Optimizing Evaluation of Patients with Low to Intermediate Risk Acute Chest Pain:
A Randomized Study Comparing Stress Myocardial Perfusion Tomography
Incorporating Stress-only Imaging to Cardiac Computed Tomography

Faisal Nabi, MD1, Mahwash Kassi, MD1, Kamil Muhyieddeen, MD2,
Su Min Chang, MD1, Jiaqiong Xu, PhD3, Leif E. Peterson, PhD3,
Nelda P. Wray4, MD, Beverly A. Shirkey4, Carol M. Ashton, MD4, and
John J. Mahmarian, MD1

Department of Cardiology, Houston Methodist DeBakey Heart & Vascular Center, Houston, TX1;
Department of Medicine, Division of Cardiology, University of California San Francisco, Fresno, CA2;
Center for Biostatistics, Houston Methodist Research Institute, Houston, TX3;
Center for Outcomes Research, Department of Surgery, Houston Methodist Research Institute,
Houston, TX, USA4

Address for Correspondence
John J. Mahmarian, MD, FACC, FASNC, FSCCT
Houston Methodist DeBakey Heart & Vascular Center
6550 Fannin Street, Suite 677
Houston, TX 77030
jmahmarian@HoustonMethodist.org
office: 713-441-2849 | fax: 713-793-7034

Word count: 5122

Financial Support: None

Running Title: SPECT vs. CT in Acute Chest Pain
ABSTRACT

Rationale
To determine if stress myocardial perfusion (SPECT) optimized with stress-only (SO) imaging is comparable to cardiac computed tomography angiography (CTA) for evaluating patients (pts) with acute chest pain (ACP).

Methods
Prospective randomized observational study in 598 ACP pts who had CTA vs. SPECT. Primary endpoint: length of hospital stay. Secondary endpoints: test feasibility, time to diagnosis, diagnostic accuracy, radiation exposure and overall cost. Median follow-up: 6.5 months with a 3.8% cardiac event rate defined as death or an acute coronary syndrome.

Results
Of 2994 patients screened, 1703 (56.9%) were not candidates for CTA due to prior cardiac disease (41%) or imaging contraindications (16%). Time to diagnosis (8.1±8.5 vs. 9.4±7.4 hours) and length of hospital stay (19.7±27.8 vs. 23.5±34.4 hours) were significantly shorter with CTA vs. SPECT (p=0.002). However, time to diagnosis (7.0±6.2 vs. 6.8±5.9 hours, p=0.20), length of stay (15.5±17.2 vs. 16.7±15.3 hours, p=0.36) and hospital costs ($4,242±$3,871 vs. $4,364±1781, p=0.86) were comparable with CTA vs. SO SPECT, respectively. SO was also superior to conventional SPECT regarding all of the above metrics and significantly reduced radiation exposure (5.5±4.4 vs. 12.5±2.7 mSv, p<0.0001).

Conclusion
Stress SPECT when optimized with SO imaging is similar to CTA in time to diagnosis, length of hospital stay, and cost with improved prognostic accuracy and less radiation exposure.
Our results emphasize the importance of SO imaging particularly in low-intermediate risk ED patients who are a population likely to have a normal test result.

**Key Words**

Single photon tomography; coronary artery calcium; cardiac computed tomography
INTRODUCTION

Stress gated tomographic myocardial perfusion imaging (SPECT) and cardiac computed tomography angiography (CTA) are both accepted modalities for evaluating low to intermediate risk patients presenting to the emergency department (ED) with acute chest pain (ACP) of uncertain cardiac etiology (1,2). Recent trials suggest that CTA reduces time to diagnosis and length of hospital stay (LOS) more than SPECT (3,4) or standard of care (SOC) (5,6). Whether CTA reduces radiation exposure or hospital costs is controversial (6). The role of non-contrast CT derived coronary artery calcium score (CACS) in patient management is also unclear (7,8).

We previously reported the value of stress SPECT in a wide spectrum of patients presenting to the ED with ACP (9). By using a stress-rest SPECT protocol, “stress-only” (SO) imaging can be performed with avoidance of the rest study if the stress study is normal (10,11). The use of SO imaging may optimize SPECT procedures by reducing time to diagnosis, LOS, radiation exposure and cost. This imaging protocol was not used in prior studies comparing SPECT to CTA (3,4). Therefore, our primary objective was to assess the relative value of SPECT vs. CTA for reducing LOS in patients with ACP where SO imaging was included within the armamentarium of SPECT protocols. LOS is a widely accepted benchmark in current clinical hospital practice which may be improved through streamlining imaging protocols and thereby reducing time to diagnosis.

MATERIALS AND METHODS

Study Population

This was a single center, randomized prospective observational study comparing CT to stress SPECT in 598 consecutive patients >18 years old who were hospitalized under
observational status awaiting SPECT for evaluation of ACP. Recruitment was from February 2009 to August 2011. Patients were evaluated for study entry upon arrival to the SPECT/CT department. SPECT was performed daily from 7AM to 5PM whereas CT was performed only Monday through Friday 7AM to 5PM. Therefore, patients were not randomized on weekends. The study was approved by the Institutional Review Board of Houston Methodist Research Institute and all patients signed informed consent. Patients excluded from enrollment are shown in Figure 1.

Stress Gated SPECT Imaging
SPECT was performed as recommended by the American Society of Nuclear Cardiology (12). A stress study was considered normal if left ventricular myocardial perfusion was homogeneous, cavity size was normal and ejection fraction was ≥50% with normal wall motion (10). All other patients underwent rest imaging.

Cardiac Computed Tomography
Patients had CACS followed by CTA using a 64-slice multi-detector scanner (Phillips). CACS was acquired in a standard fashion and calculated using the Agatston method. Studies were reported as normal (CACS=0), or showing minimal (1-10), mild (11-100), moderate (101-400) or severe (>400) calcification (13). An ECG gated CTA was performed following administration of iodinated contrast (Visapaque, General Electric Healthcare, Princeton, NJ) at 4-5 ml/sec. Patients were pretreated with beta-blockers and 1(0.4 mg) sublingual nitroglycerin. Patients with slow and stable heart rates had prospective acquisitions whereas all others had retrospective studies with/without dose modulation. Significant coronary artery disease (CAD) was defined as >50% stenosis: 51-69% (moderate); 70-90% (severe) and >90% (subtotal/total occlusion).
**Clinical Information Collected During the Index Visit**

Clinical information and results of cardiac procedures were obtained by research personnel at hospital discharge. The Thrombolysis in Myocardial Infarction and Framingham risk scores were calculated based on standard criteria (14). Time of hospital admission and discharge were captured from the medical record and time of randomization from the consent form. One of 3 nuclear and CT board certified cardiologists interpreted all studies with time of final interpretation (i.e., time of diagnosis) corresponding with their automatically captured electronic signature. Study results were available to referring physicians immediately upon electronic signature.

**Patient Follow-Up**

Clinical follow-up was prospectively obtained by telephone interview at predefined intervals of 1 week, 1 month and >6 months. Research personnel asked scripted questions regarding any subsequent: 1) ED visits; 2) hospital admissions for ACP or myocardial infarction; and 3) invasive coronary angiography (ICA) and/or coronary revascularization (CR) procedures. The date and place of all admissions and cardiac procedures were verified by medical record review. One investigator (FN) blinded to the imaging results adjudicated cardiac events. Vital status was obtained through phone follow-up or the Social Security Death Index.

**Cardiac Events**

Cardiac events were defined as: 1) cardiac death and 2) acute coronary syndrome (myocardial infarction or unstable angina) (9). Non-fatal myocardial infarction was defined as a troponin >0.10 ng/ml associated with ACP and/or ECG findings of ischemia (9). Unstable angina was defined as: 1) new onset/worsening of ACP at rest; 2) normal troponin levels;
and 3) ≥70% stenosis by ICA (9). Cardiac events were counted once in an individual patient when analyzing overall event rates. However, all cardiac events were recorded and designated as an initial or subsequent event following hospital discharge. Patient outcome was defined by time to first cardiac event or last encounter in those without events.

**Radiation Exposure**

SPECT radiation exposure was calculated based on the administered radiotracer dose: mSv = MBq x 0.0069 (99mTcTechnetium) and mSv = MBq x 0.14 (thallium-201) (15). CT radiation exposure was calculated based on total dose-length-product x 0.014 (4). In-patient radiation exposure did not include that from ICA.

**Statistical Analysis**

The primary endpoint was LOS from time of randomization (i.e., arrival to the imaging department). Secondary endpoints were to time to diagnosis from randomization (which was comprised of study acquisition and physician interpretation times), hospital costs, patient outcome and radiation exposure. Subset analysis was performed to assess primary and secondary endpoints in patients who had SO imaging vs. CTA or conventional stress/rest SPECT. Patient outcome based on CACS results was also determined. Baseline characteristics are presented as mean±SD for continuous variables, and number/percentage for categorical variables. Chi-square or Fisher’s exact test for categorical variables and t-test for continuous variables compared differences between SPECT and CTA groups. SPECT/CTA imaging protocols, radiation exposures, and subsequent resource utilization were summarized.
Accuracy and 95% confidence interval of SPECT, CTA, and CACS for predicting events were calculated with p-values based on Fisher’s exact test. Kaplan-Meier survival curves displayed cardiac events based on SPECT and CTA results with comparison using the log-rank test. Time to diagnosis and LOS were summarized as mean±SD by randomized group, and in the subgroups with normal CTA and SO SPECT. Cumulative density distributions for time to diagnosis and LOS were generated and plotted for SPECT, CT, and SO groups with differences tested using Wilcoxon rank-sum test. Hospital costs were derived from billing records spanning ED admission to hospital discharge. Costs were estimated from total billed charges multiplied by Medicare cost-to-charge ratio for the year in which the patient received care. Analyses were performed with STATA version 13 (College Station, TX: StataCorp LP). Significance was defined as two-tailed p<0.05.

RESULTS

Study Population and Imaging Feasibility (Fig. 1)

A total of 2994 consecutive patients over 29 months were admitted with ACP of whom 1703 (56.9%) were not candidates for CTA due to known cardiovascular disease (n=1235 or 41.3%) or a contraindication to imaging (n=468 or 15.6%). Of 1003 remaining eligible patients, 405 (13.5%) refused participation. The final cohort consisted of 310 patients randomized to SPECT and 288 to a CT strategy. Five patients withdrew after signing consent and 4 randomized to CTA crossed over to SPECT.

Baseline Characteristics (Table 1)

Baseline patient characteristics in each randomized strategy were comparable. Although most had a low Thrombolysis in Myocardial Infarction risk score, 1/4th had an intermediate or high Framingham risk score.
Time to Diagnosis and Length of Stay (Figs. 2 and 3)

Mean times from admission to randomization were comparable in the CT vs. SPECT strategy (11.6±7.8 vs. 12.4±8.9 hours, p=0.18). Mean time to diagnosis (8.1±8.5 vs. 9.4±7.4 hours, p=0.0002) and LOS (19.7±27.8 vs. 23.5±34.4 hours, p=0.002) were significantly shorter with CTA vs. SPECT (Fig. 2) as were median values (Fig. 3).

In a pre-specified sub-analysis where we compared patients who had a normal CTA vs. SO SPECT, time to diagnosis (7.0±6.2 vs. 6.8±5.9 hours, p=0.20) and LOS (15.5±17.2 vs.16.7±15.3 hours, p=0.36) were comparable for CTA vs. SPECT (Fig. 2). Median time to diagnosis and LOS were also comparable in patients who had CTA vs. SO SPECT (Fig. 3). Mean time to diagnosis (6.8±5.9 vs. 10.2±9.6 hours, p<0.0001) and LOS (16.7±15.3 vs. 25.6±38.3 hours, p<0.0006) were significantly shorter for SO vs. conventional SPECT, respectively (Fig. 2).

CT/SPECT Protocols and Radiation Exposure (Table 2)

Most patients randomized to SPECT had pharmacologic stress testing (223 or 73%) with adenosine (74 or 24%), regadenoson (148 or 48%) or dobutamine (1 or 0.3%). Eighty-four (27%) had treadmill exercise. Most patients (96%) received $^{99m}$Technetium based radiotracers and 74 (24%) had SO imaging. The mean $^{99m}$Technetium dose was 1454±629MBq which varied depending on imaging protocol. The mean radiation exposure was 10.9±4.4 mSv which was significantly lower with SO (5.5±4.4mSv) vs. conventional (12.5±2.7mSv, p<0.0001) SPECT.
With CT, prospective acquisitions were performed in 54 patients with retrospective helical acquisitions (with/without dose modulation) in all others. Overall radiation exposure was 12.7±4.9mSv.

Radiation exposure was significantly lower in patients who had SPECT (10.9±4.4mSv) vs. CT (12.7±4.9mSv), p<0.0001. Total inpatient diagnostic radiation exposure was also lower in patients randomized to SPECT (11.0±4.6mSv) vs. CT (13.3±5.8mSv) p<0.0001, where 4 patients had subsequent CTA in the SPECT group and 14 had subsequent SPECT in the CT group.

**Cardiac Events and Resource Utilization in the Randomized Groups (Suppl. Table 1).**

Follow-up was complete in 98% (300/307) and 99% (283/286) of patients randomized to SPECT and CT, respectively (p=0.34). Median follow-up was comparable in the SPECT (6.4, range 5.9 to 19.1 months) and CT (6.5; range 5.8 to 23.5 months) strategies, p=0.47. Twenty-three cardiac events occurred in 22 patients (event rate 3.8%) - 18 events during the index admission and 5 in follow-up. All events were unstable angina, except for 1 myocardial infarction. Event rates were similar between strategies (9 or 3.0% SPECT; 13 or 4.6% CT, p=0.39). There were no significant differences in outpatient, ED or inpatient cardiac evaluations in the 2 randomized groups or in additional cardiac testing after hospital discharge (Suppl. Table 1).

**Diagnostic Accuracy: SPECT, CTA and CACS Results (Fig. 4, Suppl. Table 2)**

SPECT was normal in 296 (96.4%) patients of whom 14 (4.7%) had ICA during the initial hospitalization (n=4) or after hospital discharge (n=10) with 2 having CR (event rate 0.7%). In the 11 (3.6%) patients with an abnormal SPECT, 9 had ICA during initial hospitalization (n=8).
or in follow-up (n=1) and 7/9 had severe (>70%) stenosis with CR in 5. SPECT accuracy for predicting events is shown in Supplemental Table 2.

A normal CTA or one with non-obstructive CAD was seen in 245 (86.9%) patients of whom 7 (2.9%) had ICA during initial hospitalization (n=2) or following hospital discharge (n=5). Only 2 (0.8%) had a subsequent cardiac event. In the 33 patients with significant CAD, 24 had single and 9 multi-vessel CAD. Nine of 13 patients with ICA had CR. In the other 20 patients, 18 had single vessel CAD with only moderate (51-69%) stenosis and no subsequent events. Event rates increased with CAD extent: normal/non-obstructive (0.8%); 1-vessel (16.7%); 2-vessel (71.4%) and 3-vessel (100%), p<0.001). CTA accuracy for predicting events is shown in Supplemental Table 2. Event rates were similarly low in patients with a normal SPECT and CTA but significantly higher in those with an abnormal SPECT vs. CTA (p=0.03) (Fig. 4).

A CACS of 0 was observed in 152 (53.9%) patients but 76 (27%) had a mild, 28 (10%) moderate and 26 (9.2%) severe CACS. Although no patient with a CACS of 0 had significant (>50%) CAD, this increased with CACS severity: 6.6% (CACS 1-100); 42% (CACS 101-400); and 64% (CACS>400). No patient with a CACS 0 had a cardiac event but this increased to 10.2% for those with a CACS >0: 4% for mild; 18% for moderate and 20% for severe CACS (p<0.001). CACS accuracy for predicting events is shown in Supplemental Table 2.

Cost

The mean cost in the CT vs. SPECT strategy was significantly less ($4,242±$3,871 vs. $5,104±$3,703, p=0.006) with a savings of $862.00/patient. However, there were no significant cost differences when CT was compared to SO SPECT ($4,242±$3,871 vs. $
$4,364±$1781, p=0.86). SO led to a cost savings of $1,233/patient (p=0.01) versus conventional SPECT.

**DISCUSSION**

We studied the relative value of stress SPECT versus CT in low to intermediate risk patients with ACP admitted to a large tertiary care city hospital based on standard metrics including test feasibility, time to diagnosis, LOS, diagnostic accuracy, relative cost and radiation exposure. A unique aspect of this study was performing SO imaging in patients whenever possible so as to not only allow comparison with CT but also conventional stress/rest SPECT. Previous studies comparing CTA to SPECT (3,4) did not incorporate SO imaging within the SPECT strategy. All other studies have compared CTA to SOC with the latter encompassing a heterogeneous assortment of testing algorithms (5,6,16).

Our study not only confirms previous reports but emphasizes the importance of optimizing SPECT protocols when evaluating patients with ACP so as to promote a patient-centered imaging approach when choosing among various testing modalities. First, our results confirm that many patients who present to the ED with ACP (57%) are not candidates for CTA either because of prior history of cardiovascular disease or a contraindication to the procedure (4,17). Conversely, SPECT has few contraindications and is an optimal test in patients with known CAD where the main clinical question is the presence and extent of myocardial ischemia (9,18). Second, radiation exposure was higher with CT vs. SPECT even though most patients (56%) underwent radiation reduction strategies with CTA using prospective or dose modulated retrospective acquisitions. The lower radiation exposure with SPECT was directly attributable to SO imaging which was performed in ~25% of patients. Third, the overall prognostic accuracy of SPECT (98%) was greater than CTA (91%, p<0.0001)
although both tests were comparable in identifying low risk patients with a normal test result (4,9). Fourth, as in previous trials, time to diagnosis, LOS and costs were significantly less with CTA than SPECT (3,4). However, advantages with CTA were lost in patients who had SO SPECT. SO imaging was also superior to conventional SPECT regarding the above metrics. Our results illustrate the importance of performing SO imaging whenever possible in low risk ED patients of whom most (>90%) will have a normal test result. Lastly, our study suggests the potential role of CACS in the ED setting since none of the 54% patients with a CACS of 0 had significant CAD by CTA or a cardiac event in follow-up.

CTA versus SPECT in Acute Chest Pain Patients. Our results confirm previous reports that many patients with ACP (57%) are not candidates for CTA (47% in CT-STAT and 51% in ROMICAT) (4,17). Conversely, SPECT has few contraindications and is an optimal test in patients with known CAD where the main clinical question is defining the presence and extent of myocardial ischemia. For example, adenosine SPECT has been shown to safely risk stratify patients even during acute myocardial infarction (18). There are several randomized studies demonstrating similar diagnostic accuracy, cardiac event rates and post discharge resource utilization with CTA vs. SOC (3-6). In 2 studies where SPECT was SOC, median times to diagnosis were significantly reduced with CTA (3.4 vs. 15 and 2.9 vs. 6.2 hours) (3,4). However, both studies used conventional SPECT which inevitably lead to hours of additional testing. In our study, median time to diagnosis was also significantly less for CTA vs. SPECT (5.9 vs. 6.7 hours, p=0.0002) – albeit only a 48 minute difference. With SO imaging, time to diagnosis was further reduced to 5.1 hours and with comparable LOS and costs as with CTA.
Importance of Stress-Only Imaging. Trials in over 20,000 patients have demonstrated the feasibility and long term safety of normal SO versus conventional SPECT (10,11) with marked reductions in radiotracer dose and radiation exposure. Chang et al reported a mean $^{99m}$Technetium dose of 788 MBq with SO vs. 2038MBq with stress-rest imaging. We also report a significantly lower radiotracer dose (644±374 vs. 1713±448 MBq) and radiation exposure (5.5±4.4 vs. 12.5±2.7 mSv) with SO versus conventional SPECT, respectively. Radiation exposure was <5 mSv in 66% of patients in the SO group - similar to the 60% incidence previously reported (10). Our low exposure rates were achieved using conventional gamma camera technology but may be further reduced to 1-2 mSv when combined with Cadmium-Zinc Telluride SPECT (19) and with 40-50% reductions in occupational exposure (20). To date, only a small minority of nuclear cardiology laboratories in North America and world-wide perform SO imaging (21). We have previously reported its value in patients with known or suspected CAD (10). The current study expands SO imaging to the large cohort of low-intermediate risk patients admitted annually through the ED with ACP. Our study demonstrates that SO imaging reduces time to diagnosis, decreases LOS and reduces costs and radiation exposure as compared to conventional SPECT in this population. Although we did not routinely use attenuation correction in our patients, this technique aids interpretation of stress-first studies as being “normal” (22) and might further increase the percentage of SO studies in an ED population such as ours.

** Coronary Artery Calcium Scoring **

CACS may have several advantages over CTA in a low risk cohort without prior CAD in that it is a rapid, easily interpretable test which has no contraindications and requires no patient preparation. CACS may also challenge SPECT which requires additional patient preparation, must be performed in conjunction with a stressor modality through coordination of medical
and technical staff, is dependent on radiotracer availability, has higher radiation exposure and may require considerable expertise for accurate interpretation. Most low to intermediate risk patients (~55%) with ACP have a CACS of 0 (7,17,23-28) in whom there is a very low likelihood of abnormal SPECT (0.8%) (7) or significant CAD as shown in the current study. Pooled data from 8 studies and ours suggest high sensitivity (96%, 95% confidence interval 92-98%) and negative predictive accuracy (99.4%, 95% confidence interval 99-100%) (7,17,23-28) for excluding ACS with CACS which is comparable to CTA or SPECT (3-7,9). Further study is needed to determine whether initial testing with CACS might safely avoid subsequent additional testing in patients with a normal result.

**Study Limitations**

This was a single center study but included patients similar to those reported in other multicenter trials comparing SPECT to CTA (3,4). Second, although our event rate was low it was comparable to other studies evaluating patients with CTA (3.8 vs. 4.4%), respectively (16). Third, most patients were not imaged in the ED but admitted under observational care since neither CTA nor SPECT were available in the evening hours. Although 24 hour/day imaging may be optimal, few hospitals currently provide this level of service. Fourth, all patients had CTA using a 64 detector scanner in a population with a mean body mass index of ~31. All patients randomized to CT also underwent calcium scoring which added ~ 2 mSv to radiation exposure. We recognize that radiation exposure would have been significantly less if we had used newer generation CT systems (29) and enrolled thinner patients than our cohort. However, in reality, most facilities still currently use conventional gamma cameras and 64-detector scanners when performing SPECT and cardiac CT, respectively. Of note, the 12.7 mSv radiation exposure we report for CTA is similar to the 12 mSv dose recently reported by the PROMISE investigators in 4,996 patients randomized to CTA from 193 sites.
in North America (30). In this regard our exposure rates are comparable to current clinical practice.

CONCLUSION
Stress SPECT when optimized with SO imaging is similar to CTA in time to diagnosis, length of hospital stay, and cost with improved prognostic accuracy and less radiation exposure. Our results emphasize the importance of SO imaging particularly in low-intermediate risk ED patients who are a population likely to have a normal test result.

DISCLOSURE
None

ACKNOWLEDGEMENTS
None
REFERENCES


Figure 1. Patients screened and excluded from study entry

Cardiac computed tomography angiography (CTA)
Stress gated tomographic myocardial perfusion imaging (SPECT)
There were no significant differences from randomization to diagnosis or hospital discharge in patients who had stress-only SPECT vs. a normal CTA. Abbreviations as in Figure 1.
Figure 3. Time to Diagnosis and Hospital Discharge in the Two Randomized Groups

A. Median values
CTA vs. SPECT
5.9 vs. 6.7 h, P = 0.0002
CTA vs. SPECT only
5.9 vs. 5.1 h, P = 0.04

B. Median values
CTA vs. SPECT
9.7 vs. 10.7 h, P = 0.02
CTA vs. SPECT only
9.7 vs. 9.6 h, P = 0.87

FIGURE 3. Time to diagnosis and hospital discharge in the randomized groups. Cumulative frequency from randomization to final diagnosis (A) and hospital discharge (B) for CTA, overall SPECT and stress-only groups. The horizontal line is at the 50th percentile. Abbreviations as in Figure 1.
Figure 4. Cardiac Events Based on SPECT and CTA Results

Survival curves show comparably low cardiac event rates in patients with normal SPECT and CTA and low rates of ICA and CR. Abbreviations as in Figure 1.
<table>
<thead>
<tr>
<th></th>
<th>Total (n=598)</th>
<th>SPECT (n=310)</th>
<th>CTA (n=288)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>53.2 ± 12.2</td>
<td>52.6 ± 11.9</td>
<td>53.9 ± 12.5</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>Female Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>332 (56.1)</td>
<td>174 (56.1)</td>
<td>158 (54.9)</td>
<td>0.76</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>178 (29.8)</td>
<td>101 (32.6)</td>
<td>77 (26.7)</td>
<td>0.05</td>
</tr>
<tr>
<td>White</td>
<td>334 (55.9)</td>
<td>172 (55.5)</td>
<td>162 (56.3)</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>69 (11.5)</td>
<td>30 (9.6)</td>
<td>39 (13.5)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>8 (1.3)</td>
<td>1 (0.3)</td>
<td>7 (2.4)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>9 (1.5)</td>
<td>6 (1.9)</td>
<td>3 (1.1)</td>
<td></td>
</tr>
<tr>
<td><strong>Body Mass Index</strong></td>
<td>31.2 ± 8.3</td>
<td>31.8 ± 9.1</td>
<td>30.5 ± 7.4</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Risk Factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>301 (50.3)</td>
<td>157 (50.7)</td>
<td>144 (50.0)</td>
<td>0.88</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>90 (15.1)</td>
<td>48 (15.4)</td>
<td>42 (14.6)</td>
<td>0.76</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>228 (38.1)</td>
<td>115 (37.1)</td>
<td>113 (39.2)</td>
<td>0.59</td>
</tr>
<tr>
<td>Current smoker</td>
<td>162 (27.1)</td>
<td>85 (27.2)</td>
<td>77 (26.4)</td>
<td>0.98</td>
</tr>
<tr>
<td>Family History CAD</td>
<td>137 (22.9)</td>
<td>66 (21.3)</td>
<td>71 (24.7)</td>
<td>0.33</td>
</tr>
<tr>
<td><strong>ASA within past 7 days</strong></td>
<td>184 (30.8)</td>
<td>97 (31.3)</td>
<td>87 (30.2)</td>
<td>0.78</td>
</tr>
<tr>
<td><strong>Severe Angina last 24hrs</strong></td>
<td>32 (5.4)</td>
<td>14 (4.5)</td>
<td>18 (6.3)</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>TIMI Risk Score</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.67</td>
</tr>
<tr>
<td>0</td>
<td>315 (52.7)</td>
<td>170 (54.8)</td>
<td>145 (50.4)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>183 (30.6)</td>
<td>90 (29.0)</td>
<td>93 (32.3)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>86 (14.4)</td>
<td>44 (14.2)</td>
<td>42 (14.6)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>14 (2.3)</td>
<td>6 (1.9)</td>
<td>8 (2.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Framingham Risk Score</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td>0-10% (low)</td>
<td>458 (76.6)</td>
<td>239 (77.1)</td>
<td>219 (76.0)</td>
<td></td>
</tr>
<tr>
<td>11-20% (intermediate)</td>
<td>113 (18.9)</td>
<td>57 (18.4)</td>
<td>56 (19.4)</td>
<td></td>
</tr>
<tr>
<td>&gt;20% (high)</td>
<td>27 (4.5)</td>
<td>14 (4.5)</td>
<td>13 (4.5)</td>
<td></td>
</tr>
</tbody>
</table>

Data were presented as mean±SDs for continuous variables, medians (interquartile ranges) if continuous variables were skewed, and numbers (percentages) for categorical variables. ASA= acetylsalicylic acid; CTA=cardiac computed tomography angiography; SPECT= gated tomographic myocardial perfusion imaging; TIMI= Thrombolysis in Myocardial Infarction
Table 2. SPECT/CT Imaging Protocols and Associated Radiation Exposure

<table>
<thead>
<tr>
<th>SPECT Protocols</th>
<th>(n/%)</th>
<th>Radiotracer Dose (MBq)</th>
<th>Radiation Exposure (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest-stress</td>
<td>124 (40.4%)</td>
<td>1698±148</td>
<td>11.7±1.0</td>
</tr>
<tr>
<td>Stress-rest</td>
<td>74 (24.1%)</td>
<td>1480±507</td>
<td>12.5±3.0</td>
</tr>
<tr>
<td>2-Day</td>
<td>35 (11.4%)</td>
<td>2253±570</td>
<td>15.5±3.9</td>
</tr>
<tr>
<td>Stress-only</td>
<td>74 (24.1%)</td>
<td>644±374</td>
<td>5.5±4.4</td>
</tr>
<tr>
<td>Stress/Rest or Rest/Stress</td>
<td>233 (75.9%)</td>
<td>1713±448*</td>
<td>12.5±2.7*</td>
</tr>
<tr>
<td>Overall</td>
<td>49 of 307 (16%) pts received &lt;5mSv</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p<0.0001 stress-only vs. stress/rest

<table>
<thead>
<tr>
<th>CTA Protocols</th>
<th>(n/%)</th>
<th>Radiation Exposure (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrospective</td>
<td>126 (44.7%)</td>
<td>16.4±3.3</td>
</tr>
<tr>
<td>Retrospective with dose modulation</td>
<td>102 (36.2%)</td>
<td>12.0±2.4</td>
</tr>
<tr>
<td>Prospective</td>
<td>54 (19.1%)</td>
<td>5.2±0.6</td>
</tr>
<tr>
<td>Overall</td>
<td>20 of 282 (7.1%) pts received &lt;5mSv</td>
<td></td>
</tr>
</tbody>
</table>

CTA=cardiac computed tomography angiography; SPECT=gated tomographic myocardial perfusion imaging
Optimizing Evaluation of Patients with Low to Intermediate Risk Acute Chest Pain: A Randomized Study Comparing Stress Myocardial Perfusion Tomography Incorporating Stress-only Imaging to Cardiac Computed Tomography

Faisal Nabi, Mahwash Kassi, Kamil Muhyieddeen, Su Min Chang, Jiaqiong Xu, Leif Peterson, Nelda Wray, Beverly Shirkey, Carol Ashton and John Mahmarian

J Nucl Med.
Published online: December 3, 2015.
Doi: 10.2967/jnumed.115.166595

This article and updated information are available at:
http://jnm.snmjournals.org/content/early/2015/12/02/jnumed.115.166595

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

JNM ahead of print articles have been peer reviewed and accepted for publication in JNM. They have not been copyedited, nor have they appeared in a print or online issue of the journal. Once the accepted manuscripts appear in the JNM ahead of print area, they will be prepared for print and online publication, which includes copyediting, typesetting, proofreading, and author review. This process may lead to differences between the accepted version of the manuscript and the final, published version.

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 2015 SNMMI; all rights reserved.