The Egyptian Journal of Hospital Medicine (April 2024) Vol. 95, Page 1559- 1564

Assessment of Left and Right Ventricular Functions by 3D Echocardiography and 2-Dimensional Strain in Patients with Inferior Defect Detected by Single-Photon Emission Computed Tomography Imaging

Eman S. EL Shahawy[1], Taghreed A. Ahmed[1], Mohamed S. EL Shahawy[2], Fatma Elhady[1]
[1] Department of Cardiology, Faculty of Medicine (For Girls) and [2]Department of Internal Medicine, Faculty of Medicine, Al-Azhar University, Cairo, Egypt
Corresponding author: Fatma Elhady, Mobile: 01226763986,
ORCID: 0009-0008-6404-2054, **Email:** fatma_elhady2013@yahoo.com

ABSTRACT
Background: The prognosis for inferior wall myocardial ischemia is better than that of other locations.
Objective: The aim of the study was to assess the function of left and right ventricles (LV and RV) in patients with inferior wall perfusion defects. **Subjects and methods:** The present study included 112 patients with positive inferior wall perfusion defect by single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI). The echocardiography was done within one month after MPI.
Results: There were decreased LV and RV functions as assessed by 2D speckle tracking echocardiography (2D-STE). and 3D echocardiography. The 2D-STE was able to identify subtle LV and RV dysfunction in about 72.5% and 40% respectively while with 3D echocardiography, LV and RV dysfunction was 75% and 46.2% respectively.
Conclusion: SPECT as a non-invasive technique; is an important tool to detect extent of myocardial ischemia. 2D speckle tracking and 3D echocardiography are able to identify subclinical LV and RV dysfunction.
Keywords: SPECT, left and RV ventricular functions, 3D Echo, 2D speckle tracking.

INTRODUCTION

The pathophysiological condition known as myocardial ischemia is multifactorial and denotes an imbalance in the supply and demand of oxygen in the heart [1]. The inferior wall is affected in about 40% of all myocardial infarctions (MIs). In the past, inferior MIs have been associated with a better prognosis than MIs located in other areas, like the anterior wall of the heart. Less than 10% of MIs to the inferior wall result in death. Nonetheless, there are a number of aggravating conditions, such as heart block, bradycardia, hypotension, right ventricular infarction, and cardiogenic shock, that raise mortality [2].

Numerous investigations have shown that between 20% and 50% of inferior wall MI patients are linked to right ventricular myocardial infarction (RVMI); less than 10% of cases had hemodynamically significant RVMI. There was little left ventricular (LV) involvement and significant RV necrosis, according to the autopsies [3]. RV function may be impacted by prolonging LV ischemia in two ways: directly by altering RV perfusions and indirectly by increasing RV afterload.

From an anatomical and physiological standpoint, the RV and LV differ greatly from one another [4]. It has been demonstrated that right ventricular (RV) dysfunction increases the risk of heart failure and death. RV dysfunction is a poor prognostic sign. Performance of the right ventricle (RV) and left ventricle (LV) are closely related for several reasons, including shared coronary artery blood supply.

The most common uses of SPECT myocardial perfusion imaging (MPI) are to determine the presence and probability of ischemia, as well as to gauge the degree of ischemia for prognostic purposes [5]. The imaging of the LV and RV has relied heavily on echocardiography, which is also easily accessible and less expensive than other techniques for evaluating RV function. It is a useful tool for a comprehensive evaluation of the dimensions and function of RVs and LVs. RV anatomy, location, and structure make it challenging to evaluate using echocardiography. Modern echocardiography methods, like cardiac deformation imaging four-dimensional echocardiography (4DE) and STE, provide potential fixes for the majority of issues with conventional echocardiography [6].

The aim of the study was to assess the function of left and right ventricles (LV and RV) in patients with inferior defects.

PATIENTS AND METHODS

Study design

The current study included 112 adult patients with known CAD and positive SPECT imaging for inferior wall myocardial defect. The SPECT imaging was done based on different clinical accepted indications. Our patients presented to the Department of Cardiology Alzhraa Hospital- Al-Azhar University, Cairo, Egypt during the period between December 2022 to October 2023.

Exclusion criteria included:

1. Patients with significant valvular heart disease.
2. Patients who had poor transthoracic echogenicity.
3. Patients who were not in sinus rhythm.

Received: 08/11/2023
Accepted: 08/01/2024

4. LV ejection fraction (EF) less than 50%.
5. Patients having comorbidity; (e.g., history of malignancy).
6. Positive SPECT with other ischemic region other than inferior wall ischemia.

All participants were subjected to a full history taking that included arterial hypertension, diabetes mellitus, dyslipidemia, a current drug profile, smoking status, and a standard 12-lead resting ECG, in addition to treadmill exercise stress testing using the Bruce Protocol modality to estimate the functional capacity (work load) of patients defined as metabolic equivalents (METs).

Assessment

Myocardial perfusion imaging (MPI)

A gated SPECT MPI study was conducted over two days. Supine and prone images were captured consecutively with a dual-head (Philips) camera equipped with low-energy, high-resolution collimators. 99mTc sestaMIBI (International Atomic energy agency, Vienna, Austria) was used in every case, the prone position was used to reduce false positive results. In each of the 17 segments, the relative percent absorption of tracers was used to calculate the myocardial perfusions. There was a quantitative and qualitative study of the findings. Each segment was given a score ranging from 0 to 4 where 0 denoted average uptake, 4 denoting absence of uptake. Different high-risk perfusion scanning signs were described separately, including abnormal regional and wall motions, transient ischemia dilatation (TID), and higher lung heart ratio (LHR).

Gated MPI was computed in conjunction with LVEF. In order to calculate LVEF from reconstructed three-dimensional data, automated edge identification software was crucial.

Transthoracic echocardiography

An echocardiography that has both two, three-dimensional (2DE, 3DE) and tissue Doppler imaging (TDI) capabilities, vivid E9 (GE Ultrasound, Herten, Norway) was used. Using a multi frequency (2.5MHz) matrix probe, instances were examined (M3S).

All images were electronically stored at EchoPAC.GE version 204 in preparation for further offline analysis. 2D and 3D echo parameters [7].

Evaluation of the left and right ventricular dimensions and functions was done in reference to the basis of the American Society of Echocardiography chambers quantification standards including, M-mode, 2-D and Echo-Doppler study [8]**.** The echocardiography was done within one month after MPI.

Tissue Doppler Imaging

For the TDI velocity we used the apical four chamber view on the septal and lateral wall for the LV and on the free wall side for the RV where the basal segment and the annulus aligned with the Doppler cursor to avoid velocity underestimation. For data acquisition, three complete cardiac cycles were collected and stored in a cine-loop format. The image sector width was set as narrow as possible to allow a frame rate acquisition greater than 80 frames/s. Special attentions was paid to the color Doppler velocity range setting to avoid any aliasing within the image.

Speckle track imaging (STE) was activated

Standard gray scale 2D images with a stable electrocardiographic recording were obtained from the apical four, apical three and apical two chamber views using 2D-speckle tracking echocardiographic examination. The longitudinal strain of the LV was also obtained. For the RV imaging standard gray scale 2D images were acquired in the apical 4CH view, with a stable electrocardiographic recording, to measure global systolic RV myocardial strain. An epicardial surface tracing was then automatically generated by the system that tracks the characteristic pattern of natural acoustic markers present in the myocardial wall ("speckles") of the LV and RV from frame to frame throughout the cardiac cycle [9]. Myocardial strain was then calculated by the change in position of the speckle pattern from the initial position. Peak systolic longitudinal strain was calculated by averaging the peak systolic values of the 18 segments for the LV and 6 segments for the RV.

3D echocardiography imaging was activated:

Using the same apparatus and 4V transducers, 3D echocardiographic imaging of the right and left ventricles was performed. Six-beat full-volume 4D data sets (about 30 vol/s) were gathered during breath-hold. The 12-slice screen was used during data collection to ensure that the LV and RV was completely covered by the set [10].

After that, the data sets were loaded into the 4DAutoLV Quantification software for analysis. The proposed LV contour was estimated. End-diastolic and end systolic LV volumes was identified automatically by the software. It was manually edited when required. Finally, the program generated LV volumes and ejection fraction. For the 4D RV data set was aligned using the RV longitudinal axes in the standard end diastolic frames. The RV free walls' posterior and anterior connections to the interventricular septum, as well as the distance between the septum and the RV free wall on the RV short axis view, were defined. The RV contours were automatically tracked during the entire cardiac cycle using the speckle-tracking approach. RV volumes, FAC, and EF were automatically measured.

Outcomes

Primary end point: Evaluation of the LV and RV function in patients with inferior defect in MPI.

Secondary end point: detection of subtle LV and RV dysfunction in patient with inferior defect in MPI by different Echo Doppler modalities 3D, 2D Speckle tracking echo.

Ethical approval:

This study was ethically approved by The Institutional Review Board of the Faculty of Medicine, Al-Azhar University. A written informed consent was obtained from each participant. This study was executed according to the code of ethics of the World Medical Association (Declaration of Helsinki) for studies on humans.

Statistical analysis

The sample size of 1- β =0.80 (80%) for the Spearman's correlation at level α =0.05 (5%), under these assumptions, amounted to 50 (G*power, version 3.1). Data of interest were retrieved from the hospital's medical records. The statistical analysis of data was performed using SPSS version (25). Numerical variables were presented as mean ± standard deviation (SD) and were compared using Student's t test and Mann Whitney U test. Categorical variables were expressed as frequency and percentage and were compared using Chi square test. Pearson's correlation test was used for the determination of the correlation coefficient (r) to test a positive or negative relationship between two variables. P value less than 0.05 was considered statistically significant.

RESULTS

In the current prospective study, the mean age was 49.7±7.3. About 59.8% of the patients were hypertensive, 51.78% were diabetics, 41.07% dyslipidemia and 45.53% were smokers. Other sociodemographic data were shown in **table (1).**

Table 1. Sociodemographic data

Characteristics		All-Patients (N=112)
Age (year) Mean ±SD		49.7±7.3
Sex		
Male	n (%)	86(76.79)
Female	n (%)	26(23.21)
Diabetes	n (%)	58(51.78)
Hypertension	n (%)	67(59.82)
Dyslipidemia	n (%)	46(41.07)
Smoking	n (%)	51(45.53)

Cardiac chest pain was seen in almost all our patients (80.3%), other symptom was dyspnea (19.6%). 70 patient (62.5%) had significant ST depression >1 mv and 26 patients (23.22%) had a negative stress test and 16 (14.28%) patients were submaximal stress test. The functional capacity assessed by treadmill exercise was (6.76±1.69).

Most LV conventional echo-Doppler parameters were within normal standards. The results of LV function assessed by 2D STE showed decrease in the average strain of the LV (-16.2±3.2) and EF % by 3D echocardiography (49.13±4.43) **(Table 2).** The 2D-STE was able to identify subtle LV dysfunction in about 72.5% while with 3D echocardiography, LV dysfunction was 75% .

Table 2. The parameters of left ventricle by different echocardiography modalities

All-Patients (N=112)	
Parameter	**Mean±SD**
LVEDD (mm)	50.75±6.53
LVESD (mm)	33.13±5.55
IVSD (mm)	9.8±1.26
LVPWD (mm)	10.43±2.18
LVEF % (M-mode)	63.5±6.76
LV FS%	34.08±5.43
LA (mm)	34.2±6.83
AO (mm)	28.0±5.35
LA/AO ratio	1.22±0.14
LVEF % (bi-plane 2D)	58.23±7.57
LV EF %(4D)	49.13±4.43
MV E velocity (cm/sec.)	72.33±20.79
MV A velocity (cm/sec.)	76.3±19.94
MV DT (msec.)	189.8±50.3
MV E/A ratio	1.03±0.34
LV Septal E' velocity (cm/sec.)	7.43±2.39
LV Lateral E' velocity (cm/sec.)	8.05±2.57
LVGLS strain %	-16.2±3.2

LVEDD; left ventricular end diastolic dimension, LVESD; left ventricular end systolic dimension, IVSD: inter ventricular septum dimension, LVPWD; left ventricular posterior wall thickness in diastole, LVEF; left ventricular ejection fraction, FS; fractional shortening, LA: left atrium, Ao: aorta, 4D: four dimension, MV E velocity: mitral valve early diastolic velocity, MV A velocity: mitral valve late diastolic velocity, MV DT: mitral valve deceleration time, LV Septal E' velocity: left ventricular septal early velocity, LV Lateral E' velocity: left ventricular lateral early velocity, LVGLS strain: left ventricular global longitudinal strain.

Echocardiographic data of the RV as shown in **table (3)**, there were increase in the basal, mid diameters, end diastolic area (EDA), end systolic area (ESA) of the RV. 32 patients (28.57%) showed decrease in fractional area change (FAC%) . Also, there was decrease in transannular plane systolic excursion (TAPSE) than normal standards as (40%) of the studied cases showed impaired TAPSE. Also, analysis of RV diastolic function showed decrease in E velocity with increase in A velocity than normal standards. 20% showed impaired relaxation while 80% were within normal range of E/A ratio standard values. Additionally, there was increase in myocardial performance Index (MPI) than normal standards. About (22.5%) showed impaired function. Concerning the average strain by 2D-STE the current study showed decrease in the magnitude of average global RV longitudinal strain detected by 2D-STE(-17.3±3.7). 40.17% of cases showed decreased RV strain. The 2D-STE was able to identify RV dysfunction in about 40% while with 3D echocardiography, RV dysfunction was 46.2%. The current results demonstrated that, there was positive correlation between average LVLS and RVGLS (r= 0.471, P= 0.04) as the LV longitudinal strain decreased the RV longitudinal strain decreased.

Table 3. The right ventricle parameters by 2D echocardiography, TDI and 3D

Parameter	**Mean±SD**
RVD1 basal diameter (mm)	39±5.2
RVD2 mid diameter (mm)	33.4±6.8
RVD3 longitudinal diameter (mm)	60.2±9.1
RV 2D EDA (cm^2)	33.2±23.2
RV 2D ESA (cm^2)	21±12.6
RV 2D FAC%	41.3±9.7
RV EF%(4D)	39.21±7.64
TAPSE (mm)	18.1±3.2
TV E velocity (cm/sec.)	51.2±16.9
TV A velocity (cm/sec.)	41.8±18.5
TV E/A ratio	1.21±0.31
Sm velocity (cm/sec.)	10.4±1.7
Em velocity (cm/sec.)	8.1±2.2
Am velocity (cm/sec.)	9.7±2.6
E/E' ratio	7.1±2.9
IVCT (sec.)	0.07±0.03
IVRT (sec.)	0.07±0.04
ET (sec.)	0.29±0.05
MP index	0.46±0.16
Global RV strain %	-17.4±4.2)

RVD1 basal diameter: right ventricular basal diameter, RVD2 mid diameter: right ventricular mid diameter, RVD3: right ventricular longitudinal diameter, RV 2D EDA: right ventricular two dimension end diastolic area, RV 2D ESA: right ventricular two dimension end systolic area, RV 2D FAC%: right ventricular two dimension fraction area change, RV EF%(4D): right ventricular ejection fraction by four dimension, TAPSE: transannular plane systolic excursion, TV E velocity: tricuspid valve early diastolic velocity, TV A velocity: tricuspid valve late diastolic velocity, Sm velocity: systolic velocity by TDI, Em velocity: early diastolic velocity by TDI, Am velocity: late diastolic velocity by TDI, E/E' ratio: early diastolic velocity of mitral valve to early diastolic velocity by TDI, IVCT: isovolumetric contraction time, IVRT: isovolumetric relaxation time, ET: ejection time, MP index: myocardial performance index.

The MPI result revealed the average LV ischemic % was (7.03±2.18), scar% was (5.73±1.1) while the total defect size was (12.78±1.6), LHR (31.8±3.39) **Table (4)**

Table 4: Descriptive statistics of LV MPI parameters

LV MPI parameters	
Ischemia% Mean±SD	7.03±2.18
Scar% Mean±SD	5.73±1.1
Total defect size Mean±SD	12.78±1.6
Lung Heart Ratio (LHR) Mean±SD	31.8±3.39

Then we classified the patients according to LVGLS into patient with impaired and preserved LVGLS. The patients with impaired LVGLS was 82 patient and 30 patients with normal LVGLS. 35 patients (42.68%) with impaired LVLGS had perfusion defect in inferior, infero-septal and infero-apical segments compared to only 5 patient (16.66%) of preserved function regarding the same segments **(Table 5).**

Table 5: Comparison between impaired and preserved patients regarding distribution of perfusion defect (segmental analysis) of the LV

MPI Defects	LVLS result		
	Impaired (n=82)	Preserved (n=30)	Total (n=112)
I, IL , n (%)	11(13.4%)	3(10.0%)	14
I, IL, IA n(%)	21(25.60%)	3(10.0%)	24
I, IL, IS n(%)	6(7.31%)	0	6
I, IS , n(%)	3(3.65%)	8(26.66%)	11
I, IS, IA n(%)	35(42.68%)	5(16.66%)	40
I, IS, IA, IL n(%)	6(7.31%)	11(36.6%)	17
Total, n(%)	82	30	112

I: inferior segment, IL: inferolateral, IA: inferoapical, IS: inferoseptal.

There was weak negative correlation between the percentage of ischemia in the defect size and the LVGLS (R=-0.125) and there was mild to moderate significant correlation between the percentage of ischemia in the defect and RV systolic function by 2D GLS (r=0.44) **Table (6**).

Table 6. Correlation between different MPI parameters and LV and RV function by 2D-STE

LV Parameters	2D GLS
Total defect size	r=0.146, P=0.185
Scar%	r=-0.039, P=0.405
Ischemia%	r=-0.125, P=0.222
LHR	r=0.405, P=0.005*
RV Parameters	**2D GLS**
Total defect size	r=0.218, P=0.177
Scar%	r=-0.173, P=0.285
Ischemia%	r=0.44, P=0.004*
LHR	r=0.142, P=0.382

*: Significant

Then when we classified these patient according to RVGLS, the patients with impaired RVGLS was 45 patients and 67patient with normal RVGLS. There was increase Lung and RV uptake in patients with impaired RV function and there was increase in scar % in the impaired group compared to preserved group. There was a statistically significant difference in the LV EF% between impaired and preserved group. **Table (7).**

Table 7. Comparison between impaired group and preserved group regarding functional analysis of the RV

Variables	Impaired (n=45)	Preserved Group (n=67)	P-value
LHR , Mean ± SD	0.34 ± 0.69	0.3 ± 0.04	0.03*
Lung uptake Increase , n(%) Normal, n(%)	 8 (17.7%) 37 (82.2%)	 0 (0%) 67 (100%)	**<0.001***
LV function: -Normal n (%) -Transient ischemic dilatation n(%)	 29(64.44%) 16 (35.56%)	 40 (59.7%) 27 (40.3%)	0.613
LV EF%, Mean ± SD	59.38 ± 6.2	62.04 ± 5.95	**0.025***
Total defect size% Mean ± SD	11.81 ± 5.78	13.42±7.16	0.46
Scar% , Mean ± SD	6.13±4.14	5.46±4.12	0.62
Ischemia% , Mean ± SD	5.69±6.78	7.92±5.7	0.26
RV perfusion -Mild Increase, n(%) -Normal, n(%)	 17(37.7%) 28(62.3%)	 5(7.46%) 62(92.54%)	**<0.001***

*: Significant

DISCUSSION

According to several studies inferior wall MI accounts for 20% to 50% of cases when RVMI occurs. Less than 10% of cases had RVMI that was hemodynamically significant. There was little left ventricular (LV) involvement and significant RV necrosis, according to the autopsies **[3].** It has been demonstrated that right ventricular (RV) dysfunction increases the risk of heart failure and death. RV dysfunction is a poor prognostic sign. Performance of the right ventricle (RV) and left ventricle (LV) are closely related for several reasons, including shared coronary artery blood supply.

Patients' age in the current study ranged from 40-60 years and males represented (76.8%) with the M: F ratio 3:1. This was near to **Malik *et al*** **[11]** that assess the relationship of inferior wall ischemia on SPECT MPI with (RCA) anatomy by angiography; the prevalence of self-reported diabetes mellitus, hypertension and dyslipidemia was 36%, 71.9% and 53.9% respectively.

As the most common symptom of CAD is central chest pain, this was seen in almost all our patients (80.3%) %). Another symptom was dyspnea (19.6%). **Rajesh *et al.*** **[3]** found 59 % of patients with inferior wall MI complain of chest pain.

Exercise ECG showed that 62.5% had ST segment depression >1 mv. The present results were similar to the results of **Tavel and Shaar** **[12]** who study ECG changes during exercise MPI and he found (59%) showed exercise ST changes.

The current study revealed that there was reduction in the overall ability to exercise by using treadmill, average METS (**6.76±1.69**). 85% of the patients completed the test and achieved their targeted HR, while 14.28% could not complete the examination. These findings were comparable with **Kim *et al.*** **[13]** who did exercise stress MPI and found that regional LV ischemia of the inferior wall was involved in RV dysfunction and decreased effort tolerance.

On assessment of LV by conventional echocardiography; our study showed normal values of LV dimensions, systolic function (EF%) and fractional shortening (FS) assessed by M-mode and biplane 2D echocardiography. While the LV global longitudinal strain assessed by 2D STE and 4D echocardiography showed decreased values than normal standards, which is approximately equivalent to **Li *et al.*** **[14]** who found in 10 cases with inferior MI, the LV strain decreased.

On assessment of RV by conventional echocardiography, there was increase in basal, mid diameters, EDA and ESA than normal standards, while the longitudinal diameter was not affected. This was near to the study by **Rajesh *et al.*** **[3]** who studied patients with acute inferior wall MI by echocardiography and found RV FAC abnormalities in (39%) and also decreased TAPSE.

Assessment of RV systolic function by TDI (S') velocity; were within the normal standards. This was reported by **Barthélémy *et al.*** **[15]** in their study, which showed that peak systolic velocity (S') only assesses longitudinal movement of the lateral wall of the right ventricle and can be normal despite significant RV dysfunction.

Additionally, there was increase in myocardial performance Index (MPI) than normal standards. About (22.5%) showed impaired function. These results were comparable to **Rajesh *et al*.** [3] who found that, the MPI by TDI was a good indicative tool for detecting RV systolic dysfunction.

Our study results showed decrease in the magnitude of RV global longitudinal strain detected by 2D-STE. 40.17% of cases showed decreased RV strain, so, RV strain can be used to detect early sub-clinical RV dysfunction in patients with stable coronary artery disease. This was concordant with **Chang *et al.*** [15] who studied patients undergoing elective coronary angiography for suspected CAD by 2D STE and found the same results.Moreover, most patients with impaired LVGLS (42.68%) showed perfusion defect in inferior, inferoseptal and inferoapical and inferolateral segments compared to only (16.66%) of preserved function regarding same segments. This was comparable to the findings of **Pereztol *et al.*** [17] who examined patients receiving PCI using SPECT MPI and came to the conclusion that the distribution seems to be more specific for the RCA if the inferoseptal segments are implicated. Similarly, the inferoapical segment may be attributed to the RCA or the LAD; however, the distribution seems to be more specific for the RCA if the inferior segments at the mid- and basal levels are involved, while the territory appears to be more specific for the LAD if the other apical segments are involved.

CONCLUSION

In patients with inferior myocardial defect, segmental analysis of MPI can predict the culprit stenosed artery, redirect the treatment strategy and predicts prognosis. 2D-STE and 3D echocardiography can detect subclinical RV and LV function impairment and could be used as a routine assessment of RV and LV in case of inferior wall ischemia.

- **Conflict of Interest Statement:** The authors have no conflicts of interest to declare.
- **Funding/Support:** The authors have not received any funding for this clinical study.

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