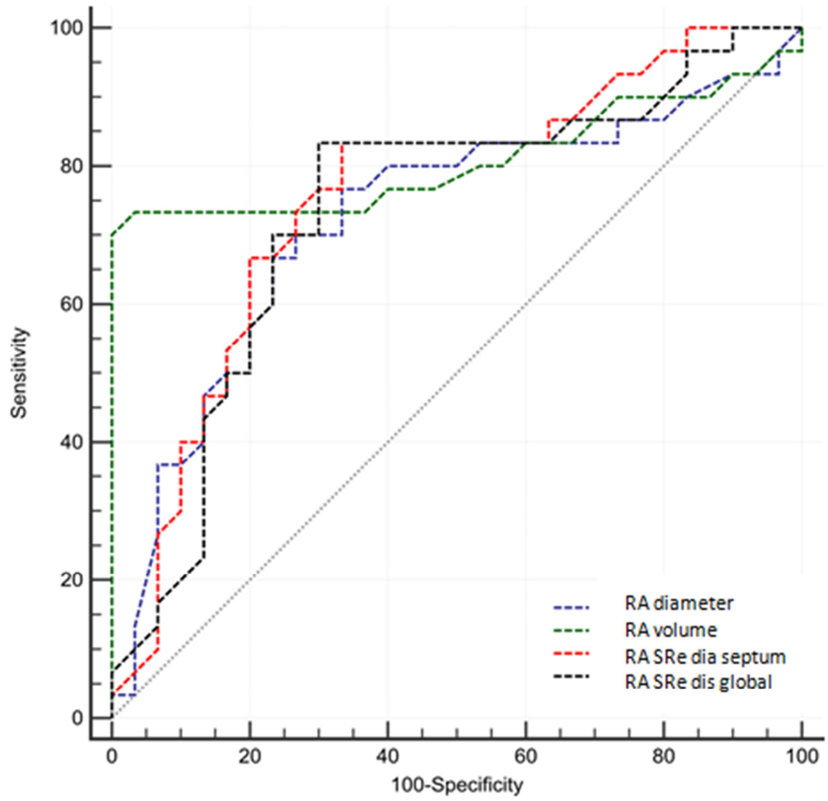

Figure 6. *Receiver-operating characteristic (ROC) curves for discrimination between cases of inferior MI with or without RV involvement using RA diameter, RA volume, RA SRe dia septum or RA SRe dia global.*

diastole (RA minimum cavity area) using a point-and-click approach. Time-volume curves were extracted from RA wall tracking which provided automatically longitudinal peak velocities achieved by RA walls 1 cm above the tricuspid annulus in systole, early and late diastole.

Definition of RA endocardial border enabled system to calculate regional longitudinal deformation of the RA walls. Peak systolic strain (εsys) and RA systolic SR (SRsys) were measured as positive curve at LV systole (representing reservoir function), early diastole (SRe) (representing conduit function), atrial diastole (SRa) (representing contractile function).

Image processing algorithm automatically subdivides the atrial wall into 12 segments distributed in septum& lateral and posterior RA wall–"roof") [12].

2.4. Statistical Analysis

Data were analyzed using IBM© SPSS© Statistics version

23 (IBM© Corp., Armonk, NY) and MedCalc© version 18.2.1 (MedCalc© Software bvba, Ostend, Belgium).

Continuous numerical variables were presented as mean and SD and inter-group differences were compared using one-way analysis of variance (ANOVA) with application of the Tukey-Kramer test for post hoc comparisons if needed.

Categorical variables were presented as number and percentage and differences were compared using the Pearson chi-squared test or Fisher's exact test as appropriate.

Receiver-operating characteristic (ROC) curve analysis was used to examine the value of echocardiographic measures for discrimination between cases of inferior MI with or without RV involvement. The area under the ROC curve (AUC) is interpreted as follows: table 1

Table 1. *Diagnostic value of area under ROC curve (AUC)****.***

Area under ROC curve (AUC)	Diagnostic value
0.9 – 1.0	Excellent
0.8 – 0.89	Good
0.7 –0.79	Fair
0.6 – 0.69	Poor
<0.6	Fail

Two-sided p-values <0.05 were considered statistically significant.

Table 2. *Comparison of 2D-echocardiographic measures in the three study groups.*

Variable	Group 1 (n=25)		Group 2 (n=30)		Group 3 (n=30)		F (2, 82)	P-value*
	Mean	SD	Mean	SD	Mean	SD		
LA diameter (mm)	33.8	6.8	35.7	8.3	39.8 a	9.7	3.7057	0.029*
LA volume (ml)	26.1	3.4	29.6	3.7	39.5 a, b	20.9	8.277	0.001**
LV ESD (mm)	29.5	9.7	36.6	12.3	37.0 a	12.1	3.567	0.033*
LV EDD (mm)	43.4	9.2	50.9 a	12.0	49.9	10.7	3.807	0.026*
LV FS (%)	34.6	5.8	28.9 a	8.4	28.5 a	9.0	4.912	0.010*
LV EF (%)	63.2	8.0	54.6 a	11.8	55.2 a	12.5	5.013	0.009**
Septum thickness (mm)	10.7	1.3	10.9	1.1	10.9	1.2	0.259	0.772
LVPW thickness (mm)	9.7	3.7	11.0 a	3.7	11.4 a	2.7	1.785	0.174
Mitral E (cm/s)	0.90	0.29	0.83	0.31	0.73	0.35	2.079	0.132
Mitral A (cm/s)	0.55	0.19	0.62	0.17	0.65	0.31	1.337	0.268
Mitral E/A	1.59	0.74	1.38	0.47	1.21 a	0.30	3.544	0.033*
Deceleration time (ms)	179	55	181	55	189	86	0.185	0.831
PAP (mmHg)	23	6	26	12	29	17	1.120	0.331

Data are mean and standard deviation (SD).
F=F-statistic.
*. One-way analysis of variance (ANOVA).
a. P-value <0.05 versus Group 1 (Tukey-Kramer test).
b. P-value <0.05 versus Group 2 (Tukey-Kramer test).

3. Results

In conventional echocardiography there was highly significant difference was present between group III (Inferior MI with RT MI), group II and group I as regard LA diameter (mm), LA volume (ml) (P-value <0.001=highly significant), LV ESD (mm), LV EDD (mm), LV FS (%), LV EF (%),& Mitral E/A (P-value <0.05=significant). While no significant difference was present between three groups in other data [table 2].

3.1. Assessment of RA Function

In conventional data there was no significant difference was present between three groups regarding RA dimensions and RA EF.

3.2. Assessment of RA Systolic Strain

A statistically high significant difference was found between group III (Inferior MI with RV MI) versus group I (control) & group II (Inferior MI without RV MI) regarding septal wall. *(P<0.001).* A statistically significant difference was found between group III (Inferior MI with RV MI) versus group II Inferior MI without RV MI) regarding RA strain sys global. *(P=0.008)* [table 3].

Table 3. *Comparison of RA strain sys in the three study groups.*

Variable	Group 1 (n=25)		Group 2 (n=30)		Group 3 (n=30)		F (2, 82)	P-value*
	Mean	SD	Mean	SD	Mean	SD		
RA strain sys septum (%)	37.5	16.3	35.7	17.4	22.5 a, b	14.8	7.408	<0.001**
RA strain sys lateral wall (%)	86.5	34.7	80.3	43.7	63.8	42.2	2.343	0.102
RA strain sys global (%)	60.4	22.4	54.9	25.3	40.4 b	24.5	5.147	0.008**

Data are mean and standard deviation (SD).
F=F-statistic.
*. One-way analysis of variance (ANOVA).
a. P-value <0.05 versus Group 1 (Tukey-Kramer test).
b. P-value <0.05 versus Group 2 (Tukey-Kramer test).

3.3. Assessment of RA SRe Dia & SRa Dia

A statistically high significant difference was found between group III (Inferior MI with RT MI) versus group II (Inferior MI without RT MI) regarding RA. SRe dia septum & global. *(P=0.005), (P<0.001)* respectively [table4].

No significant difference was present between three groups regarding RA SRa dia.

Table 4. *Comparison of RA SRe dia in the three study groups.*

Variable	Group 1 (n=25)		Group 2 (n=30)		Group 3 (n=30)		F (2, 82)	P-value*
	Mean	SD	Mean	SD	Mean	SD		
RA SRe dia septum	-1.38	0.74	-1.07	0.76	-0.77 b	0.46	5.659	0.005**
RA SRe dia lateral wall	-2.37	0.92	-1.98	0.97	-1.85	0.84	2.353	0.101
RA SRe dia global (%)	-4.41	0.67	-3.13	0.76	-3.61 b	0.55	25.454	0.000**

Data are mean and standard deviation (SD).
F=F-statistic.
*. One-way analysis of variance (ANOVA).
b. P-value <0.05 versus Group 2 (Tukey-Kramer test).
* sighificance.
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4. Discussion

A few studies showed that strain and strain rate imaging appears good for functional assessment of the right atrium. the accuracy of strain rate imaging to quantify RA deformation that can be occur as a complication of inferior STEMI specialy if associated with RV affection.

In our study 60 patients with acute inferior MI were examined for RA strain & strain rate 30 patients had inferior MI without RV infarction (group II) and 30 patients had inferior MI with RV infarction (group III). In all, 25 age-matched and sex-matched healthy volunteers were included as a control group (group I).

Statistically high significant difference was found between group III (Inferior MI with RV MI) versus group I (control) & group II (Inferior MI without RV MI) regarding septal wall systolic strain & RA global systolic strain. (*P<0.001)*, *(P=0.008)* [table 3].

statistically high significant difference was found between group III (Inferior MI with RT MI) versus group II (Inferior MI without RT MI) regarding RA.

SRe dia septum & global. *(P=0.005), (P<0.001)* respectively [table 4].

In *Nourian et al* study that assessed RA reservoir, conduit & contractile functions in 70 patients with inferior MI (43 patients without RVMI & 27 patients with RVMI) shows that the 2D speckle tracking echocardiography (2DSTE) for the evaluation of RA function showed that RA SRe, and RA SRs were lower in the patients with INFMI + RVMI than in the patients with INFMI alone, which is concordant with our study that shows statistically high significant difference between group

Table 5. *Receiver-operating characteristic (ROC) curve analysis for discrimination between cases of inferior MI with or without RV involvement using RA diameter, RA volume, RA SRe dia septum or RA SRe dia global.*

	Predictor			
ROC metric	RA diameter	RA volume	RA SRe dia septum	RA SRe dia global
AUC	0.723	0.809	0.757	0.735
SE	0.069	0.063	0.065	0.068
95% CI	0.592 to 0.831	0.687 to 0.899	0.629 to 0.859	0.605 to 0.841
Z statistic	3.238	4.879	3.985	3.460
P-value (AUC=0.5)	0.001**	<0.0001**	<0.001**	0.001**
Youden index (J)	0.433	0.700	0.500	0.533
Associated criterion	> 36.9 mm	> 35.2 ml	> -1.03	> -1.472
Sensitivity (%)	76.7	73.3	83.3	83.3
95% CI	57.7 - 90.1	54.1 - 87.7	65.3 - 94.4	65.3 - 94.4
Specificity (%)	66.7	96.7	66.7	70.0
95% CI	47.2 - 82.7	82.8 - 99.9	47.2 - 82.7	50.6 - 85.3
+LR	2.3	22.0	2.5	2.8
95% CI	1.3 - 4.0	3.2 - 153.0	1.5 - 4.3	1.6 - 4.9
-LR	0.4	0.3	0.3	0.2
95% CI	0.2 - 0.7	0.2 - 0.5	0.1 - 0.6	0.1 - 0.5
+PV (%)	69.7	95.7	71.4	73.5
95% CI	57.2 - 79.8	76.0 - 99.4	59.5 - 81.0	61.1 - 83.1
-PV (%)	74.1	78.4	80.0	80.8
95% CI	58.7 - 85.1	66.6 - 86.8	63.3 - 90.3	64.6 - 90.6

AUC=area under ROC curve, SE=standard error, 95% CI=9%% confidence interval, +LR=positive likelihood ratio, - LR=negative likelihood ratio, +PV=positive predictive value, -PV=negative predictive value.

III (Inferior MI with RT MI) versus group I (control) & group II (Inferior MI without RT MI) regarding septal wall & RA global systolic strain (P- value=<0.001, 0.008) respectively [13].

In our study the area under the curve for RA diameter, RA volume, RA SRe dia septum & RA SRe dia global for INFMI + RVMI discrimination was 0.723 (95% CI 0.592 - 0.831; P value=0.001), 0.809 (95% CI 0.687 - 0.899; P value <0.0001), 0.757 (95% CI 0.629 - 0.859; P value <0.001), 0.735 (95% CI 0.605 to 0.841; P value=0.001), respectively.

RA diameter has 76.7% Sensitivity & 66.7% specificity, RA volume has 73.3% Sensitivity & 96.7% specificity, RA SRe dia septum has 83.3% Sensitivity & 66.7% specificity & RA SRe dia global has 83.3% Sensitivity & 70% specificity for the discrimination of INFMI + RVMI from INFMI.

Also in *Nourian et al*. study The area under the curve for EDS, RA SRE, RA SRS, expansion index and diastolic emptying index, for INFMI + RVMI discrimination was 0.682 (95% CI 0.550– 0.815; p value=0.011), 0.640 (95% CI 0.512–0.768; p value=0.040), 0.400 (95% CI 0.269–0.530; p value=0.141), 0.338 (95% CI 0.209–0.467; p value=0.017), and 0.338 (95% CI 0.209–0.467; p value=0.017), respectively. EDS <27.5% had 59.3% sensitivity and 79.1% specificity for the discrimination of INFMI + RVMI from INFMI. [13]

Our study demonstrated that right atrial reservoir (εsys, SRsys) and conduit (early diastolic SRe) function were significantly reduced in patients with inferior STEMI with RV (group III) versus group II & control group. [13]

These results are concordant with the results of *Badran e al* study that studied Right atrium deformation in 118 patients with HCM & 33 healthy subjects as a control group that shows also marked decrease right atrial reservoir (εsys, SRsys) and conduit (early diastolic SRe) function in patients with HCM versus control group. [14]

Our study showed that right atrial reservoir (εsys, SRsys) and conduit (early diastolic SRe) function were significantly reduced in patients with inferior STEMI with RV (group III) versus group II & control group.

This is also concordant with *OjaghiHaghighi et al,* that studied thirty patients with a diagnosis of heart failure and the control group consisted of 32 healthy adults matched for age and sex. The right atrial deformation indices were significantly compromised in the heart failure patients versus the normal subjects (P=0.0001). [15]

In our study also there was no difference between patients who had inferior MI & those who had also RV affection regarding RA SRA which is discordant with *Yan et al*. that evaluated RA function with velocity vector imaging in patients with coronary artery disease without MI and found that RA SRA was increased in those with severe coronary artery disease compared with the ones with normal coronary arteries. [17]

Also while our study shows that there was marked decrease in RA functions in Patients with Inferior with RVMI, *Dogan et al.* compared LA function between patients with ST-elevation MI treated with primary PCI and healthy subjects in the first 48 h after hospital admission and measured only 1 single 2DSTE-derived parameter, Systolic strain, they found that systolic strain, as a marker of reservoir function, was reduced in the patients with MI. In addition, diastolic emptying index was reduced in the patient group. [5]

However, LA volumes (maximal LA volume, minimal LA volume, and pre-A LA volume) were larger in the patient group than in the normal subjects. [5]

Additionally, diastolic emptying index and passive emptying index were reduced. The authors also reported that LA volumes were higher in the patients with non-ST-segment elevation MI than in the control subjects.

Also *antoni et al* get concordant with our results but regarding LA functions when studied LA strain in 320 patients with acute MI treated with primary PCI within 48 hours compared with 35 normal subjects. There was significant decrease in LA reservoir function (140±65 vs164±41%, (p=0.03) & lower LA strain 39±10vs 33±11%, (p=0.002) in comparison with normal subjects. [16]

The same also in *Magdy et al* study, 40 patients presented with acute STEMI compared with 20 healthy subjects as a control group regarding LA strain & strain rate. All the LA global longitudinal strain (%) and strain rate (S^{-1}) parameters were significantly reduced in patient group compared to control group, the εsys (p=0.0001), the SRsys (p=0.0001), the SRe (p=0.0001), and the SRa (p=0.034) [18].

Our findings may illustrate the significance of the evaluation of RA function because it permits us to evaluate RV function from another window. According to the results of our study, some 2DSTE-derived indices of RA function were sensitive to RV dysfunction in the presence of RVMI because the appearance of impaired RA function (as evaluated by 2DSTE) preceded the appearance of the difference in the 2DSTE-derived indices of RV function.

We found impaired RA reservoir and conduit functions and preserved RA contraction function in our patients with INFMI + RVMI.

5. Limitations

Speckle tracking method is influenced by image quality, and in particular clinical conditions, they can present limitations due to the physiological growth of the myocardial chambers, which prevents, sometimes, the perfect framing of the image in the echocardiographic window. The resolution of 2D imaging may be a problem in some subjects, and inadequate border recognition of the right atrium may be another factor limiting assessment of myocardial strain. Myocardial contractility is a complex mechanism; in the present study, we investigated only the longitudinal deformation while the other components of wall deformation, like radial strain, circumferential are not included. However, approaching myocardial function using speckle tracking; is non-angle dependent and more reproducible modality that better reflects myocardial function and may allow easier patient follow up in our daily practice?

6. Conclusion

In patients with first LV inferior wall MI with RV involvement, RA functional parameters (RA septal and global strain and SR) were significantly impaired in comparison to healthy controls and patients with first LV inferior wall MI without RV affection. This result may illustrate the significant relation between RV & RA which is still under research.

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