

# Comparison of Regional Myocardial Perfusion, Left Ventricular Volume and Ejection Fraction between 8- and 16-Frame Gated SPECT

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## 8-단위영상과 16-단위영상으로 얻은 게이트 심근관류 스펙트에서 국소 심근관류, 좌심실 용적과 구혈률의 비교

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국문초록

**목적:** 게이트 심근관류 스펙트는 심근의 관류와 좌심실 기능을 동시에 평가할 수 있는 유용한 방법이다. 현재, 게이트 영상 획득시 8 단위영상이 널리 사용되지만, 아직 가장 적절한 단위영상의 수에 대해서는 논의의 여지가 있다. 본 연구는 동일한 환자에서 8 단위영상과 16 단위영상으로 게이트 심근관류 스펙트를 2회 연속적으로 시행하여 국소적 심근관류, 좌심실 용적과 구혈률등을 비교하였다. **대상 및 방법:** 42명(평균 연령: 55세, 남: 녀=26: 16)의 관상동맥 질환이 의심되거나 알려진 환자를 대상으로 안정시 Tc-99m MIBI를 이용한 게이트 스펙트를 8 단위영상과 16 단위영상으로 2회 연속하여 시행하였다. 좌심실의 확장기말 용적, 수축기말 용적과 구혈률을 각각 얻었으며 확장기말의 단층영상을 18 분절로 나누고 각 분절마다 심근의 관류정도를 4등급으로 나누어 국소적 심근관류를 평가하였다. **결과:** 8 단위영상과 16 단위영상 게이트 스펙트에서 국소적 심근관류의 일치도는 85.7% ( $\tau$ -b=0.786,  $p<0.001$ )로 우수하였다. 두 방법간에 1등급의 차이는 100 분절(13.2%), 2등급 차이는 8 분절(1.1%)이 있었고 3등급 차이는 없었다. 좌심실의 확장기말 용적, 수축기말 용적, 구혈률은 두 방법간에 높은 상관성을 보였으며( $r=0.993, 0.989, 0.935$ ), 좌심실 구혈률은 8 단위영상을 사용할 때 평균 1.8% 낮게 측정되어 통계적인 유의성은 있었으나( $p<0.05$ ), 그 차이는 크지 않았다. **결론:** 8 단위영상과 16 단위영상을 사용한 게이트 심근관류 스펙트에서 국소적 심근관류의 일치도는 우수하였으며, 좌심실의 기능적 계수의 차이도 크지 않았다. 비록 높은 단위영상을 사용했을 때 더 정확하고 자세한 정보를 얻을 수 있다 하더라도, 구혈률과 용적 등을 얻는 일상적인 임상검사에는 8 단위영상 또한 그 역할을 충분히 할 수 있을 것으로 사료된다.

**Key Words:** gated myocardial perfusion SPECT, 8-and 16-frame, regional myocardial perfusion, LV ejection fraction

Received May 31, 2003; Accepted September 14, 2003

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This study was supported by Atomic Energy Research Fund of Korean Ministry of Science.

## Introduction

Myocardial perfusion scintigraphy is a useful technique in the diagnosis and management of patients with suspected or known coronary artery disease.<sup>1,2)</sup> Gated single photon emission computed tomography (SPECT) has emerged as the most common approach to myocardial perfusion imaging. This modality allows simultaneous assessment of myocardial perfusion and left ventricular function, and has been reported to be accurate and reproducible for measuring left ventricular ejection fraction and assessment of regional wall motion and systolic wall thickening.<sup>3,4)</sup>

Optimal number of frames per cardiac cycle during the acquisition of gated SPECT is still controversial. Eight-frame gating is commonly used because of shorter processing and analysis time, reduced data storage and better image count statistics. However, it is obvious that the cardiac cycle can be more accurately described if the acquisition process involves more gating frames.

Germano et al.<sup>5)</sup> reported that the average reduction in ejection fraction by using 8-frame gating was 3.7 percent, compared to 16-frame gating. In that study,<sup>5)</sup> however, 8-frame gating datasets were made by summation of frames (1+2, 3+4, etc.), not by two separate acquisitions. In the comparison of functional parameters, converting the 16-frame datasets into 8-frame by summation of frames leads to lower ejection fractions, because this is equivalent to smoothing the time-volume curve. Whereas, the differences in regional myocardial tracer uptake were not fully evaluated between 8- and 16-frame gated SPECT.

The purpose of this study was to compare regional myocardial perfusion and LV functional parameters in subjects underwent two consecutive gated acquisitions with 8-frame and 16-frame.

## Materials and Methods

### 1. Subjects

Forty-two subjects with suspected or known coronary artery disease were enrolled in this study: six with history of myocardial infarction, 9 with unstable angina, 21 with stable angina, and 6 patients referred for preoperative risk stratification. Twenty-six were male and the mean age was 55-years (ranged from 39 to 78 years). Nineteen of them had rest perfusion defect in LV wall and none had major arrhythmia on electrocardiogram.

### 2. SPECT acquisition protocol

Each subject underwent two sets of rest-gated myocardial perfusion SPECT. Imaging was performed at 1 hour after the rest injection of 370 to 740 MBq of Tc-99m methoxyisobutyl isonitrile (MIBI). Eight-frame gating was followed by 16-frame gating within ten minutes after completion of acquisition. All protocols used for two tests were identical except number of frames. None had significant changes in heart rate and electrocardiographic findings between two tests.

Gated tomographic imaging was performed with a triple-head gamma camera (Prism 3000, Picker, USA) (N=21) or a variable angle dual-head gamma camera (Vertex Plus, ADAC, USA) (N=21) in a random way. Both cameras were equipped with low-energy, high-resolution parallel-hole collimator. Sixty-four (Vertex Plus) or 120 (Prism 3000) projections were acquired for 25 seconds each over a 180-degree (Vertex Plus) or 360-degree (Prism 3000) elliptical orbit and collected in 64×64 pixel matrixes. The heart beat length acceptance was set at 50% of R-R interval. Projection images were reconstructed into horizontal long-axis, vertical long-axis and short-axis images by using the filtered back projection algorithm.

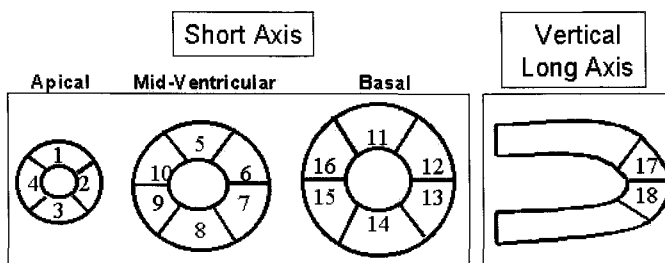


Fig 1. Schematic representation of 18 myocardial segments from tomographic slices of the left ventricle.

**Table 1.** Comparison of Regional Myocardial Tracer Uptake between 8-Frame and 16-Frame Gated SPECT regarding Normal versus Abnormal Segmental Perfusion

		8-frame gating		
		normal	abnormal	total
16-frame gating	normal	546	21	567
	abnormal	42	147	189
	total	588	168	756

Exact segmental agreement: 91.7%, Kappa: 0.769.

### 3. Interpretation of SPECT

Regional myocardial tracer uptake was visually assessed in 18 segments taken from end-diastolic short-axis and vertical long-axis images (Fig 1). Each segment was scored using 4-point scoring system (0=normal; 1=mild; 2=moderate; 3=severe reduction of tracer uptake).

Functional parameters of the left ventricle were calculated by QGS software (Cedars Sinai Medical Center, Los Angeles, Calif). The left ventricular ejection fraction (LVEF), end-diastolic volume (EDV) and end-systolic volume (ESV) of all subjects were automatically computed.

### 4. Statistical analysis

All continuous variables are expressed as mean  $\pm$  standard deviation (SD).

Kappa index and Kendall tau-b were used to evaluate the concordance of regional myocardial

tracer uptake from end-diastolic image between 8-and 16-frame gated SPECT.

The paired t test was used to compare the left ventricular functional parameters between 8-and 16-frame gated SPECT. P values <0.05 were considered significant. Pearson's correlation coefficient (r) was used to assess the correlation of the left ventricular functional parameters between 8-and 16-frame gated SPECT and the Bland-Altman plot<sup>6</sup> was used to express the absolute difference in quantitative data.

## Results

### 1. Regional myocardial tracer uptake

Segmental agreement on the presence of abnormal perfusion between 8-frame and 16-frame gated SPECT was 91.7% (693 of 756 segment, kappa=0.769, p<0.01) (Table 1). Forty-two myocardial segments showed abnormal perfusion on 16-frame

gating but were normal on 8-frame, and 21 segments were vice versa.

Six hundred forty-eight segments among a total of 756 showed exactly concordant perfusion in the visual analysis using 4-point scoring system (Table 2). Segmental agreement was fairly good as 85.7% with Kendall tau-b of 0.786. There was one-grade difference in 100 segments (13.2%) and two-grade in 8 (1.1%), and three-grade difference was not observed between two tests. Seventy-six segments were in higher grade of perfusion on 16-frame gating than on 8-frame, while 32 segments were vice versa.

In segmental analysis of 19 patients with rest perfusion defects in LV wall, myocardial uptake was

also fairly good concordant (segmental agreement: 79.8%, Kendall tau-b: 0.809, Table 3). There was one-grade difference in 63 segments (18.4%) and two-grade in 6 (1.8%).

## 2. LV functional parameters

Mean values of EDV, ESV and LVEF were slightly lower with 8-frame gating ( $108.0 \pm 46.6$  ml,  $53.5 \pm 33.9$  ml and  $54.1 \pm 10.9\%$ , respectively) than 16-frame ( $113.4 \pm 46.0$  ml,  $53.9 \pm 33.9$  ml and  $55.9 \pm 11.1\%$ , respectively). Mean difference of EDV was  $5.4 \pm 5.5$  ml ( $p < 0.05$ ) and that of ESV was  $0.3 \pm 5.0$  ml ( $p = \text{NS}$ ). Mean difference of EF was small as  $1.8 \pm 4.0\%$ , although statistically significant ( $p < 0.05$ ) (Table 4).

**Table 2.** Comparison of Regional Myocardial Tracer Uptake between 8-Frame and 16-Frame Gated SPECT with Visual Analysis using 4-Point Scoring System

		8 - frame gating				total
		grade 0	grade 1	grade 2	grade 3	
16 - frame gating	grade 0	546	21	0	0	567
	grade 1	39	54	10	0	103
	grade 2	3	20	26	1	50
	grade 3	0	5	9	22	36
	total	588	100	45	23	756

Exact segmental agreement: 91.7%, Kappa: 0.769.

**Table 3.** Comparison of Regional Myocardial Tracer Uptake between 8-Frame and 16-Frame Gated SPECT in 19 Patients with Rest Perfusion Defects by Visual Analysis using 4-Point Scoring System

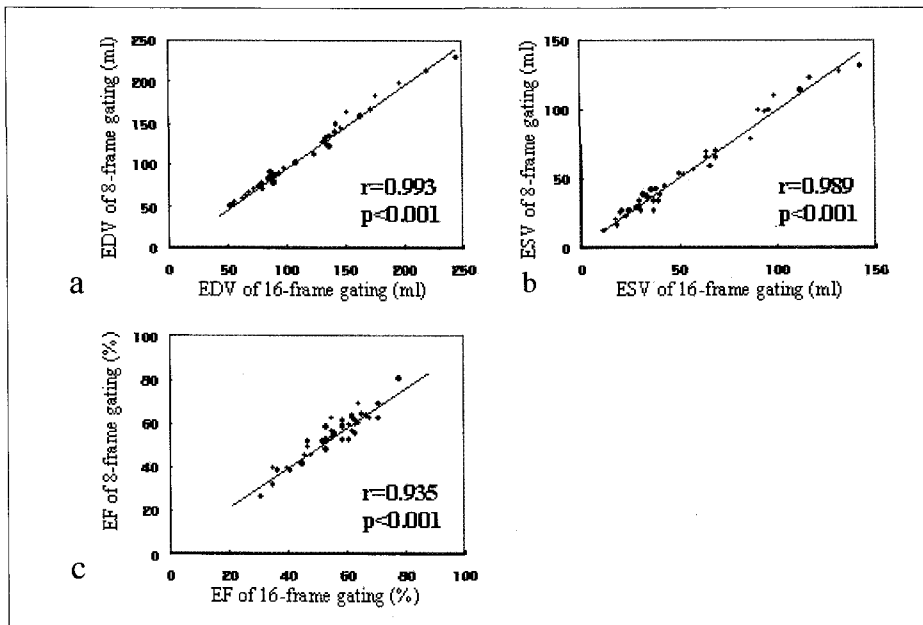
		8 - frame gating				total
		grade 0	grade 1	grade 2	grade 3	
16 - frame gating	grade 0	206	9	0	0	215
	grade 1	24	23	7	0	54
	grade 2	1	14	22	1	38
	grade 3	0	5	8	22	35
	total	231	51	37	23	342

Exact segmental agreement: 79.8%, Kendall tau-b: 0.809.

**Table 4.** Comparison of Left Ventricular Volumes and Ejection Fraction between 8-Frame and 16-Frame Gated SPECT

	8 - frame	16 - frame	Difference	p - value
EDV(ml)	108.0±46.6	113.4±46.0	5.4±5.5	<0.05
ESV(ml)	53.5±33.9	53.9±33.9	0.3±5.0	0.68
LVEF(%)	54.1±10.9	55.9±11.1	1.8±4.0	<0.05

\*: 16-frame-8-frame,: paired t test.



**Fig 2.** Correlations of (a) end-diastolic volume (EDV), (b) end-systolic volume (ESV), (c) ejection fraction (EF) between 8-frame and 16-frame gated SPECT.

Correlations of EDV, ESV and LVEF were excellent between 8-and 16-frame gated SPECT as correlation coefficient (r) of 0.993, 0.989 and 0.935, respectively (Fig 2).

The Bland-Altman plots revealed absolute differences between functional parameters measured from 8-and 16-frame gated SPECT (Fig 3). The average reduction in ejection fraction by using 8-frame gating was 1.8% with two SD value of 8.0. There was no apparent trend over a wide range of ejection fractions.

In 19 patients with rest perfusion defects in LV

wall, mean values of EDV, ESV and LVEF also showed good agreement (mean difference: 2.8±6.2 ml, 0.4±5.8 ml and 1.3±3.0%, respectively). The average reduction in EF by using 8-frame gating was also small as 1.3%, and the difference of EF was statistically not significant (p=NS) (Table 5).

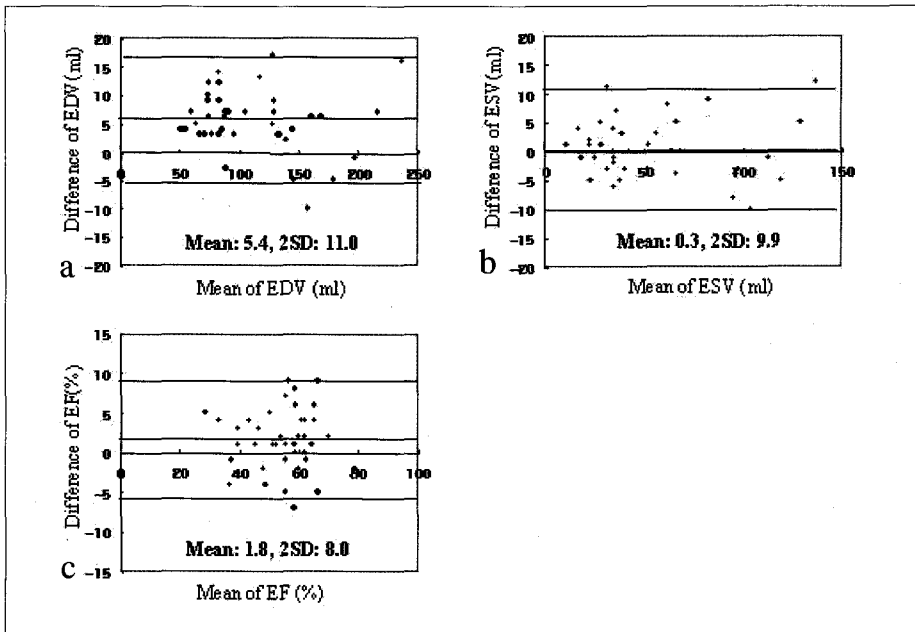
## Discussion

Gated SPECT has emerged as the most common approach to myocardial perfusion imaging. It can be used to assess a broad spectrum of parameters of

**Table 5.** Comparison of Left Ventricular Volumes and Ejection Fraction between 8-Frame and 16-Frame Gated SPECT in 19 Patients with Rest Perfusion Defects

	8 - frame	16 - frame	Difference	p - value
EDV(ml)	140.1±48.4	142.9±49.3	2.8±6.2	0.08
ESV(ml)	78.1±36.5	77.8±37.0	-0.4±5.8	0.80
LVEF(%)	46.7±10.9	48.0±10.7	1.3±3.0	0.10

\*: 16-frame-8-frame; paired t test.



**Fig 3.** Bland-Altman plots of (a) end-diastolic volume (EDV), (b) end-systolic volume (ESV), (c) ejection fraction (EF) between 8-frame and 16-frame gated SPECT.

cardiac function<sup>3,4)</sup> such as left ventricular ejection fraction, wall motion, wall thickening, ventricular volumes, transient ischemic dilation, in addition to myocardial perfusion.

A number of frames is acquired at each projection angle in gated SPECT, with each frame corresponding to a specific portion of the cardiac cycle. Optimal number of frames per cardiac cycle is still controversial, but 8-frame gating is generally preferred because 16-frame gating requires additional data storage and processing time, and may result in

images with unacceptably low counts. However, 16-frame gating can theoretically provide more accurate estimates of LV functional parameters.

Left ventricular ejection fraction has been reported to be the most important measurement of cardiac performance and a major prognostic indicator of coronary artery disease.<sup>7,8)</sup> Thus, precise and highly reproducible method for assessment of LV functional parameters is also important.

Germano et al.<sup>5)</sup> had developed and validated a fully automatic technique for quantitating LV

functional parameters from gated SPECT data in 65 subjects. LVEF measured with automatic algorithm showed good agreement with first-pass radionuclide angiography data and high reproducibility. Contrarily, Manrique et al.<sup>9)</sup> reported that gated SPECT significantly underestimated LVEF than equilibrium radionuclide angiography (ERNA) in patients with large myocardial infarction and LV dysfunction. They concluded that, although the agreement between gated SPECT and ERNA appear sufficient for routine evaluation of LVEF, ERNA should be preferred when precise measurements are required. Their conclusion was strongly argued by others<sup>10)</sup> and explained that the likely cause of the LVEF underestimation by gated SPECT was not the presence of a perfusion defect per se but the use of 8-frame as opposed to 16-frame gating.

Our results revealed high linear correlations of EDV, ESV and EF between 8-frame and 16-frame gated SPECT ( $r=0.993, 0.989, 0.935$ ) and the mean difference in LVEF between two methods was small as 1.8%, although statistically significant ( $p<0.05$ ).

There have been only limited studies regarding direct comparison of functional parameters between 8-frame and 16-frame gated SPECT. High linear agreement was reported between LVEF measured from 8-frame and 16-frame gated SPECT data in one study.<sup>5)</sup> Average reduction in LVEF by using 8-frame gating is 3.71% with no apparent trend over a wide range of ejection fraction. These results support routine use of 8-frame gated SPECT on quantitative grounds.

Imai et al.<sup>11)</sup> reported that difference of EDV, ESV and LVEF between 8 and 16 frames QGS are statistically significant, but the difference of LVEF is only 3.8%. They also suggested that 8 frames would be enough frame number per cardiac cycle on QGS for clinical use. It was further confirmed that there was a high correlation between ERNA and TI-201 gated SPECT, but higher with 16-interval gating than

8-interval gating.<sup>12)</sup> Moreover, the agreement between TI-201 gated SPECT and ERNA for LVEF measurement was strongly increased with 16-interval compared with 8-interval gating, as demonstrated by the shorter 95% confidence interval on Bland-Altman plots. Multivariate analysis showed that the difference between ERNA and gated SPECT LVEF was not dependent on the defect size but only on temporal sampling.

Results of our study are similar to those of previously mentioned studies<sup>5,11)</sup> and show somewhat superior agreement-smaller difference of LVEF compared to previous reports.<sup>5,11)</sup> It is clear that the differences in LV functional parameters exist between 8-frame and 16-frame gated SPECT as stated in our data as well as previous reports.<sup>5,11,12)</sup> However, the difference in LVEF is small from about 2% to 4%. Manrique et al.<sup>12)</sup> reported inferiority of 8-frame gating not by direct comparison of 8-frame gating with 16-frame gating, but by comparison with ERNA. In fact, in their study<sup>12)</sup>, average reduction in LVEF by using 8-interval resampled gated SPECT, compared to 16-interval gated SPECT, is only about 2%. Although gated SPECT with the use of higher framing (32-frame gating) acquisition provides comprehensive information including LV diastolic functional parameters<sup>13,14)</sup>, we suggest that 8-frame gating would be also sufficient for routine measurement of LVEF and volumes, particularly when Tc-99m labeled tracers are used with multidetector gamma camera.

In the visual assessment of regional myocardial tracer uptake, the degree of myocardial perfusion was exactly concordant between 8-frame and 16-frame gated SPECT in 648 among a total of 756 segments. The exact segmental agreement was fairly good as 85.7% with Kendall tau-b of 0.786. There was one-grade difference in 100 segments (13.2%) and two-grade in 8 (1.1%). Thirty-two segments

were found to be higher grade of perfusion defect on 8-frame gating than on 16-frame gating, while 76 segments were vice versa. Although 16-frame gating may have low image count statistics, overall sensitivity for evaluation of regional myocardial perfusion was similar between 8-frame and 16-frame gating. Keng et al.<sup>15)</sup> reported that sensitivity for detecting individual coronary artery stenosis was higher with gated images, but due to lower specificity, gated images afford similar overall sensitivity as ungated images for coronary artery disease detection. Some also reported that the difference in the sensitivity and in the specificity of both summed and end-diastolic images was not statistically significant, although there was a trend toward a better sensitivity for end-diastolic images.<sup>16)</sup>

The patient population of our study showed high incidence (23/42, 54.8%) of normal perfusion, compared to previous studies.<sup>5,9,12)</sup> But, measurement of LVEF with gated SPECT was not influenced either by the defect size evaluated by polar map or by the severity of hypoperfusion on the basis of perfusion defect score.<sup>9)</sup> In addition, there was good concordance in perfusion and LV functional parameters in 19 patients with rest perfusion defects in our study.

### Conclusion

The agreement of regional myocardial perfusion between 8-frame and 16-frame gated SPECT was fairly good and the differences in LV functional parameters were small. Although gated SPECT with the use of higher framing acquisition provides accurate and comprehensive information, 8-frame gating would be also sufficient for routine measurement of LVEF and volumes, particularly when Tc-99m labeled tracers are used with multidetector gamma camera like in our study.

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