Measurement of Left Ventricular Ejection Fraction Using Gated 99mTc-Sestamibi Myocardial Planar Images: Comparison to Contrast Ventriculography

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Using the new myocardial perfusion agent ^{99m}Tc-sestamibi and multigated acquisition on a nuclear medicine gamma camera, the left ventricular ejection fraction (LVEF) was derived in 13 patients with coronary artery disease (CAD). Cross-sectional activity profiles were used to measure the left ventricle from end-diastolic and end-systolic images. Several different geometric methods were then utilized to derive ejection fractions from the nuclear data. Comparison of the resultant ejection fractions to those obtained from contrast ventriculography showed significant correlation for all geometric methods ($P < 0.01$, $S_{y \times x} = 6.2$ to 9.6). We conclude that in patients with CAD one or more of these simple geometric methods can provide a useful estimate of the LVEF when performing ^{99m}Tc-sestamibi multigated myocardial perfusion imaging. (Henry Ford Hosp Med J 1991;39:56-9)

Myocardial perfusion scintigraphy with thallium-201 (Tl-201) has been the noninvasive procedure of choice for the diagnosis and evaluation of patients with coronary artery disease (1,2). A newly developed myocardial perfusion agent, ^{99m}technetium-sestamibi, possesses several advantages over Tl-201 (3-5). Its physical properties allow injections of higher activity into patients without increasing radiation exposure (6). The gamma rays emitted also have better energy for imaging with the gamma camera. Because of the higher count rates obtainable with ^{99m}Tc-sestamibi, it is possible to gate image acquisition to the patient's electrocardiogram in a manner similar to multigated radionuclide ventriculography ("MUGA" scan). By gating the image acquisition to the patient's electrocardiogram, multiple images of the myocardium are obtained at different phases of the cardiac cycle. Previous reports have shown that left ventricular ejection fractions (LVEFs) can be estimated from this gated data (7-9). We report here a new, simple method to derive the LVEF from gated ^{99m}Tc-sestamibi images.

Material and Methods

Patient population

Thirteen patients (ten male, three female), ranging in age from 44 to 79 years, were evaluated with both standard contrast ventriculography and gated ^{99m}Tc-sestamibi imaging. These studies were performed within 30 days of each other with no sig-nificant therapy or status change in the interim. All patients were suspected of having coronary artery disease and all gave informed consent for this study as approved by our institution's Human Rights Committee.

Contrast ventriculography

Contrast ventriculograms were obtained in the right anterior oblique projection during the injection of 30 to 45 mL of meglumine and sodium diatrizoate (Angiovist 370). Ventriculograms were recorded on 35 mm film at 50 frames/sec. Correction for image magnification was made with a calibrated grid placed at the level of the left ventricle. The ejection fraction was calculated as the percentage change between end-diastolic and end-systolic volume ([EDV − ESV]/EDV) using standard formulas. Premature ventricular beats and postextrasystolic beats were excluded.

Table 1
Ejection Fraction Results for Each Method

Patient	Cath EF	Anterior Area	LAO Area	Anterior Volume	LAO Volume	Biplane Volume
1	69	59	78	72	88	86
2	69	59	56	72	75	71
3	40	39	24	47	34	48
4	58	60	55	75	70	73
5	59	48	35	63	45	56
6	68	57	63	68	77	77
7	55	47	52	66	68	62
8	56	62	72	77	83	83
9	55	57	49	74	61	68
10	30	38	27	54	37	44
11	40	40	29	53	43	46
12	47	52	52	64	68	68
13	77	76	65	90	80	83

LAO = left anterior oblique.

Table 2
Statistical Comparison of Nuclear-Derived Ejection Fraction with Catheter Ejection Fraction for Each Method

Geometric Method	Regression Y-Intercept	Regression Slope	Standard Error of Estimate ($S_{y \times x}$)	CC (r)
Anterior area	−1.8	1.08	6.2	0.86
LAO area	24.6	0.61	9.6	0.79
Anterior volume	−9.6	0.97	7.8	0.82
LAO volume	17.5	0.60	7.6	0.80
Biplane volume	3.4	0.79	6.3	0.84

CC = coefficient of correlation, LAO = left anterior oblique.

Radionuclide imaging

Patients were given 15 mCi of ^{99m}Tc-sestamibi (^{99m}technetium-methoxy isobutyl isonitrile) (E. I. Du Pont de Nemours and Company, Inc, N Billerica, MA) intravenously at rest. One to three hours later, cardiac activity was imaged with a nuclear medicine gamma camera/computer system in the anterior and 45-degree left anterior oblique (LAO) projections using a 64 by 64 computer matrix. Image acquisition was gated to the patient's electrocardiogram at 16 frames/cardiac cycle and total acquisition time was 10 min/projection. This resulted in 16 computer images, each at a different phase of the cardiac cycle.

Radionuclide ejection fraction calculation

To improve image count statistics, the three computer images most closely associated with end-diastole were electronically summed; similarly, the three images most closely associated with end-systole were summed. This produced end-diastolic (ED) and end-systolic (ES) images suitable for measurement. Cross-sectional activity profiles were then generated along the major and minor left ventricular axes for the ED and ES images. The peaks in these activity profiles, as they cut across the ventricular walls, represent the approximate midpoints of the walls. The distances between these peaks were measured and utilized as the major and minor axis lengths in all area and volume calculations. Estimates of the LVEF were performed using five different geometric approaches:

1. Percentage change in area, anterior projection: Using the anterior projection, the elliptical area of the left ventricle was calculated for both ED and ES using the above axis measurements (elliptical area = 3.14 × semi-major axis × semi-minor axis). The percentage change in area was then calculated and used as an estimate of ejection fraction ([ED area − ES area]/ED area).

2. Percentage change in area, LAO projection: Same as method 1, except LAO projection was used.

3. Percentage change in volume, anterior projection: Using the anterior projection, the left ventricular volume was calculated using a single plane ellipse method (10) for both ED and ES. The percentage change in volume was then calculated ([EDV − ESV]/EDV) to give ejection fraction.

4. Percentage change in volume, LAO projection: Same as method 3, except LAO projection was used.

5. Percentage change in volume, biplane method: Using both the anterior and LAO projections, the left ventricular volume was calculated using a biplane ellipse method (10) for both ED and ES. The percentage change in volume was then computed, similar to above methods.

Results

For each patient, the LVEFs obtained from contrast ventriculography (cath EF) and each of the nuclear-derived methods are given in Table 1. For each nuclear-derived method of calculating LVEF, the following analysis was performed (Table 2). A best-fit regression line was calculated to provide an estimate of cath EF based on the nuclear data EF. A measure of the error involved in using this regression line as the basis for estimation is given as the standard error of the estimate, $S_{y \times x}$. The degree of correlation between the cath EF values and the nuclear-derived EF values is given as the coefficient of correlation, r. This correlation is significant for each method (P < 0.01).

Discussion

The new myocardial perfusion agent, ^{99m}Tc-sestamibi, overcomes many limitations found with Tl-201 (3-5). This radiopharmaceutical, labeled with ^{99m}technetium, emits 140 Kev photons which are ideal for gamma camera imaging. The physical half-life of 6 hours is one-twelfth that of Tl-201 and permits administration of much higher activities without increasing patient radiation exposure (6). ^{99m}Tc-sestamibi is lipophilic with high myocardial affinity. Its uptake is diffusional and is not dependent on the sodium-potassium adenosine triphosphate pump (11,12). Unlike Tl-201, ^{99m}Tc-sestamibi does not significantly wash out or redistribute over time but is relatively fixed within the myocardium (13,14). Thus myocardial images taken several

hours after injection reflect the myocardial perfusion pattern that was present at the time of injection. This allows the imaging laboratory to be physically separated from the stress laboratory.

Myocardial perfusion imaging by itself gives no quantitative information about left ventricular function, such as ejection fraction. Current nuclear methods for measuring LVEF are based on the principle that the measured activity from the left ventricle is proportional to the volume of blood within the ventricle (15). These methods require either labeling of the blood pool as in multigated radionuclide ventriculography ("MUGA" scan) or injection of a large bolus of activity as in first-pass radionuclide angiography. Because of the high activities available, ^{99m}Tc-sestamibi appears to lend itself well to the first-pass technique (16-18). This technique requires, however, that the patient be positioned beneath the gamma camera at the time the radionuclide is injected.

Recent reports have shown that LVEFs can also be derived from the myocardial images obtained several hours after ^{99m}Tc-sestamibi injection. Several of these techniques utilize ECG-gated tomographic acquisition of data (19,20). While tomography produces many advantages in both perfusion imaging and ejection fraction calculation, many nuclear imaging laboratories do not yet possess the sophisticated equipment needed for ECG-gated tomography. Those reports using gated planar imaging either apply a geometrical approach with sophisticated edge detection algorithms (7,8) or adopt a count-based method which measures wall activity (9).

Our study evaluates a simple geometric approach to ejection fraction measurement which is based on cross-sectional activity profiles through the long and short axes of the left ventricle. The software needed to generate these activity profiles is common to most nuclear medicine computer systems and the technique is easy to perform. The end-diastolic and end-systolic dimensions of the left ventricle are measured using the activity profiles. The resultant ejection fractions calculated from these measurements correlate closely with those from contrast ventriculography (Table 2).

Since there are several different geometric procedures available to estimate ejection fraction, five different methods were examined in this study. These range from simple change in ventricular area on a single projection to change in calculated ventricular volume based on two projections. Since ejection fraction is a volume-based concept (percentage change in left ventricular volume), a geometric method which estimates ventricular volumes might have an advantage over area-based methods. However, our results show no such advantage.

In utilizing a geometric method for estimating LVEF, several limitations need to be considered. The major and minor left ventricular axes in this study are measured from the activity maxima within the left ventricular walls. Since myocardial wall thickness can vary, the actual left ventricular cavity may be sized differently (21,22). The area and volume formulas utilized also assume an ellipsoid shape to the left ventricular chamber. Although used successfully in echocardiography, these do not accurately reflect true ventricular shape (10). In patients with large perfusion defects, it can be difficult to measure the left ventricle accurately.

The lack of a clear superiority of one geometric method over another may reflect both the limitations of this technique as well as the limitations in calculating LVEFs from contrast ventriculography. Future comparisons between these geometric methods and radionuclide ventriculography ("MUGA" scan) should be of interest. Because this technique is based on delayed imaging of ^{99m}Tc-sestamibi, the ejection fractions obtained represent the function of the left ventricle at rest.

In conclusion, we found in this patient population that acceptable estimates of LVEF can be obtained from gated ^{99m}Tc-sestamibi images using simple geometric methods. With this technique, any nuclear laboratory can evaluate both left ventricular function and myocardial perfusion during delayed ^{99m}Tc-sestamibi imaging.

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