METHODS

Tomographic Gated Blood Pool Radionuclide Ventriculography: Analysis of Wall Motion and Left Ventricular Volumes in Patients With Coronary Artery Disease

JAMES R. CORBETT, MD, DONALD E. JANSEN, MD, SAMUEL E. LEWIS, MD, FACC, GREGORY I. GABLIANI, MD, PASCAL NICOD, MD, NEIL G. FILIPCHUK, MD, GREGORY A. REDISH, MD, MARVIN S. AKERS, RN, CHRISTOPHER L. WOLFE, MD, JAMES S. RELLAS, MD, ROBERT W. PARKEY, MD, FACC, JAMES T. WILLERSON, MD, FACC

The use of planar radionuclide ventriculography to evaluate global and segmental ventricular function is limited by the superimposition of structures in some projections and the gross segmental resolution of the planar technique. Preliminary reports have suggested the feasibility of tomographic gated radionuclide ventriculography with rotating detector systems. This study tested the hypotheses that 1) tomographic radionuclide ventriculography detects segmental dysfunction at rest not identified with multiview planar studies and single plane contrast ventriculography, and 2) ventricular volumes and ejection fraction calculated from these studies provide data similar to those obtained with angiography and planar radionuclide ventriculography.

Gated blood pool tomograms were acquired over 180° at 15 frames per cardiac cycle during the initial 90% of the cardiac cycle. Compared with the multiview planar technique tomographic ventriculography showed an increased sensitivity for detecting left ventricular segments with significant coronary artery stenosis (97 versus 74%, $p < 0.025$) without any loss in specificity. Compared with both planar radionuclide and contrast ventriculography, tomographic radionuclide ventriculography also detected more noninfarcted left ventricular segments supplied by stenosed coronary arteries (81 versus 39 and 32%, respectively, $p < 0.01$). Tomographic radionuclide ventriculographic measurements of left ventricular volumes and ejection fraction showed close correlations with angiographic and planar radionuclide determinations. Gated blood pool tomography is a sensitive method for the evaluation of segmental wall motion and an accurate method for the measurement of global left ventricular volumes and ejection fraction.

Planar gated blood pool radionuclide ventriculography provides a relatively simple noninvasive means to assess global and regional ventricular function (1,2). However, adequate evaluation of left ventricular segmental function requires sufficient projections to view all segments tangentially. Thus, multiple additional projections (right anterior oblique, anterior, left lateral and left posterior oblique) have been added to the “best septal” projection to increase the sensitivity of radionuclide ventriculography for detecting important segmental dysfunction at rest (3,4). In individual patients, however, some sites of segmental dysfunction may be undetected, even with these additional projections. As a consequence of insufficient segmental resolution or inadequate separation of adjacent structures, or both, segmental left ventricular dysfunction may be underestimated. To overcome these limitations, sophisticated quantitative wall motion analyses are being developed (5,6).

Recent reports (7–9) have suggested the feasibility of gated blood pool tomography with rotating detector systems in patients. The three-dimensional nature of reconstructed tomograms suggests the potential of gated blood pool tomography as a highly sensitive method for detecting and localizing left ventricular segmental dysfunction and as a means for measuring ventricular volumes and ejection fraction independent of geometric considerations. Therefore, this study tested the hypotheses that 1) tomographic radio-
nuclide ventriculography detects segmental dysfunction at rest not identified with multiview planar studies and single plane contrast ventriculography, and 2) ventricular volumes and ejection fraction calculated from these same tomographic studies provide data that correlate with data obtained from angiographic studies and planar radionuclide ventriculograms.

Methods

Study patients. The study group consisted of 37 patients and 2 normal subjects. Patients were evaluated for known or suspected coronary artery disease at Parkland Memorial Hospital in Dallas, Texas between October 1982 and August 1983. There were 24 men and 13 women with a mean (+ SD) age of 48.7 ± 10.2 years (range 32 to 65). Twenty-three patients had a history of at least one previous myocardial infarction documented by electrocardiogram and cardiac enzyme determinations. Two 29 year old normal subjects were included in the study group. Patients were selected for evaluation primarily because they were scheduled for coronary angiography and were found by planar radionuclide ventriculography to have well preserved global ventricular function (ejection fraction ≥ 40%) and minimal wall motion abnormalities.

Thirty-three patients underwent cardiac catheterization with coronary angiography within a mean of 8 ± 9.7 days of radionuclide imaging. All patients had contrast left ventriculography performed in the 30° right anterior oblique projection. In three of these patients, calibration grids were not obtained. Results of the subjective assessment of wall motion were obtained from the catheterization reports. Thirty-one patients had angiographically important coronary artery stenosis defined as a 50% or greater luminal diameter narrowing. Two patients with documented transmural myocardial infarction did not have angiographically important coronary artery stenosis, but were grouped with patients with significant single vessel stenosis on the basis of segmental wall motion abnormalities detected by contrast ventriculography.

Planar imaging technique. Radionuclide ventriculography was performed after the labeling of autologous red blood cells in vitro with 30 mCi of technetium-99m pertechnetate (10). Planar studies were acquired using a standard field of view gamma camera equipped with a low energy general purpose collimator (Picker Dyna Mo). Gated first pass studies of the right heart chambers were acquired in a 30° right anterior oblique projection. The gated first pass and the anterior and lateral gated equilibrium projections were obtained at a temporal resolution of 16 frames per cardiac cycle and the septal projection at a temporal resolution of 32 frames per cardiac cycle; all studies were performed at a spatial resolution of 64 x 64 byte. Imaging time was 2 to 4 minutes for a 32 frame radionuclide ventriculogram acquired over the initial 90% of the cardiac cycle, yielding an average of 100,000 to 200,000 counts per frame.

Tomographic imaging technique. Tomographic studies were performed using a rotating wide field of view gamma camera equipped with a low energy general purpose collimator (GE 400T). They were done immediately after planar imaging with the patient in the supine position with the left arm positioned beside the head. Thirty-two gated projection image sets were obtained over 180° from 60° right anterior oblique to 30° left posterior oblique at a zoom of 1.3. Each projection image set was acquired at a temporal resolution of 15 frames over the first 90% of the cardiac cycle using standard gated acquisition software and was recorded at a spatial resolution of 64 x 64 byte using a normally equipped dedicated nuclear medicine computer system (MDS A2). Gated projection image sets were obtained for a preset time of 1 minute and contained 100,000 to 200,000 counts per frame (total activity average approximately 64 x 10⁶ counts). The radius of rotation ranged from 21 to 27 cm and was selected to minimize the distance from the detector to the chest wall. Total imaging time was approximately 32 minutes. The resolution of the imaging system at 140 keV was measured to be 15.7 mm full width half maximum at a radius of 20 cm in a 20 cm diameter cylinder using a ramp filter.

Tomographic reconstruction technique. Gated tomographic projection image sets were filtered in time and space using standard 5 point and 5 x 5 filter kernels, respectively, with cutoffs of 0.2. The projection image sets were sorted into temporally correlated projection sets before reconstruction (Fig. 1A). This was performed in batch mode on the computer using a command file written in house. Transverse sections of 1 pixel thickness were reconstructed by filtered back projection with correction for center of rotation error (Fig. 1B) (11). The filter used was the product of a Hanning low pass filter and a ramp with a frequency cutoff of 0.67. Attenuation correction was not performed. Transverse sections were reconstructed at end-diastole and end-systole using standard and commercially available software. Sagittal and short-axis sections were extracted from the reconstructed volume (Fig. 1C and D). The short-axis sections were used to generate a set of sections orthogonal to both the short-axis and sagittal sections and therefore parallel to the long axis of both ventricles. These sections are subsequently referred to as "reoriented transaxial" sections (Fig. 1E).

Interpretation of segmental wall motion. Planar and tomographic data were interpreted separately and in random order by three observers unaware of the clinical data and study results. Final readings were by consensus. In each planar projection or tomographic section, the boundary of the left ventricle was divided into five segments and wall motion was graded on a scale of 4 with 0 = dyskinesia, 1
Figure 1. Tomographic radionuclide images. A, Selected tomographic projection images from right anterior oblique to left posterior oblique (upper left across the rows to lower right). Note the anatomic labels. B, Transverse sections at end-diastole from caudad to cephalad (upper left across the rows to lower right). Note the left ventricular (LV) apex is rotated to 12 o’clock. C, Sagittal sections at end-diastole from right ventricular (RV) side to left ventricular (LV) side (upper left across the rows to lower right). D, Short-axis sections at end-diastole from apex to base (upper left across the rows to lower right). E, Reoriented transaxial sections at end-diastole from below the heart to above the heart (upper left across the rows to lower right). Note the left ventricular apex at 6 o’clock.
akinesia, 2 = severe hypokinesia, 3 = mild but definite hypokinesia, and 4 = normokinesia (12). Grades of 3 or less were considered abnormal for statistical purposes. Planar images were interpreted from a 16 frame cinematic display of the anterior, septal and left lateral projections. The right side of the heart was evaluated from a similar analysis of the gated first pass studies. Tomographic images were interpreted from a four section dynamic cinematic display of end-diastole and end-systole. Sections selected for display included reoriented transaxial and sagittal sections (parallel to and including the long axis of the left ventricle) and short-axis sections near the apex and the base of the left ventricle (Fig. 2). The free wall of the right ventricle was also included in this analysis. Wall motion abnormalities detected along the free wall of the right ventricle and inferior and posterior segments of the left ventricle were assigned to the right coronary artery. Abnormalities of the anterior and septal segments of the left ventricle were assigned to the left anterior descending coronary artery, and abnormalities of the mid-lateral and basal-lateral segments to the circumflex coronary artery. Apical abnormalities were not used to localize significant coronary stenoses by the planar and tomographic techniques, and there were no patients with isolated apical abnormalities detected by either technique.

Calculation of tomographic volumes and ejection fraction. Tomographic left ventricular volumes were calculated by two independent observers from the transaxial sections (8 to 16) through the left ventricle at both end-diastole and end-systole. Structures other than the left ventricle were removed from the appropriate sections by operator-designated masks. Left ventricular areas of interest were generated by thresholding at 56% of the peak left ventricular activity remaining in the reconstructed volume, a simple three-dimensional thresholding procedure (Fig. 3). Absolute left ventricular volumes were calculated by integrating the left ventricular areas of interest and multiplying by the volume of a single voxel (0.108 cc). The threshold used was chosen so that the tomographic end-diastolic volumes of two unblinded patients matched the angiographic volumes as closely as possible. This was important because a variation of ±5% produced an under- and overestimation of 20 and 22%, respectively, in the end-diastolic volumes of the two control patients. All patient data were calculated prospectively and without knowledge of the angiographic data.

Statistical methods. Results are reported as the mean ± standard deviation. McNemar's test was used to compare the sensitivity, specificity and predictive accuracy of wall motion abnormalities detected by planar, tomographic and angiographic techniques (13). Tomographic volumes and ejection fraction were compared with angiographic volumes and ejection fraction calculated by the Kennedy modification of the method of Dodge and Sandler (14). Comparisons of
group means were made by Student's t test (13). Tomographic ejection fraction was also compared with planar ejection fraction calculated from the best septal projection of the tomographic acquisition using background-subtracted left ventricular end-diastolic and end-systolic regions of interest (1). Correlations of these results were made by simple linear regression (13).

**Results**

**Coronary lesions.** The 39 patients in this study included 31 patients with angiographically proven coronary artery stenoses, 2 with normal coronary arteries, 4 with angina who refused angiography and 2 normal volunteers. Fourteen patients had significant single vessel disease, eight had double vessel disease and nine had triple vessel disease. Of the 105 coronary arteries for which the anatomy was known, including 6 from two normal subjects 57 had 50% or greater and 47 had 75% or greater coronary luminal diameter narrowings. There were 19 right coronary lesions, 25 left anterior descending lesions and 13 circumflex lesions. Twenty patients had a history of one previous myocardial infarction and 3 had a history of two previous infarctions. This group included 13 patients with a transmural infarct and 10 with a nontransmural infarct. Thirteen of these infarcts were anterior, 10 inferior and 3 lateral; 4 were in distributions with less than 75% coronary stenosis at angiography. As previously stated, a primary criterion for patient selection was relatively well preserved left ventricular function; the mean left ventricular ejection fraction at rest in all 39 patients studied was 50.1 ± 11.1%. There were only five patients included in this study with a left ventricular ejection fraction of 40% or less.

**Detection of segmental wall motion abnormalities.** The comparison of wall motion abnormalities detected by planar and tomographic radionuclide ventriculograms and contrast angiography with the presence or absence of significant coronary artery stenoses is shown in Table 1. Of the 31 patients with at least 1 significant coronary lesion, contrast angiography detected 25 coronary lesions, planar studies detected 22 and tomographic studies detected 30, with sensitivities of 81, 71 and 97%, respectively (p < 0.025). There were only four patients without significant coronary artery stenosis. One patient admitted to the hospital for cardiac catheterization because of a long history of recurrent chest pain had a posterior wall motion abnormality detected by tomography.

The comparisons of detected wall motion abnormalities with the specific coronary anatomy are shown in Table 2. The tomographic technique had greater sensitivity and predictive accuracy for each coronary distribution. The sensitivity of tomography for the detection of left ventricular wall motion alterations caused by a left anterior descending stenosis was significantly greater (tomography 96% versus planar 60% and angiography 60%) (p < 0.01). The predictive accuracy of tomography was also significantly greater (91 versus 69 and 69%, respectively) (p < 0.05) (Fig. 4). The sensitivity and predictive accuracy of tomography for the detection of segments supplied by a stenosed right coronary artery were not significantly increased, although in individual cases the results were striking (Fig. 5). The overall sensitivity and predictive accuracy of the tomographic technique were significantly greater than those of the planar and angiographic techniques (88 versus 57 and 56%, and 89 versus 71 and 73%, respectively) (p < 0.001). There was no difference in the specificity of the three techniques for the correct identification of ventricular segments supplied by the 48 coronary arteries without significant stenoses (Table 2).

The severity of wall motion abnormalities in the abnormal coronary distributions was compared for planar and tomographic studies. The mean wall motion scores for the planar and tomographic techniques were 2.86 ± 1.22 and 2.21 ± 1.13, respectively (p = 0.001). In the grading of abnormal coronary distributions, 41 were rated as severely hypokinetic or worse by tomography compared with 17 by

---

**Table 1. Comparison of the Sensitivity of Planar and Tomographic Methods in Detecting Wall Motion Alterations**

<table>
<thead>
<tr>
<th>Patient Group (no. of patients)</th>
<th>Abnormal Findings</th>
<th>Sensitivity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Planar</td>
<td>Tomo</td>
</tr>
<tr>
<td>No CAD (4)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1 Vessel CAD (14)</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>Multivessel CAD (17)</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>All CAD (31)</td>
<td>22</td>
<td>30</td>
</tr>
</tbody>
</table>

*p < 0.025, tomographic vs. planar method and tomographic method vs. angiography. Angio = angiography; CAD = significant coronary artery stenosis; Tomo = tomography.
Table 2. Comparison of Planar and Tomographic Methods for the Detection of Ventricular Wall Motion Alterations With Specific Coronary Artery Anatomy

<table>
<thead>
<tr>
<th>Total Vessels</th>
<th>RCA (n = 35, Abn = 19)</th>
<th>LAD (n = 35, Abn = 25)</th>
<th>LCx (n = 35, Abn = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planar</td>
<td>Tomo</td>
<td>Angio</td>
<td>Planar</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>57</td>
<td>88†</td>
<td>56‡</td>
</tr>
<tr>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specificity</td>
<td>88</td>
<td>90</td>
<td>94</td>
</tr>
<tr>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predictive accuracy</td>
<td>71</td>
<td>89</td>
<td>73</td>
</tr>
<tr>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05, †p < 0.01, ‡p < 0.001, tomographic vs. planar method and tomographic method vs. angiography.
Abn = abnormal; LAD = left anterior descending artery; LCx = left circumflex artery; RCA = right coronary artery; other abbreviations as in Table 1.

planar analysis (p < 0.001). The same grading scale was not used for angiographic studies; therefore, similar comparisons could not be made. However, in 10 vascular distributions considered akinetic or dyskinetic by angiography, the corresponding tomographic studies were in agreement. Eight coronary arteries were estimated to be narrowed 50 to 74%. Two were in myocardial distributions that were infarcted and were found to be abnormal by both imaging techniques. Of the six remaining distributions, one was considered abnormal by both, and one by tomography only.

In three patients with severe left ventricular dysfunction, including a large apical anterior aneurysm, the tomographic technique was better able to identify those coronary distributions with preserved segmental function. Table 3 shows the sensitivities of the three techniques for the detection of

Figure 4. Tomographic (TOMO) (left) and planar (right) studies at end-diastole and end-systole from a patient with 60 to 70% mid-left anterior descending artery and 85% diagonal branch stenoses. Areas of hypokinesia at the left ventricular apex and adjacent anterior septal segments are indicated with arrows in the end-systolic (ES) sections. The planar study was normal. ED = end-diastole.

Figure 5. Tomographic (TOMO) (left) and planar (right) studies at end-diastole (ED) and end-systole (ES) from a patient with stenosis of the right and the left circumflex coronary artery. Areas of hypokinesia involving the posterior and basal lateral segments are indicated (arrows). The planar study was interpreted as showing apical and septal hypokinesia compatible with left anterior descending stenosis.
Table 3. Sensitivity of Planar and Tomographic Radionuclide Ventriculography in Regional Wall Motion in Infarcted and Noninfarcted Coronary Beds

<table>
<thead>
<tr>
<th>MI distributions (n = 26)</th>
<th>Planar</th>
<th>Tomography</th>
<th>Angiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>77%</td>
<td>96%</td>
<td>85%</td>
<td></td>
</tr>
<tr>
<td>No MI distributions (n = 31)</td>
<td>39%</td>
<td>81%*</td>
<td>32%</td>
</tr>
</tbody>
</table>

*p < 0.01, tomographic method versus planar method and angiography. MI = myocardial infarction; other abbreviations as in Table 1.

ventricular segments perfused by a stenosed coronary artery with and without previous myocardial infarction. The tomographic technique had a significantly greater sensitivity than the planar and angiographic assessments for the detection of segmental dysfunction occurring in noninfarcted but stenosed coronary vascular beds (81 versus 39 and 32%, respectively, p < 0.01). The sensitivity of tomography for the detection of ventricular segmental dysfunction occurring in infarcted beds (96 versus 77 and 85%) for planar and angiographic measurements, respectively, was not significantly increased. Of the 57 regions with significant coronary artery stenosis, 18 were supplied by collateral vessels; this included 13 to infarcted and 5 to noninfarcted segments. In these 18 segments, tomography demonstrated wall motion abnormalities in all but 1 of the noninfarcted segments, planar radionuclide ventriculography in 10 infarcted and 3 noninfarcted segments and angiography in 10 infarcted and 4 noninfarcted segments.

Left ventricular volumes and ejection fraction. The correlations of the tomographically determined left ventricular volumes and ejection fraction with the angiographic volumes and ejection fractions are shown in Table 4. The correlations between tomographically determined left ventricular end-diastolic volumes and angiographic determinations in 30 patients were significant with correlation coefficients (r values) of 0.90 and 0.91 (p < 0.001), respectively, for the two observers (Fig. 6). The correlations for the left ventricular end-systolic volumes calculated from tomograms and the angiographic determinations were also significant with respective r values of 0.93 and 0.91 (p < 0.001) (Fig. 6). Similar correlations for the left ventricular ejection fractions were 0.79 and 0.75, respectively (p < 0.001) (Fig. 6). The mean left ventricular ejection fractions determined by tomography tended to be lower than the angiographic determinations (Table 4). Therefore, a second set of comparisons was also made.

Gated tomographic acquisitions are a series of 32 gated planar radionuclide ventriculograms obtained at fixed angular increments about the patients. From these 32 radionuclide ventriculograms, the best septal projection was selected for the calculation of planar left ventricular ejection fraction. The correlations of the tomographically determined left ventricular ejection fraction with planar determinations calculated from the best septal projection of the tomographic acquisition were significant with r values of 0.92 and 0.88, respectively, for the two observers. The regression line approximated that of the line of identity (Fig. 6). The inter-

Table 4. Tomographic Radionuclide Ventriculographic, Angiographic and Planar Measurements of Left Ventricular Volumes and Ejection Fraction

<table>
<thead>
<tr>
<th>EDV (ml)</th>
<th>Angiography</th>
<th>Tomo RVG</th>
<th>Observer 1</th>
<th>Interobserver Correlation Coefficient</th>
<th>Observer 2</th>
<th>Tomo RVG</th>
</tr>
</thead>
<tbody>
<tr>
<td>130.8 ± 35.4 (n = 30)</td>
<td>129.0 ± 29.9</td>
<td>r = 0.90</td>
<td>0.92</td>
<td>127.4 ± 31.1</td>
<td>r = 0.91</td>
<td></td>
</tr>
<tr>
<td>60.5 ± 27.6 (n = 30)</td>
<td>66.9 ± 26.2</td>
<td>y = 0.76x + 29.4</td>
<td>p = NS</td>
<td>66.5 ± 24.7</td>
<td>y = 0.80x + 22.5</td>
<td>p = NS</td>
</tr>
<tr>
<td>54.9 ± 12.8 (n = 30)</td>
<td>48.5 ± 11.2</td>
<td>r = 0.93</td>
<td>0.96</td>
<td>48.9 ± 12.3</td>
<td>r = 0.91</td>
<td></td>
</tr>
<tr>
<td>50.2 ± 10.6 (n = 39)</td>
<td>50.4 ± 11.0</td>
<td>y = 0.89x + 5.57</td>
<td>p = 0.04</td>
<td>50.4 ± 11.0</td>
<td>y = 0.91x + 4.67</td>
<td></td>
</tr>
</tbody>
</table>

*Comparisons of tomography vs. angiography. EDV = end-diastolic volume; EF = ejection fraction; ESV = end-systolic volume; RVG = radionuclide ventriculogram.
observer correlations for the tomographically determined left ventricular volumes (end-diastolic and end-systolic) and ejection fraction for the two observers were excellent with r values of 0.92, 0.96 and 0.88, respectively.

Discussion

Recent reports (7–9) have suggested that gated blood pool tomograms can be obtained with rotating detector systems. In a small group of patients, these studies have shown that wall motion abnormalities may be detected and global left ventricular function assessed. Unfortunately, most of these studies have lacked a significant number of patients and reasonable standards for comparison. In our study, left ventricular segmental wall motion abnormalities detected by planar and tomographic gated blood pool imaging and contrast ventriculography were compared with the coronary anatomy. Significantly enhanced sensitivities and predictive accuracies were found for the tomographic technique in the detection of left ventricular segmental dysfunction related to the distribution of significant coronary artery stenoses. Furthermore, comparisons of the tomographically determined left ventricular volumes and ejection fractions with angiographic determinations have shown a close correlation.

Limitations of planar imaging. Planar gated blood pool imaging provides a simple noninvasive means for the assessment of regional ventricular function (1,2). When multiple projections are acquired, these planar studies are a useful tool (1–4). Unfortunately, in each planar projection there is the problem of superimposed structures with incomplete separation of the cardiac chambers and limited resolution of ventricular segments. For instance, in the best septal projection (looking down obliquely on a foreshortened left ventricle), wall motion abnormalities detected along the lateral wall may be the result of significant stenosis in any one of the three major coronary arteries. For example, segmental wall motion abnormalities detected along the lateral wall ordinarily assigned to the circumflex artery distribution may, in fact, be the result of anterior wall motion abnormalities caused by left anterior descending coronary artery stenosis or inferoposterior wall motion abnormalities caused by right coronary artery stenosis superimposed on the lateral wall.
When multiple projections are available, the observer must evaluate each, and if wall motion abnormalities are detected, knowing the orientation of each projection, must mentally sort this information and assign abnormalities to specific coronary distributions. We and others have found this process to be relatively unsatisfactory (Table 2). The use of exercise testing, regional ejection fraction calculations and quantitative wall motion analysis have increased the sensitivity of the planar technique; however, they are generally limited to the septal projection and are of limited value in defining the exact distribution of segmental left ventricular dysfunction (2,5,6).

Advantages of tomographic gated blood pool imaging: assessment of segmental ventricular function. Tomographic techniques can provide accurate three-dimensional reconstruction of radionuclide distributions. As a result of this process, structures are well separated in space, and very limited ventricular segments can be assessed without concern about adjacent and potentially superimposed segments. Subsequently, an increased accuracy was found for the detection and proper assignment of wall motion abnormalities by the tomographic technique (Table 2). Our patients were selected primarily because they were scheduled for angiographic evaluation and had well preserved global ventricular function by planar gated blood pool imaging. Several of them also had a clinical history of myocardial infarction or severe and limiting angina pectoris, or both. It would not be anticipated that either planar or tomographic techniques would be as sensitive in a more general clinical group with a lower incidence of previous myocardial infarction and symptomatic coronary artery disease. However, the tomographic method appears significantly more sensitive than either planar imaging or contrast angiography in the detection of wall motion abnormalities at rest. Generally, there was an increased confidence in the determination of wall motion abnormalities by the tomographic technique compared with that of planar imaging. This was reflected in the significantly lower wall motion scores assigned abnormal segments in tomographic studies. Maublant et al. (7) studied 18 patients using similar methods and found a close correlation for data obtained with planar and tomographic techniques. Tamaki et al. (8) studied 15 patients comparing tomographic studies with planar gated blood pool imaging and contrast ventriculography and found that tomographic studies more clearly demonstrated wall motion abnormalities detected by contrast ventriculography. Unfortunately, neither of these studies compared planar and tomographic studies with the coronary anatomy. Similar to the findings in this study, both previous studies reported a significant underestimation of the extent of wall motion abnormality by the planar technique.

In our study, 23 of 35 patients in whom ventricular wall motion could be compared with the coronary anatomy had a history of at least one previous myocardial infarction. However, more than 80% of the patients studied had well preserved global left ventricular function. Because of the definition of the coronary anatomy by angiography, assessment of ventricular segmental wall motion in the distribution of normal and severely narrowed or occluded coronary arteries could be made. The tomographic technique was of particular value in the assessment of the noninfarcted segments perfused by stenosed coronary arteries where there was a greater than twofold increase in sensitivity over the planar technique and angiography (Table 3). Although only four patients were without significant coronary artery stenosis, 48 of the 105 coronary distributions assessed were without significant stenosis and the specificity of wall motion analysis of these segments was virtually identical for planar, tomographic and angiographic techniques (88, 90 and 94%, respectively).

Determination of left ventricular volumes and ejection fraction. The calculation of left ventricular volumes and ejection fraction from the tomographic reconstructions showed an excellent correlation with established techniques. The tomographic method has the advantage of reconstructing the entire three-dimensional volume and, thus, no geometric assumptions are involved. Some of the variation between the tomographic determinations and those of the more established techniques may be due to the simple thresholding technique used for edge detection in the tomographic studies. However, this technique is easily implemented on almost any nuclear medicine computer and the fact that it worked so well confirms the value of the tomographic method. Stadius et al. (15) recently reported similar data using a rotating detector system. Myers et al. (16), using 7 pinhole tomography, showed a reasonable correlation between tomographic determination of left ventricular ejection fraction and contrast ventriculography. They did not, however, report the measurements of left ventricular volumes. The assessment of ventricular end-diastolic volumes with the older relatively poor resolution tomographic cameras may be difficult in some patients because there is some loss of resolution with depth using these devices, and it may be difficult to define the mitral valve plane at end-diastole when the left atrium is dilated. However, more efficient tomographic cameras and improved collimator design should eliminate these problems. Volume determinations in this study were quite sensitive to the threshold used as reflected by the 20% underestimation and 22% overestimation in the two control patients by varying the threshold ± 5% from the 56% used. It would be anticipated that with higher resolution cameras and less filtering in the processing of these studies, a lower threshold could be used with less variation in volumes with slight changes in threshold.

Conclusion. Gated blood pool tomography using a rotating detector tomograph is a valuable means of assessing global ventricular function and regional ventricular wall motion in patients with significant coronary artery stenosis. Displays of gated tomographic data consisting of multiple
orthogonal and intersecting sections through the left and right ventricles provide an accurate means of identifying ventricular segmental wall motion abnormalities in relation to the presence or absence of significant coronary artery stenosis. Although the clinical utility of this technique may be limited by the prolonged acquisition times required with the first generation tomographic camera used, as newer tomographs become available, major improvements can be expected. Even greater gains can be expected in processing and reconstruction times with more modern computers. It can be concluded from this study that: 1) gated blood pool tomography is a sensitive method for the assessment of segmental ventricular wall motion, and 2) measurements of global left ventricular volumes and ejection fraction can be accurately made from tomographic images.

We acknowledge the technical assistance of Scotty Lyons and secretarial assistance of Patricia Powell and Belinda Lambert. We also appreciate the cooperation and assistance of the medical house officers, nurses and cardiology fellows in the medical intensive care unit and internal medicine service at Parkland Memorial Hospital, Dallas, Texas.

References