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Comparison between ^{99m}Tc-sestamibi gated myocardial perfusion SPECT and echocardiography in assessment of left ventricular volumes and ejection fraction — effect of perfusion defect and small heart

Seyed Hashem Danesh-Sani[1], Seyed Rasoul Zakavi[2], Leyla Oskoueian[1], Vahid-Reza Dabbagh Kakhki[2]
[1]Department of Cardiovascular Diseases, Imam Reza Hospital, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran
[2]Nuclear Medicine Research Center, Ghaem Hospital, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

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Abstract

BACKGROUND: Agreement between gated myocardial perfusion SPECT (GSPECT) and echocardiography (ECHO) in the calculation of left ventricular end-diastolic volume (EDV), end-systolic volume (ESV) and LVEF was assessed. Effect of perfusion defect and small hearts on this agreement was obtained. Because ECHO is a routine and widely used noninvasive modality for this purpose, we chose this technique for comparison with GSPECT.
MATERIAL AND METHODS: In a prospective study, 50 consecutive patients (age = 59.7 ± 10.64 years) underwent rest Tc99m-sestamibi GSPECT and 2-D ECHO. The LVEF, EDV and ESV were calculated using QGS (Quantitative Gated SPECT) software.
RESULTS: Fourteen (28%) patients had perfusion defect in rest phase tomograms, while 36 (72%) had no perfusion defect. There was a significant correlation between two modalities in calculation of EDV, ESV and LVEF (all: $p < 0.001$, Pearson's correlation coefficients: $r = 0.764$, 0.831 and 0.813, respectively). A good correlation was noticed even in small hearts or in patients with or without previous myocardial infarction. There was a significant difference between GSPECT and ECHO in patients with no perfusion defect as well as in patients with small heart (ESV < 25 ml). On the other hand, no remarkable difference was noticed between two techniques in the presence of perfusion defect or in patients with ESV ≥ 25 ml.
CONCLUSION: There was a good agreement between EDV, ESV and LVEF derived from GSPECT and ECHO. There was a significant difference between two modalities in small hearts and in patients without perfusion defect, although in larger ventricles or in the presence of myocardial infarction no remarkable difference between two modalities was noticed.

KEY words: gated SPECT, echocardiography, ejection fraction, end-diastolic volume, end-systolic volume

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Background

Left ventricular function indicators including left ventricular volumes (LVVs) and ejection fraction (LVEF) are powerful and reliable in terms of their diagnostic and prognostic value, especially in coronary artery disease [1–4]. Nowadays, several modalities including echocardiography (ECHO), gated myocardial perfusion single photon emission tomography (GSPECT) , cardiac magnetic resonance imaging (cMRI), and radionuclide ventriculography (RNV) are available for the assessment of LVVs and LVEF [2, 5, 6]. Consequently, physicians would be faced with results of various imaging techniques during follow-up periods. Therefore, it is necessary for a cardiologist to be familiar with agreement between these modalities [2]. In clinical practice, this task is most commonly performed using 2-D echocardiography and more or less GSPECT [7]. GSPECT offers quantification of three-dimensional assessment of regional left ventricular function and simultaneous evaluation of both LV function and perfusion in a single study [4, 8]. According to previously published studies, there seems to be good agreement between different noninvasive methods for calculation of LV

Correspondence to: Vahid-Reza Dabbagh Kakhki
Nuclear Medicine Research Center, Ghaem Hospital, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran
Phone: +98–511–8012794
E-mail: dabbaghvr@mums.ac.ir

functional indices [9]. However, concerns have been raised about the different findings in particular situations, such as in the presence of perfusion defects [8] or in patients with small heart [9–11].

In this study, we tried to assess the correlation between gated SPECT and ECHO in the evaluation of left ventricular end-diastolic volume (EDV), end-systolic volume (ESV) and LVEF. Effect of perfusion defect and small hearts on this agreement between the results obtained. Because ECHO is a routine and widely used noninvasive modality for this purpose, we chose this technique for comparison with GSPECT.

Material and methods

Study population

In a prospective study, 50 consecutive patients (22 males and 28 females) with known or suspected coronary artery disease, referred for routine GSPECT underwent gated myocardial perfusion SPECT and two-dimensional echocardiogram within a 7-d period. There were no cardiac events between two studies. The patients' mean age was 59.70 ± 10.64 years (range 37–85 years). The local ethics committee approved the study and all patients gave their informed consent.

Gated SPECT

All patients underwent two-day stress-rest Tc99m-MIBI (methoxyisobutyl-isonitrile) gated SPECT which rest images were used for this study. Rest GSPECT acquisition was started after 90 minutes of the intravenous injection of 740-925 MBq Tc99m-MIBI. Data acquisition was performed with a dual-head SPECT system with the detectors oriented at 90 degrees (Dual-Head Variable-Angle E.CAM; Siemens) equipped with a low-energy-high resolution collimator. A 20% window with 140 keV energy peak was used. A total of 32 projections (step-and-shoot mode, 25 s per view) were obtained over a 180° arc commencing from the right anterior oblique to left posterior oblique view. We used a zoom factor of 1.45 and gating at 8 frames per cardiac cycle. The images were stored in a 64 × 64 matrix in the computer and reconstructed by filtered back-projection using a Butterworth filter (cut-off value was 0.35 cycle/cm for gated data but 0.55 cycle/cm for ungated data, order = 5). No attenuation or scatter correction was applied. All reconstructed tomographic images were interpreted by consensus of 2 experienced physicians. Rest tomograms images were evaluated visually with respect to presence of defect. Based on 17-segment model and 5-point scale system (0 — normal perfusion; 1 — mildly reduced uptake; 2 — moderately reduced uptake; 3 — severely reduced uptake; and 4 — absent uptake) was used for semi-quantitative assessment of rest myocardial perfusion tomograms (including six basal, six mid-ventricular and four apical segments in short axis slices and one additional mid-ventricular apical slice in the vertical long axis) [4]. The summed rest score (SRS) was calculated. The LVEF, EDV and ESV were calculated using previously validated and commercially available automated software: QGS (Quantitative Gated SPECT) from the rest GSPECT images.

Echocardiography

The two-dimensional echocardiograms according to the criteria of the American Society of Echocardiography were acquired at rest with standard short axis, apical and parasternal views using a GE Vivid 3 ultrasound system (GE Vingmed, Horten, Norway) and a 3MHZ probe by one experienced cardiologist blind to the results of the GSPECT study. The measurements were made by tracing the endocardium in end-systolic and diastolic phases using the Biplane Simpson's rule.

Statistical analysis

Numerical values of LVEF, EDV and ESV derived from GSPECT and ECHO were compared. Continuous data were expressed as means ± SD. To determine agreement between two modalities, Pearson's correlation coefficient was used. Paired sample t-test was used for the assessment of differences between two methods. Small ventricles were defined as end-systolic volumes < 25 ml as measured with QGS [10, 11]. Differences in average EDV, ESV and LVEF between echocardiography and GSPECT in patients with small heart or with normal size heart as well as in patient with or without perfusion defect were tested with independent sample *t*-test. $P < 0.05$ was considered statistically significant. All statistical analyses were performed with SPSS for Windows (SPSS 20).

Results

The clinical characteristics of all patients are described in Table 1. The SRS was 4.62 ± 7.80 (0–28). Fourteen (28%) patients had perfusion defect in rest phase tomograms, while 36 (72%) had no perfusion defect. Table 2 shows EDV, ESV and LVEF calculated with GSPECT and ECHO in all patients as well as in patients with and without perfusion defect. There was a significant correlation between two modalities in calculation of EDV, ESV and LVEF (all: $p < 0.001$) (Figure 1). Pearson's correlation coefficients for EDV, ESV and LVEF were r = 0.764, 0.831 and 0.813, respectively ($p < 0.001$). There was also a significant correlation between two modalities in patients both with and without perfusion defect. To determine the effect of severity of perfusion defect, patients were categorized based on their SRS: mild defect — SRS ≤ 3, significant defect — SRS>3 (Table 3). The patients with ESV < 25ml on GSPECT were considered as patients with small heart [10, 11]. GSPECT and ECHO findings based on ESV < 25 ml and ESV ≥ 25 ml are shown in Table 4.

Discussion

LV functional indices have major clinical diagnostic and prognostic importance in the management of patients with known or

Table 1. Patient characteristics

Variable	n = 50
Age (mean ± SD)	59.70 ± 10.64
Sex	
Female	28 (56%)
Male	22 (44%)
History	
Diabetes mellitus	18 (36%)
Hypertension	27 (54%)
Hyperlipidemia	16 (32%)
Smoking	10 (20%)

Table 2. Calculated EDV, ESV and LVEF using rest gated myocardial perfusion SPECT (GSPECT) and echocardiography (ECHO) in all patients as well as in two subgroups: with and without perfusion defect

Variable	Patients	GSPECT	ECHO	p value
EDV	No perfusion defect	51.42 ± 19.90	72.58 ± 21.01	< 0.001
	With perfusion defect	144.93 ± 59.99	125.21 ± 49.10	0.16
	All	77.60 ± 55.10	87.32 ± 39.05	0.068
ESV	No perfusion defect	16.61 ± 19.69	33.83 ± 10.87	< 0.001
	With perfusion defect	98.43 ± 63.05	94.29 ± 37.92	0.74
	All	39.52 ± 52.04	50.76 ± 34.89	0.01
LVEF	No perfusion defect	73.58 ± 20.26	58.06 ± 8.57	< 0.001
	With Perfusion defect	33.21 ± 18.36	30.93 ± 14.30	0.33
	All	62.28 ± 26.80	50.46 ± 16.06	< 0.001

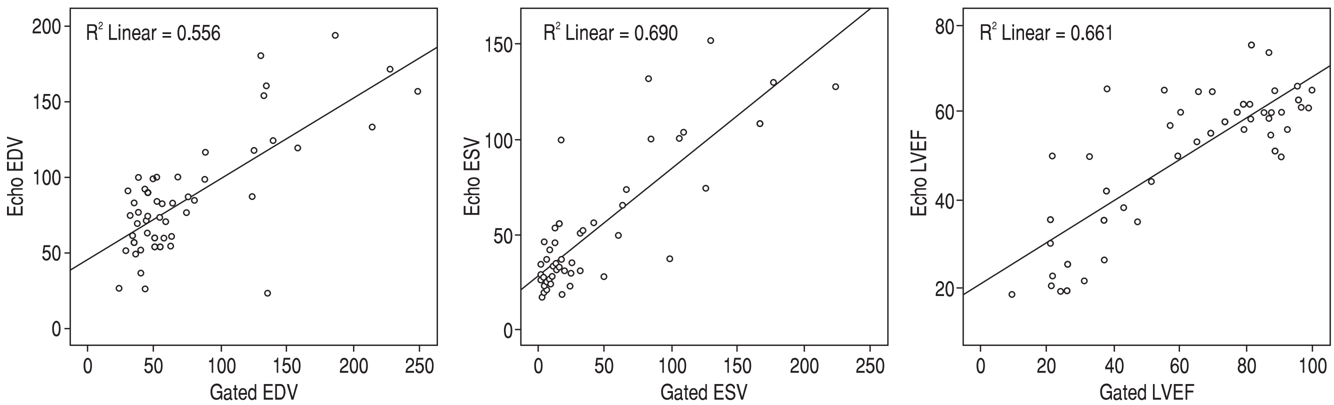

Figure 1. Scatter plot and linear correlation between echocardiography and gated myocardial perfusion SPECT (GSPECT) in caculation of EDV, ESV and LVEF

Table 3. Calculated EDV, ESV and LVEF using rest gated myocardial perfusion SPECT (GSPECT) and echocardiography (ECHO) based on summed rest score

Variable	Patients	GSPECT	ECHO	p value
EDV	SRS ≤ 3	56.68 ± 37.43	74.29 ± 24.74	0.001
	SRS > 3	143.83 ± 50.15	128.58 ± 47.85	0.30
ESV	SRS ≤ 3	22.21 ± 38.56	36.03 ± 18.70	0.002
	SRS > 3	94.33 ± 52.46	97.42 ± 33.51	0.80
LVEF	SRS ≤ 3	71.47 ± 22.37	56.97 ± 10.56	< 0.001
	SRS > 3	33.17 ± 17.26	29.83 ± 12.78	0.20

Table 4. Calculated EDV, ESV and LVEF using rest gated myocardial perfusion SPECT (GSPECT) and echocardiography (ECHO) based on ESV derived from GSPECT

Variable	Patients (n)	GSPECT	ECHO	p value
EDV	Small heart (32)	48.00 ± 19.55	66.53 ± 21.03	0.002
	No small heart (18)	130.22 ± 58.94	124.28 ± 36.45	0.55
ESV	Small heart (32)	9.56 ± 6.70	33.25 ± 15.27	< 0.001
	No small heart (18)	92.78 ± 55.07	81.89 ± 38.49	0.23
LVEF	Small heart (32)	79.09 ± 15.36	59.00 ± 9.35	< 0.001
	No small heart (18)	32.39 ± 12.69	35.28 ± 14.25	0.32

suspected CAD [12]. Previous studies have compared the accuracy of GSPECT as compared to other imaging techniques such as 2D and 3D ECHO, contrast angiography, cMRI, equilibrium radionuclide angiography (ERNA) and computed tomography [5, 9]. In this study, we examined the correlation between automatic quantitative gated SPECT and ECHO in the evaluation of LVVs and LVEF as well as effect of perfusion defect and small hearts on this agreement between the results obtained. Our study showed a good correlation between GSPECT and ECHO for the determination of EDV, ESV and LVEF, even in patients with or without myocardial perfusion defects. This correlation was also noticed in patient with small heart or with normal size heart. However when we tested the differences between GSPECT and ECHO, we saw that there was a difference between indices calculated by ECHO and GSPECT in patients with small heart, and in patients with no perfusion defect or in patients with low SRS. On the other hand, in the presence of perfusion defect, in higher SRS scores and in patients with larger ventricle (ESV ≥ 25 ml), no remarkable difference was noticed between two modalities.

Similarly to our study, previous studies that compared GSPECT and ECHO, reported good agreement between LVEF, EDV and ESV values [2, 9, 12–17]. Zanger et al. [18] reported a good agreement between ECHO and GSPECT for determination of LVEF and LVVs. Demir et al. reported strong correlation between these two modalities for the calculation of LVEF, EDV and ESV ($r = 0.91$, $r = 0.81$, $r = 0.71$, respectively) [2]. Fleming et al. reported good correlation in patients with single-vessel disease ($r = 0.76$), 2- ($r = 0.68$) and 3-vessel disease ($r = 0.68$), respectively [13]. This correlation between ECHO and GSPECT was also reported in patients with dilated cardiomyopathy [14].

In all patients, calculated ESV ($p = 0.01$) and EDV ($p = 0.06$; close to being statistically significant) using GSPECT were less than ECHO results, while LVEF ($p = 0.001$) was significantly higher in GSPECT. However, there was a significant increase in these differences in patients with small heart as well as in patients with no perfusion defect. On the other hand, in patients with perfusion defect as well as in patients with ESV ≥ 25 ml no remarkable difference was noticed between two techniques. For the description of this phenomenon in patients with small heart, several physical factors may contribute in GSPECT such as photon scatter, poor spatial resolution, and partial volume effect. Indeed, due to the limited spatial resolution of gamma cameras, the opposite endocardial edges of the left ventricle overlap, so that the ventricular cavity may become almost virtual, especially at end-systole. Increased counts of scintigraphic images at end-systole complicated the identification of LV endocardial borders. The root of this problem may be that counts from close myocardial walls spill into opposite walls, thereby distorting count profiles and causing their local maxima to be misregistered toward the center of the left ventricular cavity. Because the effect would be most pronounced at end-systole, the calculated LVEF is artifactually high [10, 11]. In patients with small ventricles, the LVEF may be overestimated because of underestimation of volumes, particularly in end-systole [10–12]. Typically, these patients have a normal heart but their LVEF may be falsely elevated. As we previously showed, in our country most people with normal myocardial perfusion and low probability of CAD have small heart (123/144: 85.4% had small heart with ESV less than 25 ml) [11]. But when the heart is larger (for example in patients with coronary artery disease in the presence of perfusion defect), the mentioned above effect would be minimized. As we can see in this study, there is no remarkable difference between ECHO and GSPECT in patients with ESV > 25 ml as well as in patients with myocardial perfusion defect.

Few papers have focused on the patients with perfusion defect. Chua et al. [8] reported a good correlation between gated SPECT and ERNA for the determination of LVEF, even in the presence of large perfusion defects. In the presence of transmural myocardial infarction, GSPECT software may impair accurate assessment of endocardial borders. In spite of this, it has been validated against other modalities (cMRI and first pass ERNA) [8]. Also Iskandarian et al. [19] and Tadamura [20] found a good correlation between gated SPECT and cMRI in patients with myocardial infarction.

Because the differences between different modalities are well-recognized, small and predictable differences should not detract from the clinical usefulness of each method.

Conclusion

We found good correlations and agreements between EDV, ESV and LVEF derived from GSPECT and ECHO. This good correlation was noticed even in small hearts or in patients with or without previous myocardial infarction. On the other hand, there was a significant difference between two modalities in patients with small hearts and in patients without perfusion defect. However in patients with larger ventricles including patients with perfusion defect, no remarkable difference between two modalities were noticed.

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