The Timing and Impact of Follow-Up Studies After Normal Stress Single-Photon Emission Computed Tomography Sestamibi Studies

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Background—The purpose of this study was to determine the prevalence and timing of routine follow-up single-photon emission computed tomography (SPECT) studies after a normal stress SPECT scan compared with the patient’s warranty period (ie, time to 1% risk of death or myocardial infarction).

Methods and Results—We identified patients at Mayo Clinic Rochester who had normal stress SPECT scans in 2002. Of 2354 patients without prior coronary artery disease, 309 (13%) had routine follow-up scans. The time to routine follow-up was a median of 2.1 years (25th percentile, 1.2 years; 75th percentile, 3.6 years). This interval was a median of 45% of the warranty period. Of the 309 patients, only 9 (3%) underwent subsequent coronary angiography, without revascularization. Of 656 patients with prior coronary artery disease, 171 (26%) had routine follow-up scans. The time to routine follow-up was a median of 1.6 years (25th percentile, 1.0 years; 75th percentile, 2.7 years). This interval was a median of 164% of the warranty period. Of the 171 patients, only 7 (4%) underwent coronary angiography, without revascularization.

Conclusions—In patients without prior coronary artery disease, routine follow-up SPECT scans are performed infrequently but well before the end of the patient’s warranty period. Routine follow-up scans are performed more commonly in patients with prior coronary artery disease but generally after the end of the warranty period. Routine follow-up SPECT scans have minimal impact on referral to catheterization or revascularization. (Circ Cardiovasc Imaging. 2010;3:520-526.)

Key Words: adenosine □ nuclear medicine □ cardiac-gated SPECT imaging

There is growing concern about increasing healthcare costs in the United States.1 Many have argued that much of currently delivered care is not efficient, as advocated by the Institute of Medicine.2 One portion of cardiovascular care that has drawn increasing attention is cardiovascular imaging. There has been extremely rapid growth of cardiac nuclear medicine procedures.3 Medicare data have shown a 6% average annual increase in cardiac imaging stress tests over an 8-year period that far exceed the rate of increase in coronary intervention, myocardial infarction (MI), or cardiac catheterization.4

One of the major strengths of stress single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI) is the low subsequent cardiac event rate in patients with a normal SPECT MPI.5,6 Although the presence of a normal scan should reassure both the patient and the ordering physician that the patient’s prognosis is excellent, follow-up testing with stress SPECT MPI often is performed routinely at scheduled intervals to provide continuing reassurance. Very scant data support this common practice. In the absence of definitive data, it has been difficult for clinical practice guideline committees to take a firm position. Many have argued that the appropriate interval for follow-up testing should be based on the available data regarding subsequent event rates. As long as the patient is within a time interval where the event rate is low (generally defined as <1% annual risk of MI or death), it is difficult to justify repeat testing in an attempt to detect occult problems that could potentially worsen prognosis.

The most definitive study regarding the “warranty period” for stress SPECT MPI was published by Hachamovitch et al.7 They showed that multiple parameters (history of coronary artery disease [CAD], stress type, diabetes, sex, and age) were important in determining the time interval before a 1% cardiac event rate occurred. They reported significant interactions between type of stress and CAD history (lower risk in patients without previous CAD undergoing exercise stress compared with all other patients) as well as between the presence of diabetes and patient sex (higher risk in female patients with diabetes compared with all other patients).7 This study tested the hypothesis that follow-up testing after normal stress SPECT MPI often is performed before expiration of the warranty period.8

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Methods

Patient Population
The study was approved by the Mayo Clinic Institutional Review Board (Rochester, Minn.). Patients who underwent stress SPECT MPI during 2002 and had a normal stress SPECT MPI were identified using the Mayo nuclear cardiology laboratory database, a prospective electronic database of all patients undergoing stress imaging procedures. The database includes all elements necessary to calculate each individual patient’s warranty period: age, sex, symptoms (chest pain and dyspnea, including character of chest pain and severity of angina and dyspnea), diabetes mellitus (insulin dependent or not), previous MI, previous percutaneous coronary intervention (PCI), previous coronary artery bypass graft (CABG) surgery, and type of stress (exercise or pharmacological).

Exclusion criteria for this study were failure to grant research authorization in accordance with Minnesota state law, any fixed defect greater than mild (ie, not due to attenuation), and any reversible defect. For patients undergoing exercise, an exercise heart rate <120 bpm was considered an exclusion criterion based on the reporting practice in our laboratory. For patients studied with adenosine, a peak adenosine dose that was <140 μg/kg per minute was also an exclusion criterion.

Pilot Study
We performed a pilot study of 302 patients from May 2005. During this month, 156 patients had normal SPECT MPI studies. Over the next 28 months, 18 (11.5%) had at least 1 follow-up SPECT MPI scan, but 43 (27.5%) had no subsequent follow-up at Mayo. As a result, we decided to use a mailed patient questionnaire for this study to reduce the percentage of patients without follow-up SPECT MPI information. The year 2002 was selected for this study to ensure that all patients had a minimum of 5 years of follow-up at the time of the mailing of the questionnaire, if necessary.

Image Interpretation and Analysis
Patients received 99mTc sestamibi and underwent a 1-day (8 to 10 mCi rest, 40 mCi stress) protocol, with tomographic imaging starting 45 to 60 minutes after injection. Tomographic imaging was then performed over a 180° arc with the step-and-shoot method. Filtered back projection was performed with a Ramp-Hanning filter. Image interpretation was performed as a consensus of 2 experienced observers. Stress and rest images were displayed in 3 planes (horizontal long axis, vertical long axis, and short axis) and scored using a 16-segment model using the short-axis segments. A 5-point scoring system was used to assess each segment (0 = absent, 1 = severely diminished, 2 = moderately diminished, 3 = mildly diminished, 4 = normal). Mild fixed defects (scores of 3) were classified as normal because most such defects represent soft tissue attenuation. More significant fixed defects or those with reversibility were considered abnormal. Abnormalities were confirmed in the long-axis images. For comparison with previously published data,6 our 5-point scoring system was recoded in reverse fashion (0 = normal, 1 = mildly diminished, 2 = moderately diminished, 3 = severely diminished, 4 = absent). The summed stress score was determined by adding perfusion grades based on the poststress short-axis segments. Using previous published criteria, the summed stress score was divided into 3 groups: 0 to 3 (low risk), 4 to 8 (intermediate risk), and ≥9 (high risk).

Warranty Period and Patient Follow-Up
The warranty period (time to 1% risk) for each patient was calculated from Hachamovitch et al tables 7 (patients with no previous MI, PCI, or CABG) and 8 (patients with known CAD defined as previous MI, PCI, or CABG). The nuclear cardiology database was searched for any follow-up stress SPECT MPI studies (to date of last complete data at initiation of analysis). For patients with a subsequent visit at the Mayo Clinic but without a follow-up scan, test-free interval was defined as the time from the 2002 scan to date of last complete data. The ratio of test-free interval to warranty period was computed. For patients with a follow-up scan at Mayo, the date of first follow-up scan and follow-up scan results were obtained from the database.

For patients without a subsequent visit at Mayo, follow-up was obtained by mailed patient questionnaire to identify the initial follow-up SPECT MPI study (if any) performed outside of Mayo and any subsequent cardiac events (MI, PCI, CABG, death). This questionnaire also included a question regarding symptoms. If patients indicated that they had a repeat nuclear cardiac scan (exercise or pharmacological), the questionnaire asked whether they had experienced any chest pain or shortness of breath within the month before the repeat SPECT MPI scan. Because 472 patients did not return the questionnaire, we assessed the vital status of all patients in the study on December 31, 2007 (5 to 6 years after their initial SPECT), using the Social Security Death Index.

Follow-Up Scans
For patients undergoing follow-up scans at Mayo, the nuclear cardiology database was used to identify intervening coronary revascularization with either PCI or CABG between the previous normal SPECT MPI study and the follow-up SPECT MPI study as well as intervening documented MI between the previous normal SPECT MPI study and the follow-up SPECT MPI study. Patients who were asymptomatic in 2002 and symptomatic on follow-up were classified as having worsening symptoms. Patients who were symptomatic in 2002 and asymptomatic on follow-up were classified as not having worsening symptoms. The remaining patients required chart review. Any of the following qualifies as worsening symptoms: increased severity or frequency of typical or atypical angina, emergency department visit for typical or atypical angina, new-onset or increased frequency of ventricular tachycardia, and new onset of congestive heart failure.

Routine scans were defined as those performed without intervening PCI or CABG, intervening MI, or worsening symptoms. Nonroutine scans were those performed after intervening PCI and CABG, after intervening MI, or after worsening symptoms.

Statistical Analysis
Categorical variables were compared between groups using the χ2 test for independence and, when appropriate, Fisher exact test.9 ANOVA was used to compare continuous variables among groups. Overall mortality was estimated using the Kaplan–Meier method. Expected survival was determined using the age- and sex-specific mortality rates from the Minnesota population. Observed survival was compared to expected survival using a 1-sample log-rank test. All analyses were performed with SAS version 9.1.3 software.

Results
Of 3010 patients, 2354 patients had no prior CAD, and 656 patients had prior CAD (Table 1). Comparison between groups revealed that patients with a history of CAD included more men, were older, had a higher prevalence of CAD risk factors, and were more likely to undergo pharmacological stress testing.

Patients Without Prior CAD
During the follow-up period, 1905 (81%) patients in this group did not have follow-up SPECT MPI performed; 449 (19%) had follow-up scans. Three hundred nine patients had routine follow-up scans (69% of the follow-up scans; 13% of the patients without prior CAD). One hundred forty (6%) had nonroutine follow-up scans after worsening symptoms (n = 127), PCI (n = 6), CABG (n = 2), or MI (n = 5).

Patients having a routine follow-up scan were similar to those having a scan after worsening symptoms or an event with respect to age, hypertension, hyperlipidemia, and diabetes. There was a trend toward more smoking (P = 0.07) in those having nonroutine scans. Patients having a routine...
Follow-up scan were more likely to be men and to have undergone exercise testing at baseline (Table 2).

The time to routine follow-up scan was a median of 2.1 years (25th percentile, 1.2 years; 75th percentile, 3.6 years). The warranty period for patients without prior CAD was calculated to be a median of 5.5 years (25th percentile, 2.5 years; 75th percentile, 8.8 years) (Figure 1). When expressed as a ratio of the warranty period, the time to routine follow-up scan was generally much less than the warranty period (median, 0.45; 25th percentile, 0.24; 75th percentile, 0.79). Only 64 patients (21% of the routine scans) had routine follow-up scans performed after the end of their calculated warranty period (Figure 2).

Patients With Prior CAD
During follow-up, 259 (39%) patients had follow-up scans. One hundred seventy-one patients had routine follow-up scans (66% of the follow-up scans; 26% of the total study group). Eighty-eight patients (34%) had nonroutine follow-up scans due to worsening symptoms (n/H11005 79) or PCI (n/H11005 9). No patient had CABG or MI before a nonroutine scan. Patients having a routine follow-up scan were similar to those having a scan after worsening symptoms or an event with respect to age, hypertension, hypercholesterolemia, diabetes, and smoking (Table 3). There was a trend (P=0.06) toward more diabetes in the nonroutine scans. Patients having routine follow-up scans were more likely to be men and to have undergone exercise stress testing at baseline.

For patients with prior CAD, the time to performance of a routine follow-up scan was a median of 1.6 years (25th percentile, 1.0 years; 75th percentile, 2.7 years). However, the calculated warranty period in these patients was only a median of 0.9 years (25th percentile, 0.8 years; 75th percentile, 1.0 years) (Figure 3). Expressed as a ratio of the warranty period, the time to routine follow-up was greater than the warranty period (median, 1.64; 25th percentile, 1.2; 75th percentile, 2.82). One hundred forty-seven (86%) patients had routine follow-up scans after their warranty period had expired (Figure 4).

Results of Follow-Up SPECT MPI
In patients without prior CAD, the summed stress score was low risk in 93% of the patients, regardless of whether the scan was routine. There was no difference in summed stress scores between the routine and nonroutine scans. Two percent of the follow-up scans were high risk (Table 4). The impact of

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**Table 1. Clinical Characteristics of the Entire Study Population**

<table>
<thead>
<tr>
<th></th>
<th>No CAD (n=2354)</th>
<th>With CAD (n=656)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>62±12</td>
<td>67±11</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Male</td>
<td>1279 (54)</td>
<td>502 (77)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1075 (46)</td>
<td>154 (23)</td>
<td></td>
</tr>
<tr>
<td>Type of stress</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Exercise</td>
<td>1544 (66)</td>
<td>370 (56)</td>
<td></td>
</tr>
<tr>
<td>Adenosine</td>
<td>810 (34)</td>
<td>286 (44)</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>1282 (55)</td>
<td>462 (71)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>1377 (59)</td>
<td>568 (87)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Smoking</td>
<td>1075 (46)</td>
<td>354 (54)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Diabetes</td>
<td>426 (18)</td>
<td>149 (23)</td>
<td>0.008</td>
</tr>
</tbody>
</table>

Data are presented as mean±SD or no. (%).

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**Table 2. Clinical Characteristics of Patients Without Prior CAD Undergoing Follow-Up SPECT MPI**

<table>
<thead>
<tr>
<th></th>
<th>No FU (n=1905)</th>
<th>Routine FU (n=309)</th>
<th>Nonroutine FU (n=140)</th>
<th>P Overall (FU vs No FU)</th>
<th>P (Routine vs Non Routine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>62±13</td>
<td>63±10</td>
<td>62±11</td>
<td>0.18</td>
<td>0.10</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>998 (52)</td>
<td>216 (70)</td>
<td>65 (46)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>907 (48)</td>
<td>93 (30)</td>
<td>75 (54)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Type of stress (baseline SPECT MPI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise</td>
<td>1220 (64)</td>
<td>233 (75)</td>
<td>91 (65)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adenosine</td>
<td>685 (36)</td>
<td>76 (25)</td>
<td>49 (35)</td>
<td>0.0001</td>
<td>0.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1017 (53)</td>
<td>181 (59)</td>
<td>84 (60)</td>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>1066 (56)</td>
<td>221 (72)</td>
<td>90 (64)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Diabetes</td>
<td>333 (17)</td>
<td>60 (19)</td>
<td>33 (24)</td>
<td>0.16</td>
<td>0.11</td>
</tr>
<tr>
<td>Smoking (current)</td>
<td>191 (10)</td>
<td>18 (6)</td>
<td>15 (11)</td>
<td>0.06</td>
<td>0.08</td>
</tr>
<tr>
<td>Peak HR (exercise only)</td>
<td>151±16</td>
<td>147±16</td>
<td>144±15</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age-predicted maximum (exercise only), %</td>
<td>93±9</td>
<td>93±9</td>
<td>90±8</td>
<td>0.0005</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Data are presented as mean±SD or no. (%). FU indicates follow-up; HR, heart rate.
follow-up scans on subsequent care is shown in Table 5. Of the 309 patients without prior CAD who underwent routine follow-up studies, only 9 (3.0%) went on to have a coronary angiogram. Thus, for every 34 patients who underwent routine follow-up studies, only 1 was referred to coronary angiography. No patient had subsequent PCI or CABG.

In patients with prior CAD and routine follow-up scans, 91% were low risk, and only 3% were high risk. The summed stress score was worse ($P<0.03$) in the nonroutine scans. Only 80% of these were low risk, and 9% were high risk (Table 6). Of the 171 patients with prior CAD who had routine follow-up studies, only 7 (4.1%) went on to have a coronary angiogram (Table 5). Thus, for every 24 patients who underwent routine follow-up studies, only 1 patient was referred to coronary angiography. No patient had subsequent PCI or CABG.

### Overall Survival

The 5-year survival of the entire cohort of 3010 patients was 94% (95% CI, 93% to 95%). Five-year survival was 94% in the patients without CAD and 92% in patients with prior CAD (Figure 5). The overall survival in the entire cohort was significantly better than expected ($P=0.017$) as was the survival in patients with and without CAD ($P<0.001$ for each). In patients without prior CAD, 5-year survival was 87% after adenosine and 96% after exercise ($P<0.001$).

### Discussion

To our knowledge, this study is the first to determine the distribution of follow-up testing intervals after a normal stress SPECT MPI scan and to compare each patient’s interval with his or her warranty period. Although the prognostic value of SPECT MPI in patients with known or suspected CAD is well established, routine follow-up testing after a prior normal SPECT MPI scan has been studied infrequently. The results of our study reveal that for patients who had normal stress SPECT MPI in 2002 and no history of CAD, retesting during the next 5 years is being performed at a relatively low rate (19% of patients). Approximately two thirds of the follow-up scans are being performed as a routine scan, and the majority of these follow-up scans are being performed before the midpoint of the patient’s warranty period. Only 21% of the follow-up scans were performed after expiration of the warranty period.

### Table 3. Clinical Characteristics of Patients With Prior CAD Undergoing Follow-Up SPECT MPI

<table>
<thead>
<tr>
<th></th>
<th>No FU Scan (n=397)</th>
<th>Routine FU Scan (n=171)</th>
<th>Nonroutine FU Scan (n=88)</th>
<th>$P$ Overall</th>
<th>$P$ (FU vs No FU)</th>
<th>$P$ (Routine vs Non Routine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>67±11</td>
<td>67±10</td>
<td>66±10</td>
<td>0.33</td>
<td>0.20</td>
<td>0.42</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>282 (71)</td>
<td>151 (88)</td>
<td>69 (78)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>115 (29)</td>
<td>20 (12)</td>
<td>19 (22)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Type stress (baseline SPECT MPI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise</td>
<td>205 (52)</td>
<td>121 (71)</td>
<td>44 (50)</td>
<td>&lt;0.0001</td>
<td>0.002</td>
<td>0.0001</td>
</tr>
<tr>
<td>Adenosine</td>
<td>192 (48)</td>
<td>50 (29)</td>
<td>44 (50)</td>
<td>&lt;0.0001</td>
<td>0.43</td>
<td>0.7</td>
</tr>
<tr>
<td>Hypertension</td>
<td>276 (70)</td>
<td>124 (73)</td>
<td>62 (71)</td>
<td>0.71</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>337 (85)</td>
<td>156 (91)</td>
<td>75 (85)</td>
<td>0.12</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>Diabetes</td>
<td>84 (21)</td>
<td>37 (22)</td>
<td>28 (32)</td>
<td>0.09</td>
<td>0.24</td>
<td>0.06</td>
</tr>
<tr>
<td>Smoking (current)</td>
<td>24 (6)</td>
<td>8 (5)</td>
<td>6 (7)</td>
<td>0.74</td>
<td>0.73</td>
<td>0.95</td>
</tr>
<tr>
<td>Peak HR (exercise only)</td>
<td>141±15</td>
<td>142±13</td>
<td>140±14</td>
<td>0.38</td>
<td>0.47</td>
<td>0.22</td>
</tr>
<tr>
<td>Age-predicted maximum (exercise only), %</td>
<td>90±9</td>
<td>91±8</td>
<td>89±10</td>
<td>0.15</td>
<td>0.33</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Data are presented as mean±SD or no. (%). FU indicates follow-up; HR, heart rate.
period. There were no revascularization procedures after these routine scans.

For patients with a history of CAD, retesting during 5-year follow-up was performed more often but was still relatively low (39% of patients). However, because the warranty period for these patients is much shorter (median, 0.9 years), the follow-up scans usually were performed after expiration of their warranty period. One hundred forty-seven patients (86% of the routine scans) were retested after their warranty period had expired. Nevertheless, there were no revascularization procedures after these routine scans.

**Clinical Implications**

There is no evidence that routine follow-up SPECT MPI scans improve patient outcomes. In the absence of worsening symptoms, the rationale for their use is to identify treatable occult problems that could potentially worsen prognosis. This rationale would seem to be questionable before the end of the warranty period when the patient’s prognosis is known to be favorable. It would seem to be relevant after the expiration of the warranty period when the patient’s prognosis is less well established and potentially less favorable. The implications for routine follow-up scans are very different for patients with and without prior CAD because of the major impact of prior CAD on the warranty period after a normal stress SPECT MPI scan. In patients without prior CAD who underwent routine follow-up scans in our study, the median warranty period was 5.5 years, but the median time to follow-up scan was only 2.1 years. The median ratio of time to routine scan to warranty period was only 0.45, suggesting that more than half of the patients were tested before the midpoint of their warranty period. The timing of these scans may explain the low rate of highly abnormal scans and the absence of any subsequent revascularization. As a result, referral to coronary angiography was very infrequent (1 patient in every 34 having a follow-up study), and there was no referral to revascularization.

In contrast, of the patients who had prior CAD, the majority in our study were retested after the expiration of their warranty period. The median ratio of time of routine scan to warranty period was 1.64, indicating that more than half of the patients were tested not only after expiration of the warranty period, but also after an additional 50% of the warranty period had passed. These patients may have been exposed to a higher risk of cardiac events during this interval, but this study is greatly underpowered to assess this possibility. Nevertheless, only 3% of the routine scans in this group had a high-risk summed stress score. As a result, referral to coronary angiography was very infrequent (1 patient in every 24 having a follow-up study), and there was no referral to revascularization.

**Appropriateness Criteria**

The American College of Cardiology Foundation and American Society of Nuclear Medicine SPECT MPI appropriate...
ness criteria were published in 2005 while the follow-up data on the patients in this study was already in progress. Several tables in this document are relevant to follow-up testing. For patients without prior PCI or CABG, stable or no symptoms, and a normal prior SPECT MPI, 2 indications (see Table 4, items 21 and 22) address follow-up testing for patients who were at high CAD risk, but there are no indications for patients at low-to-intermediate CAD risk. For patients who are asymptomatic after a prior PCI or CABG, only selected time intervals after PCI or CABG are addressed without any mention of abnormalities or a prior scan. Thus, the appropriateness criteria do not provide guidance regarding many patients in this cohort. Revisions to the 2005 document were published in May 2009 after the collection of follow-up data on patients in the present study was completed. This revised document addresses many of the patient categories that were missing in the 2005 document but does not specifically consider each patient’s warranty period.

Limitations
The study population consisted of patients referred to a single academic hospital-affiliated laboratory located in the midwestern United States. The ordering physicians were salaried Mayo staff physicians with no direct financial incentives to order additional nuclear tests. Results may not be generalizable to other institutions. The use of medical procedures, including stress SPECT MPI, varies greatly in different locations throughout the country, as documented by the Dartmouth healthcare atlas. Eighty percent to 85% of Medicare SPECT procedures are performed in outpatient laboratories not affiliated with hospitals. The growth rate in these outpatient laboratories was >15% per year between 1998 and 2006 and far exceeded the growth in hospital-based laboratories.

It is difficult to judge worsening symptom status from clinical notes. To the degree that clinical notes do not document symptoms that are actually worsening, the number of scans ordered for worsening symptoms may be underestimated. Five-year follow-up of our entire cohort of patients was accomplished by review of our database, chart review when necessary, and a mailed patient questionnaire for those without follow-up at the Mayo Clinic. A considerable number of patients (15%) did not return their questionnaires, so we had incomplete information regarding subsequent testing and nonfatal cardiac events. We only report stress SPECT studies that were able to confirm independently because we found that patients often reported erroneously on their subsequent tests. Some patients may have undergone other procedures, including stress echocardiography and CT coronary angiography. The potential impact of such additional testing on outcomes is unknown and could have conceivably altered the conclusions of this study. Incomplete ascertainment prevented us from reporting on the rate of subsequent nonfatal events. It also may have led to an underestimate of the rate of follow-up stress studies. However, the overall survival of patients was excellent and better than an age- and sex-matched population, indicating that the patients who did not return questionnaires did well. Although the average annual mortality of 1.2% exceeded the <1% mortality assumed after a normal exercise SPECT, it represents total mortality (rather than cardiac mortality) in an older population in whom 36% underwent adenosine testing. In previous studies from our laboratory, we have found that total deaths are more than twice the number of cardiac deaths. Our finding of lower survival after adenosine testing is consistent with prior studies and reflects the older age and increased risk factors of patients undergoing adenosine testing, explaining the shorter warranty period that Hachamovitch et al reported after adenosine testing compared to exercise.

We did not assess changes in medical therapy after follow-up scans. Intermediate-risk and high-risk scans

Figure 5. A, Overall survival of the total study group compared to expected survival. B, The subgroup without prior CAD compared to expected survival. C, The subgroup with prior CAD compared to expected survival. Five-year survival in the total study group was significantly better than expected (P=0.017), as was the survival in each subgroup (P<0.001 for each).
(≤10% of patients with and without prior CAD) are likely to have led to intensified medical therapy.

**Opportunity for Improvement**

Given the growth in cardiac imaging services and rising interest in fiscal responsibility, providers are increasingly encouraged to use SPECT MPI in the most appropriate manner. SPECT MPI is ordered by both cardiologists and noncardiologists, many of whom may be unaware or unfamiliar with appropriateness criteria or the concept of a warranty period following a normal stress SPECT MPI study. Physicians may be ordering routine follow-up stress SPECT MPI to reassure themselves or their patients when the risk of an actual event is very low. Conversely, they may not be aware of the importance of follow-up testing for patients who may be at a higher risk, such as those who have a history of CAD. Better physician education may result in more effective use of nuclear imaging resources, improved patient care, and decreased costs. Incorporating the science of a warranty period into appropriateness criteria ratings may strengthen their effectiveness.

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**Disclosures**

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**References**


**CLINICAL PERSPECTIVE**

Although follow-up testing with stress single-photon emission computed tomography (SPECT) myocardial perfusion imaging is sometimes performed after a normal stress SPECT scan, the prevalence of this practice and its timing compared with the patient’s warranty period (ie, time to 1% risk of death or myocardial infarction) is unknown. We followed a cohort of 3010 patients (2354 without prior CAD and 656 with prior CAD) who had normal stress SPECT scans in 2002 for a minimum of 5 years. In patients without prior CAD, routine follow-up SPECT scans were performed infrequently (13%) but well before the end of the patient’s warranty period. In patients with prior CAD, routine follow-up scans were performed more commonly (26%) but generally after the end of the patient’s warranty period. In both groups, routine follow-up SPECT scans had minimal impact on referral to catheterization or revascularization.
The Timing and Impact of Follow-Up Studies After Normal Stress Single-Photon Emission Computed Tomography Sestamibi Studies

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