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Assessment of Right Ventricular Performance by 4D Echocardiography and 2D Speckle Tracking in Patients with Inferior Defect Detected by SPECT Imaging

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Abstract

Early detection of subtle right ventricular dysfunction has a good prognostic value and redirects the treatment strategy plans. Our aim is to assess the right ventricular performance by 2D speckle tracking and 4D echocardiography in patients with inferior hypo-perfusion defects detected by SPECT imaging. A hospital based cross sectional study included 40 individuals, positive for inferior wall hypo-perfusion defect by SPECT MPI imaging. The study group individuals underwent full history taking, clinical examination, conventional echocardiography, tissue Doppler imaging (TDI), 2D-speckle tracking, and 4D-echocardiography of the RV. 16 patients (40%) of our study population showed decreased average global RV longitudinal strain (-14.92±1.81) and decreased 4D RV function (EF%) 34.32 ± 7.65. TAPSE was decreased in the impaired group (14 ± 2.28) compared to (20.96 ± 2.64) in the preserved group. Qualitative analysis of the perfusion scan showed mild increase in the lung heart ratio among the impaired group (0.34 ± 0.69) compared to the preserved group (0.3 ± 0.04), with increased RV uptake among 7 cases from the impaired group as compared to only 2 cases from the preserved group. 68.8% of the RV impaired study group had MPI hypo-perfusion defects in inferior, infero-septal, and infero-apical regions compared to only (12.5%) of the preserved group. The impaired group showed totally scared defects (37.5%) compared to only (12.5%) of the preserved group. Our finding highlights that speckle tracking and 4D echocardiography enable more accurate assessment of the RV morphology and functions. Furthermore, SPECT imaging could be a good guide for the culprit stenosed artery.

Keywords: Right ventricle dysfunction, 4D-echocardiography, 2D speckle tracking.

1. Introduction

Myocardial ischemia is a pathophysiological multi-factorial state which involves a complex interaction between the myocardium and the coronary vessels. Basically, it represents unbalanced supply to demanded oxygenation of the myocardium [1]. SPECT (Single photon emission computed tomography) MPI

(Myocardial Perfusion Imaging) is mostly used to assess the possible ischemic stenosis of the coronaries and their severity to assess the prognosis [2]. Inferior wall myocardial infarctions (MIs) approximately involve 40% of all MIs. Fortunately, inferior MI has a prognosis better than other cardiac walls, especially the anterior wall MI. Inferior wall MI is of 10% mortality rate. However, several complications such as additive RV infarction, arrhythmia, hypotension, and cardiogenic shock could worsen the prognosis [3].

For long time, the right ventricle was considered less relevant in cardiac diseases than the left ventricle and was regarded as the forgotten neglected chamber of the heart. Nowadays, the Right Ventricular role in the management and in the prognosis of lots of cardiac diseases increased [4].

Moreover, the evaluation of RV function by echocardiography is challenging than that of left ventricle mainly due to the RV complexity structure and its asymmetry [5].

Recently, speckle-tracking echocardiography provides objective measures for segmental and global ventricular function quantification independent of the angle of incidence, ventricular size and cardiac rotation [6].

Three-dimensional (3D) echocardiography has an advantage in detecting RV volumes and reconstructing images which could be performed both online and offline. Nowadays, new solutions for real time acquisitions are available to get accurate RV functional measures [7].

The aim: This study aims to assess right ventricular performance by 4D echocardiography and 2D speckle tracking echocardiography in patients with inferior defect detected by SPECT imaging.

2. Patients and Methods

This hospital-based cross-sectional study was carried out between May 2021 to May 2022. We studied 40 patients from the gamma nuclear unit (in Al Zahraa hospital) with the following inclusion criteria: all participants had positive inferior wall defects detected by SPECT MPI imaging. The exclusion criteria in our study included: cases with significant valvular heart disease, poor transthoracic echogenicity, not in sinus rhythm, LV EF less than 52%, comorbidities (ex., history of malignancy), and positive SPECT for other ischemic regions rather than the inferior wall.

All participants gave their verbal consent according to the ethical committee's approval at (FMG) Faculty of Medicine for Girls. 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 (workload) of patients defined as METs [8].

Technetium myocardial perfusion scan functional data was collected together with markers for high-risk perfusion scans (e.g., increased lung heart ratio (LHR), transient ischemic dilatation (TID), abnormal wall motion abnormalities (WMA) [9].

Conventional transthoracic echo-Doppler study was done using Vivid-9GE system (GE, USA) using multifrequency (2.5–3.5 MHz) (M5SC) probe. Stored 3-5 cycles with breath holding used for offline analysis by the EchoPAC.GE program, version no. 204, to assess 2D speckle tracking echocardiography (STE), where the endocardial surface of the RV was traced manually using new software (a point-and-click approach). The system then automatically traces the epicardial surface through the cardiac cycle, frame to frame, which tracks the acoustic speckle pattern of the RV myocardial wall. 14 Strain was calculated as the positional changes in speckles' pattern from their initial positions. By averaging the sum of all RV six segments, the global RV peak longitudinal (GLS) strain was obtained [10]. Reference value for normal GLS is -20% [11].

Then the 4D probe was activated; 6-beat full volume 3D sets (≥ 30 vol/s) while patient holds breath. RV must be fully included in the data set by using the 12-slice display. RV volumes over time are automatically calculated, showing end diastolic, end systolic, and stroke volumes in addition to EF%. Reference value of 4D EF >45% is considered normal in reference to the American Society of Echocardiography chamber quantification standards [12].

3. Statistical analysis of data

Data was collected and statistically analyzed using IBM SPSS software package version 25. Analysis of the categorical variables was done using Chi square test, numerical variables using Student's t test. Bi-variate correlation coefficient "r" performed for continuous variables, multivariate correlation (logistic regression) to compare possible predicting values between groups. Diagnostic performance of MPI tomographic data for echo-evidenced RV dysfunction assessment performed using receiver operating characteristics (ROC) curves. A P value <0.05 was considered statistically significant.

4. Results

Our study included more males (85%) and only six females (15%), aged between 40 and 60 years (77.5%), with a mean age of 49.7±7.3 years. By collecting 2D STE and 4D echocardiographic data, we classified the patients into two groups: the impaired group (Group I) included 16 patients (40%); 14 males (87.5%) and 2 females (12.5%) with impaired RV function; and a preserved group (Group II) included 24 patients (60%); 20 males (83.3%) and 4 females (16.7%) with preserved RV function. Both study groups were similar regarding all demographic data and the frequencies of risk factors.

As shown in figure 1 by comparing the two groups, regarding RV conventional echo-parameters, there was a statistically significant difference regarding TAPSE values: lower TAPSE in the impaired group (14 ± 2.28) compared to (20.96 ± 2.64) in the preserved group (P<0.05). A ROC curve was constructed in comparison to 4D RV EF%, and it was found that TAPSE ≤ 16 had a sensitivity of 56% and a specificity of 100% in detecting RV functional impairment (AUC: 0.99).

As shown in Table .1 by comparing RV segmental longitudinal strain between both groups, a statistically significant difference was found to be lower values in the impaired group. As shown in Table 2 comparing the two groups regarding 4D echocardiographic parameters showed statistically significant lower values in the impaired group.

Both groups were shown regarding the treadmill functional score (METs) and time of exercise. There were higher frequencies of ST segment depression in the preserved group (79%), compared to the impaired group (25%).A s show in table 3 our study showed a significant difference between the two groups regarding MPI-derived functional parameters; there was higher lung tracer uptake with increased lung heart ratio and right ventricular perfusion in the impaired group than the preserved group, as shown in. As shown in Table .4 it was observed that 68.8% of the impaired group had the same 3 hypoperfusion defects: inferior, infero-septal, and infero-apical segments, compared to only 12.5% in the preserved group.

As shown in figure 2 ROC curves of LHR and quantitative defect analysis parameters compared to RVEF < 45% showed that both LHR and defect scar% yielded higher diagnostic performance (AUC: 0.661 and 0.540 respectively), (sensitivity :0.75 and 0.93 respectively) in comparison to the linear indices.

Table 1: Comparing the two groups' RV strain results:

Groups / Items	Impaired RV Group (n=16)	Preserved RV Group (n=24)	Test of significance
RV free wall basal strain * Mean ± SD	-26.31±7.77	-31.25±13.46	t=1.146 P=0.151
RV free wall mid strain * Mean ± SD	-15.13±6.89	-25.88±8.37	t=4.255 P=0.000*
RV free wall apical strain * Mean ± SD	-11.69±4.64	-23.67±10.12	t=5.052 P=0.000*
RV free wall strain * Mean ± SD	-17.21±2.99	-23.69±5.14	t=4.540 P=0.000*
RV septal basal strain * Mean ± SD	-13.19±3.54	-18.75±8.82	t=2.388 P=0.022*
RV septal mid strain * Mean ± SD	-15.38±4.92	-21.67±7.85	t=2.846 P=0.007*
RV septal apical strain * Mean ± SD	-15.31±4.75	-23.71±8.15	t=3.710 P=0.001*
Global RV strain * Mean ± SD	-14.92±1.81	-22.32±2.1	t=11.529 P=0.000*

*P value < 0.05 is considered significant.

Table 2: Comparison between the two groups regarding 4D echo parameters:

Items / Groups	Impaired RV Group (n=16)	Preserved RV Group (n=24)	Test of significance
RVEF%[1] * Mean ± SD	34.32 ± 7.65	51.85 ± 5.41	t=7.934 P=0.000*
EDV[2] (ml) * Mean ± SD	71.06 ± 28.81	66.67 ± 19.1	t= 0.581 P= 0.564
ESV[3] (ml) * Mean ± SD	45.75 ± 21.48	31.96 ± 8.9	t= 2.433 P= 0.025*
SV[4] (ml) * Mean ± SD	26.25 ± 10.35	34.96 ± 11.51	t=2.437 P= 0.02*

*P value < 0.05 is considered significant. [1]Right ventricular ejection fraction, [2]End diastolic volume, [3]End systolic volume, [4] stroke volume.

Table (3): Comparison between the two groups regarding functional analysis and right ventricular perfusion:

Groups / Items	Impaired RV Group (n=16)	Preserved RV Group (n=24)	Test of significance
LHR[1]: Mean ± SD	0.34 ± 0.69 (0.24-0.49)	0.3 ± 0.04 (0.23-0.39)	t=2.159 P=0.03*
Lung uptake Increase Normal	 3 (18.7%) 13 (81.3%)	 0 (0%) 24 (100%)	 X^2 = 4.865 P= 0.027*
RV perfusion *Mild Increase *Normal	 7(43.7%) 9(56.3%)	 2(8.4%) 22(91.6%)	X^2=6.906 P= 0.009*

*P value < 0.05 is considered significant. [1] Lung Heart Ratio.

Table (4): Comparison between the two groups regarding distribution of perfusion defect (segmental analysis):

Groups / Items	Impaired RV Group (n=16)	Preserved RV Group (n=24)	Test of significance
Number of segments:			
*2	3 (18.7%)	6 (25%)	
• I[1], IS[2]	2	2	
• I, IL[3]	1	4	
*3	11 (68.8%)	14 (58.3%)	
• I, IA[4], IS	11	3	
• I, IA, IL	0	9	X^2=17.123
• I, IL, IS	0	2	P=0.004*
*4- I, IS, IL, IA	2 (12.5%)	4 (16.7%)	

*P value < 0.05 is considered significant., [1] Inferior, [2] Infero-septal, [3] Infero-lateral, [4] Infero-apical

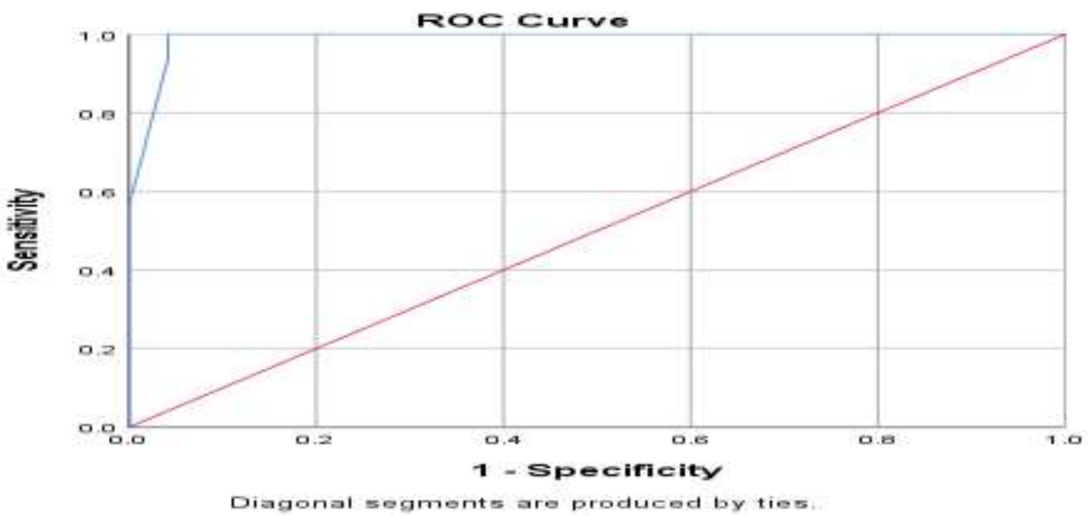

Figure 1: ROC curve of TAPSE in relation to 4D RV EF%

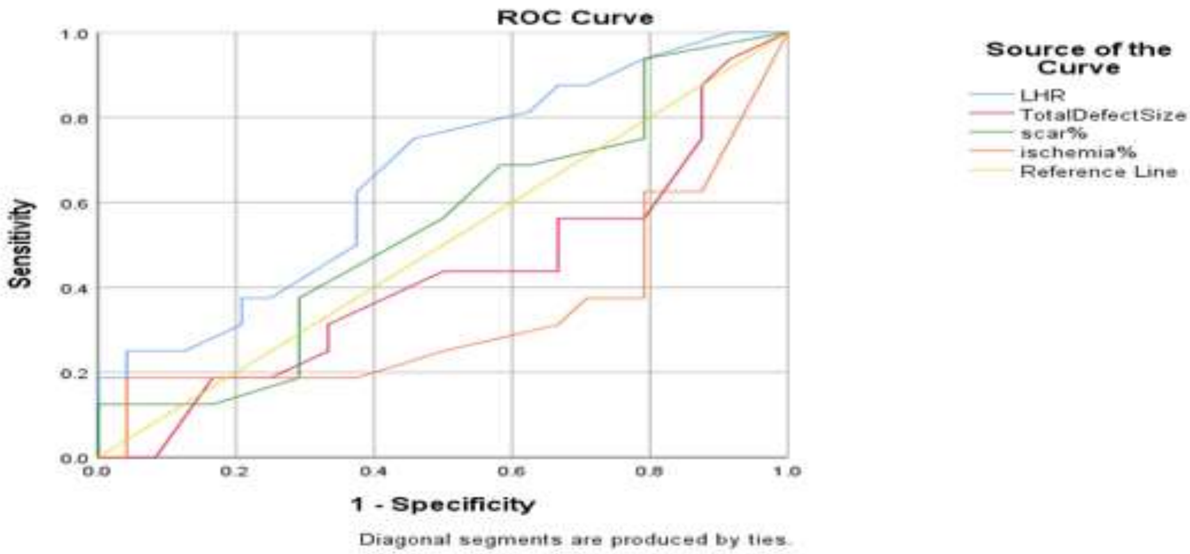

Figure 2: Receiver operating characteristics curves for LHR (Lung Heart Ratio) and quantitative defect analysis parameters in relation to RVEF by 4D.

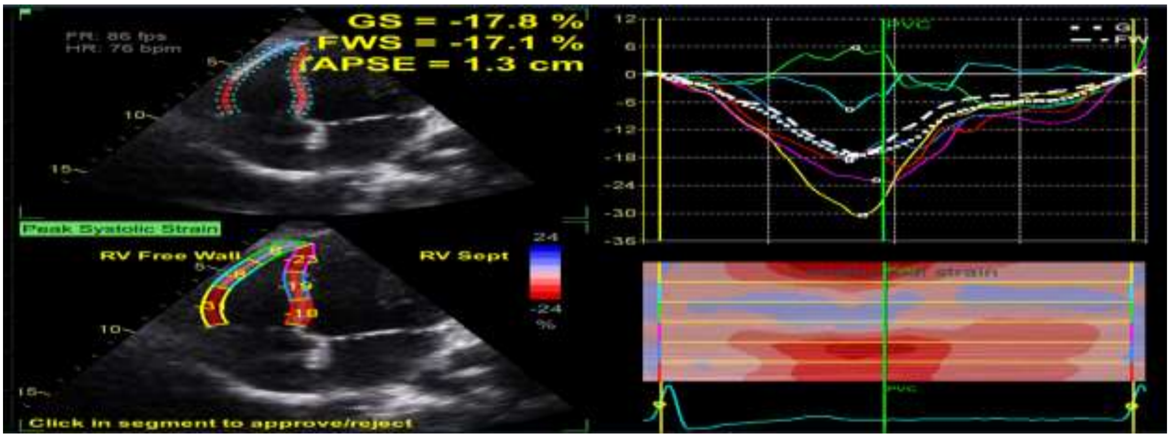

Figure 3: Offline analysis of 2D speckle tracking of RV showing impaired strain (case no.25-Impaired group).

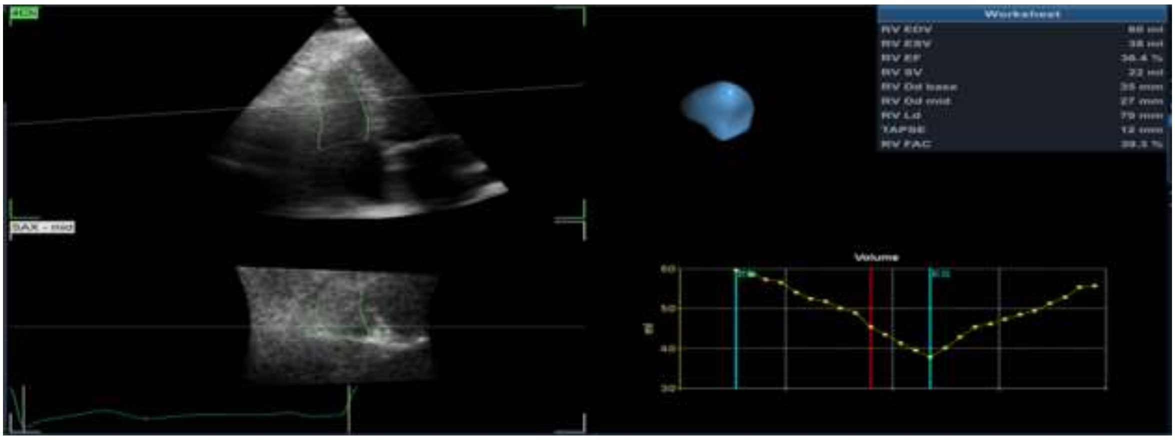

Figure 4: 4D echocardiographic offline analysis of the RV showing impaired function (case no.25-Impaired group).

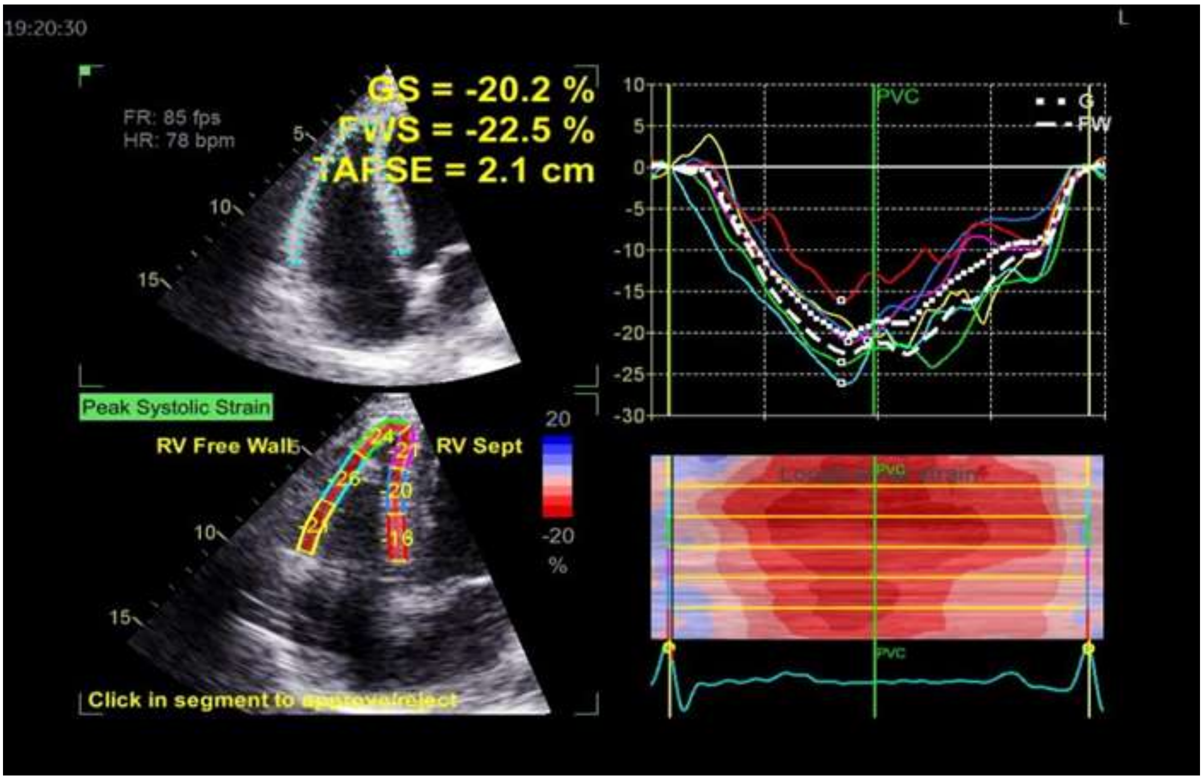

Figure 5: Offline analysis of 2D speckle tracking of RV showing normal strain (case no.4 - preserved group).

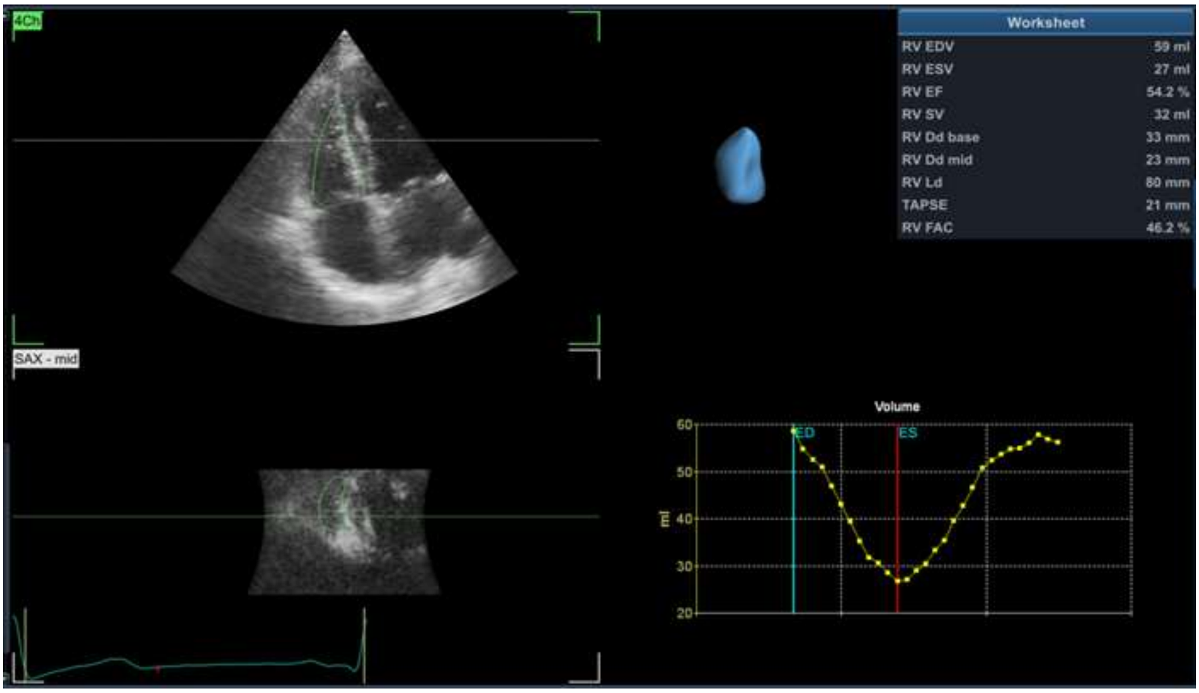

Figure 6: Offline analysis of 4D echocardiography of the RV showing preserved systolic function (case no.4 - preserved group).

5. Discussion

Our study comprised 40 patients with inferior wall hypoperfusion defects diagnosed by SPECT MPI. Predominantly male gender showed higher prevalence of inferior wall defects, with the M:F ratio of 5:1. This was concordant with the study done by Sony Manuel [13], who evaluated 35 patients with inferior wall MI by echocardiography to detect involvement of RV infarction. In his study, 80% of the patients were males, while 20% were females, with a M:F ratio of 4:1.

After classifying the study population into subgroups regarding speckle tracking and 4D echocardiographic parameters, we studied the main predictor parameters for the possible presence of RV dysfunction.

Regarding stress ST segment depression, the preserved group showed significant ST segment depression >1 mV (79%) compared to only 25% of the impaired group (P=0.001). The result of our study was consistent with Kang et al[14] , whose study demonstrated that exercise-induced ST depression poorly predicts the location of myocardial ischemia. His study comprised 247 cases with inferior leads ST depression; contrary to what was expected, patients had LAD territory perfusion defects.

Our results regarding MPI functional [15] parameters—the increase in lung and RV uptake—were consistent with Mannting, who reported that in myocardial perfusion studies, increased RV uptake could help identify RV pressure overload. Increased RV uptake without pulmonary or valvular heart disease indicates significant backward failure, which has a significant bad prognostic indication. Gomez [16] said that since RV myocardial blood flow is mainly from the right coronary artery (RCA) in the right dominant coronary circulation. So, it can be a good chance if SPECT imaging detects RV ischemia in patients with LV inferior wall ischemia. This was also concordant with Farag et al [17], they studied 34 patients with an inferior wall defect MPI, most of whom were men, and found that 17 patients (50%) had RV perfusion abnormalities. In some of the patients with CAD and LV inferior wall perfusion abnormalities, using technetium-labeled tracers, a hypoperfusion pattern suggestive of right ventricular ischemia might be seen.

Most of our impaired patients (68.8%) showed perfusion defects in inferior, infero-septal, and infero-apical segments, compared to only 12.5% of the preserved group regarding the same segments. The previous results in our study put forth the hypothesis that the RCA could be the dominant vessel in those patients due to involvement of the infero-septal segment together with RV impairment.

This was explained by Paulo D. et al [18] , they investigated six cadaveric hearts for the relation between the coronary anatomy and the corresponding supplied myocardium according to the 17-segment model using CT (of the American Heart Association (AHA)). Four hearts were right coronary dominant, one was left dominant, and one was co-dominant. RCA appears to be the arterial blood supply of infero-septal segments in all the examined hearts. There was an overlap between the LAD artery and RCA territories in the infero-septal region.

Also, Pereztol et al [19], studied 50 patients undergoing PCI by SPECT MPI. They concluded that if the infero-septal segments were involved, it’s likely to be specific more to RCA, but if adjacent other inferior segments were involved; it’s likely to be specific more for LAD artery. Likewise, the infero-apical segment specially the mid and basal levels is more specific for RCA, but if other apical segments were involved, it’s likely to be specific more for the LAD artery. Furthermore, Segal et al [20], reported that additional adjacent segmental analysis can help clarifying SPECT imaging role in locating the diseased vessel. Thus, explaining the fact that MPI SPECT localizes the culprit lesion by coronary angiography almost in 85% of overall cases but fails to predict the additional involvement of other vessels in 29% of overall cases. By comparing both groups as regards conventional 2D eccho-Doppler study and tissue Doppler imaging, all RV echo parameters showed no statistical difference except for TAPSE; the impaired group showed lower values (14 ± 2.28) compared to (20.96 ± 2.64) in the preserved group (P = 0.000). Thus, we could rely on TAPSE as an easy and available diagnostic tool to detect RV impairment. Our study showed positive mild to moderate significant correlation between the percentage of ischemia in the defect area and RV systolic function by 2D GLS (r=0.44). This is supported by Wang et al [21], they reported that the longitudinal myocardium accounts for 70% of myocardial fiber, and longitudinal function ischemic injuries occur earlier than systolic function injuries in the other directions. So, longitudinal systolic strain could identify myocardial ischemia earlier. Our study showed that the scar percentage as well as the LHR had high sensitivity but low specificity to predict RV impairment. In that issue, there are limited studies discussing the sensitivity of quantitative parameters of MPI perfusion defects' impact on RV function; but Martinez et al [22], reported that increased Tl-201 lung uptake is a bad predictor of subsequent cardiac events. In addition, Won et al [23], reported that although LHR had low sensitivity in identifying severe coronary artery disease, it could be helpful in abnormal SPECT myocardial perfusion to stratify the risk and show the prognosis. Adelstein et al [24], had reported in a study that; higher scar burden detected by SPECT MPI impacts the survival rate negatively.

6. Conclusion

Conventional 2D echocardiography has many limitations, especially in RV assessment, and could miss some impaired cases, so assessment using 2D-STE and 4D echocardiography if available could detect subtle RV function impairment specially in case of inferior wall ischemia.

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