

Comparison of Emory and Cedars-Sinai methods for assessment of left ventricular function from gated myocardial perfusion SPECT in patients with a small heart

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To evaluate the effect of left ventricular (LV) size on the calculation of LV function from gated myocardial SPECT with Emory and Cedars-Sinai programs, we performed ^{99m}Tc -tetrofosmin gated SPECT on 49 patients with ischemic heart disease. End-diastolic volume (EDV), end-systolic volume (ESV), and ejection fraction (EF) were semi-automatically calculated by each program. All patients underwent left ventriculography (LVG) within 3 months before and after the SPECT study. We grouped the patients into 22 with a calculated ESV obtained from LVG of over 50 ml (group A) and 27 with an ESV value of 50 ml or below (group B). We then compared the ESV values from gated SPECT with those from LVG in each group. In group A, the ESV from both Emory and Cedars-Sinai programs similarly correlated well with those from LVG ($r = 0.92$ and $r = 0.93$, respectively), but in group B, the ESV calculated from the Cedars-Sinai program correlated less with those from LVG ($r = 0.53$) than those from the Emory program did ($r = 0.70$). The calculated LV volumes had more errors in the Cedars-Sinai program than in the Emory program, when a patient had a small heart.

Key words: gated SPECT, ^{99m}Tc -tetrofosmin, LV function

INTRODUCTION

VARIOUS METHODS for calculating global left ventricular (LV) functional parameters from gated myocardial perfusion single photon emission computed tomography (SPECT) have been developed, and several automated and reproducible programs are widely available.^{1–4} One of the most commonly used forms of definition of LV myocardial boundaries for global LV functional analysis is the Cedars-Sinai method that applies Gaussian fitting to profiles of myocardial intensities and approximation to an elliptic sphere.^{3,5} Although this method is accurate and

reproducible in calculating LV volume,^{3,6,7} essential errors are associated with the detection of endocardial boundaries in some patients. The more recent Emory method recognizes myocardial boundaries at each phase of the cardiac cycle by using percent wall thickening based on changes in regional myocardial intensity throughout the cardiac cycle.^{4,8} From these defined boundaries, LV volumes at end-diastolic and end-systolic phases, myocardial mass and ejection fraction (EF) can be accurately calculated.⁴

The present study used gated myocardial perfusion SPECT with ^{99m}Tc -ethylenebis[bis(2-ethoxyethyl)phosphine] (tetrofosmin) on 49 patients with ischemic heart disease. We then evaluated the accuracy of LV functional analysis from gated myocardial SPECT by comparing the Emory and Cedars-Sinai method results with those of left ventriculography (LVG). We describe the advantages and disadvantages of each method, especially in patients with a small heart.

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MATERIALS AND METHODS

Study population

The study group consisted of 49 patients with either proven or suspected ischemic heart disease who had undergone gated ^{99m}Tc -tetrofosmin myocardial perfusion SPECT imaging. The group included 37 men and 12 women with a mean age of 62 ± 10 years (ranging from 25 to 76 years). Thirty-one patients had Q-wave myocardial infarction, and 18 patients had stable angina pectoris. Patients with primary cardiomyopathy, atrial fibrillation, or complete left bundle branch block were not included in this study.

Cardiac catheterization

All patients underwent LVG within 3 months (mean 33 ± 27 days) of the gated myocardial SPECT study. With the area-length method, end-diastolic volume (EDV), end-

systolic volume (ESV), and EF were calculated from 60 degree right anterior oblique images in each patients.

^{99m}Tc -tetrofosmin gated SPECT

Myocardial perfusion SPECT imaging with electrocardiographic gating was done at rest in the supine position 40–60 minutes after intravenous injection of 740 MBq of ^{99m}Tc -tetrofosmin. To remove the tracer accumulated in the gallbladder, all patients drank milk between tracer injection and image acquisition. With a triple-headed SPECT gamma camera (PRISM 3000; Marconi/Shimadzu) equipped with low-energy general-purpose collimators, a total of 20 projection images were obtained over 360 degrees in 6-degree increments, 50 seconds per view. An ECG R-wave detector provided a gate to acquire 8 frames per cardiac cycle. The total acquisition time was approximately 17 minutes. Data were recorded in 64×64 matrices onto a magnetic disc. Energy discrimination was

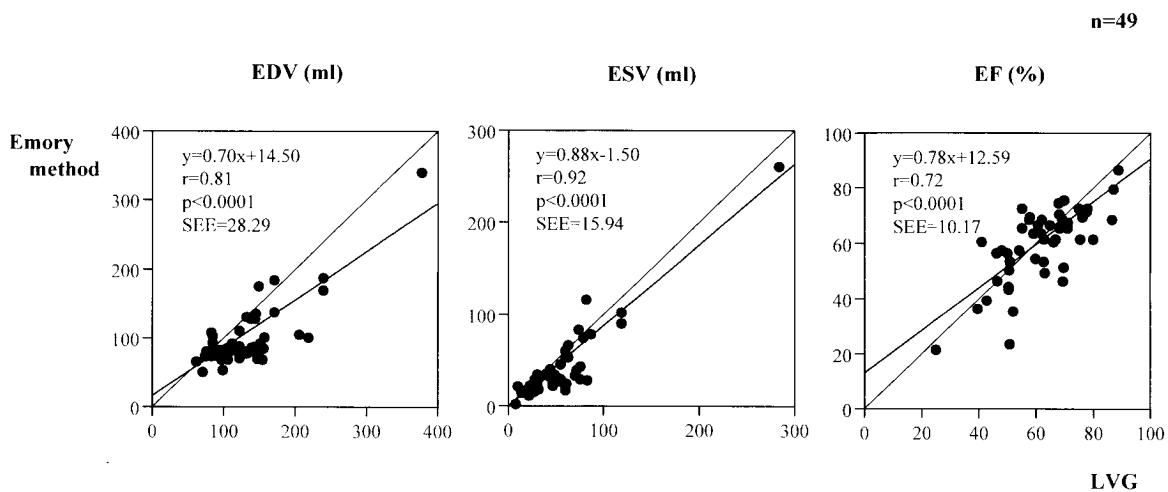


Fig. 1 The EDV, ESV, and EF values calculated from gated SPECT and Emory program in 49 subjects correlated well with those from LVG.

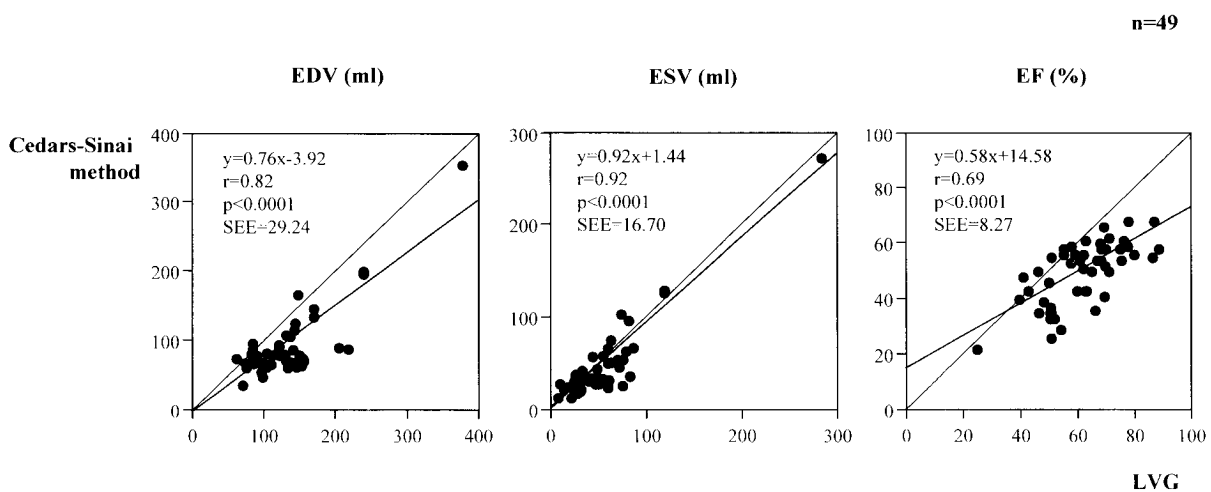


Fig. 2 The EDV, ESV, and EF values calculated from gated SPECT and Cedars-Sinai program in 49 subjects correlated well with those from LVG.

centered on 141 keV with a 20% window. After transaxial tomograms were reconstructed from the gated projection data with a Butterworth filter, oblique angle tomograms were reconstructed with a Ramp filter. The parameter of the Butterworth filter was order 4, and the cutoff frequency was 0.20 cycles/pixel.

Image processing

The values for EDV, ESV and EF were semi-automatically calculated from the gated myocardial short-axis tomograms with the Emory and Cedars-Sinai programs. When extremely high levels of radioactivity accumulated in the liver and gallbladder, causing essential errors in the automatic detection of myocardial boundaries, we used visual correction in image processing by each method. The values obtained from gated SPECT and each program

were compared with those from LVG in all patients. To evaluate the effect of LV volume on the results of the analyses, we grouped the patients into 22 (group A) and 27 (group B) with an ESV calculated from LVG more or less than 50 ml, respectively, and compared the ESV values from gated SPECT with those from LVG in each group.

Statistical analysis

All data are represented as the means \pm S.D. The correlations and regressions between the values were assessed by a simple linear least squares method. A p value of 0.05 or less was considered significant.

RESULTS

The values for EDV, ESV and EF calculated from LVG

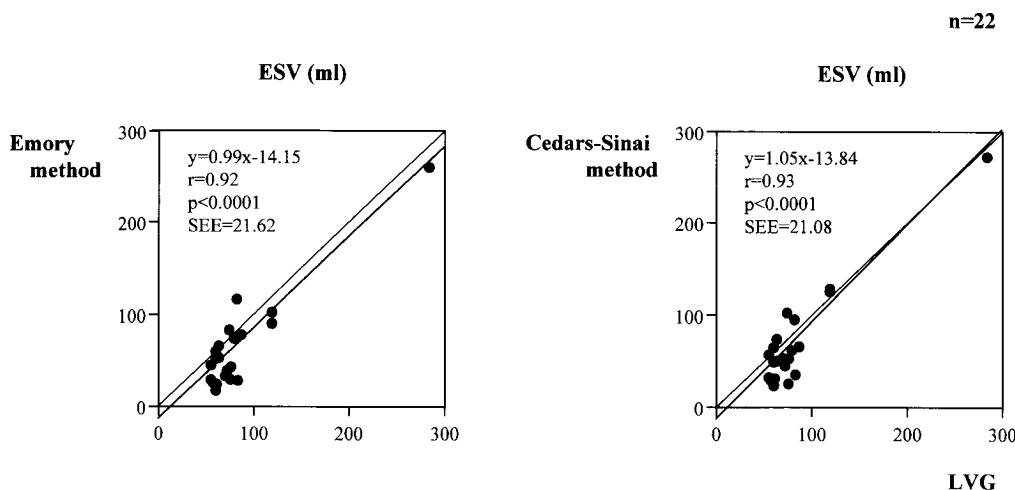


Fig. 3 In group A patients with ESV values from LVG more than 50 ml, the ESV values calculated from gated SPECT and Emory program correlated well with those from LVG, as well as those from gated SPECT and Cedars-Sinai program.

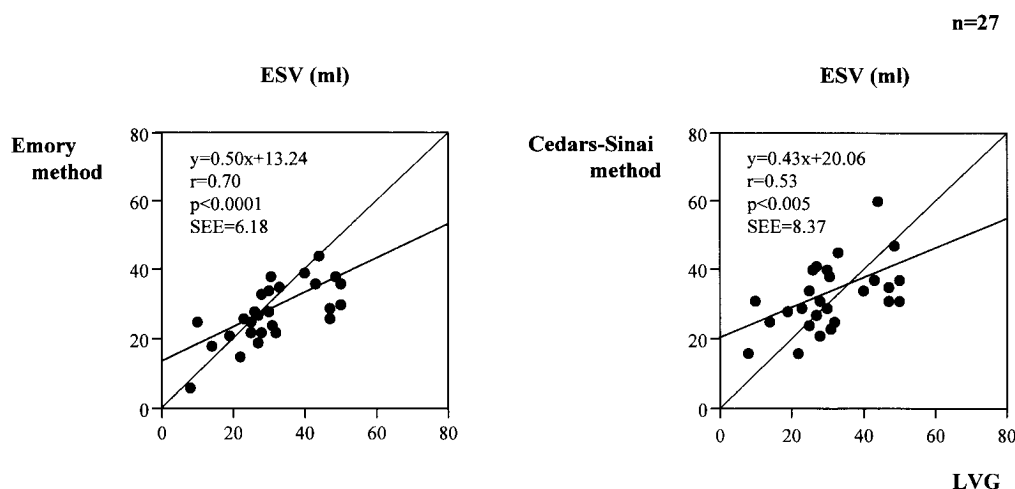
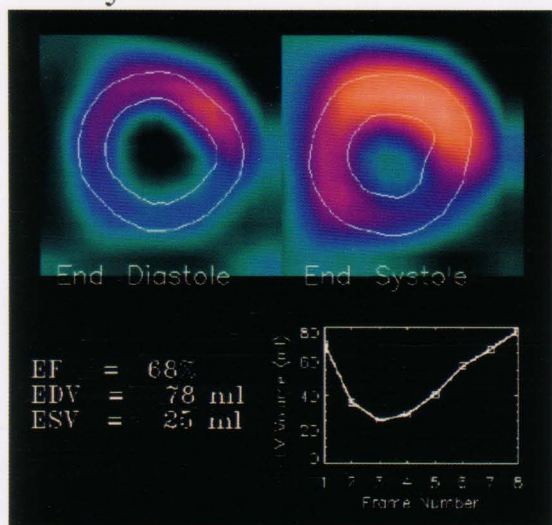


Fig. 4 In group B patients with ESV values from LVG of 50 ml or less, the ESV values calculated from gated SPECT and Emory program correlated well with those from LVG, as well as those from gated SPECT and Cedars-Sinai program.

Emory method



Cedars-Sinai method

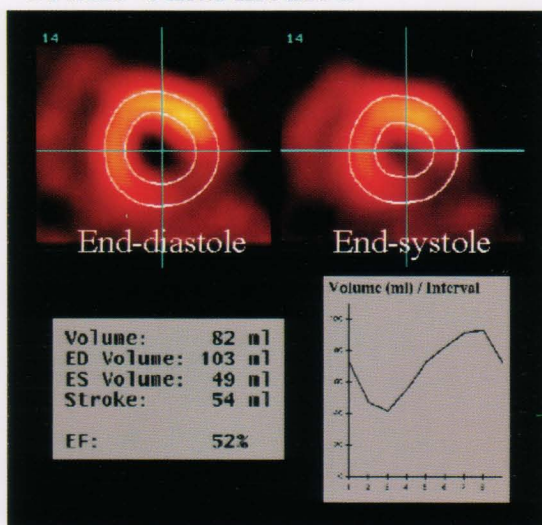


Fig. 5 The calculation of LV function parameters from Emory and Cedars-Sinai programs in a representative case of group B. The obtained values from LVG were 85 ml of EDV, 27 ml of ESV, and 68% of EF. The values from Emory method were close to those from LVG.

were 131.7 ± 55.0 (62–378) ml, 54.1 ± 42.0 (8–284) ml and 61.5 ± 13.3 (25–89) %, respectively.

Manual correction was required for gated SPECT image processing in one patient (2.0%) with both programs, and in one other (2.0%) only with the Cedars-Sinai program. All parameters calculated from gated SPECT and the Emory program for all 49 patients correlated well with the values from LVG (EDV: $r = 0.81$, $y = 0.70x + 14.50$; ESV: $r = 0.92$, $y = 0.88x - 1.50$; EF: $r = 0.72$, $y = 0.78x + 12.59$) (Fig. 1). Similarly, all parameters obtained from the Cedars-Sinai program in the same patients correlated well with the values from LVG (EDV: $r = 0.82$, $y = 0.76x - 3.92$; ESV: $r = 0.92$, $y = 0.92 + 1.44$; EF: $r = 0.69$, $y = 0.58x + 14.58$) (Fig. 2). In group A, the ESV values obtained from the Emory program showed good correlation with those from LVG ($r = 0.92$, $y = 0.99x - 14.15$), as well as with those from the Cedars-Sinai program ($r = 0.93$, $y = 1.05x - 13.84$) (Fig. 3), but in group B, the ESV values from the Cedars-Sinai program correlated less with those from LVG ($r = 0.53$, $y = 0.43x + 20.06$) than those from the Emory program did ($r = 0.70$, $y = 0.50x + 13.24$) (Fig. 4).

A representative case in a patient in group B is shown in Figure 5. This patient was a 55-year-old male with old posterolateral myocardial infarction. In this case, LVG was done 80 days before the myocardial SPECT study, and the values obtained representing LV function were 85 ml of EDV, 27 ml of ESV, and 68% of EF. The values calculated by the Emory method (EDV: 78 ml, ESV: 25 ml, EF: 68%) were close to those from LVG, but the Cedars-Sinai method results contained many errors in the calculation of LV volumes and EF values (EDV: 103 ml, ESV: 49 ml, EF: 52%).

DISCUSSION

The present study found that LV functional parameters obtained from ^{99m}Tc -tetrofosmin gated myocardial perfusion SPECT and the Cedars-Sinai and Emory programs correlated well with those from LVG as previously described,^{3,4,6,7} but in patients with a small heart volume, the Cedars-Sinai program contained more errors than the Emory program in the calculated ESV values.

Because the diagnostic and prognostic power derived from understanding left ventricular function can be added to that provided by assessing myocardial perfusion, gated SPECT has gained worldwide acceptance, and is now clinically used routinely in an increasing number of institutions. A major advance in gated SPECT technology is the development of objective, automatic, and reproducible means of calculating the left ventricular ejection fraction. One of the most popular is the Cedars-Sinai method. The accuracy and reproducibility in the calculation of LV functional parameters from the Cedars-Sinai program and gated myocardial perfusion SPECT has been established,^{3,6,7} but few studies have shown errors in the determination of LV myocardial boundaries associated with this program. We found that the EF values calculated with the Cedars-Sinai method were widely dispersed, especially in patients with a small heart. Such dispersion is probably due to essential errors in the detection of LV myocardial boundaries. The Cedars-Sinai method identifies myocardial boundaries by asymmetric Gaussian fitting to three dimensional count profiles of myocardial intensities.⁵ The myocardial boundaries are determined as the points of 65% S.D. of these count profiles, and modified with three dimensional approximation to an

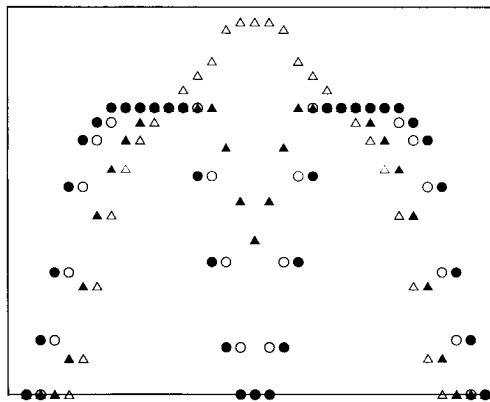


Fig. 6 The count profile analyses derived from the computer simulation. When the thickness of myocardium was fixed at 3 pixels, the curves were affected in the situation that the LV diameters were smaller than 9 pixels.

	Myocardial Thickness (pixels)	LV diameter (pixels)
●	3	15
○	3	13
▲	3	11
△	3	9

elliptic sphere. In hearts with a small LV volume, the count profiles, especially on the endocardial surface side, are more affected by not only image resolution, but also by scatter from tracer accumulation in the adjacent myocardium. Our study with computer simulation data by using the parameters of the resolution of the SPECT system used in the present study (3.75 mm of pixel size and 9.5 mm of full width at half maximum) confirmed the essential error in these circumstances (unpublished data). We fixed the thickness of the myocardium at 3 pixels (approximately 11 mm) in the simulation study. The profile curves were affected, especially in the endocardial part, when the LV diameter was smaller than three times the myocardial wall thickness (Fig. 6), but the peaks were less affected than the shape of the profile curves. Therefore, the calculated LV volumes might contain more errors in the Cedars-Sinai program than in the Emory program in this setting. In addition, respiratory and physical motion also may strongly affect the profile curves in a small heart, because of comparatively low spatial and temporal resolution of the gated SPECT image.

The calculation of LV functional parameters from the Emory program and gated myocardial perfusion SPECT is accurate.⁴ The determination of myocardial boundaries by this method is also based on count profiles of myocardial intensities, as with the Cedars-Sinai method. It defines the peak of count profiles as the center of the myocardium on short-axis tomograms in two dimensions, and assumes that the myocardial thickness in the end-diastolic phase is approximately 10 mm. The determination of myocardial boundaries in the other phase is based on the percent wall thickening calculated from changes in regional myocardial intensity throughout the cardiac cycle. The relationship between the myocardial thickness and the percent wall thickening was determined from a previous fundamental study, and the myocardial boundaries were defined with reference to calculated myocardial thickness and the center of the myocardium (the peaks of count profiles) in

each phase.⁸ Therefore, the essential errors in the determination of endocardial boundaries due to scatter are less than those in the Cedars-Sinai method, and the Emory program can perform more accurate calculations in patients with a small heart. Since the calculation of ESV emphasizes the prognostic value of LV functional analysis,^{9,10} the accurate assessment of small LV volumes is clinically important. The present method with gated myocardial perfusion SPECT and the Emory program is useful for patients with a small heart as a non-invasive, accurate assessment of myocardial perfusion and LV function.

The parameters used for image processing affect the calculated volumes, because the determination of myocardial boundaries is based on count profile curves with the present automated programs. The percentage of S.D. of the count profiles in image processing with the Cedars-Sinai program used to determine myocardial boundaries directly affected the calculated volumes. In addition, the order and cutoff frequency of the Butterworth filter affected the image resolution and count profiles. Therefore, changes in these parameters for image processing might improve the accuracy of the LV volume calculation even with the Cedars-Sinai program when patients have a small heart. Fundamental investigation is necessary to determine the appropriate parameters for individual patients.

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