Quantitative Gated Myocardial SPECT: Effect of Collimation on Left-Ventricular Ejection Fraction

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Objective: Left-ventricular ejection fraction (LVEF) can be computed from gated myocardial perfusion SPECT studies using quantitative algorithms. The purpose of this study was to compare the LVEF obtained using the conventional high-resolution parallel-hole collimator (HRC) to the Cardiofocal™ collimator (CFC) (Siemens Medical Systems, Hoffman Estates, IL) using a quantitative LVEF program.

Methods: Thirty-four patients (15 men, 19 women; mean age = 62 y) had either treadmill or pharmacological stress testing with 25–30 mCi ^{99m}Tc sestamibi injected at peak stress. Conventional gated SPECT imaging was performed approximately 30 min poststress, first with the HRC collimator, then with the CFC, using the same acquisition parameters on a single-head gamma camera. Traditional (TRAD) determination of LVEF using planar gated blood pool and/or cardiac catherization also was obtained for each patient.

Results: The correlation in LVEF between the CFC and HRC acquisitions was excellent, r = 0.99. The correlation between CFC and TRAD LVEF was good, r = 0.95, as was the HRC and TRAD correlation, r = 0.97. The mean LVEF value for HRC was slightly less than TRAD (54% vs. 55.4%), while the CFC mean LVEF was higher (62% vs. 55.4%). Although CFC LVEF correlated well with HRC, mean LVEF value using CFC was higher than HRC.

Conclusion: The choice of collimator may alter the LVEF obtained from gated SPECT perfusion studies.

Key Words: gated myocardial imaging; collimators; gated perfusion SPECT

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Quantitative myocardial perfusion SPECT scanning has become a routine noninvasive method to assess both ischemia and infarction in patients with known or suspected coronary artery disease (*1,2*). Recently, myocardial perfusion scans have been acquired in gated mode, allowing left-ventricular performance to be assessed as well. By using quantitative geometric algorithms, the left-ventricular ejection fraction (LVEF) has been computed from these gated SPECT studies (*3–9*). These methods have been validated in several clinical studies using a standard set of imaging conditions and reconstruction parameters. For routine clinical use, quantitative gated myocardial SPECT algorithms must provide reproducible LVEF from studies obtained from a wide range of imaging systems, acquisition protocols and reconstruction methods (*10–13*). Since acquisition and reconstruction protocols vary from institution to institution, the effect of acquisition and reconstruction methods on the computation of ejection fraction (e.g., reconstruction filter, models), as well as, the effect of collimation on the computation of LVEF from these methods should be evaluated. The purpose of this study was to evaluate the effect of collimation on the computation of LVEF from quantitative gated myocardial perfusion SPECT.

Typically, either a high-resolution parallel-hole collimator (HRC) or a low-energy, all-purpose parallel-hole collimator is used for myocardial perfusion SPECT imaging. A nonparallel-hole collimator has been designed specifically for use in cardiac perfusion imaging, the Cardiofocal™ (CFC) collimator (Siemens Medical Systems, Hoffman Estates, IL). The CFC collimator uses a variably focused design, optimized to image the heart, and maintains the spatial resolution of an HRC collimator, while providing twice the count sensitivity of the HRC collimator (*14*). The CFC collimator avoids the potential truncation problems associated with cone and fanbeam collimators, by gradually changing its focus to parallel-hole geometry at the edge of the collimator. To date, the CFC collimator has been used to image both ^{201}Tl and ^{99m}Tc perfusion agents, and has been shown to improve lesion detectability by visual inspection (Hawman PC, *personal communication*, 1997). The objective of this study was to compare the LVEFs obtained using the conventional HRC to the CFC, using one widely available version of a quantitative gated myocardial SPECT program (QGS; Cedars-Sinai Medical Center, Los Angeles, CA), and to compare the QGS LVEF values to the traditional LVEF computational methods of planar gated blood-pool imaging and cardiac catherization in a population of patients normally referred to the nuclear medicine department for quantitative myocardial perfusion imaging.

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MATERIALS AND METHODS

Patient Studies

Thirty-four patients (15 men, 19 women; mean age = 62 y) had either treadmill or pharmacological stress testing with 925–1110 MBq (25–30 mCi) ^{99m}Tc sestamibi injected at peak stress. The patients were chosen randomly from the routine clinical caseload of patients referred to nuclear medicine for quantitative perfusion imaging. Gated SPECT imaging was performed using 64 projection views over 180° from the 45° right anterior oblique projection to the 45° left posterior oblique projection, acquired in a 64 × 64 matrix at 20 s per view, commencing approximately 30 min poststress. The SPECT study was first acquired with the HRC collimator, then with the CFC using the same acquisition parameters, on a single-head gamma camera system (DiaCam with ICON™ computer; Siemens Medical Systems, Hoffman Estates, IL).

Both HRC and CFC studies were reconstructed using a Butterworth filter with a cutoff frequency of 0.66 Nyquist and an order of 2.5. The transverse HRC and CFC gated SPECT scans were reoriented into short- and long-axis oblique views using standard software. From the reconstructed images, quantitative gated SPECT, QGS, processing was performed using the recommended procedure, and the computed LVEFs noted. Traditional (TRAD) determination of LVEF also was obtained for each patient, either from planar gated blood-pool imaging (GBP) or from left ventriculography performed at the time of cardiac catherization (CATH). Gated blood-pool imaging or CATHs were performed within 2 wk or less of the gated myocardial SPECT scan.

Statistical Analysis

For the 34 patients, the LVEFs obtained from the QGS processing, using the CFC and HRC collimators, were compared with each other, and to the TRAD calculation of LVEF using a variety of statistical methods. Computed were the mean LVEF value and the standard deviations of the mean, the correlation coefficient (r), the standard error of the estimate (SEE), and the slope/intercept of the fitted line.

TABLE 1
Summary of Individual Patient's LVEF Values Calculated Following Planar Imaging (TRAD) and SPECT Using Two Different Collimators (HRC and CFC)

Patient	Sex	Stress type	Age	LVEF CFC	LVEF HRC	LVEF TRAD
1	M	T	51	62	59	65
2	F	T	72	59	50	50
3	F	T	54	68	61	60
4	F	T	32	69	65	65
5	F	T	73	73	67	72
6	F	T	70	67	61	62
7	F	T	50	56	48	47
8	F	T	63	60	53	55
9	M	T	70	67	59	63
10	F	T	67	53	42	45
11	F	T	60	51	38	37
12	M	T	56	46	34	35
13	F	T	56	71	65	60
14	F	P	75	56	48	50
15	F	P	80	63	56	58
16	M	T	55	74	68	69
17	M	T	53	53	43	45
18	F	P	67	76	69	65
19	M	T	61	63	55	53
20	M	P	55	45	32	33
21	F	P	78	54	43	43
22	M	T	73	75	70	72
23	M	T	73	66	59	60
24	M	P	42	80	76	75
25	M	T	67	68	60	57
26	M	T	66	56	46	48
27	M	T	55	60	52	55
28	F	T	45	67	61	65
29	F	T	48	72	67	60
30	F	P	76	38	19	25
31	F	T	56	59	51	55
32	F	T	62	41	30	38
33	M	T	68	56	47	50
34	M	T	76	64	57	63

T = treadmill exercise, P = pharmacologic stress.

RESULTS

Comparison of Collimators

The LVEFs obtained from the CFC and HRC gated myocardial SPECT studies, as well as the traditional LVEF computation, are given in Table 1 for the 34 patients. The overall correlation in LVEF between the CFC and the HRC acquisitions was excellent, with r = 0.992, $P < 0.001$ and SEE = 1.67.

The linear regression of units of percent LVEF times 100 between the HRC and the CFC collimators was:

$$\text{CFC} = 0.79 \times \text{HRC} + 19.3. \quad (1)$$

A graph of the CFC versus HRC collimated LVEFs is given in Figure 1.

The mean LVEF value using the Cardiofocal collimator was higher than that obtained using the high-resolution collimator. For the 34 patients, the mean LVEF value using the CFC collimator was 62% ± 10% with a mean LVEF of 54% ± 13% for the HRC collimator.

Comparison to Traditional Left-Ventricular Ejection Fraction

The correlation between the Cardiofocal QGS LVEF and the traditional computation of LVEF also was good, r = 0.954, $P < 0.003$, SEE = 3.67. The correlation between the high-resolution collimated QGS LVEF and the traditional computation of LVEF was slightly better at r = 0.971, $P < 0.016$, SEE = 2.91. The mean LVEF value for HRC was slightly less than the traditional method (54% ± 13% versus 55.4% ± 12%), while the CFC mean LVEF was higher (62% ± 10% versus 55.4% ± 12%).

The linear regression equation between the CFC collimator and the TRAD LVEF was:

$$\text{CFC} = 0.89 \times \text{TRAD} + 13.0. \quad (2)$$

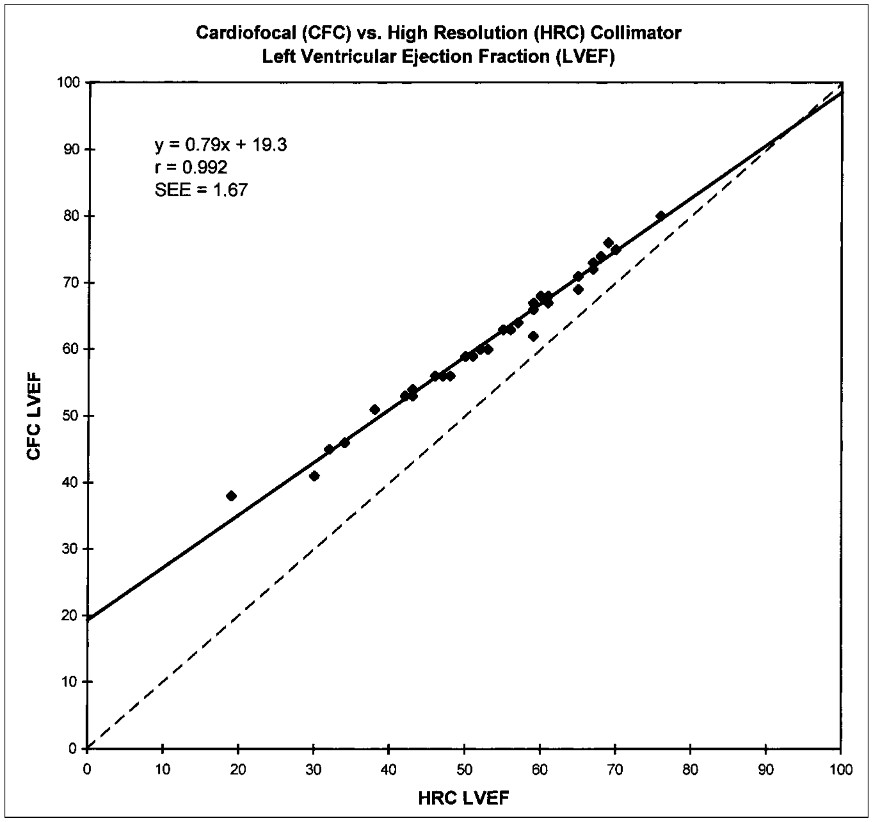

FIGURE 1. Comparison of the left-ventricular ejection fractions (LVEFs), determined by quantitative gated myocardial perfusion SPECT imaging (QGS), using the Cardiofocal™ collimator (CFC) with LVEFs from the high-resolution parallel-hole collimator (HRC). The solid line is the line of regression; the dotted line is the line of identity.

The linear regression equation between the HRC and the TRAD LVEF was:

$$\text{HRC} = 0.91 \times \text{TRAD} + 6.4. \quad (3)$$

The CFC-collimated QGS LVEF values versus the TRAD LVEF values are shown in Figure 2 and the HRC-collimated LVEFs versus the traditional LVEFs are illustrated in Figure 3.

DISCUSSION

It is well known that varying SPECT acquisition parameters (e.g., number of image projections, choice of collimator, etc.) and SPECT reconstruction parameters (e.g., reconstruction filter type and cutoff) can affect the reconstructed images. When comparing cardiac SPECT studies to normal databases, it is important that the acquisition and reconstruction parameters mimic the conditions under which the normal SPECT perfusion studies were acquired. When using gated myocardial SPECT processing algorithms to compute indices of cardiac function, it is important to understand how imaging parameters affect outcomes, in this case the LVEF computation. In this study, use of the Cardiofocal collimation overestimated the LVEF somewhat as compared to the traditional methods of LVEF assessment (planar gated blood-pool SPECT and cardiac catherization).

The CFC collimator, which was designed specifically for myocardial perfusion imaging, does not use parallel-hole geometry, as does classical high-resolution and low-energy all-purpose collimators. The variable focus of the CFC collimator serves to improve count statistics while maintaining high-resolution, equivalent to that of the HRC collimator. Thus, the CFC collimator permits single-head gamma cameras to produce studies with the equivalent count statistics of dual-head gamma cameras, which are considered to be the systems of choice for nuclear cardiology examinations. Obtaining dual-head equivalent count statistics with a single gamma camera head is a strong advantage for departments performing nuclear cardiology using only single-head gamma cameras. In clinical trials, the CFC collimator faired better than parallel-hole collimators in identifying myocardial perfusion defects (Hawman PC, *personal communication*, 1997). Moreover, the CFC collimator was shown not to produce image artifacts nor any distortions, which would limit its use for visual assessment of perfusion defects (*14*). It would, thus, be advantageous to use CFC collimation for perfusion imaging, which now includes quantitative functional analysis.

Using HRC collimation, 29 of the 34 patient LVEF values were within 5% of the TRAD LVEF value (the typically accepted reproducibility of LVEF calculations). In contrast, using CFC collimation, 15 of 34 patients had CFC LVEF values within 5% of the LVEF computed by TRAD methods. In 19 of 34 patients, the CFC LVEF differed from the TRAD LVEF calculation by more than 5% in LVEF, and in these 19 patients, the CFC LVEF always was higher in magnitude than the TRAD LVEF. No attempt has been made here to evaluate the overall accuracy of the QGS algorithm. This study was intended to evaluate the use of a popular quantitative program using 2

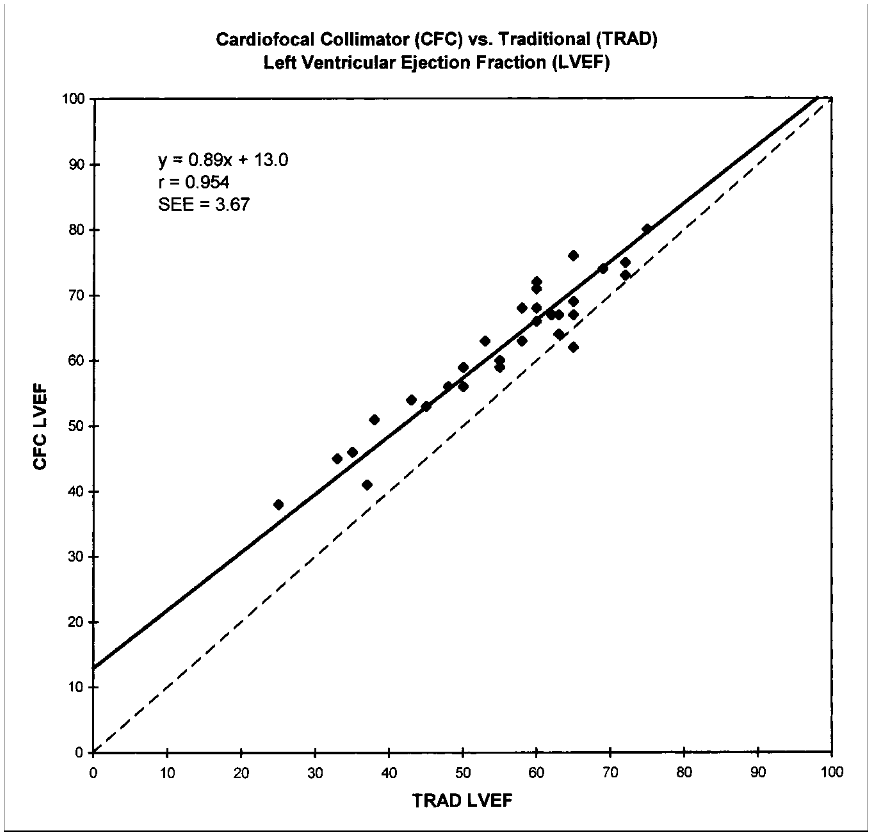

FIGURE 2. Comparison of the left-ventricular ejection fractions (LVEFs), determined by quantitative gated myocardial perfusion SPECT imaging (QGS), using the Cardiofocal™ collimator (CFC) with the LVEFs computed using traditional methods (TRAD) for computing LVEF (planar gated blood pool and cardiac catherization). The solid line is the line of regression; the dotted line is the line of identity.

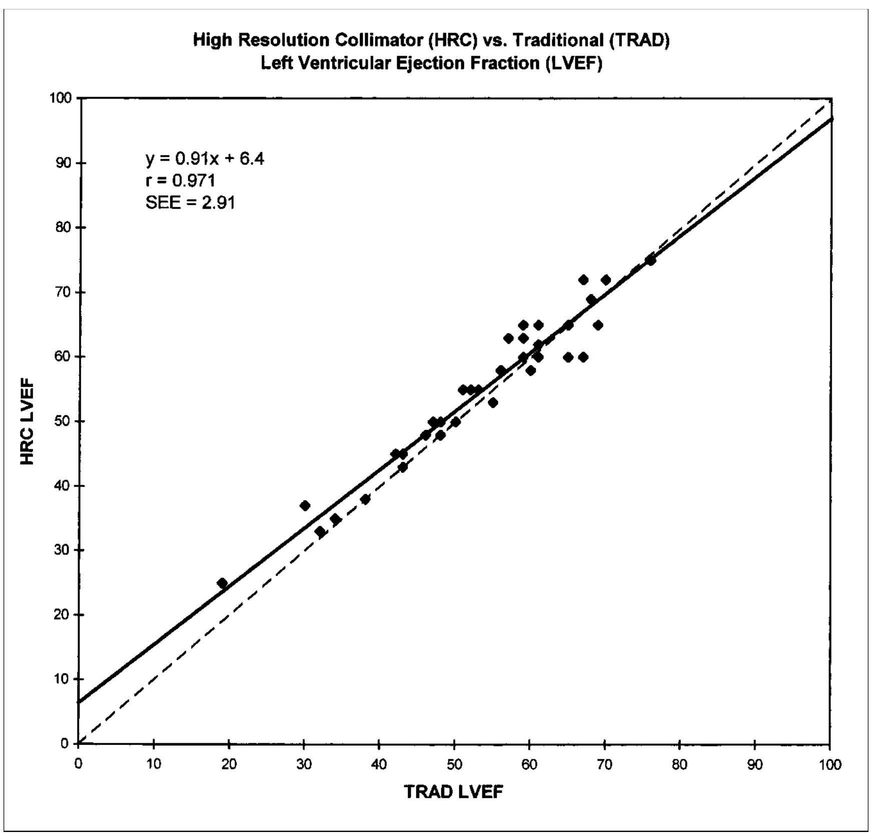

FIGURE 3. Comparison of the left-ventricular ejection fractions (LVEFs), determined by quantitative gated myocardial perfusion SPECT imaging (QGS), using the high-resolution parallel-hole collimator (HRC) with the LVEFs computed using traditional methods (TRAD) for computing LVEF. The solid line is the line of regression; the dotted line is the line of identity.

dissimilar collimators. Studies have been performed validating the QGS algorithm, which is in regular clinical use in a large number of nuclear medicine departments (*5*).

Using quantitative gated SPECT algorithms, such as QGS, the program must define the myocardial edges, in other words endocardium and epicardium, which are affected by spatial resolution, pixel size and statistical noise. The CFC and the HRC have approximately the same equivalent spatial resolution, thus resolution effects should be comparable. The CFC images contain more than twice the statistical content of the HRC studies. This increased statistics should improve myocardial edge definition, yet the CFC LVEF differed from standard methods of LVEF computation by a greater degree than HRC acquisition. The slight pixel size difference between the CFC and HRC collimators may account for the average 8% difference in LVEF.

The positioning of the heart using CFC is critical, and care must be taken to ensure that the heart is completely within the CFC's central field of view in each of the SPECT projections (*14*). In a patient population being studied for coronary artery disease, the size of the cardiac silhouette may be large. One possible reason for the higher computed LVEFs using CFC could be the variable focus and the relative position of end diastole and end systole. If the left ventricle would appear slightly larger in end diastole relative to end systole, the LVEF could appear to be increased compared to the parallel-hole geometry of the HRC collimator. Patient positioning and cardiac size may play a role in increasing the CFC LVEF values.

CONCLUSION

Although Cardiofocal collimator LVEF computed using the QGS program correlated well with high-resolution collimated studies and with traditional methods of LVEF computation, the mean LVEF value using CFC was higher than both the HRC and the TRAD LVEF values. The difference was more striking at lower LVEF values, $< 40\%$ (Figure 1). The choice of collimator affects the LVEF calculated from quantitative gated SPECT myocardial perfusion scans.

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