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ORIGINAL PAPER

A comparison of 8 and 16 frames gated SPECT imaging for determination of left ventricular volumes and ejection fraction: effects of gender and myocardial counts

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Abstract
In myocardial gated SPECT imaging each cardiac cycle is divided into 8 or 16 temporal frames and the cause of the difference between 8 and 16 frames is not specified exactly. The aim of this study was to investigate the effect of myocardial detector counts and gender on the difference between 8 and 16 frames and also to compare the LVEF obtained by 8 and 16 frames with echocardiography. The study population included 84 patients who underwent gated SPECT imaging. Left ventricular parameters were assessed on 8 and 16 frames gated SPECT. LVEF was also measured with two-dimensional echocardiography within 5–10 days after gated SPECT imaging. There was a good correlation between 8 and 16 frames for calculation of LVEF ($p=0.00$, $r=0.860$), EDV ($p=0.00$, $r=0.965$) and ESV ($p=0.00$, $r=0.956$) in all patients. But the difference between 8 and 16 frames for calculation of LVEF ($p=0.00$), EDV ($p=0.014$) and ESV ($p=0.00$) was statistically significant. This difference was assessed separately in females, males, patients with high photon counts and patients with low photon counts and in all subgroups was statistically significant difference in the estimation of LVEF and ESV ($p<0.05$) but no significant difference in the estimation of EDV ($p>0.05$). Echocardiography resulted in smaller LVEF as compared to 8 and 16 frames gated SPECT studies and there was a significant difference between the two methods ($p=0.00$). The myocardial detector counts and gender have no effect on the difference between 8 and 16 frames methods and the LVEF on echocardiography is smaller than the gated SPECT, but the 8-frame is closer to echocardiography.

Keywords 8 and 16 frames gated SPECT · LV volumes · Ejection fraction · Echocardiography

Introduction

Electrocardiographic (ECG) gated SPECT imaging is a suitable method for simultaneous evaluation of perfusion and left ventricular function. For gated SPECT imaging, each cardiac cycle (R wave to R wave) acquired by ECG is divided into 8 or 16 temporal frames and counts accumulated in each frame [1, 2].

The choice of the 8 or 16 framing interval in myocardial perfusion gated SPECT is still an unresolved issue. The use of 16 frames gated SPECT should improve the temporal resolution and allow more accurate determination of left ventricular volumes (LVV) and left ventricular ejection fraction (LVEF). however, the higher count density in each frame with 8-frame acquisition, as compared to 16-frame acquisition, may cause higher image quality [3–6]. previous studies have shown that 8-frame gated SPECT as compared to 16-frame, generated smaller end-diastolic volume (EDV), larger end-systolic volume (ESV) and lower ejection fraction (EF) [3–7].

In two previous studies, left ventricular ejection fraction of 8 and 16 frames gated SPECT had been compared to the result of equilibrium radionuclide angiography (ERNA) and radionuclide ventriculography (RNVG). These studies showed that the 8 frames studies underestimated LVEF compared to 16 frames studies. Left ventricular ejection fraction obtained from 16-frame gated SPECT data correlated well with those determined by RNVG and ERNA [8, 9]. In studies for comparison of gated SPECT imaging with echocardiography for the

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measurement of LVEF reported that echocardiography was in good agreement with gated SPECT imaging for determination of LVEF, however, the values of LVEF derived by using gated SPECT were significantly higher than those measured by using echocardiography [10–12]. myocardial detector counts and gender seems impressive parameters for 8 and 16 frames gated SPECT that not be considered.

So the aim of this study was to evaluate the effect of myocardial detector counts and gender on the difference between 8 and 16 frames and also was to compare the LVEF from 8 and 16 frames with echocardiography.

Materials and methods

Patient selection

Data from 84 patients, 40 males with a mean age of 55.6 ± 8.1 years and 44 females with a mean age of 54.5 ± 9.5 years (mean $\pm$ SD) who referred to the Nuclear Medicine Center for myocardial perfusion imaging were used in this study. All patients who were selected, have summed stress score (SSS) < 4, so that the patient's ischemia did not effect on the results of the study.

Imaging protocol

Gated SPECT images were acquired using a 2-day stress-rest protocol and only stress studies were used in this study. 44 patients (23 males and 21 females) had stress with treadmill and 40 patients (17 males and 23 females) had stress with dipyridamole. ^{99m}Tc-sestaMIBI was injected intravenously by weight to compensate the count loss in obese patients as shown in Table 1, at the peak treadmill exercise and 4 min after dipyridamole injection. Acquisition was started after 30 min of exercise peak and 60 min after dipyridamole stress. During the imaging, all patients were supine position and placed their arms above their heads [13].

Table 1 Table of injectable activity-based patient body weight

Weight (Kg)	Activity (MBq)	Weight (Kg)	Activity (MBq)
55	555	85	777
60	592	90	814
65	629	95	851
70	666	100	888
75	703	105	925
80	740	110	962

Image acquisition

SPECT imaging was performed using a dual-head gamma camera (Siemens Symbia Evo Excel) in 32 projections were acquired over a 180° arc from right anterior oblique to left posterior oblique and duration of each projection was 30 s, Matrix Size was 64×64 and Zoom was 1.45. Data were reconstructed with the filter back-projection method by using the Butterworth filter (cutoff frequency 0.5) without attenuation correction.

Gated acquisition was done with 8 and 16 frames per cardiac cycle with a beat acceptance window of 30% of the average R–R interval by using the forward-backward gating method. LVV and LVEF were measured by using a software package from Cedar Sinai (quantitative gated SPECT (QGS), version 2012.3, October 2012).

Echocardiography

Two-dimensional echocardiography was performed within 5–10 days after gated SPECT imaging. Echocardiography examinations were performed for all patients in the left lateral decubitus position, with the use of an echocardiography machine (Philips-Affiniti 50 cardiovascular Ultrasound Systems, 2015) equipped with 2–4 MHz transducer and LVEF was measured by biplane Simpson method by one experienced cardiologist blind to the results of the gated SPECT study.

Myocardial photon counts

To calculate the myocardial photon counts, raw image from summation of 32 patients' projections was used. An ellipse was drawn around the myocardium to exclude surrounding activity and only the photon counts of the myocardium were measured, as shown in Fig. 1. The myocardial photon counts were calculated for all patients and Patients were divided into 2 groups: high count (mean + standard deviation) and low count (mean − standard deviation).

Statistical analysis

Statistical analysis was performed with SPSS software (version 23). The correlation of left ventricular volumes and ejection fraction derived using the 8 with 16 frames was evaluated by spearman's correlation analysis. The paired *t*-test was used for the comparison of variables measured with 8 and 16 frames and echocardiography. p-value less than 0.05 was considered as statistically significant.

Results

There was a good correlation between 8 and 16 frames gated SPECT for calculation of LVEF ($p=0.00$, $r=0.860$, Fig. 2a). However, the mean ejection fraction measured by the 16-frame method ($70.67\% \pm 8.6\%$) was higher than that obtained from the 8-frame method ($65.57\% \pm 8.07\%$) and the difference was statistically significant ($p=0.00$, Fig. 3a).

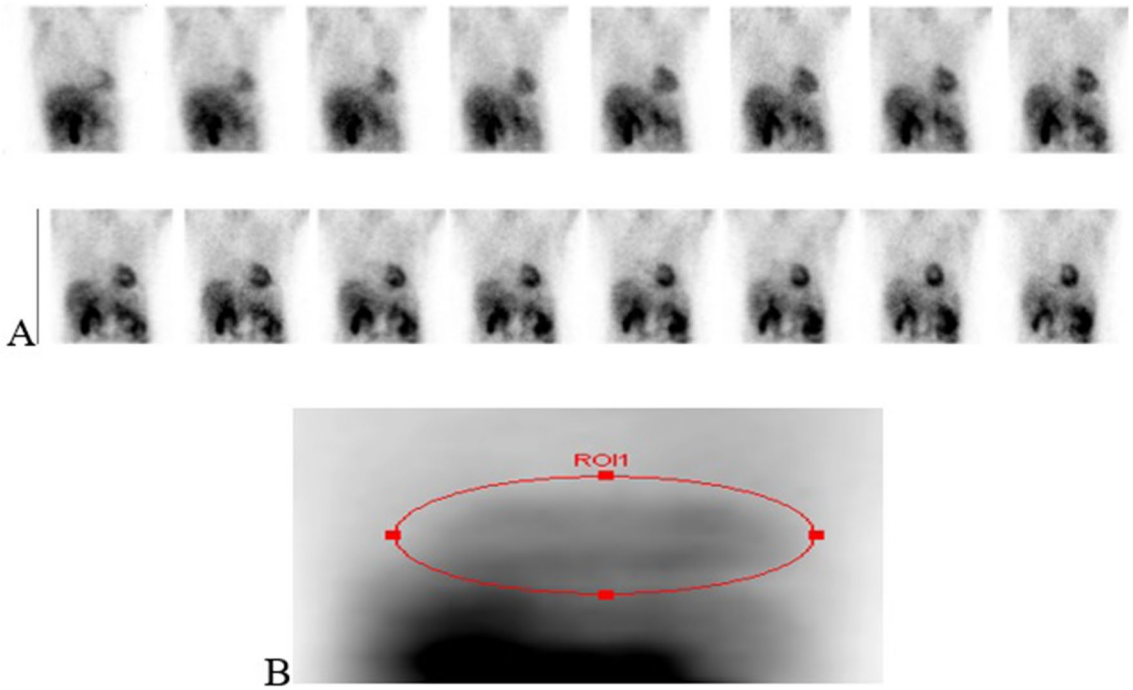

Fig. 1 **a** 16 views of 32 views of raw data. **b** The summation of 32 views of the myocardium by manually drawn elliptical is separated from other parts

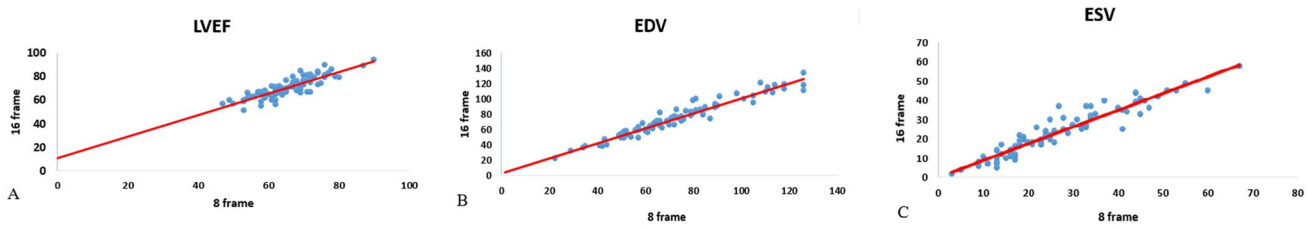

Fig. 2 Correlation between the **a** LVEF, **b** EDV, **c** ESV obtained from 8 and 16-frames gated SPECT of all patients

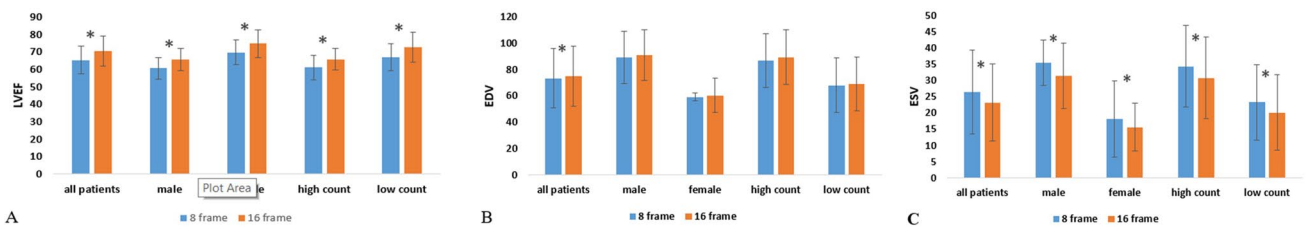

Fig. 3 Comparison of 8 and 16-frames gated SPECT for all patient, male, female, high and low count in **a** LVEF, **b** EDV, **c** ESV

There was a good correlation between 8 and 16 frames gated SPECT for calculation of EDV (p = 0.00, r = 0.965, Fig. 2b). However, the mean EDV measured by the 16-frame method (75.15 ± 22.56 ml) was higher than that obtained from the 8-frame method (73.57 ± 22.43 ml) and the difference was statistically significant (p = 0.014, Fig. 3b).

There was a good correlation between 8 and 16 frames gated SPECT for calculation of ESV (p = 0.00, r = 0.956, Fig. 2c). However, the mean ESV measured by the 16-frame method (23.30 ± 11.85 ml) was smaller than that obtained from the 8-frame method (26.58 ± 12.97 ml) and the difference was statistically significant (p = 0.00, Fig. 3c).

Impact of gender

In male's patients

16-frame gated SPECT resulted in larger EDV, smaller ESV, and a higher ejection fraction as compared to 8-frame gated SPECT studies, as shown in Table 2. There was statistically significant difference in the estimation of LVEF (p = 0.00, Fig. 3a) and ESV (p = 0.00, Fig. 3c). However, there was no statistically significant difference in the estimation of EDV (p = 0.08, Fig. 3b).

In female's patients

Similarly, 16-frame gated SPECT resulted in larger EDV, smaller ESV and a higher ejection fraction as compared to 8-frame gated SPECT studies, as shown in Table 2. There was statistically significant difference in the estimation of LVEF (p = 0.00, Fig. 3a) and ESV (p = 0.00, Fig. 3c). However, there was no statistically significant difference in the estimation of EDV (p = 0.099, Fig. 3b).

Impact of photon counts

The mean myocardial photon counts in 84 patients was $999 \times 10^3 \pm 186 \times 10^3$. There were 24 patients in the high count group ($1230 \times 10^3 \pm 131 \times 10^3$) and 60 patients in the low count group ($906 \times 10^3 \pm 123 \times 10^3$).

In both groups, 16-frame gated SPECT resulted in larger EDV, smaller ESV and a higher ejection fraction as compared to 8-frame gated SPECT studies, as shown in Table 3. There was statistically significant difference in the estimation of LVEF and ESV in both groups (p = 0.00, Fig. 3a, c). However, there was no statistically significant difference in the estimation of EDV in both groups (high count: p = 0.057, low count: 0.072, Fig. 3b).

Table 2 Comparison of LV volumes and LVEF (mean ± SD) obtained by 8 and 16-frames in males and females

	EDV (ml)	ESV (ml)	LVEF (%)
Females 8-frame	59.3 ± 3	18.3 ± 7.1	69.9 ± 7
Males 8-frame	89.2 ± 19.8	35.6 ± 11.8	60.8 ± 6
Females 16-frame	60.5 ± 13.6	15.7 ± 7.3	75.0 ± 8
Males 16-frame	91.2 ± 19.1	31.6 ± 10.1	65.8 ± 6

Table 3 Comparison of LV volumes and LVEF (mean ± SD) obtained by 8 and 16-frames in low and high photon count groups

	EDV (ml)	ESV (ml)	LVEF (%)
High count 8-frame	86.9 ± 20.3	34.5 ± 12.6	61.3 ± 7
Low count 8-frame	68.2 ± 20.9	23.4 ± 11.7	67.2 ± 8
High count 16-frame	89.6 ± 20.7	30.9 ± 10.5	65.9 ± 6
Low count 16-frame	69.3 ± 20.5	20.2 ± 10.9	72.5 ± 9

Comparison of LVEF from 8 and 16 frames with echocardiography

In all groups, echocardiography resulted in lower LVEF as compared to 8 and 16 frames gated SPECT studies, as shown in Table 4. However, the mean LVEF with echocardiography is closer to 8-frame than 16-frame gated SPECT. There was statistically significant difference between echocardiography and gated SPECT in the estimation of LVEF in all groups, as shown in Fig. 4 (p = 0.00).

Discussion

The results of 8 and 16 frames gated SPECT imaging in all patients, both sexes and patients with high and low myocardial detector counts were compared in this study. The differences of LVEF, EDV and ESV in all patients were statistically significant between 8 and 16 frames. 16-frame gated SPECT studies result in larger EDV, smaller ESV and higher LVEF as compared to 8-frame studies. These results were also obtained in previous studies [3–7].

The results of this study showed that the EDV and ESV in male patients and the LVEF in females were in both

Table 4 Comparison of LVEF (mean ± SD) obtained by 8 and 16-frames with echocardiography

	Echocardiography (%)	8-frame (%)	16-frame (%)
All patients	54.5 ± 3.8	65.6 ± 8.1	70.7 ± 8.6
Males	56.5 ± 3.7	60.8 ± 6.2	65.8 ± 6.3
Females	56.5 ± 3.9	70.0 ± 7.0	75.0 ± 8.0
High count	55.7 ± 3.6	61.3 ± 7.0	65.9 ± 6.2
Low count	56.3 ± 4.0	67.2 ± 7.7	72.5 ± 8.6

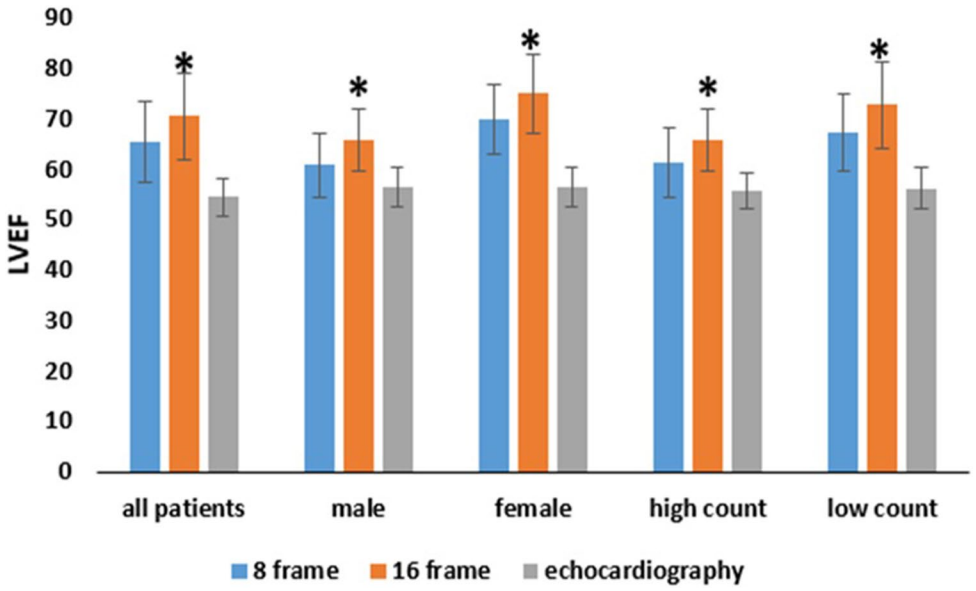

Fig. 4 Comparison of LVEF obtained from 8 and 16-frames gated SPECT with Echocardiography

types of 8 and 16 frames gated SPECT imaging that these results were also observed in the Ansari et al. study [7]. Incorrect calculates of left ventricular volumes in small hearts might lead to smaller EDV and ESV and higher LVEF in female patients [14]. The present study shows that gender has no effect on the difference between 8 and 16 frames for calculation of LVEF and ESV and there was statistically significant difference between 8 and 16 frames in both males and females. But for calculation of EDV, there was no statistically significant difference between 8 and 16 frames in both males and females.

The results of this study showed that the myocardial detector counts had no effect on the difference between 8 and 16 frames for calculation of LVEF and ESV and there was statistically significant difference between 8 and 16 frames in patients with high photon counts and low photon counts. But for calculation of EDV, there was no statistically significant difference between 8 and 16 frames in both groups. Sachin et al. studied the effect of the amount of injectable radiopharmaceutical on difference between 8 and 16 frames and concluded that the amount of injectable dose had no effect on the difference between 8 and 16 frames gated SPECT imaging [5].

According to previous studies and also in this study, it was found that parameters such as dose of injectable radiopharmaceutical [5], use of arrhythmia rejection [4], myocardial photons counts, gender and the presence or absence of perfusion defect [7] did not affect on the difference between 8 and 16-frames and in all of these conditions at 16 frame, the LVEF is higher, EDV is larger and the ESV is smaller than 8-frame. It seems that the reason for this difference is due to the higher temporal resolution of 16-frame than 8-frame. The end-systolic frame in an 8-frame imaging includes residual volume from systole/diastole on either side and hence is larger than that in a 16-frame gated SPECT imaging.

Previous studies reported that LVEF was underestimated by using 8 frames as compared to 16 frames gated SPECT, these results were confirmed by studies comparing LVEF obtained by gated SPECT with other reference standards such as RNVG, ERNA and MRI [8, 9, 15]. Compared with ERNA studies, the Bland–Altman method showed underestimated LVEFs and larger 95% limits of agreement in lower framing gated SPECT [8].

In comparison of gated SPECT imaging with echocardiography for calculation of LVEF, the results of previous studies show that there was a statistically significant difference between the two methods and the LVEF from gated SPECT to be higher than echocardiography [10–12], but Hovland et al. showed that the LVEF from echocardiography to be higher than gated SPECT [16]. In this study, it was found that the LVEF obtained by gated SPECT is statistically significantly different from echocardiography, and the LVEF from gated SPECT to be higher than echocardiography. But the average LVEF in echocardiography is closer to 8-frame. Based on our equipment we use 2D echocardiography but 3D echocardiography or cardiac MRI may have accurate results as compare to 2D echocardiography and we suggest that this be investigated in future studies.

Conclusion

Our study shows that the myocardial detector counts and gender have no effect on the difference between 8 and 16 frames gated SPECT imaging for calculation of left ventricular parameters. The LVEF on echocardiography is lower than the gated SPECT, and the 8-frame is closer to echocardiography, thus the acquisition of 8 frames may be the preferred mode for gated SPECT imaging.

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Conflict of interest The authors declare that they have no conflict of interest. I certify that there is no actual or potential conflict of interest in relation to this article.

Ethical approval All stages of this research have been reviewed by the ethics committee of Semnan University of Medical Sciences. Approval number is (IR.SEMUMS.REC.1398.186).

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