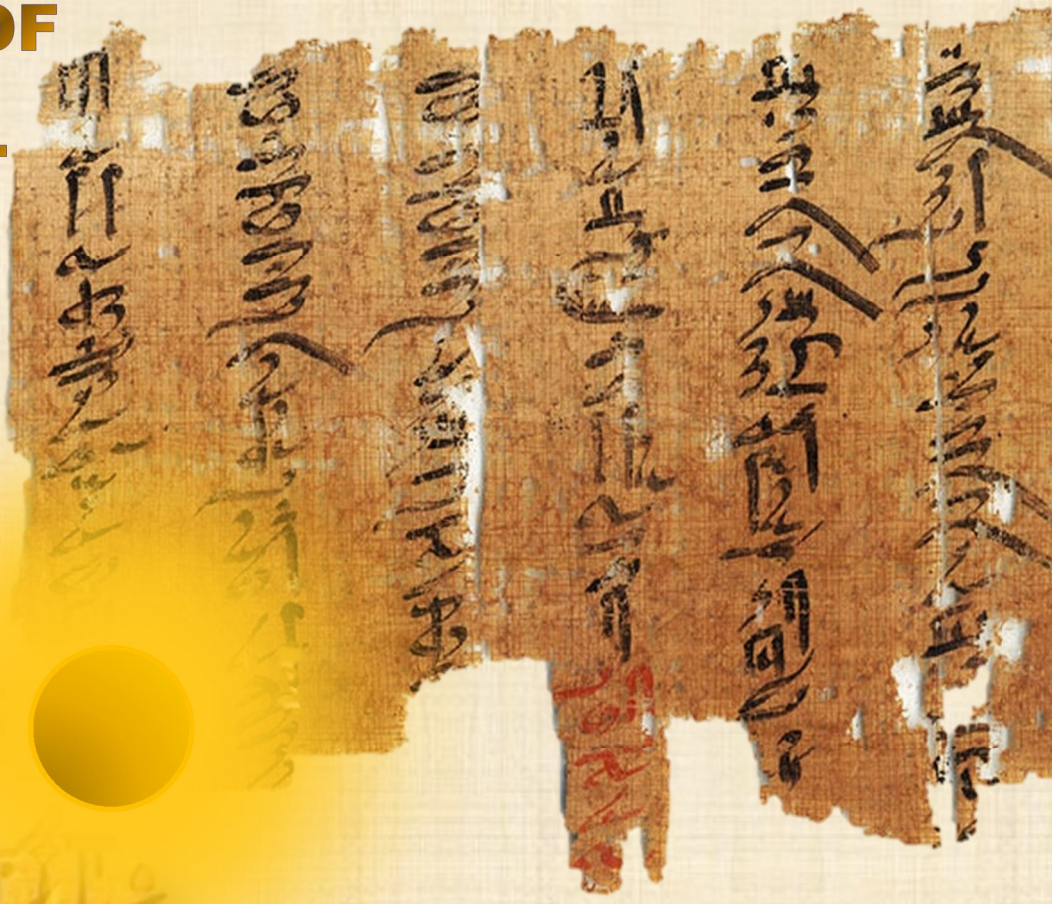
IJMA

International Journal of Medical Arts

VOLUME 2, ISSUE 4, AUTUMN 2020)



http://ijma.journals.ekb.eg/

Print ISSN: 2636 - 4174

Online ISSN: 2682 - 3780

International Journal of Medical Arts 2020; 2 [4]: 749-756.

Available online at Journal Website
https://ijma.journals.ekb.eg/
Main subject [Medicine [Cardiology]] *

Original article

Impact of Ischemic Cardiomyopathy on Right Ventricular Function using Speckle Tracking Echocardiography

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Received at: June 02, 2020; Revised at: July 22, 2020; Accepted at: July 24, 2020

DOI: 10.21608/ijma.2020.31638.1132

ABSTRACT

Background: Ischemic cardiomyopathy [ICM] refers to the reduced pumping ability of the heart due to damage of myocardium as a result of ischemia. Thus, early detection of coronary artery disease could save the myocardium. Speckle tracking emerged as a new diagnostic tool, but its role in ischemic cardiomyopathy is not well addressed.

Aim of the work: To assess right ventricle [RV] function by two-dimensional [2D] speckle tracking imaging in patients with ICM.

Patients and Methods: This study included 38 patients with ICM and 30 healthy subjects as a control group. Conventional echo-Doppler parameters of right ventricular function together with tissue Doppler imaging derived RV strain and speckle-tracking echo-derived RV global strain [STE-RVGST] were addressed.

Results: The two groups were matched in age and sex. ICM had significantly higher values of LV Tei index [0.90±0.28] versus control group [0.51±0.13] with p value <0.001. Compared to control group, ischemic cardiomyopathy patients had significantly dilated right ventricular [RV] dimensions and volumes with impaired systolic and diastolic function. In this study RV tissue Doppler imaging [TDI] revealed statistically significant low Free Ea [6.76±2.72 versus 8.20±1.86], Free Sa [8.00±2.86 versus 10.91±1.10], TD-derived RV strain [19.83±15.19 versus 33.87±5.82] in ICM than control group. Speckle tracking derived global longitudinal strain was statistically lower in ICM [-10.01±3.7] versus -18.83±3.34 in control group.

Conclusion: Patients with ischemic cardiomyopathy have both systolic and diastolic RV dysfunction, Speckle tracking echocardiography have an additive role in assessment of RV systolic dysfunction.

Keywords: Cardiomyopathy; Speckle tracking; Right ventricle; Ischemia; Coronary Artery Disease.

Please cite this article as: Aboualia AM, Zaki ER. Impact of Ischemic Cardiomyopathy on Right Ventricular Function using Speckle Tracking Echocardiography. IJMA 2020; 2[4]: 749-756. DOI: 10.21608/ijma.2020.31638.1132

* Main subject and any subcategories have been classified according to research topic.

INTRODUCTION

The most common cause of heart failure [HF] is ischemic heart disease [IHD][1]. Ischemic cardiomyopathy is a myocardial disorder in which the heart muscle structure and function are abnormal as a result of ischemia [2]. The right ventricle plays an important role in the morbidity and mortality of patients presented with signs and symptoms of cardiopulmonary disease[3]. Right ventricular dysfunction is common in ischemic cardiomyopathy ICM. The pathophysiology may be related to altered loading condition[4]. Despite improvements in diagnosis and treatment in cardiovascular diseases, there is no significant improvement in heart failure prognosis at the desired level [5].

Echocardiography is an essential routine tool to evaluate left and right ventricular cardiac function non-invasively with several conventional parameters of systolic and diastolic functions. Because the available new techniques of such as 2D speckle tracking imaging for assessing RV systolic function is still limited in routine practice but had been recommended in the guideline of the American Society of Echo-cardiography [6]. However, the benefit of 2D speckle tracking imaging of subtle RV systolic dysfunction in patient with LV ischemic cardio-myopathy has not been firmly established.

AIM OF THE WORK

The aim of this work was to assess RV function by 2D speckle tracking imaging in patients with ICM.

PATIENTS AND METHODS

This study is coherent study enrolled 38 consecutive ICM patients selected from patients who were admitted in the coronary care unit of Al-Zahraa University Hospital between February 2019 and November 2019 with the sample size calculated using sample size excel calculator[7]. The study also included 30 age and sex matched healthy individuals as a control group. We excluded patients with non-ischemic dilated cardiomyopathy, organic valvular heart disease, history of inferior myocardial infarction, congenital heart disease, significant arrhythmia and poor echo-window. An oral informed consent was taken from all participants. All studied cases were subjected to the following: careful medical history tacking with special emphasis on risk factors of coronary artery disease [CAD] [e.g., hypertension, diabetes mellitus, history of smoking, chest pain, previous myocardial infarction, previous coronary intervention and history of congenital heart disease]; detailed clinical examination with special emphasis on signs of LV and RV dysfunction; twelve lead surface resting echocardiogram [ECG] for rate, rhythm, evidence of recent or old myocardial ischemia or infarction and detection of arrhythmia, and Transthoracic echocardiography.

The diagnosis of ischemic cardiomyopathy was established as left ventricular [LV] dysfunction [EF less than 50%] with history of ischemic heart disease proved by previous coronary angiography± intervention. The Trans-thoracic echocardiography was performed using Vivid-E9 [GE system] with tissue Doppler and speckle tracking imaging capability; attached to echo-Pac work station 201. Images were obtained from parasternal and apical windows using multi-frequency matrix probeM3S [3.5 MHz]. All measurements were taken on three consecutive beats and the mean values were used. No measurements were taken within five cycles of an ectopic beat and the following parameters were obtained:

I- **Conventional echo-Doppler** performed according to the standards of the American Society of Echocardiography chamber quantifications [6]:

a. **left ventricular** dimensions and volumes , ejection fraction, resting segmental wall motion abnormalities, left atrial dimension, and indices of LV diastolic function [peak early diastolic filling velocity "MV-Evel" , peak late diastolic filling velocity "MV-A vel", the ratio between MV-E vel and MV-A vel"MV-E/A" and deceleration time of the early mitral flow "MV-EDT"], LV Tei index was calculated from both trans mitral and trans-aortic Doppler signals using the following formula: LV TEI index = [a time –b time]/b time. The LV a time was measured from the end of one trans mitral flow signal to the start of the following one which represents the sum of LV isovolumic contraction time [LV-IVCT], ejection time [LV-ET] and isovolumic relaxation time [LV-IVET]. The LV b time represents LV-ET ejection time and it was

measured from the start to the end of trans-aortic Doppler flow signal.

b. **Study of RV function:** based on the American Society of Echocardiography and the European Association of Cardiovascular Imaging guideline[6] the following was measured:

1. RV outflow tract dimensions including end diastolic and end-systolic dimensions [RV end diastolic dimension and RV end-systolic dimension] obtained from two dimensional [2D]-guided M-mode of the parasternal short-axis view at the level of the aorta left atrium.

2. Basal RV dimension [basal RVD] measured from 2D apical four-chamber view and corresponds to the RV minor dimension at the level of the tricuspid annulus.

3. Mid-cavity RV linear dimension [Mid RVD] measured as the transversal RV diameter in the middle third of RV inflow, approximately half away between maximal basal diameter and the apex at end diastole at the level of papillary muscle.

4. Longitudinal RV diameter [long RVD] measured as the linear longitudinal dimension from the base of the RV at the level of tricuspid annulus to the right ventricular apex.

5. Right ventricular ejection fraction derived from RV end diastolic and end systolic volumes.

6. RV fraction area change measured as RV end-diastolic area [RVED area] minus RV end-systolic area [RVES area] divided by [RVED area].

7. Tricuspid annular plane systolic excursion [TAPSE], using a 2D –guided apical four-chamber view. The M mode cursor was placed through the lateral tricuspid annulus in such a way that the annulus moved along the M-mode cursor. The total systolic displacement was measured from the end –diastole to the highest points of the contraction.

8. Trans-tricuspid Doppler flow velocities including early [E] and late [A] diastolic peak velocities, E/A ratio, and deceleration time [DT].

9. RV Tei index by measurement of time interval from the end of one to the onset of the next tricuspid flow pattern, which represents the sum of isovolumic contraction time, isovolumic relaxation time, and ejection time [am interval]. Ejection time [bm] was measured from pulmonary Doppler flow signal[6].

RV tei index= am-bm/bm

II- Tissue Doppler imaging [TDI] parameters: TDI function was activated at the apical four-chamber for data acquisition greater than 100 frames/s with special attention to the color Doppler velocity range sitting to avoid any aliasing within the image. Off-line analysis of the digital stored loops was done by trace profile and placing the sample volume at the free wall of RV at the level of the tricuspid annulus in apical four-chamber view. The trace profile was displayed to measure peak systolic annular velocity [Sa], early diastolic velocity [Ea], late diastolic velocity [Aa] and the ratio between E velocity from pulsed – Doppler echocardiography Ea was calculated as E/Ea. Tissue Doppler – derived RV strain was obtained from the average of basal, mid, and apical RV segments[6].

III- STE- derived RV global strain [STE-RVGST] was obtained with a software package [Echo-pac, USA] from the apical view, to measure global RVSTE. Standard gray scale 2D image were obtained at a frame rate of 70-90 frames /s. the RV endocardial border was traced manually from an end –systole frame. Then the epicardial border was automatically detected by the software, and the region of interest was manually adjusted to include the entire RV myocardial wall as in figure [1]. The quality tracking was verified and the region of interest was modified, and corrected if necessary to obtain optimal tracking[6].

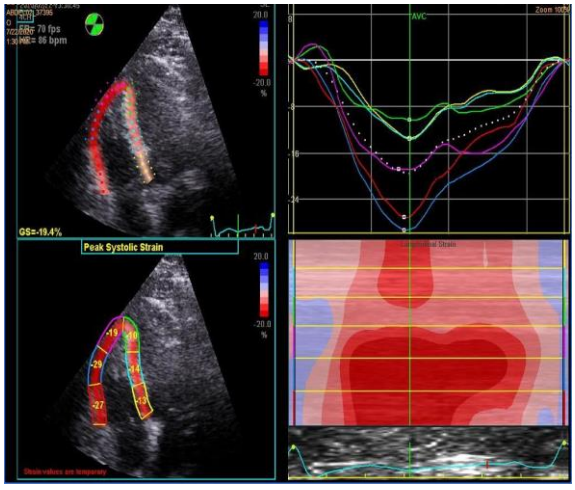

Figure [1]: Speckle tracking echocardiography derived right ventricle global strain of patient No. [21].

[e]Statistical methods: Data were collected, revised, tabulated, and statistically analyzed. Quantitative data were expressed as mean ±SD. The unpaired Student t-test was used for testing statistically significant difference between the means of two samples. The X^2–test was used to detect statistically significant relation between different variables [qualitative data]. The result was considered significant when P value was less than 0.05 and highly significant when less than 0.01.

RESULTS

This study was conducted on 68 participants, consisting of 38 patients with ICM [group I], in addition to 30 age and sex matched healthy subjects as a control group [group II]. The mean age of ICM patients was 57±9.3 years, whereas that of the control group was 55.8±7.7 years [P=0.4]. The ICM patients included 33[86.8%] men and 5 [13.2%] women, whereas the control group included 26 [86.7%] men and 4 [13.3%] women. As regards the risk factors, there were 22 hypertensive patients [58%], 21 diabetic patients [55%], and 19 patients were smokers [50%] while 15 patients [50 %] in the control group were smokers and no hypertensive nor diabetic patients in the control group. The ICM showed high statistically significant hypertension and DM than control group.

Table [1] showed the conventional echo-parameters in ICM and control group where there is statistically significant high LVEDD, LVESD, LAD dimensions and LA/Ao ratio in Group I [ICM] than control group [group II] while statistically significant low FS and EF in Group I [ICM] than control group [group II] and no statistically significant difference in aortic root diameter. These finding is sensible as the patient is cardiomyopathic and control is free from cardiac diseases.

Group I [ICM] had significantly higher values of MV-E vel, and LV Tei index, with significantly lower value of MV-DT compared to group II [CL] [Table 2]

In evaluation of conventional RV 2D and M-mode parameters there is significant high basal, mid and longitudinal RVD, RVEDV, RVESD, RVED area, RVES area in group I [ICM] than control group [Group II] and statistically significant low RVEF, TAPSE, RV-FAC in group I [ICM] than control group [group II] and no significant difference as regard RVEDD and RVESD [table 3 and figure 2].

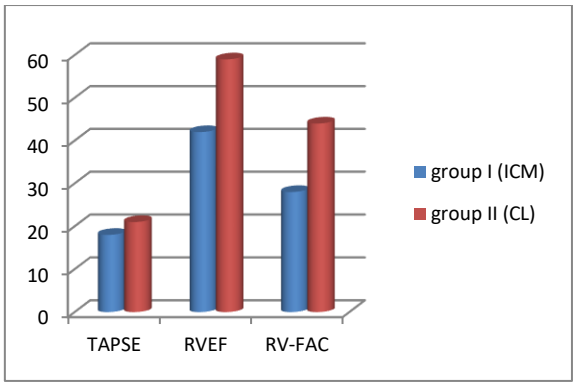

Figure [2]: Comparison between group I [ICM] and group II [CL] in respect to TAPSE&RVEF and RV-FAC %: p <0.003 for TAPSE, p<0.001 for RVEF and RV-FAC%.

While in evaluation of conventional RV Doppler parameters there is significantly higher values of TV-A vel, TV-SPG and RV Tei index in Group I [ICM] compared to control group [group II] and statistically significantly lower values of TV-EDT, TV E/A and Pulm- TVI in group I [ICM] compared to control group [group II]. There was no significant difference in TV-E vel between the two groups [ICM and CL] [Table 4].

In this study RV TDI and speckle tracking parameters revealed statistically significant low Free Ea, Free Sa, TD-derived RV strain and STE-RVGST in Group I [ICM] than control group [group II] and no statistically significant difference in Free Aa and E/Ea [Table 5 and Figure 3].

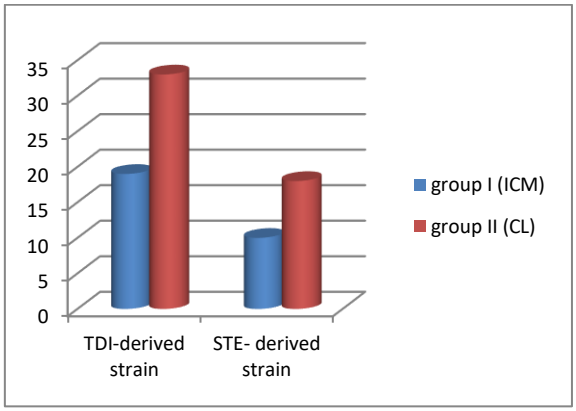

Figure [3]: Comparison between group I [ICM] and group II [CL] in respect to TDI-derived RV strain and STE-derived RV strain: TDI- derived RV strain [p <0.000] and RV-GLS [p<0.000].

There was significant negative correlation between LVEF% and RV Tei index [r=-44, P<0.01] with significant positive correlation between LVEF% and RVGLS [r=0.61, P<0.001] [Figure 4].

Table [1]: Comparison between group-I [ICM] and group II [CL] by conventional M-mode and 2-D echo parameters

Variables	ICM [n:38]	CL [no:30]	P value
LVEDD [mm]	65.02±6.9	48.46±4.29	<0.001*
LVESD [mm]	53.97±6.7	30.28±4.3	<0.001*
FS [%]	15.8±5.5	37.10±4.9	<0.001*
LVEF [%]	34.60±8.0	64.46±4.4	<0.001*
LAD [mm]	46.7±6.1	37.7±3.6	<0.001*
AoD [mm]	29.2±3.2	30.2±4.7	0.3
LA/Ao	1.6±0.2	1.2±0.1	<0.001*
LVEDV [ml]	153.6±43.2	70.67±14.2	<0.001*
LVESV [ml]	114.2±38.2	34.14±7.1	<0.001*

CL, control group; ICM, ischemic cardiomyopathy; LVEDD: left ventricular end diastolic dimension; mm: millimeter; LVESD: left ventricular end systolic dimension; FS: fraction shortening; LVEF: left ventricular ejection fraction; LAD: left atrial dimension; AoD: aortic root dimension; LA/Ao: ratio between left atrium and aortic root dimension; LVEDV: left ventricular end diastolic volume; ml: milliliter; LVESV: left ventricular end systolic volume; *: significant.

Table [2]: LV conventional Doppler flow parameters in group I and group II

Variables	ICM [n:38]	CL [no:30]	P value
MV-E vel [m/s]	0.79±0.20	0.62±0.10	<0.001*
MV-A vel[m/s]	o.57±0.23	0.58±0.13	0.9
MV-E/A ratio	2.0±3.4	1.1±0.2	0.1
MV-DT [sec]	120.6±37.0	174.3±37.21	<0.001*
LV Tei index	0.90±0.28	0.51±0.13	<0.001*

CL: control group; ICM: ischemic cardiomyopathy; m/s: meter per second; MV-E vel: peak early diastolic filling velocity; MV-A vel: peak late diastolic filling velocity; MV-E/A: the ratio between MV-E vel; MV-A vel; MV-EDT: deceleration time of the early mitral flow; sec: seconds; LV: left ventricular; * significant.

Table [3]: M-mode and 2D echo RV parameters in group I [ICM] and group I [CL]

Variables	ICM [n:38]	CL [no:30]	P value
RVEDD [mm]	23.21±8.22	23.0±3.1	0.9
RVESD [mm]	18.23±7.27	17.85±2.49	0.7
Basal RVD [mm]	41.65±8.86	31.85±3.73	<0.001*
Mid RVD [mm]	30.81±10.20	25.93±3.03	0.01*
Longitudinal RVD [mm]	74.42±14.76	57.10±5.67	<0.001*
RVEDV [mm]	54.5±32.9	34.0±18	0.01*
RVESV [ml]	32.65±21,60	18.31±15.33	<0.001*
RVEF%	40.44±8.02	59.03±5.10	<0.001*
TAPSE [mm]	18.31±4.31	21.03±2.89	0.003*
RVED area [cm2]	22.87±13.83	12.61±1.96	<0.001*
RVES area [cm2]	16.33±9.98	6.91±0.98	<0.001*
RV-FAC %	28±9.0	44±8.0	<0.001*

CL: control group; ICM, ischemic cardiomyopathy; RVEDD: right ventricular end diastolic dimension; mm: millimeter; RVESD: right ventricular end systolic dimension; RVD: right ventricular dimensions; RVEDV: right ventricular end diastolic volume; ml: milliliter; RVESV: right ventricular end systolic volume; RVEF%: right ventricular ejection fractional percentage; TAPSE: tricuspid annular plane systolic excursion; RVED: right ventricular end diastolic; cm^2: square centimeter; RVES: right ventricular end systolic; RV-FAC%: right ventricular fraction area change percentage; *: significant.

Table [4]: RV conventional Doppler flow parameters in group I [ICM] and group II [CL]

Variables	ICM [n:38]	CL [no:30]	P value
TV-E vel [m/s]	0.55±0.20	0.59±0.07	0.2
TV-A vel [m/s]	0.51±0.18	0.43±0.05	0.01*
TV-DT [sec]	127.481±51.60	201.60±52.43	<0.001**
RV E/A ratio	1.20±0.58	1.43±0.20	0.03*
TR vel [m/s]	3.12±0.77	2.49±0.46	<0.001**
TV-SPG [mmHg]	40.31±15.39	22.28±3.93	<0.001**
RVSP [mmHg]	50.31±15.39	32.28±3.93	<0.001**
Pulm- TVI [cm]	15.02±4.32.	19.05±2.91	<0.001**
RV Tei index	0.72±0.33	0.44±0.11	<0.001**

CL: control group; ICM: ischemic cardiomyopathy; T-E vel: tricuspid peak velocity of early filling; m/s: meter per second; T-A vel: tricuspid peak velocity of late velocity; TVDT: tricuspid valve deceleration time; RV E/A: Trans-tricuspid early to late diastolic peak velocities ratio; TR vel: peak systolic velocity across tricuspid valve; TV-SPG: peak systolic pressure gradient across tricuspid valve; mmHg: millimeter mercury; RVSP: right ventricular systolic pressure; Pulm-TVI: pulmonary flow time velocity integral; cm: centimeter; RV: right ventricular; *, significant.

Table [5]: RV TDI and STE parameters of RV function in group I [ICM] and group II [CL]

Variables	Group I ICM [n:38]	Group II CL [no:30]	P value
Free Ea [cm/sec]	6.76±2.72	8.20±1.86	0.01*
Free Aa [cm/sec]	9.86±3.86	10.07±2.00	0.2
E/Ea	8.13±7.4	7.19±3.8	0.2
Free Sa [cm/sec]	8.00±2.86	10.91±1.10	<0.001*
TD-derived RV strain %	19.83±15,19	33.87±5.82	<0.001*
STE-RVGST %	-10.01±3.7	-18.83±3.34	<0.001*

CL: control group; ICM: ischemic cardiomyopathy; Free Ea: peak early diastolic annular velocity; cm/s: centimeter per second; Free Aa: peak late diastolic annular velocity; E/Ea: peak velocity of early filling/peak early diastolic annular velocity; Free Sa: peak systolic annular velocity; RV: right ventricle; TD-derived RV strain: tissue Doppler derived right ventricular strain; STE-RVGST: speckle-tracking echo-derived right ventricular global strain; *: significant.

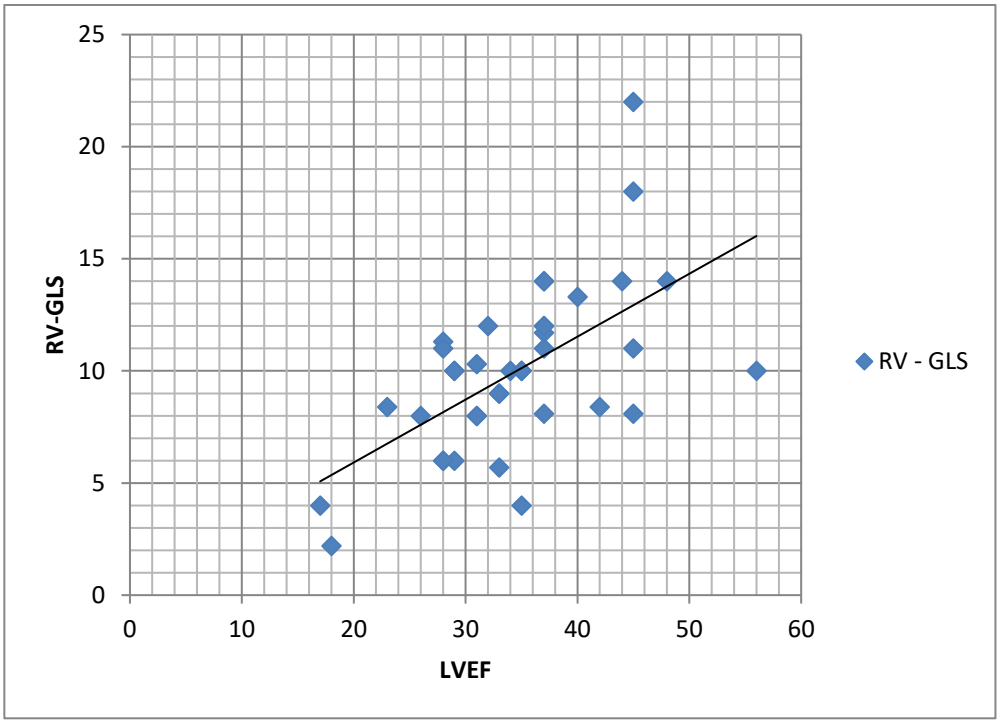

Figure [4]: Correlation between LVEF and RV-GLS

DISCUSSION

Patients with ICM have an increased risk of mortality that directly proportionate to reduction of left ventricular Ejection fraction. RV evaluation is important in all clinical stages of HF even if RV systolic dysfunction is note clinical evident. Several studies have suggested that RV dysfunction is an important prognostic factor in patients with ICM and has been well established to be a better marker for exercise capacity than LV function in both ischemic and dilated cardiomyopathy[8].

Accurate assessment of RV function in patients with ischemic cardiomyopathy by 2D STE represents a promising non-invasive method because cardiovascular magnetic resonance is not readily widely available beside its high cost which is considered a major limitation[9].

The present study comprised 38 patients with ICM, in addition to 30 normal individuals as a control group. As the baseline for choose our patients in this study, the parameters of LV function were altered in patients with ICM compared to the normal subjects.

Although sex is matched in both groups but male predominance was present, which may be caused by high prevalence of ischemic heart disease and heart failure in males.

In the current study RV was more dilated at the basal level, the mid cavity level and longitudinal RV diameter in ischemic cardio-myopathic patients. ICM patients have increased RVEDD and RVESD with reduction of RVEF% and TAPSE in comparison with the control group. Our results were concordant with an Egyptian study done by **William and El Kilany**[10] who assessed right ventricular function by echocardiography in 100 patients with chronic

heart failure due to dilated cardiomyopathy and found that RV dilatation at the basal level is present in 36%, at the mid cavity level in 23% and at longitudinal RV diameter in only 20% of patients with chronic heart failure. Also, **Özdamar et al.**[11] found that RV diameters [basal, mid and longitudinal diameters] was increased. Also, RVEDV and RVESV were found to be increased in ICM patients with reduction of RVEF% when compared to control group.

In accordance to our study, **Mouton et al.**[12] found that RVFAC and TAPSE were reduced in ischemic subgroup of their study. Also, **Wasemiller et al.**[13] and **Parcharidou et al.**[14] found right ventricular ejection fraction in reduced and right ventricular end-diastolic and end-systolic volumes were increased in ischemic subgroup of their studies.

As regard RV conventional Doppler parameters in our study, we demonstrated significant higher values of TR-vel and so TVSP in ICM patients compared to the control group, which is concordant with what was reported by **Özdamar et al.**[11] and **Tigen et al.**[15]. RV functions are more sensitive to increased afterload. pulmonary hypertension leading to deterioration of RV systolic function[11]**.**

Regarding RV tissue Doppler systolic and early diastolic velocities in our study, ICM patients showed lower values of [TV-Sa and TV-Ea] than control group. These findings indicate impairment of RV function in patients with ICM. In accordance to these finding, **Özdamar et al.**[11], **Mouton et al.**[12] and **Parcharidou et al.**[14] found that the values of TV-Sa and TV-Ea are lower in ICM than control group.

As regard RV TDI-derived strain we found significant difference between ICM and normal subject in the apical but not in the basal segments. Our result was in concordant with **Rudski et al.**[3] who reported that apical RV strain was higher than basal RV strain.

In our study RV-GLS showed a significantly lower value in ICM patients compared to normal subjects. These finding was concordant with what was reported by **Mouton et al.**[12]. The clinical utility of STE in assessment of RV function is supported by our finding as it is unaffected by Doppler angle.

The presence of significant negative correlation between LVEF% and RV Tei index [r = -44, P <0.01] and significant positive correlation between LFEF% and RVGLS [r=0.61, P<0.001] reflect the relation of RV systolic and diastolic dysfunction to LV dysfunction in ICM patients.

Conclusion: Patients with ischemic cardiomyopathy have both systolic and diastolic RV dysfunction, Speckle tracking echocardiography have an additive role in assessment of RV systolic dysfunction.

Study limitations: The left ventricle-GLS measurement program was used in this analysis to measure the RV strain due to the lack of proper ventricular program in our echo system. Using RV dedicated software to calculate RV GLS could yield a little different result than the ones found in this report. Considerable number of ischemic cardio-myopathic patients had diabetes mellitus and hypertension which may affect RV function parameters beside the pathology of ischemic cardiomyopathy.

Financial and non-financial Relationships and Activities of Interest

Authors declare: None

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Print ISSN: 2636-4174
Online ISSN: 2682-3780