An Assessment of the Sensitivity of the Cedars-Sinai Quantitative Gated SPECT Software to Changes in the Reconstruction of the Short-Axis Slices

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Objective: This study assessed whether variations in count density, reconstruction filtering parameters and the short-axis orientation selected for reconstructions of myocardial short-axis slices significantly influenced the left ventricular ejection fraction (LVEF) calculated from a gated myocardial perfusion SPECT study.

Methods: The Cedars-Sinai quantitative gated SPECT software package was used to estimate the LVEF from gated ^{99m}Tc-sestamibi and ^{201}Tl gated SPECT studies in 20 patients. Oblique slices were reconstructed 12 times for each study, independently varying the filter cutoff and the orientation of the short axis each time.

Results: There were no clinically significant changes in the LVEF over the range of cutoff frequencies or orientation for either the ^{201}Tl or ^{99m}Tc-sestamibi studies. There was excellent agreement between the LVEF calculated from the ^{201}Tl and ^{99m}Tc-sestamibi studies on the same patients using the default filter (mean difference = 0.25% points).

Conclusion: The Cedars-Sinai quantitative gated SPECT software package for parallel-hole collimators can be used with confidence to obtain an LVEF, and is not sensitive to variations in count density, filtering parameters or short-axis orientation.

Key Words: quantitative gated SPECT; left ventricular ejection fraction; technetium-99m-sestamibi; thallium-201

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Assessing coronary artery disease includes investigating myocardial perfusion, left ventricular (LV) function and myocardial viability. Thallium-201 and ^{99m}Tc-sestamibi are both currently used to investigate myocardial perfusion. Thallium-201 has the advantage of offering viability assessment, while ^{99m}Tc-sestamibi provides the opportunity to assess LV function, including left ventricular ejection fraction (LVEF), myocardial thickening, regional wall motion and gated first-pass information (*1*,*2*) when used with electrocardiograph (ECG) gating.

Gated perfusion SPECT splits each SPECT projection into several time bins, commonly 8 or 16, each recording a fraction of the cardiac cycle (*1*). Processing gated SPECT studies involves reconstructing the image set corresponding to each time bin to obtain a corresponding set of short-axis slices representing the perfused myocardium at each stage of the cardiac cycle. The technique used to calculate the LVEF from gated SPECT data is discussed elsewhere (*1*). It was developed at the Cedars-Sinai Medical Center (Los Angeles, CA) and is commonly known as the quantitative gated SPECT (QGS) package. The software is available from several nuclear medicine equipment manufacturers.

The Cedars-Sinai QGS package is a fully automatic package that can segment the left ventricle out of a set of short-axis slices and determine the valve plane, endocardial and epicardial surfaces to obtain end diastolic volume (EDV), end systolic volume (ESV), stroke volume (SV) and calculate the LVEF (*1*). The Cedars-Sinai QGS package is rapid and has shown excellent agreement between its LVEF values and those derived from conventional radionuclide measurements of LVEF in phantom studies and clinical patient studies using ^{99m}Tc-sestamibi (*1*). As with any automated analysis, however, the quality of the output data is somewhat dependent on the quality of the input data. In particular, the package relies on the user to select the optimal postreconstruction filter parameters and short-axis orientation for reconstructing the short-axis slices.

Before adopting the LVEF as a routine feature for patient reports, it is important to ascertain to what degree operator-dependent procedures could influence the calculated LVEF values and to determine which are the most reliable parameters for image reconstruction.

Technetium-99m-sestamibi already is widely used for assessing myocardial perfusion and LV function. The use of ^{201}Tl in gated SPECT (*3*,*4*) currently is being investigated because it has the potential to provide all 3 indicators of myocardial disease—myocardial perfusion, viability and LV function. This study investigated how well the Cedars-Sinai QGS package performed when the SPECT study reconstruction was subjected to deliberate variations in count density, filtering parameters and short-axis orientation for both ^{201}Tl or ^{99m}Tc-sestamibi.

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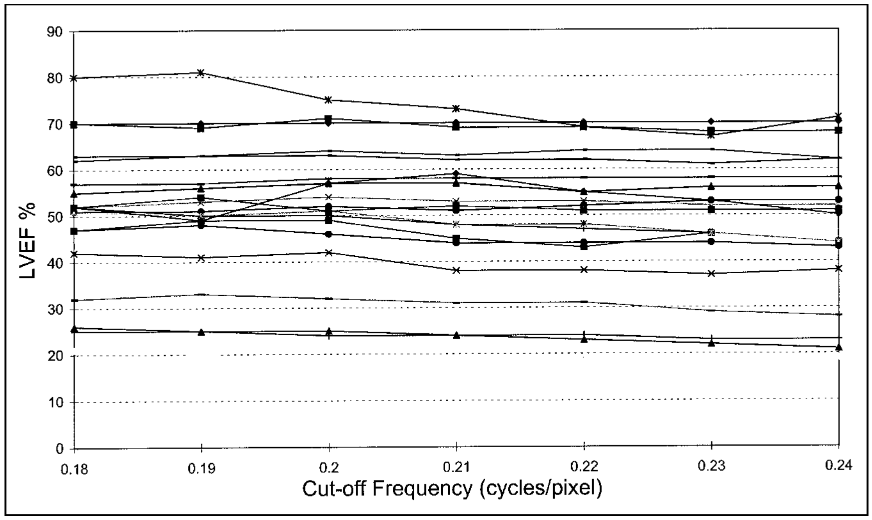

FIGURE 1. LVEF values obtained across range of cutoff frequencies used for ^{201}Tl scans. Each line represents the range of LVEF measurements for 1 patient.

MATERIALS AND METHODS

To best demonstrate how the QGS package would perform under a wide range of conditions, all patients having myocardial imaging at St. George Hospital, Department of Nuclear Medicine for a period of 2 mo had a gated ^{201}Tl rest SPECT and gated ^{99m}Tc-sestamibi stress SPECT. This differed from the standard protocol only in that the ^{201}Tl SPECT scans were gated. From these studies, a group of 20 patients was selected with a range of normal, infarcted and ischemic hearts (12 normal, 4 single perfusion defects, 4 multiple perfusion defects). The population included both men and women (14 men, 6 women) with a mean age of 63 y (range 41–80 y).

All studies were acquired on a triple-detector gamma camera fitted with low-energy high-resolution collimators. Forty projections, of 25 s duration each, were acquired for each detector over a 120° elliptical orbit giving a total of 120 projections over 360°. Projections were collected into 8 separate time bins and the ECG gating was set to reject cycles with duration outside ± 50% of the mean. The images were acquired with a magnification of 1.42 and a matrix size of 64 × 64.

Eighty MBq ^{201}Tl were injected intravenously 10 min before scanning. Right and left arm and leg electrodes were placed supraclavicularly, lateral to the midclavicular line and below the costal margin on the right and left sides, respectively. Patients were imaged supine, feet first with arms raised over their head. Acquisition and set-up were identical for ^{99m}Tc-sestamibi imaging, performed 40–60 min after injecting 1000 MBq ^{99m}Tc-sestamibi at peak stress. The stress gated SPECT study indicates the peak stress perfusion, however, the gated data are acquired with a resting ECG and, therefore, a resting LVEF is derived.

All analysis and reconstruction was performed on an Odys-

TABLE 1
Change in LVEF with Change in Filter Cutoff Frequency

	Mean change in LVEF (n = 20)	Standard deviation of change	No. of patients with >5% points between LVEFs
^{201}Tl	4.4% points	3.4% points	5
^{99m}Tc-sestamibi	2.2% points	1.5% points	0

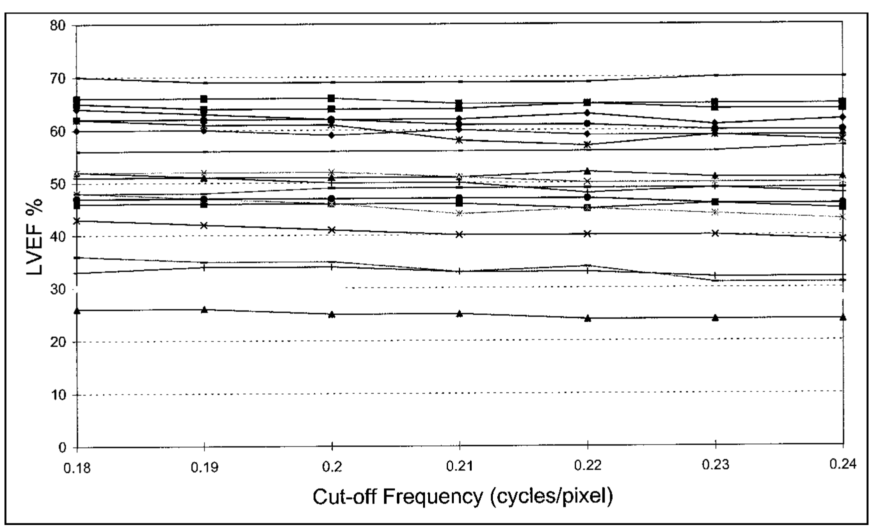

FIGURE 2. LVEF values obtained across range of cutoff frequencies used for ^{99m}Tc-sestamibi scans. Each line represents the range of LVEF measurements for 1 patient.

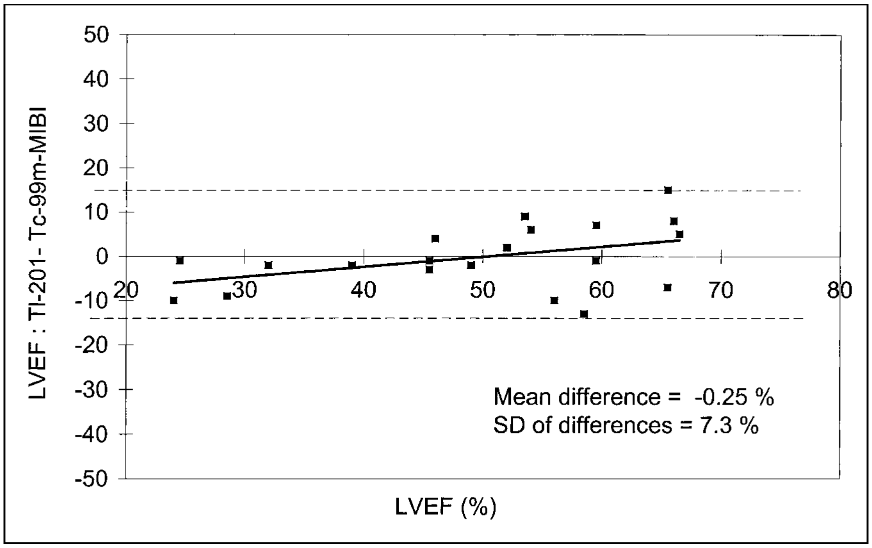

FIGURE 3. Bland-Altman plot. The difference between the ^{201}Tl and ^{99m}Tc-sestamibi LVEF is plotted against the average LVEF of ^{201}Tl and ^{99m}Tc-sestamibi.

sey workstation (with software version 8.3; Picker, Cleveland, OH). The gated studies were each reconstructed 12 times, varying either the filter cutoff or the short-axis orientation each time. First, transverse slices were reconstructed using a ramp filter and then were smoothed using a three-dimensional Butterworth filter (order 5.0) with a different cutoff frequency used each time: 0.18, 0.19, 0.2, 0.21 (the default value), 0.22, 0.23 and 0.24 cycles/pixel. Short-axis orientation was selected by an experienced user and this orientation remained constant through variations in cutoff frequency for each scan in this part of the study.

To investigate the impact that variations in the short-axis orientation would have on resultant LVEFs, images were reconstructed with a constant cutoff frequency (0.21 cycles/pixel for the ^{99m}Tc-sestamibi scans and a cutoff chosen by an experienced user (0.18 or 0.19 cycles/pixel) for the ^{201}Tl scans). Once the axis of the left ventricle was determined, the short axis was rotated by 5° and by 10° on either side of the LV axis in the plane of the horizontal long axis.

Each of these reconstructions provided a separate and unique set of gated short-axis slices which were analyzed using the QGS package to obtain LVEF, EDV, ESV and SV values.

RESULTS

The LVEF values obtained from ^{99m}Tc-sestamibi images were slightly more stable against variations in filter cutoff frequency than those derived from the ^{201}Tl scans. The results are presented in Figures 1 and 2 and summarized in Table 1. Five patients showed a difference greater than 5 percentage points between the highest ^{201}Tl LVEF measurement and the lowest. A change of 5 percentage points or more usually is considered clinically significant, although in all of these cases the LVEF values were in the normal range so the variation observed would be unlikely to influence the patient's clinical management.

At the default cutoff frequency (0.21 cycles/pixel for both ^{201}Tl and ^{99m}Tc-sestamibi) the counting rate in the myocardium for the ^{99m}Tc-sestamibi images was higher than for the ^{201}Tl images by a factor of 4 and, although the Bland-Altman plot (*5*) (Fig. 3) demonstrates a tendency for the ^{201}Tl study to give a slightly lower LVEF than the ^{99m}Tc-sestamibi images for patients with a low ejection fraction (20%–40%), this trend was not statistically significant ($P = 0.265$).

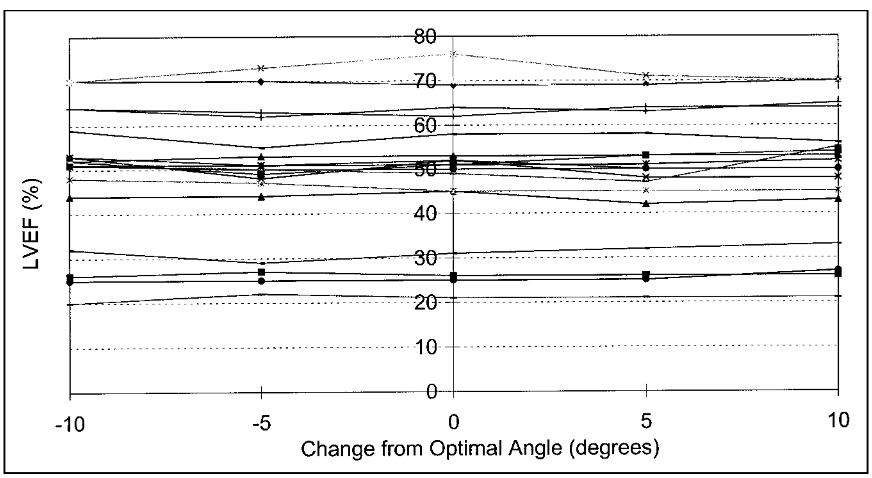

FIGURE 4. LVEF values obtained from ^{201}Tl scans for each short-axis orientation analyzed. Each line represents LVEF measurements for 1 patient.

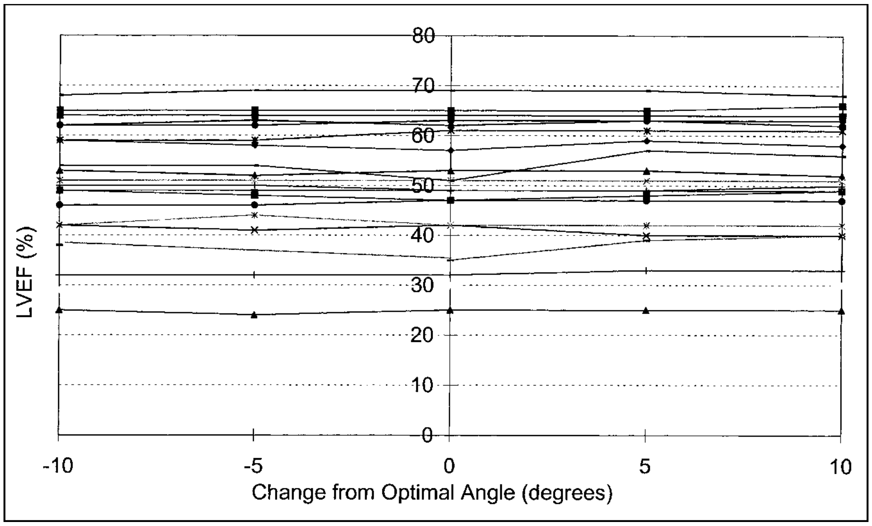

FIGURE 5. LVEF values obtained from ^{99m}Tc-sestamibi scans for each short-axis orientation analyzed. Each line represents LVEF measurements for 1 patient.

Overall, the mean difference between the LVEF obtained from ^{201}Tl and ^{99m}Tc-sestamibi was 0.25 percentage points and the SD of differences was 7.3%.

Varying the short-axis orientation during reconstruction had no clinically significant effect on LVEF results, as can be seen in Figures 4 and 5 and as summarized in Table 2. The 3 patients with variations in LVEF of greater than 5 percentage points also had normal LVEF measurements and, again, this was not considered clinically significant.

DISCUSSION

Choices made by the operator during image reconstruction have the potential to significantly alter the appearance of the short-axis slices that are used by the QGS package to calculate LVEF. This study demonstrated that the user's choice of filter cutoff had little impact on the final LVEF measurement as long as the cutoff remained within a restricted range of values. An experienced user would be unlikely to choose a filter cutoff outside of the range used in this study. This applies to the use of both ^{201}Tl and ^{99m}Tc-sestamibi. Similarly, the LVEF measurement obtained was not significantly affected if the axis of the left ventricle was slightly mispositioned. Moreover, there was little variation in the LVEF measurement derived, regardless of whether ^{201}Tl (which returns a relatively low-count density) or ^{99m}Tc-sestamibi (with superior counting statistics) was used.

In both settings (variation of filter cutoff and short-axis orientation), the gated SPECT using ^{99m}Tc-sestamibi gave slightly more consistent results than the gated SPECT using ^{201}Tl. It was, however, only a very small difference and indicates that a gated ^{201}Tl stress/redistribution protocol would be a suitable alternative to a gated ^{99m}Tc-sestamibi/^{201}Tl protocol for assessing myocardial function.

TABLE 2
Change in LVEF with Change in Short-Axis Orientation

	Mean change in LVEF (n = 20)	Standard deviation of change	No. of patients with >5% points between LVEFs
^{201}Tl	3.1% points	1.9% points	2
^{99m}Tc-sestamibi	1.9% points	1.5% points	1

There is no recommended reconstruction protocol for ^{201}Tl studies with the QGS package. Since the results using ^{201}Tl were stable along the range of cutoff frequencies examined, the default value of 0.21 cycles/pixel would be a reasonable choice on the grounds of simplicity and consistency.

Volume measurements also are displayed with the LVEF results. These values were not examined in this study as the camera manufacturer warns that these numbers have not yet been validated as an absolute measure of volume (*6*). It has been shown that any inaccuracy in estimating volumes will be present in proportion for all volumes measured and so have minimal impact on EF results (*7*).

CONCLUSION

The LVEF calculated by the Cedars-Sinai QGS package was found to be robust in the face of variation in the reconstruction filter cutoff and variation in the orientation of the short axis. The algorithm appears to be insensitive enough to increases in noise that it is practical to use it with the lower count density images produced with ^{201}Tl.

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