Prone Versus Supine Thallium Myocardial SPECT: A Method to Decrease Artifactual Inferior Wall Defects

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Artifactual inferior wall defects as a result of diaphragmatic attenuation of activity are a frequent source of error in thallium myocardial single photon emission computed tomography (SPECT) studies. Thirty-four patients and 11 clinically normal volunteers were studied prospectively to see if specificity of inferior wall defects for right coronary artery disease could be improved by scanning patients prone versus supine. All individuals were scanned both prone and supine, in random order, following symptom limited treadmill exercise. Images were acquired at 3° steps, 25 sec per frame, in a 180° elliptical orbit always beginning in the 45° right anterior oblique position relative to the patient. Polar maps generated from the short axis slices were used to calculate the average regional activity. The prone studies showed consistently higher inferior wall activity compared to the supine studies on both the exercise (182 ± 22 vs. 160 ± 23, $p \leq 0.001$) and 4-hr delay studies (183 ± 20 vs. 175 ± 21, $p \leq 0.001$). Prone imaging resulted in a significantly higher specificity for RCA disease compared to supine imaging (90% vs. 66%, $p < 0.05$) with an improvement in accuracy from 71% to 82%. Sensitivity, specificity, and accuracy for left anterior descending and left circumflex artery disease were not significantly affected by patient position during imaging. All patients having SPECT thallium myocardial perfusion studies should be imaged prone to minimize artifactual inferior wall defects and improve accuracy.

J Nucl Med 30:548–555, 1989

Although thallium is widely used for myocardial imaging, the low-energy photon of the mercury x-ray that is emitted (69–83 keV) is suboptimal for imaging. One of the significant problems which results is the frequent occurence of artifactual left ventricular wall defects caused by photon attenuation by extra cardiac soft tissues. Decreased anterior and upper septal wall activity seen in women is a result of overlying breast (*1*). This problem is usually avoided by securing the breast with tape or elastic bandages in an upward position. Diminished thallium activity in the inferior wall in both sexes is caused by interposition of the diaphragm between the myocardium and camera. With planar technique, attenuation of inferior wall activity is most apparent in the anterior and left lateral views when the patient is imaged supine. However, the same views acquired with the patient in the right lateral decubitus position or with the patient upright show balanced myocardial thallium activity (*2,3*). Unfortunately, these simple maneuvers to decrease artifactual inferior wall defects cannot be used with single photon emission computed tomography (SPECT) or result in an unacceptable distance between patient and camera.

SPECT is rapidly becoming the preferred method for thallium myocardial perfusion studies. SPECT is better than planar technique for localizing coronary artery disease as well as identifying patients with multivessel disease (*4*). However, the old problem of decreased inferior wall activity remains. Numerous studies have reported relative decreased inferior wall activity in normal patients (5–9). It has also been reported that the specificity of posterior territory defects is lower than the specificity of anterior defects, and is worse than that obtained with planar imaging (*8,10*). Attempts to quantify abnormalities with circumferential profiles or polar mapping and comparison to normal populations have

Received Aug. 25, 1988;; revision accepted Nov. 11, 1989.

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TABLE 1
Exercise and Hemodynamic Data

	Group 1 (n = 34)	Group 2 (n = 11)
Age (yr)	62.0 ± 8.7	32.4 ± 7.6
Exercise time (min)	7.0 ± 2.5	13.9 ± 3.0
Peak heart rate (bpm)	122 ± 18	182 ± 7
Peak blood pressure (mmHg)	161 ± 29	167 ± 23
Patients with ≥1 mm ST↓	16	0
Patients with chest pain	16	0

not always improved diagnostic accuracy, in part a result of the large standard deviation of normal inferior wall activity (*8,11*).

Since the heart is anchored in the mediastinum only at the base and is therefore mobile, it occurred to us that imaging the patient prone instead of supine could favorably alter the spatial relationship between the diaphragm and inferior wall of the myocardium and still allow for optimum SPECT technique. Although prone imaging has been suggested to lessen patient discomfort (*12*) there have been no reports comparing the diagnostic accuracy of images obtained in both positions. (The reader is referred to the recent publication by Esquerre, Coca, Martinez, and Guiraud. *J Nucl Med* 1989; 30: 398-401—*ED*). Accordingly, we undertook a prospective study comparing prone versus supine thallium SPECT imaging to see if a) there was a relative increase in inferior wall activity when patients were imaged prone, and b) whether specificity for right coronary artery lesions was improved without decreasing sensitivity.

METHODS

Patients

Two groups of patients were studied. Individuals in Group 1 were suspected of having coronary artery disease (CAD) or had known coronary artery disease. Patients with coronary artery bypass grafts, valvular disease or cardiomyopathy were not included. There were 34 men who had an average age of 62.0 ± 8.7 yr. Six patients had EKG evidence of prior myocardial infarction (three anterior and three inferior). All patients had a coronary arteriogram within 2.8 ± 5.0 wk of the thallium test. Significant CAD was considered to be present when there was 70% or greater luminal narrowing of at least one major epicardial vessel, defined as right (RCA), left anterior descending (LAD), first and second diagonal, left circumflex (LCX), and first and second obtuse marginal arteries. Twenty-eight patients (Group 1A) had significant disease: 14 had single vessel, 12 had double vessel, and two had triple vessel disease.

Individuals in Group 2 were clinically normal and were considered to have less than a 2% probability of coronary disease on the basis of age, sex, and ST response to treadmill exercise (*13*). The average age of this group was 32.4 ± 7.6 yr. There were six men and five women.

Treadmill Exercise

Individuals performed symptom-limited exercise according to the Bruce protocol. Mean exercise time, peak heart rate, blood pressure, and ST response for both groups are shown in Table 1. Individuals in Group 1 generally did not achieve 85% of their age predicted maximal heart rate because of fatigue or angina. One hundred eleven MBq (3 mCi) of thallium-201 chloride (^{201}Tl) were injected intravenously 1 min prior to stopping exercise.

Imaging

All individuals were imaged prone and supine during one session. When imaged prone, patients kept both arms extended above their head. When imaged supine, the left arm was held over the head while the right arm was allowed to rest at the side. The order of the scans was randomized with the second scan immediately following the first. Twenty-three patients were first imaged prone and 22 patients were first imaged supine. The time interval between ^{201}Tl injection and the first scan was 11.4 ± 3.5 min. The time interval between ^{201}Tl injection and the second scan was 53.9 ± 6.8 min. Patients returned 4 hr after exercise for delayed scans. Patients were imaged prone and supine in the same order as the early scans.

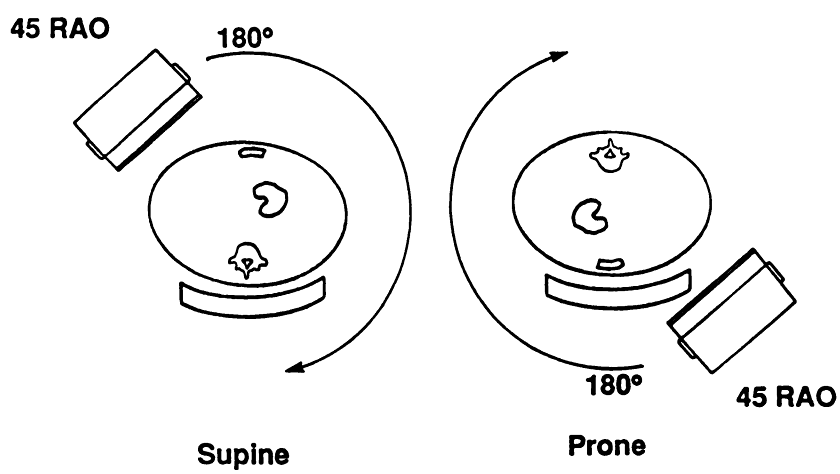

FIGURE 1
Schematic diagram showing the relationship of camera to patient for supine and prone studies. The direction of scan is always from right anterior oblique to left posterior oblique, relative to the patient.

TABLE 2
Regional Average Count Per Pixel Calculated from Normalized Polar Maps

	sep	lat	ant	inf
	Early			
prone	177 ± 20	212 ± 18	190 ± 20	182 ± 22
supine	171 ± 22	207 ± 16	194 ± 19	160 ± 23
p value	<0.05	NS	NS	<0.001
	Delay			
prone	181 ± 18	207 ± 18	192 ± 16	183 ± 20
supine	183 ± 19	212 ± 16	201 ± 15	175 ± 21
p value	NS	<0.05	<0.001	<0.001

Acquisition and Processing of Thallium Images

Images were acquired with a large field-of-view gamma camera fitted with a low-energy, medium sensitivity, medium resolution collimator. Fifteen percent windows were centered on the 69 keV and 170 keV photopeaks. Images were acquired in a 64 × 64 matrix at 3-degree steps, 25 sec per frame, in a 180° elliptical orbit beginning in the 45° right anterior oblique position. The direction of orbit was always right anterior oblique to left posterior oblique, relative to the patient, regardless of whether the patient was prone or supine (Fig. 1).

Images were processed with a ramp-Butterworth filter (0.35 roll-off, order 4) and images were reconstructed in 1-pixel-thick slices along the short, vertical long, and horizontal long axes of the heart. A polar map was constructed from sixteen contiguous short axis slices. No correction was made for differences in cardiac size among patients.

Polar maps were used to determine the average regional myocardial counts per pixel for all exercise and delayed studies. Polar maps were first normalized to maximum, then divided into four equal quadrants representing the anterior, septal, inferior, and lateral walls. The average pixel value in each quadrant was determined by computer.

All exercise studies were examined for upward creep of the myocardium during image acquisition. The sixty planar projections of each study were reframed into one composite image and normalized to maximum. The composite images were displayed on a black and white as well as color monitor. A straight line was drawn along the inferior wall of the myocardium. The maximum deviation of the line from horizontal was measured in number of pixels.

Image Interpretation

All images were read by one experienced observer during two sessions. The observer had no knowledge of the clinical history, exercise data, or angiographic findings. Furthermore, the images were interpreted without knowing whether the study was performed prone or supine. Studies were read primarily on the basis of visual interpretation of the images, although semiquantitative data in the form of polar maps was also available. Areas of relative hypoperfusion in the anterior and septal regions were attributed to LAD disease, hypoperfusion in the inferior region to RCA disease, and hypoperfusion in the lateral region to LCX disease. Due to the variable anatomic blood supply of the apex, hypoperfusion in this region was not ascribed to any particular vessel. Defects were also noted to be fixed or reversible at four hours, although no distinction was made in the final analysis. A subjective evaluation was also made of the image quality, considering such factors as target to background activity ratio, smoothness of ventricular outline, and homogeneity of myocardial thallium activity. Images were graded as poor, fair, or good.

Arteriography

Coronary arteriograms were read independently by the attending cardiologist who had no knowledge of the thallium findings. Vessels were judged subjectively and a visual estimate was made of the degree of luminal narrowing.

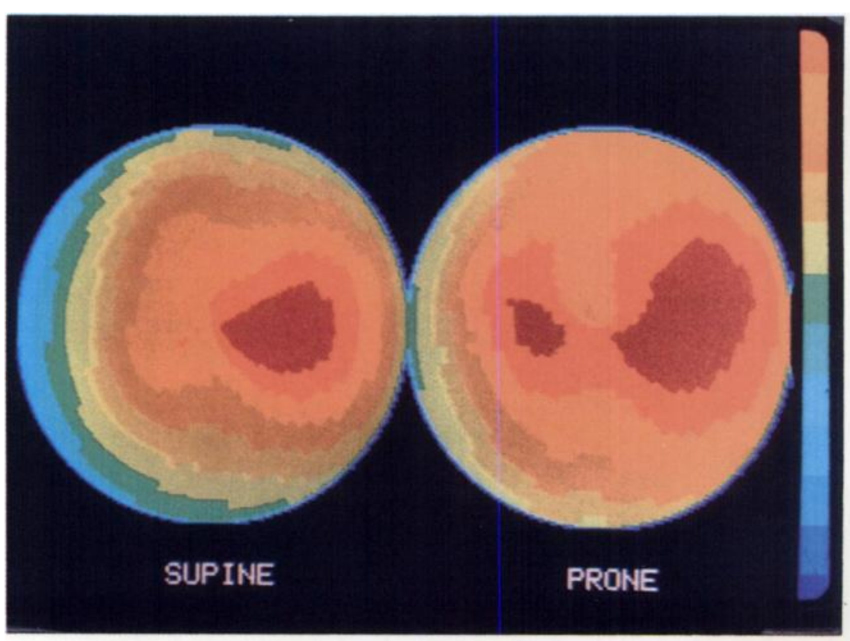

FIGURE 2
Composite polar maps generated from the exercise studies of 11 clinically normal individuals. Compared with the supine map (left), the prone map (right) shows more uniform distribution of activity throughout the myocardium with the greatest difference seen in the inferior and septal regions.

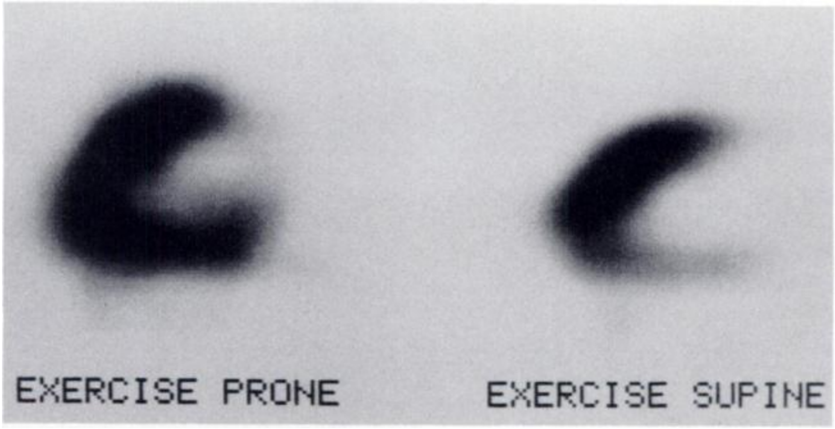

FIGURE 3
Vertical long axis cuts through mid left ventricle of a 66-yr-old man with a normal EKG and normal coronary arteriogram. The prone study (left) which was done first is normal whereas the supine study (right) shows an inferior defect.

Statistical Methods

Student's paired t-test was used to compare regional mean pixel values between prone and supine studies. A significant difference was considered present when the p value was less than 0.05. To compare the diagnostic properties of the two tests, a bootstrap procedure with 500 replications was used to construct 95% confidence intervals for those indices. Tests were considered significantly different if the confidence intervals did not overlap. Sensitivity and specificity were also compared by computing a Z-score using the binomial test. A p value less than 0.05 was considered significant.

RESULTS

The regional average value per pixel calculated from normalized polar maps is shown in Table 2. Activity in the anterior and lateral walls was not significantly different between the prone and supine studies obtained after exercise. However, activity in the septum was slightly higher when patients were imaged prone. Activity in the inferior wall was much greater when patients were imaged prone as opposed to supine, and this difference was highly significant.

Patient position did not cause a difference in relative septal activity on the delayed studies. The anterior and lateral walls showed an increase when patients were imaged supine, but this difference was not seen on the early views. Only the inferior wall showed a consistent highly significant difference in both the early and delayed views, with greater activity seen when patients were imaged prone.

TABLE 3
Comparison of Sensitivity, Specificity, and Accuracy of Prone Versus Supine Imaging

	Prone	Supine
Overall		
SENS	75% (21/28)	79% (22/28)
SPEC	82% (14/17)	59% (10/17)
ACC	78% (35/45)	71% (32/45)
RCA		
SENS	69% (11/16)	81% (13/16)
SPEC	90% (26/29)	66% (19/29)*
ACC	82% (37/45)	71% (32/45)
LAD		
SENS	60% (09/15)	53% (08/15)
SPEC	87% (26/30)	87% (26/30)
ACC	78% (35/45)	76% (34/45)
LCX		
SENS	46% (06/13)	46% (06/13)
SPEC	100% (32/32)	100% (32/32)
ACC	84% (38/45)	84% (38/45)

*$p < 0.05$.

TABLE 4
Comparison of Sensitivity, Specificity, and Accuracy of Studies Depending on Order of Acquisition

	First study	Second study
Overall		
SENS	86% (24/28)	68% (19/28)
SPEC	76% (13/17)	65% (11/17)
ACC	82% (37/45)	67% (30/45)
RCA		
SENS	75% (12/16)	75% (12/16)
SPEC	77% (17/22)	78% (28/36)
ACC	76% (29/38)	77% (40/52)
LAD		
SENS	78% (07/09)	48% (10/21)
SPEC	90% (26/29)	84% (26/31)
ACC	87% (33/38)	69% (36/52)
LCX		
SENS	54% (07/13)	38% (05/13)
SPEC	100% (32/32)	100% (32/32)
ACC	87% (39/45)	82% (37/45)

TABLE 5
Image Quality of Prone Versus Supine Studies

	Prone	Supine
Good	36	42
Fair	9	3
Poor	0	0

TABLE 7
Analysis of 20 False-Positive Studies in Relation to Patient Position and Creep

	Patient position	
	Prone	Supine
Upward creep	0	7
No creep	7	6

Figure 2 shows the composite polar maps generated from the 11 clinically normal individuals (Group 2) who were studied. The map generated from the prone studies shows more activity in the inferior wall and septum in all of the slices from apex to base. Differences in the other regions are less marked. Forty-two of the 45 individuals studied showed a measurable increase in inferior wall activity when imaged prone. The difference was striking in about one quarter of patients. One such example is shown in Figure 3.

The fact that this quantitative difference in inferior wall activity is clinically important is demonstrated in Table 3. Sensitivity for RCA disease is slightly, though not significantly, lower when patients are imaged prone. However, specificity is dramatically better and this results in an overall improvement in accuracy compared to supine imaging. As expected from the quantitative data, sensitivity, specificity, and accuracy for LAD and LCX disease is not significantly affected by patient position during imaging. The overall effect on the detection of CAD is improved accuracy and higher specificity without a significant loss of sensitivity when patients are imaged prone as compared to supine.

The effect of time of acquisition on accuracy, independent of patient position, is shown in Table 4. Overall sensitivity declines as the time interval between thallium injection and acquisition increases. However, there is no significant difference in specificity between the first and second studies.

Individual acceptance of lying prone was equally good (or equally bad, depending on the patient) compared to lying supine. Half preferred the former position. Subjective evaluation of image quality showed a slight advantage for supine imaging (Table 5) although this difference did not diminish the greater advantage derived from imaging patients prone.

TABLE 6
Analysis of 25 Studies Showing Upward Creep in Relation to Position and False Positives

	Patient position			
	Prone		Supine	
No. patients with Upward creep	6		19	
First study		4		14
Second study		2		5
No. false positive	0		7	

All of the exercise studies were examined for signs of apparent cephalad migration of the inferior wall. The so-called "upward creep" was seen in 28% (25/90) of studies (Table 6). Among the 25 studies showing upward creep, 19 were supine studies whereas only six were prone. Interestingly, seven of the 25 studies were the second imaging procedure performed.

There were 20 studies with perfusion defects in a region supplied by a normal or nonsignificantly diseased coronary artery. All of these defects were in the anterior, septal, inferior, or apical region. Upward creep was only seen in 35% (7/20) of these studies (Table 7). Conversely, only 28% (7/25) of studies showing upward creep were associated with false-positive studies. The degree of upward creep was one pixel in 15 studies (three false positives) and 2 pixels in ten studies (four false positives). Curiously, 1 pixel and 3 pixel downward motion of the inferior wall, respectively, was seen in two studies, the latter showing a false positive LAD defect.

DISCUSSION

The problem of diaphragmatic attenuation of inferior wall activity has been known for many years (*2,14–15*). In planar imaging, this problem is avoided, or at least minimized, by imaging the patient in the right lateral decubitus position for the 70° left anterior oblique view (*2*), or upright for the anterior view (*3*). Implicit in this observation is that the heart is somewhat mobile within the mediastinum so that changing an individual's position favorably alters the spatial relationship between the heart and diaphragm.

Recently there has been a groundswell of support for using SPECT in conjunction with thallium myocardial perfusion imaging. Though some of the claims for SPECT are controversial, it is generally acknowledged that SPECT is better than planar imaging for localizing disease and for identifying patients with triple vessel disease (*4*). What has generally not been discussed is the often poor performance of SPECT when it comes to the diagnosis of RCA disease, or more specifically,

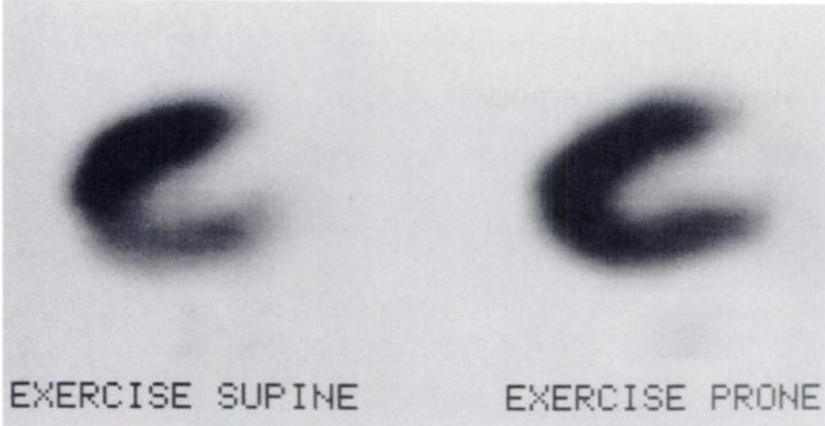

FIGURE 4
Verticle long axis cuts through mid left ventricle of a 71-yr-old man with a normal EKG and coronary arteriogram showing 20–30% narrowing in the RCA and fourth obtuse marginal. The supine study (left) which was done first shows an inferior defect whereas the prone study (right) is normal.

the absence of it. It has been pointed out before that there is a trade-off between the problems of superimposition of structures in planar imaging and attenuation in SPECT (*10*).

What struck us immediately in switching from planar to SPECT myocardial imaging a few years back was the great variability in the normal appearance of the inferior wall with SPECT. This observation has also been made by others. Tamaki et al. (*9*) using quantitative circumferential count profiles found that normal thallium uptake was relatively low in the inferior and septal regions in the middle and basal short axis sections as well as the inferoposterior regions in the long axis sections. Garcia et al. (*8*) reported that a significantly larger defect in the posterior as compared to anterior region was needed to confidently predict disease because of the larger normal standard deviation of the posterior territory. Iino et al. (*7*) reported that six of 24 normal controls showed marked reduction of inferior wall activity to 60–69% of the maximum activity present in other regions. The problem of attenuation of inferior wall activity undoubtedly contributes to the large variability and sometimes poor specificity reported for RCA disease. In a series of reports by Maddahi et al. specificity for RCA disease was reported to be 62–81% with an overall specificity for coronary disease of 56–63% (*16–19*). These values are similar to the ones obtained in this study when patients were imaged supine. Other investigators using visual and/or quantitative analysis have reported a specificity for RCA disease in the range of 33–92% (*5,9,11,20–22*). Unfortunately quantitation does not always significantly improve specificity (*9*) and can even make it worse (*11*).

Quantitative analysis is not helpful in differentiating between true disease and artifactual defects when dealing with large standard deviations. The same problem is faced by an experienced physician reading a film subjectively. The problem is not just recognizing that the inferior wall may have less activity and defining a lower threshold of normalcy. The problem is that individuals without coronary disease may present with a wide spectrum of findings in the inferior region from gross defects to homogeneous distribution of activity. Therefore, one may define criteria that will maximize sensitivity at the expense of specificity, or vice versa.

In all of the studies cited above patients were imaged supine. On the basis of our data, it seems clear that imaging a patient prone goes far to correct this problem, at least in men. It has been reported that women tend to have balanced myocardial activity when imaged supine because the breast attenuates activity from the

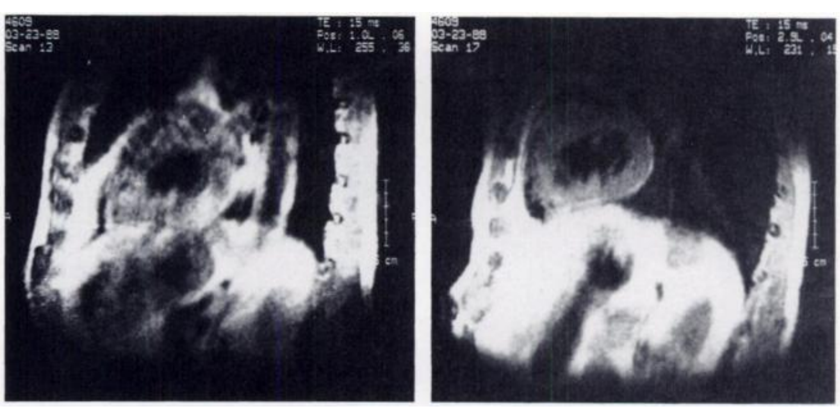

FIGURE 5
MR scan of the man who had the false positive supine thallium scan shown in Figure 4. The images are sagittal cuts through the mid left ventricle obtained with the patient supine (left) and prone (right). The supine image shows "backward flop" of the heart with partial obscuration of the inferior wall by the diaphragm. In contrast, the prone image shows the heart more anterior in the chest with good separation between heart and diaphragm.

anteroseptal region (*5,6*). Although there were five women in Group 2, the numbers are too small to draw conclusions about prone imaging. However, prone imaging has the added convenience of using the weight of the body to keep the breast in an optimal position.

We do not have an explanation for the small but significant decrease in anterior and lateral wall activity that was measurable in the prone images obtained 4 hr after exercise. However, this finding was not visually appreciable and did not affect accuracy.

The values for sensitivity reported in this study should be viewed in light of the fact that half of the studies were performed an average of 54 min after thallium injection. As one would expect from early redistribution of activity, sensitivity of the first study was higher than that of the second study, even when no distinction was made between prone and supine acquisitions. However, since the order of the acquisitions was randomized, it is still valid to compare the relative values for prone and supine imaging. These values were not significantly different.

The effect of study order on specificity should be minimal in individuals without coronary artery disease since myocardial thallium uptake is homogeneous and washout is uniform. In patients with coronary artery disease, evaluation of normally perfused regions could be affected by differential rates of washout from abnormally perfused myocardium. However, once again the random order of acquisition would mean that this theoretical problem would affect prone and supine imaging equally. As shown in Table 4, the overall specificity for coronary artery disease as well as the specificity for individual vessels is not significantly different regardless of whether the study was acquired first or second. Therefore, the higher specificity for RCA disease when patients were imaged prone as compared to supine must be related to patient position rather than time of acquisition.

We looked for the upward creep that has been mentioned by Friedman et al. (*23*) as a cause of false-positive defects. Only a minority of patients in our study showing upward creep had false-positive defects and only a minority of patients with false-positive defects had evidence of upward creep. Therefore we feel that upward creep is only a partial explanation for false-positive inferior wall defects. It is interesting to note that creep was more common in supine versus prone imaging by a margin of more than 2:1 and that none of the prone false-positive studies showed evidence of upward creep whereas creep was seen in 58% of supine false-positive studies. The fact that prone imaging seems to decrease upward creep may be an additional reason for improved specificity for RCA lesions and deserves further investigation.

In order to seek confirmation of our theory that movement of the heart relative to the diaphragm was the mechanism responsible for the improvement seen in prone imaging, one patient had a magnetic resonance (MR) scan. The thallium scan, shown in Figure 4, was normal when the patient was imaged prone but showed a marked inferior wall defect when the patient was imaged supine. The MR scan obtained with the patient lying prone showed the heart to abut the chest wall with good separation between the inferior wall and diaphragm. In contrast, the MR scan obtained while the patient was supine showed a large space between the heart and chest wall filled with fat as well as partial overlap between the inferior wall and diaphragm (Fig. 5). We call this phenomenon "backward flop" and think this supports our theory.

Regardless of whether upward creep, backward flop, or some other mechanism is responsible for the poor specificity of inferior wall defects for RCA disease, it should be pointed out that coronary anatomy is variable and that hypoperfusion of the inferior wall can be due to disease in the left circulation with an entirely normal right coronary artery. As such, these defects represent true disease but are misclassified due to the need for a simple and uniform system of classification.

In conclusion, prone myocardial thallium SPECT imaging greatly improves the accuracy of the test by decreasing artifactual inferior wall defects resulting from diaphragmatic attenuation. It is a simple modification that can be easily performed and is well accepted. All patients undergoing routine SPECT myocardial perfusion imaging at our medical center are now imaged prone.

REFERENCES

1. Rabinovitch M, Suissa S, Elstein J, et al. Sex-specific criteria for interpretation of thallium-201 myocardial uptake and washout studies. *J Nucl Med* 1986; 27:1837–1841.
2. Johnstone DE, Wackers FJTh, Berger HJ, et al. Effect of patient positioning on left lateral thallium-201 myocardial images. *J Nucl Med* 1979; 20:183–188.
3. Jacobson AF, Parker JA, Royal HD, et al. Supine versus upright anterior images: comparison in Tl-201 myocardial scintigraphy. *Radiology* 1987; 163:691–695.
4. Strauss HW, Boucher CA. Myocardial perfusion studies: lessons from a decade of clinical use. *Radiology* 1986; 160:577–584.
5. DePasquale E, Nody A, DePuey EG, et al. Quantitative rotational thallium-201 tomography for identifying and localizing coronary artery disease. *Circulation* 1988; 77:316–327.
6. Van Train K, Maddahi J, Wong C, et al. Definition of normal limits in stress Tl-201 myocardial rotation tomography. *J Nucl Med* 1986; 27:899.
7. Iino T, Toyosaki N, Katsuki T, et al. Evaluation of diseased coronary arterial branches by polar representations of thallium-201 rotational myocardial imaging. *Clin Nucl Med* 1987; 12:688–693.
8. Garcia EV, Van Train K, Maddahi J, et al. Quantifi-

cation of rotational thallium-201 myocardial tomography. *J Nucl Med* 1985; 26:17–26.
9. Tamaki N, Yonekura Y, Mukai T, et al. Stress thallium-201 emission computed tomography: quantitative versus qualitative analysis for evaluation of coronary artery disease. *JACC* 1984; 4:1213–1221.
10. Kirsch CM, Doliwa R, Buell U, Roedler D. Detection of severe coronary heart disease with TI-201: comparison of resting single photon emission tomography with invasive arteriography. *J Nucl Med* 1983; 24: 761–767.
11. Ziada G, Hayat N, Mohammed M, et al. Quantitative analysis of stress thallium-201 studies: comparison of SPECT and planar imaging in detection of CAD. *Nucl Med Commun* 1986; 7:427–435.
12. Brust KD, Graham MM. Aspects of patient imaging with SPECT. *J Nucl Med Technol* 1987; 15:133–137.
13. Diamond GA, Forrester JS. Analysis of probability as an aid in the clinical diagnosis of coronary-artery disease. *N Engl J Med* 1979; 300:1350–1358.
14. Wackers FJTh, Sokole EB, Samson G, et al. Atlas of TI-201 myocardial scintigraphy. *Clin Nucl Med* 1977; 2:64–74.
15. Gordon DG, Pfisterer M, Williams R, Walaski S, Ashburn W. The effect of diaphragmatic attenuation on TI-201 images. *Clin Nucl Med* 1979; 4:150–151.
16. Maddahi J, Van Train KF, Wong C, et al. Comparison of TI-201 single photon emission computerized tomography (SPECT) and planar imaging for evaluation of coronary artery disease. *J Nucl Med* 1986; 27:999.
17. Maddahi J, Van Train KF, Prigent F, et al. Utility of TI-201 myocardial rotational tomography with polar mapping for evaluation of patients without myocardial infarction. *Circulation* 1986; 74(supp II):42.
18. Maddahi J, Van Train KF, Prigent F, et al. Quantitation of TI-201 myocardial single-photon emission computerized rotational tomography: development, validation, and prospective application of an optimized computerized method. *J Nucl Med* 1986; 27:899.
19. Maddahi J, Van Train KF, Prigent F, et al. Utility of TI-201 myocardial rotational tomography with polar mapping for evaluation of patients without myocardial infarction. *J Nucl Med* 1987; 28:588–589.
20. Coel M, Gushiken B. The reliability of thallium-201 myocardial tomography in a clinical setting without exclusions for drugs or suboptimal exercise. *Clin Nucl Med* 1988; 13:155–158.
21. Tamaki N, Yonekura Y, Mukai T, et al. Segmental analysis of stress thallium myocardial emission tomography for localization of coronary artery disease. *Eur J Nucl Med* 1984; 9:99–105.
22. Nohara R, Kambara H, Suzuki Y, et al. Stress scintigraphy using single-photon emission computed tomography in the evaluation of coronary artery disease. *Am J Cardiol* 1984; 53:1250–1254.
23. Friedman J, Van Train K, Maddahi J, et al. "Upward creep" of the heart: a frequent source of false-positive reversible defects on TI-201 stress-redistribution SPECT. *J Nucl Med* 1986; 27:899–900.