

Prognostic Implications of Combined Prone and Supine Acquisitions in Patients with Equivocal or Abnormal Supine Myocardial Perfusion SPECT

Sean W. Hayes, MD^{1,2}; Andrea De Lorenzo, MD¹; Rory Hachamovitch, MD, MSc³; Sanjay C. Dhar, MD²; Patrick Hsu, MD²; Ishac Cohen, PhD¹; John D. Friedman, MD^{1,2,4}; Xingping Kang, MD¹; and Daniel S. Berman, MD^{1,2,4}

¹Department of Imaging, Division of Nuclear Medicine, Cedars-Sinai Medical Center, Los Angeles, California; ²Department of Medicine, Division of Cardiology, Cedars-Sinai Medical Center, Los Angeles, California; ³Department of Medicine, Division of Cardiology, University of Southern California, School of Medicine, Los Angeles, California; and ⁴Department of Medicine, University of California Los Angeles, School of Medicine, Los Angeles, California

Although acquisition of ^{99m}Tc-sestamibi myocardial perfusion SPECT (MPS) with the patient in the prone position is commonly used to minimize attenuation artifacts, the impact of combined prone and supine imaging on the prognostic evaluation of coronary artery disease (CAD) has not been determined. The prognostic implications of MPS obtained in both prone and supine positions in patients with perfusion defects on supine MPS were evaluated. **Methods:** We studied 3,834 patients who were monitored for 24.2 ± 6.0 mo after rest ²⁰¹Tl/stress ^{99m}Tc-sestamibi MPS acquired during 1994–1995, when prone acquisition was performed only in patients with inferior wall perfusion defects that might represent attenuation or motion artifact. **Results:** During follow-up, there were 132 hard events (cardiac death or myocardial infarction) and 375 total events (hard events or late myocardial revascularization). Overall, patients who underwent prone and supine acquisitions had similar characteristics to those who underwent supine-only imaging, with the exception of being more commonly male. In multivariable analysis, there were similar independent predictors for hard events and total events; the type of acquisition (prone and supine or supine-only) was not a significant predictor of either of these outcome events. After risk adjustment, the predicted event rates were nearly identical for patients undergoing prone and supine compared with supine-only studies. Both observed and predicted hard event rates of patients with normal prone and supine versus supine-only imaging were very low (observed, 0.7%/y and 0.5%/y, respectively; predicted, 1.5% over 24 mo for both). There was no reduction in the higher rates of events associated with abnormal scan results with the combination of prone and supine imaging. **Conclusion:** Patients with inferior wall defects on supine MPS that are not present on prone MPS have a low risk of subsequent cardiac events, similar to that of patients with normal supine-only studies.

Key Words: myocardial perfusion SPECT; sestamibi; prognosis; prone imaging

J Nucl Med 2003; 44:1633–1640

Received Dec. 10, 2002; revision accepted Mar. 28, 2003.
For correspondence or reprints contact: Daniel S. Berman, MD, Department of Imaging, Cedars-Sinai Medical Center, 8700 Beverly Blvd., Room A-041, Los Angeles, CA 90048-1865.
E-mail: Daniel.berman@cshs.org

Myocardial perfusion imaging has traditionally been performed with the patient in the supine position. Supine images, however, are often associated with diaphragmatic attenuation of the inferior wall, thus subject to false-positive inferior wall defects that reduce test specificity (1,2). In 1989, Esquerre et al. (3) demonstrated that, for ²⁰¹Tl myocardial perfusion SPECT (MPS), imaging patients in the prone position markedly improved the specificity in evaluating inferior wall abnormalities by minimizing diaphragmatic attenuation (Fig. 1). A subsequent study from our group described overall sensitivity and specificity of 80% and 93% of prone MPS for the diagnosis of coronary artery disease (CAD) (4). After finding that prone MPS might cause false-positive anteroseptal defects (4), we decided to perform routine supine SPECT, with an additional prone SPECT acquisition in patients with inferior wall perfusion defects whose MPS studies would have been interpreted as abnormal by supine MPS alone, but in whom the defects in might represent attenuation or other artifact (5).

The incremental prognostic value of MPS using supine images for predicting cardiac outcomes has been demonstrated (6,7), and a normal MPS study has been shown to be associated with a low risk of events. However, the prognostic value of normal MPS with the addition of prone images to scan interpretation has not yet been assessed. Although prone imaging may decrease artifacts, the elimination or reduction of perfusion defects may also mask defects truly representing CAD, thus adversely affecting patient prognosis. The purpose of this study was to determine (a) whether patients with perfusion defects in the supine images who subsequently undergo prone MPS that is interpreted as normal have the same low event rate as patients with normal supine-only scans and (b) whether the results associated with increasing scan abnormality are similar in patients undergoing prone and supine or supine-only imaging.



FIGURE 1. Postexercise ^{99m}Tc -sestamibi MPS images of 83-year-old asymptomatic man. Perfusion defect is noted in inferior and inferoapical walls in poststress supine images. Poststress prone images are normal, demonstrating that apparent perfusion defect is secondary to soft-tissue attenuation. Normal wall motion was noted on gated SPECT.

MATERIALS AND METHODS

Study Population

We identified 4,466 consecutive patients who underwent dual-isotope MPS with either exercise or adenosine stress between January 1, 1994, and December 31, 1995. During this time, our standard protocol was to perform a prone MPS acquisition only in patients in whom an inferior wall perfusion defect observed in the supine study was considered to be possibly artifactual and would have resulted in an overall interpretation as equivocal or abnormal.

Patients with known valvular heart disease or cardiomyopathy ($n = 64$), as well as those who had myocardial revascularization within 60 d of the index MPS (8) ($n = 395$), were excluded. Of the initial population, 173 patients (4.5%) were lost to follow-up. The study therefore consisted of 3,834 patients, of whom 3,179 (83.0%) underwent supine imaging only and 655 (17.0%) underwent both supine and prone imaging.

Rest ^{201}Tl Imaging

All patients underwent rest ^{201}Tl /stress ^{99m}Tc -sestamibi MPS as previously described (9). For rest imaging, weight-adjusted ^{201}Tl (111–167 MBq [3.0–4.5 mCi]) was injected intravenously and acquisition was performed 10 min after injection.

Exercise Myocardial Perfusion Protocol

Patients performed a symptom-limited treadmill exercise test using a standard Bruce protocol. Leads aVF, V_1 , and V_5 were continuously monitored and a 12-lead electrocardiogram (ECG) was recorded at each minute of exercise. At peak exercise, a weight-adjusted dose of ^{99m}Tc -sestamibi (925–1,480 MBq [25–40 mCi]) was injected, and exercise was continued for 1 min after injection. MPS acquisition was initiated 30 min after isotope injection. Whenever possible, β -blockers and calcium channel blockers were discontinued 48 h before testing, and nitrates were discontinued at least 6 h before testing.

Adenosine Myocardial Perfusion Protocol

Patients were instructed not to consume caffeine-containing products for 24 h before the test. Adenosine was infused intravenously at a rate of 140 $\mu\text{g}/\text{kg}/\text{min}$ for 6 min. At the end of the third minute of infusion, weight-adjusted ^{99m}Tc -sestamibi was injected.

Image acquisition was initiated approximately 60 min after isotope injection.

During both types of stress, blood pressure was measured and recorded at rest, at the end of each stress stage, and at peak stress. Maximal degree of ST segment change at 80 ms after the J point of the ECG was measured and assessed as horizontal, upsloping, or downsloping. ECG responses were considered positive when ≥ 1 mm of horizontal or downsloping or ≥ 1.5 mm of upsloping ST segment depression developed at 80 ms after the J point in patients with normal baseline ECG, negative when these changes were absent, and nondiagnostic when baseline changes in the ECG precluded interpretation during exercise.

MPS Acquisition Protocol

MPS acquisitions (Fig. 2) were performed with a large-field-of-view gamma camera and a high-resolution collimator, obtaining projections over a semicircular 180° arc. For ^{201}Tl imaging, 2 energy windows were used: a 30% window centered on 70 keV and a 20% window centered on the 167-keV peak. For ^{99m}Tc -sestamibi, a 15% window centered on the 140-keV peak was used. Acquisition protocols for poststress supine imaging used 32 projections, with 25 s per projection for a dual-head camera, and 64 projections, with 20 s per projection for a single-head camera. For poststress prone acquisition, 15 s per projection were used, with 32 or 64 projections for dual- or single-head, respectively. For rest ^{201}Tl , 32 projections and 35 s per projection were used for the dual-head and 64 projections with 25 s per projection for single-head.

Image Interpretation

Semiquantitative visual interpretation was performed with short-axis and vertical long-axis myocardial tomograms and a 20-segment model, as previously described (10). These segments were assigned on 6 evenly spaced regions in the apical, midventricular, and basal slices of the short-axis views and 2 apical segments on the midventricular long-axis slice. Each segment was scored by consensus of 2 experienced observers using a 5-point scoring system (0 = normal, 1 = equivocal, 2 = moderate reduction of isotope uptake, 3 = severe reduction of uptake, and 4 = absence of detectable tracer uptake in a segment). When a segment demonstrated a lower score on either supine or prone imaging than in the other position, the lower score was assigned to that segment. On the basis of the number and severity of segments with scores >2 , the observers judged the study results as normal, probably normal, equivocal, probably abnormal, or definitely abnormal (10).

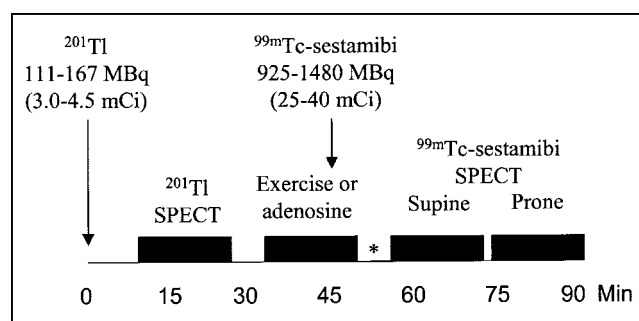


FIGURE 2. Injection and acquisition protocol for prone and supine MPS study. *15 min for exercise, 1 h for no walk adenosine (adapted and reprinted with permission of (24)).

To further define the study results as normal or abnormal, the summed stress score (SSS) was considered, from addition of the scores of the 20 segments of the stress ^{99m}Tc -sestamibi images (10). SSSs of <4 were considered normal, between 4 to 8 mildly abnormal, and >8 moderately to severely abnormal. For purposes of this study, the SSS had to be <4 and the final interpretation had to be normal or probably normal for the study to be considered normal. Similarly, patients with equivocal, probably abnormal, and definitely abnormal final MPS interpretations were grouped as abnormal.

Patient Follow-Up

Patient follow-up was performed by scripted telephone interview by individuals blinded to the patients' test results. Hard events were defined as either cardiac death, as noted and confirmed by review of death certificate and either hospital chart or physician's records, or nonfatal myocardial infarction, as evidenced by the appropriate combination of symptoms, ECG, and enzyme changes. Total events were defined as hard events or late revascularization (>60 d after the index MPS study) (8). Patients were monitored for 24.2 ± 6.0 mo (all for at least 1 y).

Likelihood of CAD

The prescan likelihood of CAD was calculated with CADENZA (Advanced Heuristics Inc.), using Bayesian analysis of prescan patient data (11). For the patients who underwent adenosine stress testing, the history and resting ECG information were considered, whereas for those who underwent exercise stress testing, the prescan likelihood of CAD included history and exercise test information.

Statistical Analysis

Continuous variables were expressed as mean value \pm SD and compared using a Student *t* test with correction for multiple comparisons when appropriate. Comparisons of categorical variables were computed by a χ^2 statistic. A *P* value of 0.05 was used to define statistical significance in univariate analysis. A Cox proportional hazards model was used to identify variables independently associated with cardiac events. Multivariable models were developed using hard or total events as the endpoints of interest. In this study, the goal of modeling was to determine all potential confounders of the relationship between MPS results and adverse outcomes. This approach included setting a threshold of *P* < 0.20 for entry into the model. Hence, the likelihood of finding a significant relationship between prone imaging and increased risk of adverse events would be maximized.

RESULTS

Patient Population

The 3,179 patients who underwent supine-only imaging and 655 patients who underwent supine and prone imaging are characterized in Table 1. Patients who had prone and supine acquisitions were more frequently male than patients who had supine-only MPS. By all other comparators, the groups were not significantly different.

Table 2 demonstrates patient characteristics by MPS acquisition types and normal or abnormal MPS results. Within each acquisition type, differences were as follows: for patients undergoing prone and supine imaging, those with abnormal studies were more frequently male, had a higher

TABLE 1
Patient Characteristics

Characteristic	Prone and supine (<i>n</i> = 655)	Supine-only (<i>n</i> = 3,179)
Age (y)	66.7 \pm 11.1	65.7 \pm 12.3
Male sex	487 (74.4)	1,899 (59.7)*
Hypertension	319 (48.7)	1,499 (47.2)
Diabetes	100 (15.3)	467 (14.7)
Hypercholesterolemia	328 (50.1)	1,466 (46.1)
Smoking	81 (12.4)	381 (12.0)
Family history of CAD	169 (25.8)	862 (27.1)
History of MI	155 (23.7)	800 (25.2)
History of revascularization	216 (33.0)	1,044 (32.8)
Digitalis use	44 (6.7)	269 (8.5)
Angina	246 (37.6)	1,216 (38.3)
Shortness of breath	35 (5.3)	178 (5.6)
Adenosine stress	217 (33.1)	1,071 (33.7)
Prescan likelihood of CAD	0.39 \pm 0.36	0.36 \pm 0.34*
Abnormal rest ECG	464 (70.8)	2,308 (72.6)
SSS	6.3 \pm 8.8	6.5 \pm 9.3

**P* < 0.05 .

MI = myocardial infarction.

Values in parentheses are percentage.

prescan likelihood of CAD, and had more frequent abnormal rest ECG than patients with normal scans. For patients studied in the supine position only, those with abnormal studies were significantly older and more frequently male, with a history of myocardial revascularization, were on digitalis, and had a higher prescan likelihood of CAD. Comparing patients with normal scans by the 2 acquisition types, the only significant difference was the higher frequency of males in the prone and supine group. Comparing patients with abnormal scans, not only were the patients undergoing prone and supine more often male than those undergoing supine MPS alone, but also they less frequently had prior revascularization, were on digitalis or had rest ECG abnormality, as well as had a lower SSS.

Outcome Events

During follow-up, there were 132 hard events (52 myocardial infarctions and 83 cardiac deaths) and 375 total events. Overall, the annualized hard event rate was 1.8% and the total event rate was 5.2%. Event rates were higher for patients undergoing adenosine stress: 3.2% of hard events per year and 7.4% of total events per year, versus 1.1% and 4.2% of hard and total events per year, for exercise stress (*P* < 0.001). Patients imaged only in the supine position had, with adenosine or exercise stress, hard event rates of 3.6% and 1.0% and total event rates of 7.8% and 4.0%, respectively (*P* < 0.001 for comparison between adenosine and exercise stress). Patients who had prone and supine imaging had, with adenosine or exercise stress, hard event rates of 1.6% and 1.1% and total event rates of 5.5% and 5.3%, respectively (*P* > 0.05).

TABLE 2
Patient Characteristics by MPS Acquisition Types and Normal or Abnormal MPS Results

Characteristic	Prone and supine (<i>n</i> = 655)		Supine-only (<i>n</i> = 3,179)	
	Normal (<i>n</i> = 368)	Abnormal (<i>n</i> = 287)	Normal (<i>n</i> = 1,880)	Abnormal (<i>n</i> = 1,299)
Age (y)	64.4 ± 11.3	69.7 ± 10.1	63.0 ± 12.6	69.7 ± 10.6*
Male sex	260 (70.7)	227 (79.1)*	958 (51.0) [†]	941 (72.4)* [‡]
Hypertension	172 (46.7)	147 (51.2)	799 (42.5)	700 (53.9)
Diabetes	38 (10.3)	62 (21.1)	205 (10.9)	262 (20.2)
Hypercholesterolemia	183 (49.7)	145 (50.5)	847 (45.1)	619 (47.7)
Smoking	44 (12.0)	37 (12.9)	228 (12.1)	153 (11.8)
Family history of CAD	92 (25.0)	77 (26.8)	495 (26.3)	367 (28.3)
History of MI	23 (6.3)	132 (46.0)	144 (7.7)	656 (50.5)
History of revascularization	56 (15.2)	160 (55.7)	165 (8.8)	799 (61.5)* [‡]
Digitalis use	24 (6.5)	20 (7.0)	108 (5.7)	161 (12.4)* [‡]
Angina	128 (34.8)	118 (41.1)	756 (40.2)	460 (35.4)
Shortness of breath	16 (4.3)	19 (6.6)	82 (4.4)	96 (7.4)
Adenosine stress	97 (26.4)	120 (41.8)	490 (26.1)	581 (44.7)
Prescan likelihood of CAD	0.34 ± 0.30	0.44 ± 0.34*	0.33 ± 0.29	0.45 ± 0.35*
Abnormal rest ECG	228 (62.0)	236 (82.2)*	1,164 (61.9)	1,144 (88.1)* [‡]
SSS	0.5 ± 0.9	13.8 ± 8.7*	0.5 ± 0.9	15.2 ± 9.1* [‡]

**P* < 0.05 normal vs. abnormal scan in acquisition category.

[†]*P* < 0.05 normal prone and supine vs. normal supine-only.

[‡]*P* < 0.05 abnormal prone and supine vs. abnormal supine-only.

MI = myocardial infarction.

Values in parentheses are percentage.

Table 3 demonstrates annualized event rates according to scan results and type of stress for patients imaged in prone and supine or supine-only positions. Of note, 368 of 655 patients with equivocal or abnormal supine MPS who underwent additional prone imaging had normal final interpretations. In both acquisition types, hard and total event rates increased with worsening scan results, although this did not reach statistical significance in patients who under-

went adenosine stress and prone and supine acquisition. Importantly, the annualized hard event rate was as low in patients with normal prone and supine scans as in those with normal supine studies. Furthermore, for each category of SSS, hard and total event rates, with either exercise or adenosine stress, were not significantly different between patients in the prone and supine and supine-only groups.

TABLE 3
Annualized Event Rates

Rate	Prone and supine (<i>n</i> = 655)			Supine-only (<i>n</i> = 3,179)		
	Normal	Mildly abnormal	Moderately to severely abnormal	Normal	Mildly abnormal	Moderately to severely abnormal
Total						
Hard events (%)	0.7	0.5	2.9*	0.5	1.6	4.8*
Total events (%)	2.8	7.9	9.3*	1.8	7.7	11.9*
<i>n</i>	368	97	190	1,880	382	917
Exercise						
Hard events (%)	0.6	0.9	2.8*	0.4	0.7	3.2*
Total events (%)	2.6	10.0	9.9*	1.5	7.0	10.1*
<i>n</i>	271	57	110	1,390	231	487
Adenosine						
Hard events (%)	1.0	0	3.1	1.1	3.3	6.8*
Total events (%)	3.2	5.1	8.5	2.6	8.9	14.2*
<i>n</i>	97	40	80	490	151	430

**P* < 0.05 across scan categories.

Univariate Predictors of Cardiac Events

Descriptive characteristics and nuclear variables of patients with events versus those without events during follow-up are presented in Tables 4 and 5 for hard events and total events, respectively. Patients with hard events demonstrated greater abnormality in all variables assessed with the exception of hypertension (borderline higher in the event group), smoking, family history of early CAD, and angina. Of importance, there was also no difference in the frequency of prone and supine or supine-only acquisitions in the patients with and without hard events. Regarding total events (Table 5), those with events demonstrated a greater abnormality in most variables. The variables that were not significantly different between these groups were hypercholesterolemia, smoking, family history of early CAD, angina, shortness of breath, and abnormal rest ECG. As with hard events, there was also no difference in the frequency of prone and supine or supine-only acquisitions in the patients with and without total events.

Multivariable Predictors of Events

In the overall study population, Cox proportional hazards analysis revealed that age ($\chi^2 = 9.2$, $P = 0.002$), a history of myocardial infarction ($\chi^2 = 4.5$, $P = 0.03$), digitalis use ($\chi^2 = 12.1$, $P < 0.0001$), adenosine stress ($\chi^2 = 10.0$, $P = 0.002$), and the SSS ($\chi^2 = 38.2$, $P < 0.0001$) constituted the model most predictive of hard events. For total events, age ($\chi^2 = 13.4$, $P = 0.001$), digitalis use ($\chi^2 = 15.3$, $P =$

TABLE 4

Univariate Predictors of Hard Events

Predictor	With hard events (<i>n</i> = 132)	Without hard events (<i>n</i> = 3,702)
Age (y)	72.1 ± 11.5	65.7 ± 12.0*
Male sex	98 (74.2)	2,288 (61.8)*
Hypertension	73 (55.3)	1,745 (47.1)
Diabetes	31 (23.5)	536 (14.5)*
Hypercholesterolemia	46 (34.8)	1,748 (47.2)*
Smoking	18 (13.6)	444 (12.0)
Family history of CAD	39 (29.5)	992 (26.8)
Digitalis use	32 (24.2)	281 (7.6)*
History of MI	71 (53.8)	884 (23.9)*
History of revascularization	70 (53.0)	1,190 (32.1)*
Angina	50 (37.9)	1,412 (38.1)
Shortness of breath	19 (14.4)	194 (5.2)*
Adenosine stress	78 (59.1)	1,210 (32.7)*
Prescan likelihood of CAD	0.46 ± 0.34	0.37 ± 0.31
Position		
Prone	17 (12.9)	638 (17.2)
Supine	115 (87.1)	3,064 (82.8)
Abnormal rest ECG	16 (12.1)	111 (3.0)*
SSS	16.5 ± 11.4	6.1 ± 8.9*

* $P < 0.05$.

MI = myocardial infarction.

Values in parentheses are percentage.

TABLE 5

Univariate Predictors of Total Events

Predictor	With total events (<i>n</i> = 375)	Without total events (<i>n</i> = 3,459)
Age (y)	69.5 ± 10.4	65.5 ± 12.2*
Male sex	277 (73.9)	2,109 (61.0)*
Hypertension	197 (52.5)	1,621 (46.9)*
Diabetes	85 (22.7)	482 (13.9)*
Hypercholesterolemia	177 (47.2)	1,617 (46.7)
Smoking	46 (12.3)	416 (12.0)
Family history of CAD	106 (28.3)	925 (26.7)
Digitalis use	52 (13.9)	261 (7.5)*
History of MI	170 (45.3)	785 (22.7)*
History of revascularization	222 (59.2)	1,038 (30.0)*
Angina	142 (37.9)	1,320 (38.2)
Shortness of breath	27 (7.2)	186 (5.4)
Adenosine stress	170 (45.3)	1,118 (32.3)*
Prescan likelihood of CAD	0.50 ± 0.34	0.37 ± 0.31*
Position		
Prone	67 (17.9)	588 (17.0)
Supine	308 (82.1)	2,871 (83.0)
Abnormal rest ECG	53 (14.1)	263 (7.6)
SSS	13.2 ± 10.6	5.7 ± 8.7*

* $P < 0.05$.

MI = myocardial infarction.

Values in parentheses are percentage.

0.0001), adenosine stress ($\chi^2 = 9.2$, $P = 0.003$), and the SSS ($\chi^2 = 84.2$, $P < 0.0001$) constituted the most predictive model. Figures 3 and 4 illustrate that, after risk adjustment using the multivariable model, hard and total event rates

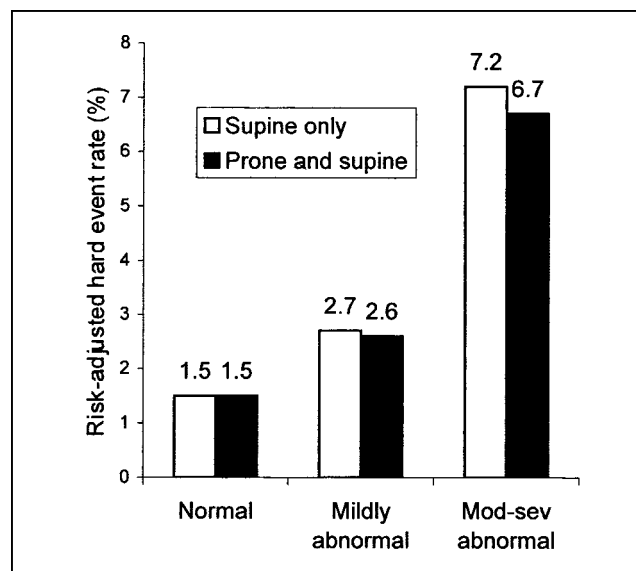


FIGURE 3. Risk-adjusted hard event rates in patients undergoing supine-only or prone and supine acquisition, according to MPS interpretation. $P < 0.0001$ across scan categories; $P > 0.05$ for comparisons between supine-only or prone and supine. Mod-sev = moderately to severely abnormal.

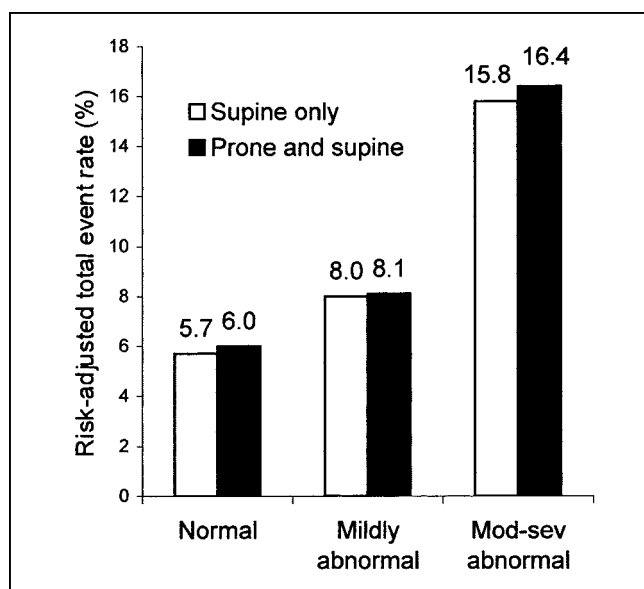


FIGURE 4. Risk-adjusted total event rates in patients undergoing supine-only or prone and supine acquisition, according to MPS interpretation. $P < 0.0001$ across scan categories; $P > 0.05$ for comparisons between supine-only or prone and supine. Mod-sev = moderately to severely abnormal.

were not significantly different between patients who underwent supine-only or prone and supine acquisitions.

DISCUSSION

To our knowledge, this is the first study to address the prognostic value of MPS acquired in the combined prone and supine positions. In this study, patients with supine MPS demonstrating findings that would have rendered the interpretation of the inferior wall as equivocal or abnormal underwent prone imaging, and their findings were compared with those of a larger group of patients from the same time period who underwent supine-only MPS. Overall, patients who underwent prone and supine acquisitions had similar characteristics as those who underwent supine-only imaging, with the exception of being more commonly male. In univariate analysis, the type of acquisition (supine-only or prone and supine) was not a significant predictor of either hard or total events. In addition, in a multivariable analysis, the predictors of hard events and total events were similar; the type of acquisition (prone and supine or supine-only) was not a significant predictor of either of these outcome events. After risk adjustment using the multivariable models for hard events or total events, predicted event rates were almost identical for patients undergoing prone and supine compared with supine-only studies. Importantly, both the observed and predicted hard event rates of patients with normal prone and supine versus supine-only imaging were very low (observed, 0.7%/y and 0.5%/y, respectively; predicted, 1.5% over 24 mo for both). Furthermore, there was no reduction in the higher rates of events associated with

abnormal scan results with the combination of prone and supine imaging.

Although MPS has been demonstrated to have high sensitivity and specificity for detection of CAD as well as excellent prognostic value, a common problem with MPS is artifactual reduction in apparent radiotracer uptake in the inferior left ventricular wall attributed to diaphragmatic attenuation, which can result in false-positive interpretations. With either ^{201}Tl or $^{99\text{m}}\text{Tc}$ -sestamibi studies (1,2), though less frequent in the latter, diaphragmatic attenuation may impair either sensitivity or specificity of MPS for detection of CAD, depending on whether it is overestimated (i.e., a true defect is falsely attributed to attenuation) or underestimated (an attenuation defect is falsely considered a perfusion defect). With the use of gated MPS, the distinction of true from artifactual defect can be more easily made (12); however, a problem remains, because with gated MPS, true myocardial perfusion defects due to subendocardial infarction that are associated with a normal contraction pattern might be falsely attributed to soft-tissue attenuation (13). Nonuniform attenuation correction has also been shown to improve the specificity and normalcy rate of MPS (14–16). This approach, however, requires specialized hardware and software and, in some implementations, may overcorrect the inferior wall, leading to lower sensitivity for detection of a true perfusion defect (17). By comparison, the approach of prone and supine imaging, described in this article, can be performed on virtually any SPECT camera without the need for specialized hardware or software.

The prone position results in an anterior shifting of the heart and a lowering of the diaphragm and the subphrenic organs, so that performing MPS acquisition in this position reduces the interposition of these tissues and organs between the inferior wall and the SPECT camera (3). The use of the prone position for ^{201}Tl imaging has been shown to result in improvement of specificity for the diagnosis of right coronary artery disease and overall improvement in accuracy compared with supine imaging (4,18–20). Higher absolute counts have been reported in the inferior wall with prone imaging with both ^{201}Tl (4,18) and $^{99\text{m}}\text{Tc}$ -sestamibi (19,20). The use of prone MPS acquisitions alone, however, may be associated with an artifactual anterosseptal or anterior defect (4), presumably caused by attenuation from a rib or the sternum, which is associated with the closer approximation of the heart and these structures in the prone position. In our experience, when we attempted prone MPS only to reduce the frequency of artifactual inferior abnormalities, the associated anterior distribution artifacts, raising the possibility of left anterior descending CAD, were even more problematic, frequently resulting in unnecessary referral to catheterization; thus, we would not recommend prone-only MPS acquisitions.

Because of the inferior and anterior wall artifacts associated with supine and prone MPS, respectively, we introduced the use of combined prone and supine MPS acquisitions in our group in 1994. The patients included in this

article were chosen from a period in which we used the combined acquisitions only when there was a perceived abnormality on the supine MPS acquisitions. After finding that approximately 20% of our patients were requiring additional prone studies (655/3179 [17%] in this study), because of the disruption of the imaging schedule by the unpredictable need for the additional prone acquisitions, we initiated routine supine and prone acquisitions on all patients in 1996. It is worth noting that this combined supine and prone approach is probably only applicable to radiotracers that do not rapidly redistribute, such as ^{99m}Tc -sestamibi or ^{99m}Tc -tetrofosmin. Because of the problem of rapid redistribution of ^{201}Tl associated with mild coronary stenoses (21), sequential supine and prone imaging after stress is less applicable with this agent, since the disappearance in the prone position of a defect observed with supine MPS might be a consequence of redistribution within a true defect.

Several limitations of the supine and prone MPS technique should be mentioned. The combined imaging requires additional camera time that may not be available in many laboratories. Additionally, a small proportion of patients cannot lie in the prone position for the time required for MPS. Effective attenuation-correction methods have been developed that may prove to be more efficient than the combined supine and prone approach (14,22,23). Regarding our study design, because the supine images were interpreted before the prone images, the supine results influenced the combined supine and prone interpretation. However, it was not our intent to demonstrate that prone imaging is superior to supine but, rather, that the combined approach is more effective than supine imaging alone. Furthermore, although prone imaging affected our final interpretation, we do not have information as to how often the addition of prone imaging changed patient management. Whereas the patients in this study had only inferior wall defects in the supine position that were further evaluated with prone imaging, we have noted that other attenuation artifacts (e.g., breast) and motion artifacts seen in supine MPS are also clarified by the addition of prone imaging; this anecdotal experience requires further study.

CONCLUSION

The combined use of prone and supine MPS acquisition was associated with the same event rates by MPS results as those in patients with supine-only studies. Importantly, normal prone MPS in patients with initially equivocal or abnormal supine MPS had the same low event rates as those in patients with normal supine-only studies. Since decisions for catheterization after MPS are frequently based on risk assessment, our findings suggest that the addition of the prone acquisition to supine MPS might lead to more appropriate clinical decisions.

ACKNOWLEDGMENTS

This work was supported in part by a grant from Bristol-Myers Squibb Medical Imaging Inc. (Billerica, MA) and by the CAPES (Coordenação de Auxílio de Pessoal de Nível Superior), Brazil.

REFERENCES

1. Strauss HW, Boucher CA. Myocardial perfusion studies: lessons from a decade of clinical use. *Radiology*. 1986;160:577–584.
2. DePuey EG. How to detect and avoid myocardial perfusion SPECT artifacts. *J Nucl Med*. 1994;35:699–702.
3. Esquerre J-P, Coca FJ, Martínez SJ, Guiraud RF. Prone decubitus: a solution to inferior wall attenuation in thallium-201 myocardial tomography. *J Nucl Med*. 1989;30:398–401.
4. Kiat H, Van Train KF, Friedman JD, et al. Quantitative stress-redistribution thallium-201 SPECT using prone imaging: methodologic development and validation. *J Nucl Med*. 1992;33:1509–1515.
5. Berman DS, Kiat H, Germano G, et al. Tc-99m sestamibi SPECT. In: De Puey EG, Berman DS, Garcia EV, eds. *Cardiac SPECT Imaging*. New York, NY: Raven Press; 1995:121–146.
6. Hachamovitch R, Berman DS, Kiat H, et al. Exercise myocardial perfusion SPECT in patients without known coronary artery disease: incremental prognostic value and use in risk stratification. *Circulation*. 1996;93:905–914.
7. Hachamovitch R, Berman DS, Shaw LJ, et al. Incremental prognostic value of myocardial perfusion single photon emission computed tomography for the prediction of cardiac death: differential stratification for risk of cardiac death and myocardial infarction. *Circulation*. 1998;97:535–543.
8. Staniloff HM, Forrester JS, Berman DS, et al. Prediction of death, myocardial infarction, and worsening chest pain using thallium scintigraphy and exercise electrocardiography. *J Nucl Med*. 1986;27:1842–1848.
9. Berman DS, Kiat H, Friedman JD, et al. Separate acquisition rest thallium-201/stress technetium-99m sestamibi dual isotope myocardial perfusion single-photon emission computed tomography: a clinical validation study. *J Am Coll Cardiol*. 1993;22:1455–1464.
10. Berman DS, Hachamovitch R, Kiat H, et al. Incremental value of prognostic testing in patients with known or suspected coronary artery disease: a basis for optimal utilization of exercise myocardial perfusion single photon emission computed tomography. *J Am Coll Cardiol*. 1995;26:639–647.
11. Diamond GA, Staniloff HM, Forrester JS, et al. Computer-assisted diagnosis in the noninvasive evaluation of patients with suspected coronary artery disease. *J Am Coll Cardiol*. 1983;1:444–455.
12. DePuey EG. Artifacts clarified by and caused by gated myocardial perfusion SPECT. In: Germano G, Berman DS, eds. *Clinical Gated Cardiac SPECT*. New York, NY: Futura Publishing Co.; 1999:183–237.
13. Choi KM, Judd RM, Kim H, et al. Detection of unrecognized myocardial infarction (MI) by contrast MRI in patients referred for coronary angiography [abstract]. *Circulation*. 2001;104(suppl 2):638.
14. Ficaro EP, Fessler JA, Shreve PD, Kritzman JN, Rose PA, Corbett JR. Simultaneous transmission/emission myocardial perfusion tomography: diagnostic accuracy of attenuation-corrected Tc-99m sestamibi single-photon emission computed tomography. *Circulation*. 1996;93:463–473.
15. Hendel RC, Berman DS, Follansbee W, Heller GV, Cullom SJ. A multicenter clinical trial to evaluate the efficacy of correction for photon attenuation and scatter in SPECT myocardial perfusion imaging. *Circulation*. 1999;99:2742–2749.
16. Hendel RC, Corbett JR, Cullom SJ, DePuey EG, Garcia EV, Bateman TM. The value and practice of attenuation correction for myocardial perfusion SPECT imaging: a joint position statement from the American Society of Nuclear Cardiology and the Society of Nuclear Medicine. *J Nucl Cardiol*. 2002;9:135–143.
17. Harel F, Genin R, Daou D, et al. Clinical impact of combination of scatter, attenuation correction, and depth-dependent resolution recovery for ^{201}Tl studies. *J Nucl Med*. 2001;42:1451–1456.
18. Segall GM, Davis MJ. Prone versus supine thallium myocardial SPECT: a method to decrease artifactual inferior wall defects. *J Nucl Med*. 1989;30:548–555.
19. Lisbona R, Dinh L, Derbekian V, Novales-Díaz JA. Supine and prone SPECT Tc-99m MIBI myocardial perfusion imaging for dipyridamole studies. *Clin Nucl Med*. 1995;20:674–677.
20. Peralta C, Loboguerrero A, Liehn J, et al. Quantitative comparison of prone and supine myocardial SPECT MIBI images. *Clin Nucl Med*. 1995;8:678–684.

21. Gutman J, Berman DS, Freeman M, et al. Time to completed redistribution of thallium-201 in exercise myocardial scintigraphy: relationship to the degree of coronary artery stenosis. *Am Heart J*. 1983;106:989–995.
22. Gibson PB, Demus D, Noto R, et al. Low event rate for stress-only perfusion imaging in patients evaluated for chest pain. *J Am Coll Cardiol*. 2002;39:999–1004.
23. Links JM, Becker LC, Rigo P, et al. Combined corrections for attenuation, depth-dependent blur, and motion in cardiac SPECT: a multicenter trial. *J Nucl Cardiol*. 2000;7:414–425.
24. Berman DS, Germano G. Myocardial perfusion single photon approaches. In: Pohost GM, O'Rourke RA, Berman DS, Shah PM, eds. *Imaging in Cardiovascular Disease*. New York, NY: Lippincott Williams & Wilkins; 2000:159–194.





The Journal of
NUCLEAR MEDICINE

Prognostic Implications of Combined Prone and Supine Acquisitions in Patients with Equivocal or Abnormal Supine Myocardial Perfusion SPECT

Sean W. Hayes, Andrea De Lorenzo, Rory Hachamovitch, Sanjay C. Dhar, Patrick Hsu, Ishac Cohen, John D. Friedman, Xingping Kang and Daniel S. Berman

J Nucl Med. 2003;44:1633-1640.

This article and updated information are available at:
<http://jnm.snmjournals.org/content/44/10/1633>

Information about reproducing figures, tables, or other portions of this article can be found online at:
<http://jnm.snmjournals.org/site/misc/permission.xhtml>

Information about subscriptions to JNM can be found at:
<http://jnm.snmjournals.org/site/subscriptions/online.xhtml>

The Journal of Nuclear Medicine is published monthly.
SNMMI | Society of Nuclear Medicine and Molecular Imaging
1850 Samuel Morse Drive, Reston, VA 20190.
(Print ISSN: 0161-5505, Online ISSN: 2159-662X)

© Copyright 2003 SNMMI; all rights reserved.