Assessment of Agreement between Gated SPECT Myocardial Perfusion Imaging and Echocardiography for Measurement of Left Ventricular Parameters in Dilated Cardiomyopathy Patients

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ABSTRACT

Background: Left ventricular function, volumes and regional wall motion provide valuable diagnostic information and are of long-term prognostic importance in patients with dilated cardiomyopathy (DCM). This study was designed to assess the agreement between the 2D-echocardiography and gated single-photon emission tomography (SPECT) for evaluation of these parameters in patients with DCM.

Patients and methods: Gated SPECT and 2D-echocardiography were performed in 60 patients having DCM. Gated SPECT data, including left ventricular volumes and left ventricular ejection fraction (LVEF), were processed using an automated algorithm. Standard technique was used for 2D-echocardiography. Regional wall motion was evaluated using both modalities and was scored by two independent observers using a 4-point scoring system for 5 specific walls.

Results: The overall agreement between the two imaging modalities for the assessment of regional wall motion was 95% (286/300 walls). With gated SPECT left ventricular ejection fraction (LVEF), end-diastolic volume (EDV), and end-systolic volume (ESV) were 27.38±6.71%, 214.73±75.35 ml, and 158.33±63.22 ml, respectively, and 31.25±5.09%, 185.05±55.63 ml, and 123.47±46.00 ml, respectively, with echocardiography. The correlation between gated SPECT and 2D-echocardiography was moderate ($r = 0.59$, $P<0.001$) for the assessment of LVEF. The correlation for EDV and ESV were also moderate, but with wider limits of agreement ($r = 0.62$, $P<0.001$ and $r = 0.65$, $P<0.001$, respectively) and significantly higher values were obtained with gated SPECT ($P<0.001$). For EDV, Bland-Altman measurements agreement analysis between the two methods demonstrated good agreement with finding of bias 29.68 and showed large limits of agreement, 95% upper and lower limit of agreement in 148.82 to -89.45 ml interval. For ESV, Bland-Altman measurements agreement analysis between them demonstrated good agreement with finding of bias 33.3 and showed large limits of agreement, 95% upper and lower limit of agreement in 130.12 to -63.52 interval. For LVEF, Bland-Altman measurements agreement analysis between them demonstrated good agreement with finding of bias 3.9 and 95% upper and lower limit of agreement in +14.8% to -7.0% interval.

Conclusion: Gated SPECT and 2D-echocardiography correlate well and by Bland- Altman agreement analysis they exhibit good agreement with large limits for the assessment of LV function and LV volumes. Like 2D-echocardiography, gated SPECT provides reliable information about LV function and dimension with the additional advantage of perfusion data.

Key words: **Myocardial perfusion imaging, gated SPECT, perfusion defect, EDV, ESV, LVEF, Agreement, Correlation, 2D-echocardiography.**

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INTRODUCTION

Dilated cardiomyopathy (DCM) is the most common cardiomyopathy and has a poor prognosis. DCM is characterized by ventricular re-modeling producing chamber dilatation, normal or decreased wall thickness, and diminution in systolic function. Impaired systolic function causes an increase in left ventricular end-diastolic volume (LVEDV) and left ventricular end-systolic volume (LVESV) with reduced left ventricular ejection fraction (LVEF). Left ventricle volume, LVEF, and regional wall motion provide valuable diagnostic information and are of long-term prognostic importance in patients with DCM.

Myocardial perfusion imaging (MPI) is a valuable tool in the management of patients with cardiovascular disease. With its unique ability to evaluate perfusion at the cellular level and to assess perfusion at peak exercise stress, MPI plays an important role in diagnosing cardiovascular disease, establishing prognosis, assessing the effectiveness of therapy, and evaluating viability. ECG gated SPECT myocardial perfusion imaging (GSMPI) offers the potential to simultaneously assesses LVEF and LV cavity, end systolic volume (ESV) and end diastolic volume (EDV) in addition to myocardial perfusion, wall motion and wall thickening with just one acquisition procedure (1).

Two-dimensional echocardiography can provide excellent images of the heart, paracardiac structures, and the great vessels. Of all the indications for echocardiography, the evaluation of ventricular systolic function is perhaps the most common. Echocardiography also permits reevaluation of ventricular size and function so that disease progression, recovery and deterioration and also response to therapy may be monitored noninvasively. In patients with ventricular dysfunction, echocardiography is also used to evaluate the appropriateness of therapy (2).

ElectrocardiographyGSMPI is a well practiced diagnostic modality at National Institute of Nuclear Medicine and Allied Sciences (NINMAS) and is routinely used to assess LV function (LVEF, wall motion, wall thickening), myocardial perfusion and volumes simultaneously. GSMPI has become a popular technique in the management of CAD in Bangladesh since 2001(9). For LV parameters measurement 2D echocardiography has been established as a method of choice in our country. However, there are considerable debates about the superiority of GSMPI and 2D echocardiography regarding their diagnostic accuracy in DCM patients. The purpose of this study is to evaluate the accuracy of gated SPECT for the assessment of LVEF, LV volumes, and regional wall motion in such patients and also to assess whether there is an agreement to more routinely used 2D echocardiography.

PATIENTS AND METHODS

This is a cross sectional analytical study carried out at the National Institute of Nuclear Medicine & Allied Sciences (NINMAS), Bangabandhu Sheikh Mujib Medical University, campus, from July 2013 to June 2014, for a period of 12 months. A total number of 60 adult patients (56 males and 04 females) with known case of DCM referred to NINMAS for GSMPI were included with an age range of 28 to 70 years. Patients with uncontrolled HTN, H/O cardiogenic shock, left ventricular failure, cardiac arrythmia, implanted pacemaker or LBBB were excluded from this study. This study protocol was based on the regulations of the hospital ethical committee. Proper history was taken from all patients according to the data collection sheet. The study was jointly carried out in the National Institute of Nuclear Medicine & Allied Sciences (NINMAS) and the department of cardiology, Bangabandhu Sheikh Mujib Medical University (BSMMU), Shahbag, Dhaka. All patients had undergone GSMPI as well as 2D echocardiography during the study. Left ventricular parameters were measured in stress and rest phase of one day stress-rest protocol of GSMPI and parameters obtained from rest phase were compared against those obtained from conventional 2D echocardiography done within 15 days to one month apart from MPI study.

For the pre procedure counseling and evaluation of patients with DCM, there was face to face interview session between each patient and a nuclear medicine physician. Best possible attempts were made to maintain adherence to quality control recommendations from renowned authorities (8) at all levels of patient preparation, radiopharmaceutical preparation and dispensing, image acquisition, image processing and image interpretation.

SPECT acquisition with ECG gating at the post-stress scan was done 15-30 minutes after stress injection of 10 mCi of Tc-99m-sestamibi and at the rest phase scan was done 45-60 minutes after 25 mCi of tracer on the same day following the post-stress scan. Acquisition of SPECT images were done with the double-headed SPECT scintillation camera (Siemens E cam) with detectors placed 76° to each other. Acquisition time was 20 seconds per projection requiring about 14 minutes per patient per scan. Butterworth filtering with cutoff of 0.5 cycles/sec and order 7 was used.

During processing a second check for quality of images were done. Adequacy of target to background ratio, motion artifact, extracardiac activity, inferior wall artifact, breast attenuation and accuracy of gating were checked once again. Processing of GSMPI images included checking for slice orientation, concordance of stress & rest slices of LV, definition of mid LV cavity & mid ventricular slices in short axis (SA), vertical long axis (VLA) & horizontal long axis (HLA) sections, masking of area outside LV, centering axis of LV and finally a visual check if any part of LV image is getting truncated by falling outside the region of interest (ROI) in gated images. For quantitative assessment of LVEF, EDV & ESV, 4D-MSPECT v4.2 software (Invia, LLC 2007) provided by Siemens medical solutions, Inc was applied to process & interpret raw GSMPI images. Perfusion data, measurements of LV volumes, LVEF and LV wall motion were obtained from GSMPI images.

M-mode and two-dimensional echocardiography was performed by experienced operators. The subject is asked to lie in the semi recumbent position on his or her left side with the head elevated. The left arm is tucked under the head and the right arm lies along the right side of the body. A standardized imaging protocol was adopted with cross-sectional imaging of the left ventricle immediately distal to the mitral valve tips and apical two-dimensional imaging based on orthogonal four- and two-chamber views.

M-mode measurements applied the leading edge to leading edge principle as recommended by the American Society of Echocardiography. M-mode left ventricular ejection fraction based on the cubed method was equal to (end-diastolic volume — end-systolic volume)/ end-diastolic volume where the end diastolic volume= EDD3 and end-systolic volume = ESD3. M-mode left ventricular ejection fraction was also calculated using the Teichholz correction, where end-diastolic volume = 7/(2.4 + EDD) x EDD3 and end-systolic volume =7/(2.4+ESD) x ESD3. 2D echo left ventricular ejection fraction was also evaluated by Simpson's biplane method of discs with manual planimetry of the endocardial border in end-diastolic (largest) and end-systolic (smallest) frames. Volumes were calculated from three cardiac cycles disregarding ectopic and postectopic beats with derivation of left ventricular ejection fraction.

Echocardiography studies were performed with Vivid 7 Dimension/Vivid 7 Pro, Version 7. X. X. X, GE Medical System Echocardiography Machine. All echocardiograms were digitalized on online optical disks and displayed side by side in a quad screen format. Parasternal long axis view (PLA), parasternal short axis view (PSA), at the level of papillary muscle level, apical long axis (ALA), 4 chambers, 2 chambers views were analyzed at rest. Digitalized images (PLA, SA, Apical 4 chamber, Apical 2 chamber) were obtained at rest, in the 1st minute of each stage, at peak of the stress, at recovery when HR & BP reach baseline values in DSE.

Statistical analysis was performed on statistical software SPSS (Statistical Package for Social Sciences) for windows 20. In SPSS, data were analyzed by two stages. Initially descriptive statistics such as frequency, percentage, mean, SD, range were calculated for the basic demographic characteristics and LVEF, LV volumes and RWMA of the study patients. The results of 2D echocardiographic measurements were compared to gated SPECT. Parameters (LVEF, EDV, ESV) measured using echocardiography and gated SPECT , continuous data were expressed as mean ± SD. The agreement between LVEF, EDV, ESV derived from gated SPECT and 2D echocardiography data were determined with a linear regression analysis (Pearson correlation coefficient r) and Bland-Altman (3) plots were constructed to observe if the differences between parameters plotted against respective geometric means of LV parameters falls within two standard deviations (SD) of difference (difference average, average +1.96 standard deviation, average -1.96 standard deviation, bias between two methods, upper and lower 95% limit of agreement) . For values of $p = 0.05$ were statistically significant.

For the assessment of regional wall motion similar to gated SPECT, 2D echocardiography also highlighted on 5 walls (anterior, inferior, lateral, septal and apical) and 4 point scoring system (1 = normal, 2 = hypokinetic, 3 = akinetic, 4 = dyskinetic) was used. Again, segmental wall motions were divided into two catagories – considered as normal and abnormal (hypokinetic, akinetic and dyskinetic). The agreement for segmental wall motion was assessed with 2 x 2 tables and weighted kappa statistics (4).

RESULTS

The GSMPI and 2D echocardiography was performed in 60 patients with known case of DCM. Among the 60 study patients there was 56 males and 4 females. The mean age of the study population was 51.68 years, ranging from 28 to 70 years with a mean height of 155.51 cm, ranging from 135-170 cm and mean weight 64.6 kg, ranging from 45-95 kg. There were 9 patients below 40 years, 7 patients within 40 to 49 years, 28 patients within 50 to 59 years and 16 patients around 60 years or more.

Table 1 : Demographic and base line characteristics of the study population

Characterstics	Mean ± SD	Range
Age (years)	51.68±9.79	28-70
Height (cm)	155.51±6.68	135-170
Weight (kg)	64.6±10.57	45-95
Age group	**Number**	**Percentage**
<40	9	15.0
40 – 49	7	11.7
50 – 59	28	46.7
≥ 60	16	26.7

Table 2 shows that all the study subjects were at some stages of clinical evaluation for known or suspected CAD referred for GSMPI. Thirty one patients were came for screening purpose to evaluate CAD. Fifty four patients were known cases of old myocardial infarction under medical management and came for assessment of myocardial viability. Eight patients had percutaneous transluminal coronary angioplasty (PTCA) and one patient had coronary artery bypass grafting (CABG) done who came for assessment after revascularization.

Table 2: Distribution of patients from their indication of doing GSMPI (n=60)

Indication for MPI	Number	Percentage
Screening for CAD	31	51.7
Screening for OMI	54	90.0
Post PTCA	8	13.3
Post CABG	1	1.7

Comparison shows mean difference ± SD of quantitative measurements of LV parameters (LVEF, EDV, ESV) by the MPI and 2D echocardiography in Table 3.

Table 3: Comparison between mean EDV, ESV and EF by MPI and 2D echocardiography:

Attributes	MPI (mean ± SD) with range	ECHO (mean ± SD) with range	Mean difference ± SD
EDV (ml)	214.73 ± 75.35 110-493	185.05 ± 55.63 98-353	29.68±59.57
ESV (ml)	158.33±63.22 71-381	123.47 ± 46.00 62-255	34.30±49.15
EF (ml)	27.38±6.71 23-50%	31.25±5.09 13-48%	3.87 ± 5.56

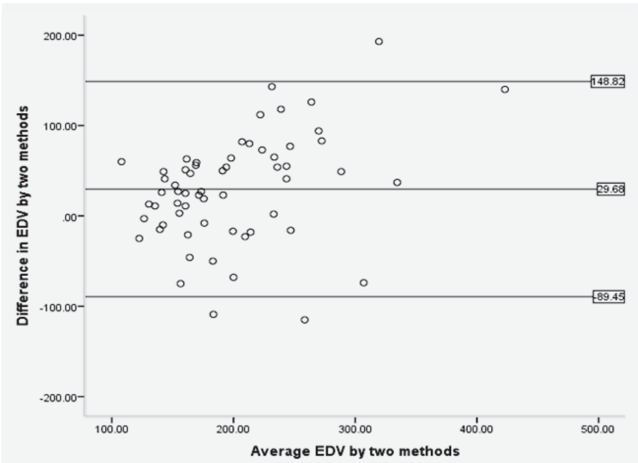

Figure 1 (a)

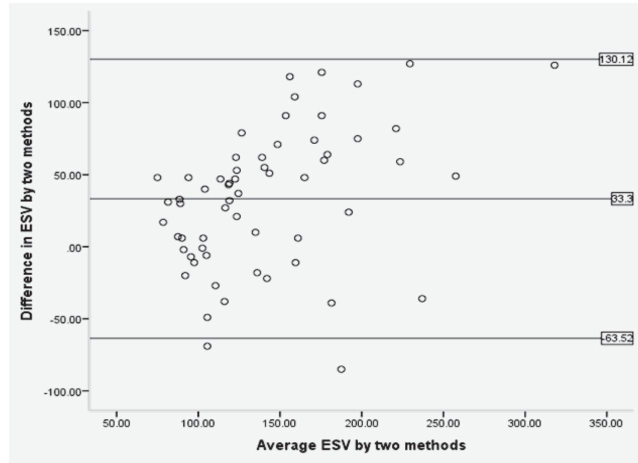

Figure 1 (b)

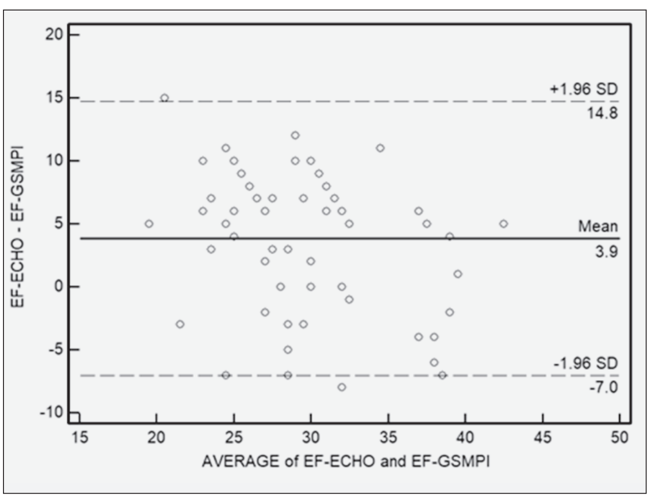

Figure 1 (c)

Figure 1: The agreement is represented in Bland Altman plot where differences between GSMPI and 2D echocardiography for measurement of EDV (a), ESV(b), LVEF(c) at rest in same patient fall within two SD of the mean difference. Geometric means of LVEDV, LVDSV and LVEF measurements by GSMPI and 2D echocardiography both at rest in each patient are plotted in X axis and difference between EDV, ESV and LVEF measurements by GSMPI and 2D echocardiography both at rest in each patient are plotted in Y axis. The central line represents overall mean difference of EDV, ESV and LVEF measurements by that two investigation methods. The outer pair of lines represents ±1.96 SD of difference.

Table 4: Assessment of agreement between MPI and 2D echocardiography by kappa statistics in detecting wall motion abnormality.

Wall motion		ECHO				
		Abnormal	Normal	Total	*k*	*P*
MPI	Abnormal	**259**	6	265		
	Normal	8	**27**	35	0.77	<0.001
	Total	267	33	300		

Table 4 shows the Kappa agreement analysis to see the agreement between MPI findings and 2D echocardiography findings in evaluation of regional wall motion abnormalities. A total 267 (89%) abnormal wall motion evaluated by 2D echocardiography, out of which 259 (86%) walls had abnormal wall motion and 8 (3%) walls had normal wall motion evaluated by MPI. A total 33 normal wall motion evaluated by 2D echocardiography, out of which 27 (9%) walls had normal wall motion and 6 (2%) walls had abnormal wall motion evaluated by MPI. Among them 259 walls show similar abnormal and 27 walls shows similar normal wall motion by those two method. Overall agreement was 95%.

The results of the two modalities (MPI and 2D echocardiography findings) analysis found Kappa value = 0.77 with p value <0.001 for detection of regional wall motion abnormalities. This measure of agreement is statistically significant with good agreement between MPI & 2D echocardiography findings in evaluation of regional wall motion abnormality.

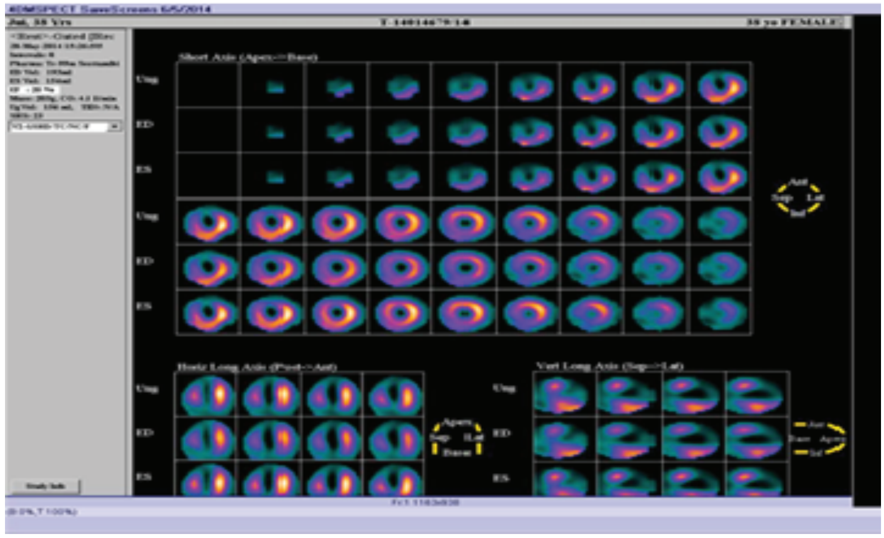

Figure 2. Gated SPECT Myocardial Perfusion Imaging image of a 38 years old female patient shows the dilatation of left ventricular cavity by large EDV=193 ml, large ESV= 154 ml and lower EF= 20% , antero-apical and septal ischemia, all parameters diagnosed her as a Dilated Cardiomyopathy patient.

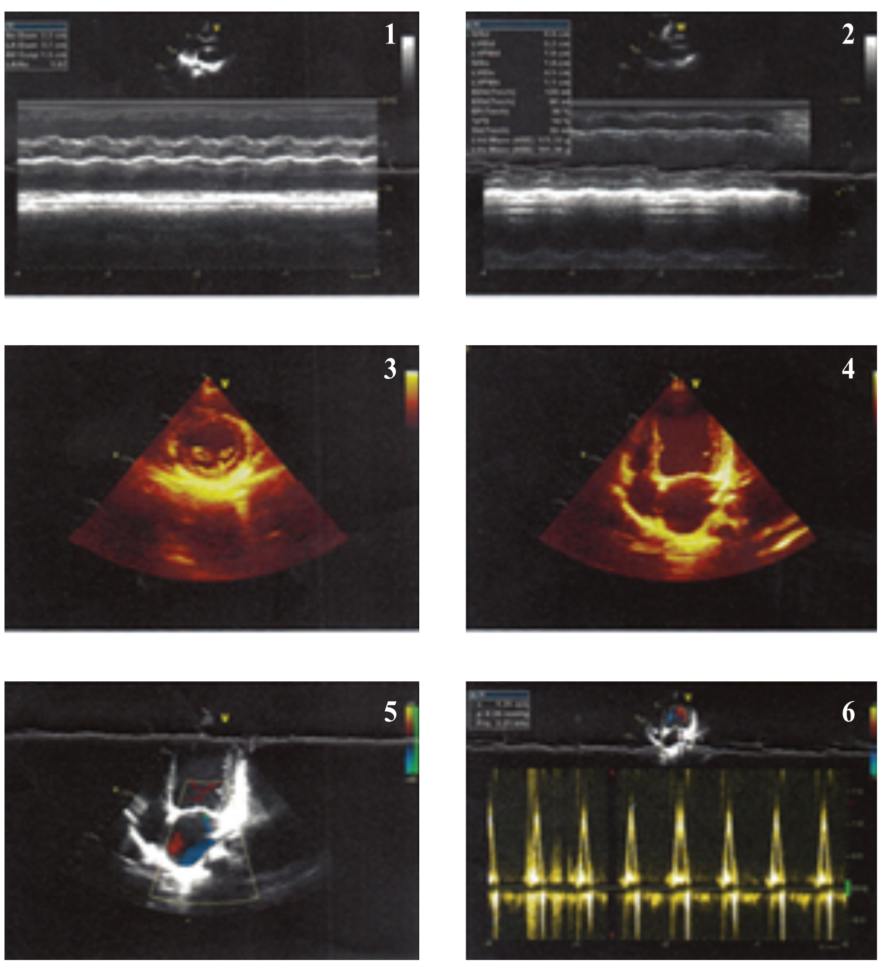

Figure 3. 2D echocardiographic image of same female patient shows dilatation of left ventricle, Left ventricular EDD (End Diastolic Diameter)= 5.2 cm and ESD (End Systolic Diameter) = 4.5 cm, EDV (End diastolic volume) in Teich. method=139 ml , ESV(End Systolic Volume) in Teich. method=90 ml, EF (Ejection Fraction)= 30% and image 6 shows compensatory tachycardia ,all the parameters diagnosed her as Dilated Cardiomyopathy patient.

DISCUSSION

The study attempted to assess agreement between GSMPI and 2D echocardiography for measurement of LV parameters (LV-EDV, LV-ESV, LV-EF and RWMA). Previously published reports suggest that 2D echocardiography and radionuclide GSMPI correlated well for comparing left ventricular ejection fraction and volumes in case of severely depressed LV function as well as LV dilatation. This study utilizes the LV wall motion also and assessing the agreement of 2D echocardiography and GSMPI performed in patients with DCM. Especially when DCM patient want to assess myocardial performance before coronary revascularization GSMPI gives them valuable information about myocardial perfusion as well as LV parameters at the same time, which is not possible for conventional 2D echocardiography. So, If there is an agreement between them, the patient may be benefited by doing GSMPI instead of two investigation which will be less time consuming, cost effective and more informative for the patient. In clinical practice, gated SPECT may be a good alternative for patients with limitations for optimal echocardiography visualization. Furthermore, it may be routinely used for patients who may also need to be assessed for myocardial viability and/or ischemia at the same time.

Agreement analysis of RWMA on the basis of specific walls were done for the first time in the country by this study and reveals good agreement between GSMPI and 2D echocardiography. Many previous studies compared the GSMPI and 2D echocardiography RWMA on the basis of segmental wall motion. Berk, et al. (5,6) demonstrated that the exact segmental agreement for assessment of regional wall motion between GSMPI and 2D echocardiography was 56%. In this study, the agreement for specific wall motion was assessed with 2 X 2 tables and weighted kappa statistics. An exact overall agreement was 95% found, with a kappa value of 0.77, indicating good agreement between the two methods in detecting RWMA. This is higher than the previous studies done by Berk (5,6).

In current study, Bland-Altman measurements analysis (3) between those two methods demonstrated good agreement for measurement of EDV with finding of large limits of agreement, 95% upper and lower limit of agreement in 148.82 to -89.45 ml interval and that for ESV was limit of agreement in 130.12 to -63.52 interval.

Nichols et al. (5) compared different analysis programs to correlate gated SPECT data to echocardiography in patients with severe perfusion defects, and demonstrated an overestimation of LV volumes with gated SPECT when QGS was used, especially in those patients with large LV volumes. Fourteen similar results were reported by Vourvori, et al. (5). On the other hand, Cwajg, et al. (6) evaluated 109 patients with both 2D-echocardiography and gated SPECT (using both Tl-201 and Tc-99m MIBI), and demonstrated good correlation between the two modalities for assessing LV volumes, but with slightly larger LV volumes on echocardiography than on gated SPECT. So, it can be said that Gated SPECT and 2D-echocardiography correlate well for the assessment of LV function and LV volumes. Like 2D-echocardiography, gated SPECT provides reliable information about LV function and dimension with the additional advantage of perfusion data.

Among the noninvasive modalities, MRI is considered the gold standard, because of high accuracy and reproducibility for volume measurements (12). It has been documented that despite small systematic differences, agreement between gated myocardial SPECT and MRI is good over a wide range of volumes and EF values using the QGS method (12). But in the study of Chuang et al (11) it was estimated that there was poor agreement (r = 0.43 0.46) between MRI and any of the biplane echocardiographic methods and agreement is poor between biplane and volumetric methods regardless of imaging modality. In the current study, results of echocardiographic assessment of volumes do in conformity with available literature correlate with gated-SPECT of myocardium on the same quantitative level, but echocardiography significantly underestimates results of LV volumes measurement also patients with Dilated cardiomyopathy. This finding can be interpreted in several ways. One can suggest that the main reason for this could be a not quite accurate geometrical tangential capture of LV in its long axis in individual apical echocardiographic projections leading into underestimation of echocardiographic measurement of LV volumes comparing to gated-SPECT.

Zanger, et al. (7) reported an agreement between echocardiography and gated SPECT for determination of LVEF and volumes. Nasrin et al. (9) found in her study that Gated SPECT and 2D echocardiography correlates quite well for the assessment of left ventricular function and left ventricular volumes in patients with DCM.

CONCLUSION

Gated SPECT was found to have good correlation with 2D echocardiography for measuring LV volumes and LVEF. In clinical practice, gated SPECT may be a good alternative for patients with limitations for optimal echocardiography visualization. Furthermore, it may be routinely used for patients who may also need to be assessed for myocardial viability and/or ischemia at the same time. Contrary to the labor intensive and more observer dependent echocardiography techniques that are widely used to assess LV volumes and LVEF, gated SPECT technique is fast, nearly completely automated, and highly reproducible.

DISCLOSURE

No competing financial interest exists.

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