Quantitation of Regional Ejection Fractions Using Gated Tomographic Imaging With $^{99m}$Tc-Sestamibi*

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Background: Gated single photon emission CT (SPECT) sestamibi imaging allows the simultaneous assessment of myocardial perfusion and left ventricular function.

Objective: The purpose of this study was to evaluate a technique for quantitative regional wall motion assessment using gated SPECT $^{99m}$Tc-sestamibi imaging.

Patients and interventions: Fourteen subjects without cardiac pathology and 25 patients who had experienced myocardial infarction (MI) were studied. After tomographic reconstruction of gated short-axis slices, the identification of endocardial borders was made using a standard edge-detection program in systole and diastole in each of five selected slices. Regional ejection fraction (EF) and myocardial perfusion were determined for five regions within each slice. Ten patients underwent echocardiographic regional wall-motion analysis, the results of which were compared to corresponding regional EF results.

Results: High interobserver reproducibility in the assessment of regional EFs was found, with $r$ values ranging from 0.94 to 0.98. In patients with anterior and inferior MIs, the regional EFs were abnormal in the anterior and septal regions, and the inferior and lateral regions, respectively. The regional EFs correlated significantly with regional perfusion in the anterior walls ($r = 0.71; p = 0.0001$), the lateral walls ($r = 0.66; p = 0.0001$), and inferior walls ($r = 0.54; p = 0.0004$). There was a significant association between the regional EFs and the echocardiographic regional wall motion assessment at the base ($p < 0.0001$), mid-ventricle ($p = 0.0004$), and apex ($p = 0.0003$).

Conclusions: Gated SPECT images obtained $^{99m}$Tc-sestamibi can provide reproducible quantitative, segmental regional EFs for multiple left ventricular slices that are significantly associated with subjective regional wall motion assessment by echocardiography.

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Key words: gated single photon emission CT; myocardial infarction; regional ejection fraction; sestamibi; $^{99m}$Tc

Abbreviations: EF = ejection fraction; MI = myocardial infarction; SPECT = single photon emission CT

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Materials and Methods

Study Groups

Normal Group: Resting studies in 14 patients who had not experienced infarction were obtained as a part of protocols...
involving patients with noncardiac chest pain. There were five men (36%) and nine women (64%). The mean age was 67 years (range, 42 to 84 years). These patients had no significant risk factors for coronary artery disease, no history of coronary disease, including treatment with percutaneous coronary intervention or coronary artery bypass grafting, and no history or ECG evidence of myocardial infarction (MI). During chest pain, their ECG findings were normal.

MI Group: Resting studies in 25 patients with MI were obtained 5 to 7 days after they had experienced the MI as part of an ongoing study of early (ie, < 6 h) reperfusion therapy for acute MI. These patients met the standard criteria for the identification of an ST-segment elevation acute MI and qualified for treatment with thrombolytic agents. There were 21 men (84%) and 4 women (16%). The mean age was 61 years (range, 44 to 80 years). Categorized by the localization of their ST-segment elevation, 13 patients experienced inferior MIs and 12 patients experienced anterior MIs. All patients had enzymatic and ECG evidence of MI. The mean (±SEM) time to reperfusion therapy was 291 ± 227 min.

Radionuclide Preparation

$^{99m}$Tc-sestamibi was prepared using a sterile nonpyrogenic, lyophilized kit. After $^{99m}$Tc was added to the kit, the mixture was boiled for 10 min then cooled. Radiochemical purity was confirmed using thin-layer chromatography. After giving informed consent, each patient received 20 to 30 mCi of sestamibi prior to the acquisition of the resting tomographic images.

Radionuclide Acquisition

Acquisition was performed within 6 h of the injection of the sestamibi with a commercially available tomographic gamma camera system (9409 system; Elscint Ltd; Haifa, Israel). Images were gated to the R wave of the ECG, and image acquisition was interrupted for one beat if the R-R interval varied by > 15% of the preceding R-R interval. Sixteen frames were acquired per R-R interval. Images were acquired for 60 s each, in a 64 × 64 byte mode matrix, at each of 30 stops (every 6°) from 45° right anterior oblique to 45° left posterior oblique, with the patient in the supine position. No acquisition was prematurely terminated.

SPECT Image Reconstruction

Ungated Images: The 16 gated images acquired at each of the 30 stops were summed to form an ungated image, and were reconstructed using standard back-projection algorithms and a Ramp-Hanning filter, as previously described. Significant parameters employed in this processing were stored for use in the processing of the gated images, including the regions of interest and the angles used in the reconstruction.

Five representative short-axis slices were identified using predetermined guidelines. The apical slice was chosen by identifying the region where the left ventricular cavity was first visible and moving one slice toward the base of the ventricle. The basal slice was chosen by noting where a decrease in anterior septal activity was first visualized and moving two slices toward the apex of the ventricle. The three middle slices were chosen by dividing the distance between the apical and basal slices into thirds. The locations of these slices were used for the assessment of perfusion and were stored for use during the reconstruction of the gated images.

Gated Images: Before gated reconstruction, data from the 16 frames were added by pairs (eg, 1–2, 3–4, 5–6) to form 8 frames. Transaxial images were constructed for each of the eight frames using the same processing as that for the ungated images. Following reconstruction, the five short-axis slices were identified using the parameters from the ungated images for each of the eight frames, and the eight generated frames for each slice were stored from diastole to systole to be replayed in cine format.

Determination of Endocardial Borders

The gated images were initially displayed in cine mode to observe endocardial wall motion and to identify regions of poor perfusion where edge detection might be difficult. To permit the use of a standard edge-detection algorithms, as employed for gated radionuclide ventriculography (the conventional second-derivative threshold method; Elscint Ltd), the images were phase-inverted by subtracting each pixel from a count of 255. As a consequence of the inversion, the end-systolic frame then had the lowest counts.

On the first image of each slice (the diastolic image), a master region of interest was placed in the mid-myocardium. Within this region, the endocardial border was identified using a standard edge-detection algorithm, in which either the second derivative was zero or a threshold of 45% of the maximal pixel value was reached along 6° radii. After the endocardial edge was identified, the counts within this border were determined on each of the other seven images. The image with the fewest counts in this region of interest was identified as the systolic frame, and it was used for subsequent processing. Each diastolic and systolic image was then expanded from a 64 × 64 matrix to a 256 × 256 pixel matrix with interpolation and smoothing. A circular region of interest was placed in the mid-myocardium (Fig 1), and the endocardial border was generated by the edge-detection program on both the diastolic and systolic images (Fig 2), as noted above. The geometric center of the region of interest on the diastolic frame was then determined. The 0° mark was set at the 12 o’clock position on the image using this center, and angles were measured clockwise from this point. Regional borders were determined by the following angles, starting at 315°: anterior, 315° to 45°; lateral, 45° to 135°; inferior, 135° to 225°; inferoseptal, 225° to 270°; and anteroseptal, 270° to 315°. The number of pixels within each region was calculated. The septum at the apex was not divided, resulting in 24 regions per ventricle.

The systolic image was divided into the same five regions, using both of the following two center points: the same center with the same x and y coordinates as the diastolic frame (the fixed center method) and the geometric center of the systolic region of interest (the variable center method). In the fixed center method, the ventricle moves around the center point, which is fixed in space. In the variable center method, the center point moves with the ventricle. Diastolic and systolic areas were determined for each of the 24 regions, using both methods, and employing geometric models previously described.

Ejection Fraction Calculations

Using the diastolic and systolic areas, ejection fractions (EFs) were determined as follows:

1. For each of the 24 individual regions, regional EF by slice =

\[
\frac{\text{diastolic area} - \text{systolic area}}{\text{diastolic area}}
\]

2. For each of the five regions (regional walls from apex to base), regional EF =

\[
\frac{\text{sum of diastolic areas in 5 slices} - \text{sum of systolic areas in 5 slices}}{\text{sum of diastolic area in 5 slices}}
\]
For this calculation, the apical regions were multiplied by two thirds, as dictated by the geometric models.3

3. For each of the five short-axis slices, EF by slice =

\[
\frac{\text{sum of diastolic area in 5 regions}}{\text{sum of systolic areas in 5 regions}} - \frac{\text{sum of diastolic areas in 5 regions}}{\text{sum of diastolic areas in 5 regions}}
\]

For the apex, only four regions were used.

**Observer Variability**

All studies were read by experienced nuclear cardiologists and/or nuclear medicine physicians, who were blinded to all clinical, demographic, and other data about the patients. A total of 15 studies with normal and abnormal findings were analyzed by two different observers to assess interobserver variability. The studies were again analyzed by the same observers at least 1 week later to assess intraobserver variability.

**Correlation of Perfusion With Regional EFs**

The average perfusion in each region (wall) was assessed on noninverted images and was determined by averaging the pixels in that region based on the pixel with the highest value in that slice. For the purposes of comparing the regional EFs and perfusion measurements between patient groups, each regional measurement was divided by the mean of the respective measurement in studies with normal findings.

**Comparison to Echocardiography**

Ten patients who had experienced MIs underwent echocardiographic evaluation within 24 h of the gated SPECT study. The individual echocardiograms were reviewed by two blinded observers, by consensus, using a 16-segment echocardiographic model and subjectively graded regional wall motion on a scale of 1 to 4 (1, normal motion; 2, mild-to-moderate hypokinesis; 3, severe hypokinesis to akinesis; and 4, dyskinesis). The regional wall motion scores then were compared to, and correlated with, regional EFs derived from the fixed center gated SPECT studies at the basal, mid-ventricular, and apical levels. The scores from the lateral wall, which is divided into anterior and inferior segments at the mid-ventricle and base in the echocardiographic model, were averaged, thus reducing the 16-segment model to a 14-segment model, as was employed in the SPECT studies.

**Statistical Analysis**

Interobserver and intraobserver variabilities were determined using a paired t test and simple correlation. Differences in regional EF between patients who had and had not experienced MIs were compared using an unpaired t test. Correlation analysis for normalized perfusion and EF were performed using statistical software (SAS; SAS Institute; Cary, NC). The association of regional EFs and echocardiographic wall motion score was assessed with software using a single-factor analysis of variance (StatView 4.0; Abacus Concepts Inc; Berkeley, CA). A p value of < 0.05 was considered to be significant. Data were expressed as the mean ± SEM, unless otherwise noted.

**Results**

**Reproducibility**

A high degree of interobserver reproducibility was found in the assessment of regional EFs, with r
values ranging from 0.94 to 0.98. Absolute interobserver differences in regional EF measurements were small and ranged from 0.8 to 5.4 EF points. In addition, intraobserver reproducibility was very high, with correlation coefficients ranging from 0.95 to 0.97, and mean differences ranging from 0.1 to 2.5 EF points (Table 1).

### Regional EFs

In healthy subjects, the EFs determined by the fixed center method for the three free-wall regions, which were similar in the three basal slices (anterior, 60%; lateral, 63%; and inferior, 52%) (Table 2). In contrast, the two septal regions had lower EFs in these same slices. Frequently, the ventricular cavities in the apical slice and slice 2 were obliterated during systole, resulting in higher regional EFs in all regions.

In patients who had experienced an MI, the affected region appeared to have a depressed EF by the fixed center method, and a normal EF by the variable center method. Conversely, the regional EF in the opposing wall was normal by the fixed center method, and artificially depressed by the variable center method (Fig 3, 4). In view of these findings, all further analysis was limited to the results of gated studies, as determined by the fixed center method. The regional EFs obtained in patients who had experienced anterior and inferior MIs are presented in Tables 3 and 4, respectively.

### Regional Perfusion

The average perfusion in each region was determined by averaging the pixels in that region based on the pixel with the highest value in that slice. The average perfusion in the studies with normal findings ranged from 74 to 93%. The inferior wall tended toward lower average pixel values in the base and fourth slice, but not in the other slices.

In contrast, perfusion was decreased significantly in the anterior, anteroseptal, and inferoseptal regions following anterior MI. Similarly, after an inferior MI, perfusion was significantly decreased in the inferior segments compared to that in healthy subjects. The apical slice was affected in all four regions in studies

### Table 1—Regional EF Reproducibility (n = 15)*

<table>
<thead>
<tr>
<th>Region</th>
<th>Interobserver</th>
<th>Intraobserver</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r Value</td>
<td>Difference</td>
</tr>
<tr>
<td>Anterior</td>
<td>0.98</td>
<td>1.8 ± 3.4†</td>
</tr>
<tr>
<td>Lateral</td>
<td>0.98</td>
<td>1.8 ± 4.2</td>
</tr>
<tr>
<td>Inferior</td>
<td>0.94</td>
<td>0.80 ± 6.7</td>
</tr>
<tr>
<td>Inferoseptal</td>
<td>0.96</td>
<td>5.4 ± 11</td>
</tr>
<tr>
<td>Anteroseptal</td>
<td>0.97</td>
<td>1.6 ± 6.4</td>
</tr>
</tbody>
</table>

*Values given as mean ± SD, unless otherwise indicated. Difference = difference in EF measurement, interobserver or intraobserver.
†p < 0.05.

**Figure 2.** The endocardial boundary was drawn in diastole (left side) and in systole (right side). The geometric center of the diastolic frame was chosen, then was placed at the same position on the systolic frame (ie, the fixed center).
after anterior MIs, and in the inferior, inferoseptal, and lateral regions in studies after inferior MIs (Table 5).

Correlation of Perfusion With Regional EFs

The magnitude of impairment in EF for all slices correlated with the extent of perfusion deficit in each slice, as measured by sestamibi. The correlation was best for the anterior wall \((r = 0.71; p < 0.0001)\) [Fig 5], but was also highly significant for the lateral wall \((r = 0.66; p < 0.0001)\) and inferior wall \((r = 0.54; p = 0.0004)\) [Fig 6, 7, respectively]. In the inferoseptal and anteroseptal walls, the correlations were weaker \((r = 0.26\) and \(p = 0.11,\) and \(r = 0.44\) and \(p < 0.005,\) respectively).

Correlation of Regional EFs With Echocardiographic Wall Motion Scores

A total of 140 individual segments were analyzed by both gated SPECT scanning and echocardiography. All patients had experienced an MI. Slice 5 was considered to be representative of the cardiac base, slice 3 to be representative of the mid-ventricular level, and slice 2 as the best approximation of the apex. In general, an increase in the echocardiographic wall motion score was associated with a fall in regional EF (Fig 8, 9). This relationship was less satisfactory for the apex, where systolic shortening, partial volume effects, and cavity obliteration resulted in less accurate regional EF estimates by the gated SPECT method. There was a significant association between echocardiographic score and regional EF at the base \((p < 0.0001)\), the mid-ventricular level \((p = 0.0004)\), and the apex \((p = 0.0003)\).

**Discussion**

In the current study, the simultaneous assessment of regional EFs and perfusion was achieved using gated SPECT imaging with \(^{99m}\)Tc-sestamibi. Not only did regional function correlate well with the location of the MI, but there was also a significant association with qualitative regional wall motion assessment by echocardiography. Additionally, the measurements were reproducible, with low interobserver and intraobserver vari-

### Table 2—Regional EFs, Normal Studies, Fixed Center Method \((n = 14)\)*

<table>
<thead>
<tr>
<th>Slice</th>
<th>Anterior, %</th>
<th>Lateral, %</th>
<th>Inferior, %</th>
<th>Inferoseptal, %</th>
<th>Anteroseptal, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>55 ± 3</td>
<td>63 ± 5</td>
<td>42 ± 6</td>
<td>10 ± 8</td>
<td>19 ± 6</td>
</tr>
<tr>
<td>Fourth</td>
<td>54 ± 4</td>
<td>53 ± 5</td>
<td>44 ± 6</td>
<td>27 ± 6</td>
<td>31 ± 7</td>
</tr>
<tr>
<td>Mid-ventricle</td>
<td>53 ± 5</td>
<td>57 ± 6</td>
<td>45 ± 7</td>
<td>24 ± 5</td>
<td>24 ± 8</td>
</tr>
<tr>
<td>Second</td>
<td>74 ± 9</td>
<td>76 ± 9</td>
<td>78 ± 9</td>
<td>74 ± 9</td>
<td>60 ± 14</td>
</tr>
<tr>
<td>Apex</td>
<td>99 ± 1</td>
<td>95 ± 6</td>
<td>95 ± 5</td>
<td>97 ± 3</td>
<td>97 ± 3</td>
</tr>
<tr>
<td>All slices</td>
<td>60 ± 4</td>
<td>63 ± 5</td>
<td>52 ± 6</td>
<td>38 ± 5</td>
<td>30 ± 6</td>
</tr>
</tbody>
</table>

*Values given as mean ± SEM.
ability. Thus, the simultaneous evaluation of regional function and perfusion can be performed using a single acquisition of data, providing additional, potentially prognostic information in patients who have recently experienced an MI.

The global EF provides important diagnostic and prognostic information in patients following MI. However, the beneficial effects of thrombolytic therapy may be masked when global left ventricular function is considered alone, especially as it has been shown that the analysis of ventricular asynergy significantly enhances risk stratification in this setting. The comparison of regional function (by echocardiography) and regional perfusion (by thallium scintigraphy) has been shown to be complementary in the noninvasive assessment of patients following MI. However, this type of assessment requires two imaging modalities, with the associated difficulty of proper alignment for purposes of image comparison. Although first-pass evaluation of global left ventricular function and perfusion with \(^{99m}\)Tc-sestamibi can be performed in relatively rapid succession, the ability to assess regional function by the first-pass technique is limited. Gated SPECT imaging provides the unique ability to assess global left ventricular function, and myocardial perfusion with a single study.

Radionuclide imaging with \(^{99m}\)Tc-sestamibi is uniquely suited for the evaluation of patients following MI. An initial injection of this radiopharmaceutical determines whether the myocardium is at risk before thrombolysis in patients experiencing acute MI, while a later repeat injection shows the actual infarct size, providing noninvasive assessment of treatment efficacy. These images can be gated to the R wave of the ECG and displayed in cine format to approximate cardiac wall motion. This methodology should permit the simultaneous assessment of regional perfusion and wall motion in individual myocardial segments.

In the current study, an analysis of gated SPECT images in healthy patients revealed a range of EFs for individual sections of each myocardial slice. Similar variability has been reported by other investigators using both qualitative approaches and quantitative approaches. The variability in these data were related to several technical factors. First, patient motion may occur during the 30-min acquisition, and the effects of this motion would be expected to be more pronounced in an area-based or volume-based technique compared to those in a count-based technique. Second, the methodology of the analysis required the enlargement of small images, and variability in the edges of the final image reflected the sum of multiple acquisition steps, with

Table 3—Regional EFs, Anterior Infarction, Fixed Center Method (n = 12)*

<table>
<thead>
<tr>
<th>Slice</th>
<th>Anterior, %</th>
<th>Lateral, %</th>
<th>Inferior, %</th>
<th>Inferoseptal, %</th>
<th>Anteroseptal, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>48 ± 4†</td>
<td>60 ± 3</td>
<td>36 ± 5</td>
<td>22 ± 5</td>
<td>25 ± 6</td>
</tr>
<tr>
<td>Fourth</td>
<td>31 ± 4†</td>
<td>43 ± 5</td>
<td>34 ± 5</td>
<td>21 ± 5</td>
<td>22 ± 4</td>
</tr>
<tr>
<td>Mid-ventricle</td>
<td>15 ± 6†</td>
<td>40 ± 6†</td>
<td>30 ± 5†</td>
<td>24 ± 8‡</td>
<td>10 ± 5</td>
</tr>
<tr>
<td>Second</td>
<td>1 ± 5‡</td>
<td>24 ± 10†</td>
<td>37 ± 8‡</td>
<td>9 ± 9‡</td>
<td>- 5 ± 11‡</td>
</tr>
<tr>
<td>Apex</td>
<td>53 ± 16∥</td>
<td>72 ± 12‡</td>
<td>75 ± 12</td>
<td>53 ± 16∥</td>
<td>53 ± 16∥</td>
</tr>
<tr>
<td>All slices</td>
<td>28 ± 3∥</td>
<td>46 ± 5∥</td>
<td>37 ± 5∥</td>
<td>21 ± 5∥</td>
<td>14 ± 5∥</td>
</tr>
</tbody>
</table>

*Values given as mean ± SEM.
†p < 0.10.
‡p < 0.001.
∥p < 0.05.
||p < 0.01.

Table 4—Regional EFs, Inferior Infarction, Fixed Center Method (n = 13)*

<table>
<thead>
<tr>
<th>Slice</th>
<th>Anterior, %</th>
<th>Lateral, %</th>
<th>Inferior, %</th>
<th>Inferoseptal, %</th>
<th>Anteroseptal, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>51 ± 3</td>
<td>37 ± 7†</td>
<td>17 ± 5†</td>
<td>12 ± 7</td>
<td>23 ± 5</td>
</tr>
<tr>
<td>Fourth</td>
<td>54 ± 3</td>
<td>38 ± 7†</td>
<td>27 ± 4‡</td>
<td>27 ± 7</td>
<td>34 ± 6</td>
</tr>
<tr>
<td>Mid-ventricle</td>
<td>52 ± 3</td>
<td>32 ± 6‡</td>
<td>37 ± 5</td>
<td>30 ± 9</td>
<td>31 ± 8</td>
</tr>
<tr>
<td>Second</td>
<td>54 ± 6‡</td>
<td>51 ± 7‡</td>
<td>58 ± 8‡</td>
<td>44 ± 15</td>
<td>43 ± 13</td>
</tr>
<tr>
<td>Apex</td>
<td>87 ± 7</td>
<td>93 ± 6</td>
<td>96 ± 4</td>
<td>84 ± 8‡</td>
<td>84 ± 8‡</td>
</tr>
<tr>
<td>All slices</td>
<td>54 ± 2</td>
<td>41 ± 5‡</td>
<td>34 ± 3∥</td>
<td>32 ± 7</td>
<td>31 ± 6</td>
</tr>
</tbody>
</table>

*Values given as mean ± SEM.
†p < 0.01.
‡p < 0.10.
∥p < 0.05.
additive noise level. Third, the effect of this noise became more apparent as each slice was divided into smaller sections. Fourth, factors such as heart rate, BP, and medications were not controlled for in this study, and these could be expected to affect loading conditions and regional function. Finally, while Tc agents have more ideal imaging characteristics than other myocardial imaging agents, there is still significant background activity from the lung, liver, and bowel, making edge detection less optimal, especially in the inferior wall.

Data variability was also related to the intrinsic properties of the left ventricle. In healthy patients, the apical slice showed the greatest overall variation in EFs, and this was seen to a lesser extent in the second slice, just adjacent to the apex. This phenomenon was likely

**Table 5—Normalized Regional Perfusion in Anterior (n = 12) and Inferior (n = 13) MI Patients**

<table>
<thead>
<tr>
<th>Slice</th>
<th>Anterior</th>
<th>Lateral</th>
<th>Inferior</th>
<th>Infraoseptal</th>
<th>Anteroseptal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.74 ± 0.21</td>
<td>0.93 ± 0.02</td>
<td>0.75 ± 0.04</td>
<td>0.67 ± 0.031</td>
<td>0.66 ± 0.031</td>
</tr>
<tr>
<td>I</td>
<td>0.84 ± 0.01</td>
<td>0.84 ± 0.05</td>
<td>0.69 ± 0.03</td>
<td>0.70 ± 0.04</td>
<td>0.81 ± 0.03</td>
</tr>
<tr>
<td>Fourth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.66 ± 0.041</td>
<td>0.91 ± 0.03</td>
<td>0.75 ± 0.03</td>
<td>0.70 ± 0.051</td>
<td>0.75 ± 0.061</td>
</tr>
<tr>
<td>I</td>
<td>0.83 ± 0.01</td>
<td>0.85 ± 0.04</td>
<td>0.63 ± 0.031</td>
<td>0.79 ± 0.03</td>
<td>0.87 ± 0.02</td>
</tr>
<tr>
<td>Mid-ventricle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.61 ± 0.041</td>
<td>0.89 ± 0.03</td>
<td>0.74 ± 0.031</td>
<td>0.73 ± 0.051</td>
<td>0.68 ± 0.051</td>
</tr>
<tr>
<td>I</td>
<td>0.83 ± 0.01</td>
<td>0.88 ± 0.03</td>
<td>0.68 ± 0.031</td>
<td>0.85 ± 0.02</td>
<td>0.89 ± 0.02</td>
</tr>
<tr>
<td>Second</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.61 ± 0.041</td>
<td>0.87 ± 0.021</td>
<td>0.78 ± 0.03</td>
<td>0.82 ± 0.051</td>
<td>0.72 ± 0.061</td>
</tr>
<tr>
<td>I</td>
<td>0.85 ± 0.02</td>
<td>0.88 ± 0.02</td>
<td>0.73 ± 0.021</td>
<td>0.89 ± 0.02</td>
<td>0.92 ± 0.02</td>
</tr>
<tr>
<td>Apex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.69 ± 0.041</td>
<td>0.81 ± 0.031</td>
<td>0.80 ± 0.041</td>
<td>0.85 ± 0.041</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>0.88 ± 0.04</td>
<td>0.83 ± 0.021</td>
<td>0.79 ± 0.021</td>
<td>0.92 ± 0.041</td>
<td></td>
</tr>
<tr>
<td>All slices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0.66 ± 0.031</td>
<td>0.88 ± 0.02</td>
<td>0.76 ± 0.03</td>
<td>0.73 ± 0.041</td>
<td>0.72 ± 0.021</td>
</tr>
<tr>
<td>I</td>
<td>0.85 ± 0.01</td>
<td>0.86 ± 0.03</td>
<td>0.68 ± 0.031</td>
<td>0.81 ± 0.02</td>
<td>0.88 ± 0.02</td>
</tr>
</tbody>
</table>

*Values given as mean ± SEM. Normalized regional perfusion is the average isotope activity in each region of a slice divided by the highest isotope activity in any single pixel of that slice. A = anterior MI; I = inferior MI.
†p < 0.01.
‡p < 0.05.
§p < 0.001.
||p < 0.10.

**Figure 5.** Correlation between regional EFs and perfusion in anterior myocardial segments. ● = patients.

**Figure 6.** Correlation between regional EFs and perfusion in lateral myocardial segments. ● = patients.
related to partial volume effects, cavity obliteration, and movement of the segment out of the plane of the section due to long-axis shortening. Septal EFs, when divided into anterior and inferior regions, were significantly reduced compared to those in the free-wall regions, but this finding has been reported previously using equilibrium radionuclide angiography. The septum is shared between the right and left ventricles, and movement toward the center of the left ventricular cavity is tethered by the attachment to the right ventricle, resulting in lower derived EFs in these regions.

In MI patients, the fixed center method produced regional EFs that were reduced in areas of transmural infarction and preserved in noninfarct regions. Although previous investigators have concluded that the variable center method may be more desirable in achieving uniform regional EFs in healthy subjects, our results indicate that regional EF analysis should be carried out using a fixed center methodology.

The relation of perfusion to regional wall motion was imperfect, however, and was likely a consequence of several factors. Volume status and medication use were not controlled for. Additionally, in patients who had recently experienced MIs, the tethering of normal myocardial segments adjacent to infarcted regions may occur, and, at the time of hospital discharge imaging, myocardial stunning and compensatory hyperkinesia may be present in as many as one third of patients. Furthermore, autopsy studies have suggested that the correlation between fibrosis and regional wall motion is generally weak. Nevertheless, there was a highly significant association between regional EFs and the findings of a qualitative echocardiographic regional wall motion assessment, suggesting that the derived regional EFs were representative of actual wall motion at the time of the study. The lack of absolute agreement between the two methods is likely related to inherent difficulties encountered when comparing discrete with continuous variables, imperfect registration of myocardial segments, and the comparison of qualitative and quantitative analyses of different imaging modalities.
Previous investigators have examined the correlation between qualitatively assessed regional wall motion and thickening by gated SPECT imaging compared to echocardiographically derived data and have also found high levels of correlation between the two methodologies. Normal limits for the quantitative assessment of regional function have been reported using a different method, but with variability similar to that in this study. These measurements also have been shown to correlate closely with the visual assessment of regional wall motion and thickening by gated SPECT scanning.

Limitations

Any study attempting to define regional wall motion is hampered by the lack of an absolute "gold standard" and by imperfect registration. This study was limited by the lack of patients with true lateral infarctions and by the fact that the patients in the normal group did not undergo catheterization. Even in the groups of patients who had experienced anterior and inferior infarction MIs, the numbers were small. No attempt was made to standardize the hemodynamic or therapeutic status of the patients involved in the study, and the effects of these factors on regional EF assessment remain unknown. Finally, quantitative analysis of regional wall motion in areas of infarction may be hampered by low counts, resulting in potentially less accurate automated regional EF calculations. Despite these limitations, the technique outlined in the current study permitted reliable, simultaneous, and reproducible assessments of regional wall motion and perfusion, in both healthy subjects and patients who had experienced MIs.

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