Applicability of Appropriateness Criteria for Stress Imaging
Similarities and Differences Between Stress Echocardiography and Single-Photon Emission Computed Tomography Myocardial Perfusion Imaging Criteria

Robert B. McCully, MD; Patricia A. Pellikka, MD; David O. Hodge, MSc; Philip A. Araoz, MD; Todd D. Miller, MD; Raymond J. Gibbons, MD

Background— Appropriateness criteria for stress imaging have been published to promote the effective use of stress nuclear scintigraphy and stress echocardiography. We sought to evaluate the application of the stress echocardiography appropriateness criteria to patients undergoing stress echocardiography in an academic medical center.

Methods and Results— The stress echocardiography criteria were applied to 298 consecutive patients who underwent stress echocardiography. Patients were rated as appropriate, uncertain, inappropriate, or not classifiable. Results were compared with those of a previous analysis in the same patients using the single-photon computed tomography myocardial perfusion imaging (SPECT MPI) criteria. The level of agreement between 2 cardiac nurse abstractors for categorizing appropriateness by the stress echocardiography criteria was good (κ=0.72). Overall, 54% of patients were classified as appropriate, 8% as uncertain, and 19% as inappropriate; 19% were not classifiable. By the SPECT MPI criteria, 64% of patients were classified as appropriate, 9% as uncertain, and 18% as inappropriate; 9% were not classifiable (P<0.001 compared with stress echocardiography criteria). By the stress echocardiography criteria, 6 clinical situations or indications accounted for more than 90% of the inappropriate tests; most of these involved asymptomatic patients.

Conclusions— Applying stress echocardiography appropriateness criteria to a patient population is feasible, although 1 in 5 of our patients was not classifiable. Overall, the stress echocardiography criteria classified patients differently compared with the SPECT MPI criteria. Future refinements of the appropriateness criteria for stress imaging should address gaps in the criteria and disparities between the stress echocardiography and SPECT MPI criteria. (Circ Cardiovasc Imaging. 2009;2:213-218.)

Key Words: coronary heart disease ■ echocardiography ■ imaging ■ scintigraphy ■ stress ■ tomography

The growth in the use of cardiovascular imaging has come under scrutiny in recent years, and the current use of cardiovascular imaging by health care providers has been suggested as an example of the inefficient use of health care resources. Thus, to promote more efficient use of imaging techniques in the clinical setting, the American College of Cardiology Foundation (ACCF) has developed methods for creating appropriateness criteria for cardiovascular imaging.1

Clinical Perspective on p 218

In 2005, a document of appropriateness criteria for single-photon emission computed tomography myocardial perfusion imaging (SPECT MPI) was published.2 This was followed in 2006 by the publication of appropriateness criteria for cardiac computed tomography and cardiac MRI3 and in 2007 by the publication of appropriateness criteria for transthoracic and transesophageal echocardiography.4 Most recently, appropriateness criteria for stress echocardiography have been published.5 Investigation into the use of SPECT MPI appropriateness criteria for stress testing in clinical practice has just begun.6 The application of stress echocardiography appropriateness criteria has not yet been assessed.

The appropriateness criteria for SPECT MPI and stress echocardiography were developed using similar methods. Since the evidence in support of both stress SPECT MPI and stress echocardiography is similar and the existing guidelines from the American College of Cardiology (ACC) and the American Heart Association (AHA) have similar recommendations for SPECT MPI and stress echocardiography, we anticipated in an earlier study6 that the appropriateness criteria for stress echocardiography would be quite similar to those for SPECT MPI. Although the documents are similar in many respects, the appropriateness classification for identical clinical scenarios is sometimes different for the 2 stress imaging modalities.

We undertook this study (1) to examine the appropriateness criteria for stress echocardiography applied to a group of patients undergoing stress echocardiography at the Mayo Clinic (Rochester, Minn) and (2) to test the hypothesis that the classification of these patients using these criteria would be similar to their classification by SPECT MPI appropriateness criteria.

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Methods

In an earlier report of a recent study, we applied the SPECT MPI appropriateness criteria of the ACCF and the American Society of Nuclear Cardiology to 2 patient populations who underwent stress imaging during the 2-week period between May 1, 2005, and May 15, 2005. This time frame was selected intentionally to examine the appropriateness of testing before the publication of any ACCF appropriateness criteria documents. The study population for that study included 284 patients who underwent stress SPECT MPI and 298 patients who underwent stress echocardiography.

The study population for the present study consisted of the same 298 patients who underwent stress echocardiography during the 2-week period. Patients were excluded if they had not given research authorization or if they had undergone hemodynamic stress echocardiographic studies for assessment of valvular heart disease. The echocardiography laboratory at the Mayo Clinic has a prospectively maintained stress echocardiography research database, which was used to obtain information about patient demographics, symptoms, and the reasons for stress testing. When necessary, the electronic medical records of patients were also reviewed for additional information (eg, to determine a patient’s exercise tolerance or the specific type of proposed surgery). The stress echocardiography appropriateness criteria document addresses 42 clinical indications categorized into 8 appropriateness tables. For this study, we excluded indication 42 in appropriateness table 8, which addressed viability. Because multiple indications for stress echocardiography may apply in an individual patient, each patient was categorized by applying 7 appropriateness tables in the following hierarchical order: risk assessment: postrevascularization (appropriateness table 7); risk assessment: preoperative evaluation for noncardiac surgery (appropriateness table 5); risk assessment after acute coronary syndrome (appropriateness table 6); risk assessment with prior test results (appropriateness table 4); detection of coronary artery disease (CAD) or risk assessment: asymptomatic (appropriateness table 1); and detection of CAD or risk assessment: asymptomatic or without chest pain syndrome or anginal equivalent (appropriateness tables 2 and 3). As in the first study, numerous assumptions were needed to apply the appropriateness criteria. Patients who had dyspnea rather than chest pain as a presenting symptom were considered symptomatic with atypical angina so that their pretest probability of having CAD could be estimated. The Framingham score that determines the risk of future hard cardiac events was calculated rather than the score that includes angina as an event. A patient receiving lipid-lowering drug therapy was given a value of +2 for the low-density lipoprotein component of the score.

Using the appropriateness criteria document, 2 experienced cardiac registered nurse abstractors reviewed patient demographics and other relevant information and classified each patient as appropriate, inappropriate, or uncertain. Patients who did not fit any of the clinical situations in the appropriateness criteria were judged to be not classifiable. The level of agreement between the 2 raters was analyzed, and any discrepancies were adjudicated by 2 cardiologists, 1 from the stress echocardiography laboratory (R.B.M.) and 1 from the nuclear cardiology laboratory (R.J.G.). Additionally, a review of the data identified 25 patients who underwent stress echocardiography for preoperative evaluation who were not classifiable by the stress echocardiography criteria but were appropriate by the SPECT criteria, a combination that should not occur without an error. These patients were independently reviewed by the 2 cardiologists. The final classification results were compared with those of the previously performed analysis of the same patient population that used SPECT MPI appropriateness criteria.

The authors had full access to the data and take responsibility for its integrity. All authors have read and agree to the manuscript as written. The study was conducted with approval from the Mayo Clinic Institutional Review Board.

Statistical Analysis

With regard to the classification of the patients by the 2 nurses, agreement was assessed using $\kappa$ statistics. For the comparison between the classification of patients by stress echocardiography and by SPECT MPI, the Bowker test of symmetry was used to compare the entire patient group. For each individual classification category, the McNemar test was used to compare assignments by stress echocardiography versus SPECT MPI criteria.
Clinical Situation

The highest number of appropriate studies was performed for detection/risk assessment of CAD in symptomatic patients. Of the 109 patients in this category, 103 (94%) were classified as appropriate.

Most inappropriate studies were performed for detection/risk assessment of CAD in asymptomatic patients. Of the 43 patients in this category, 31 (72%) were classified as inappropriate and 11 (26%) were classified as uncertain. Six clinical situations accounted for more than 90% of the 57 patients with inappropriate indications for testing according to the appropriateness criteria for stress echocardiography (Table 3).

Comparison With SPECT MPI

Appropriateness Criteria

This study population of 298 patients had previously been classified by the SPECT MPI criteria with the following results: 191 patients (64%) were classified as appropriate (CI, 58% to 70%), 27 (9%) as uncertain (CI, 6% to 13%), and 52 (18%) as inappropriate (CI, 14% to 23%); 28 (9%) were not classifiable (CI, 6% to 13%). When the overall classification of patients by stress echocardiography criteria was compared with that by the SPECT MPI criteria, there was a significant difference ($P<0.001$; Figure 1). The probability values for the paired comparison of the 4 appropriateness rating categories were as follows: for the appropriate patients, $P<0.001$; for the uncertain patients, $P=0.77$; for the inappropriate patients, $P=0.42$; and for those not classifiable, $P<0.001$. The level of agreement between the SPECT MPI and stress echocardiography criteria for the study population is detailed in Table 4.

Of the 298 patients, 38 (13%) were classified as appropriate by the SPECT MPI criteria but not by the stress echocardiography criteria (first column, Table 4). The appropriate SPECT MPI indications for these 38 patients were as follows: asymptomatic patients with high coronary heart disease risk (n=12), asymptomatic patients at 5 or more years after coronary artery bypass grafting (n=11), intermediate-risk surgery patients "with poor exercise tolerance or intermediate-risk predictors" (n=12), symptomatic patients after revascularization (n=2), and a patient with an Agatston score of more than 400 on computed tomography (n=1). The aforementioned 23 patients who were asymptomatic with high coronary heart disease risk or at 5 or more years after coronary artery bypass graft were classified as uncertain by the stress echocardiography criteria. Five of the 38 patients were intermediate-risk surgery patients with poor exercise tolerance and no or minor risk predictors, a clinical situation classified as inappropriate by the stress echocardiography criteria. The remaining 10 of the 38 were not classifiable by the stress echocardiography criteria; 7 of these were intermediate-risk surgery patients with normal exercise tolerance and intermediate-risk predictors, a clinical situation not covered by the stress echocardiography criteria.

There were 25 other patients who were not classifiable by the stress echocardiography criteria but were classified as uncertain or inappropriate by the SPECT MPI criteria (fourth row, Table 4). These 25 patients were in the following categories: preoperative assessment (n=17), postrevascularization (n=7), and risk assessment with prior test results (n=1). Seven of the 11 patients who were uncertain by the SPECT MPI criteria were asymptomatic patients at 2 or more years after percutaneous coronary intervention who had been symptomatic before revascularization. This clinical situation is not covered by the stress echocardiography criteria. Four of

### Table 2. Categorization and Final Classification of 298 Study Patients Using Appropriateness Criteria for Stress Echocardiography

<table>
<thead>
<tr>
<th>Appropriateness Table Description and No.</th>
<th>Appropriate (n=159)</th>
<th>Uncertain (n=25)</th>
<th>Inappropriate (n=57)</th>
<th>Not Classifiable (n=57)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk assessment: postrevascularization (table 7)</td>
<td>33</td>
<td>11</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Risk assessment: preoperative evaluation for noncardiac surgery (table 5)</td>
<td>19</td>
<td>0</td>
<td>10</td>
<td>31</td>
</tr>
<tr>
<td>Risk assessment after acute coronary syndrome (table 6)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Risk assessment with prior test results (table 4)</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Detection of CAD or risk assessment: symptomatic (table 1)</td>
<td>103</td>
<td>0</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Detection of CAD or risk assessment: asymptomatic or without chest pain syndrome or anginal equivalent (tables 2 and 3)</td>
<td>1</td>
<td>11</td>
<td>31</td>
<td>0</td>
</tr>
</tbody>
</table>

The numbers in each cell represent the number of patients in each category.

### Table 3. Clinical Situations Accounting for More Than 90% of Inappropriate Referrals for Stress Echocardiography Using Appropriateness Criteria for Stress Echocardiography

<table>
<thead>
<tr>
<th>Clinical Situation</th>
<th>Appropriateness Indication</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection of CAD or risk assessment, asymptomatic, low CHD risk (Framingham)</td>
<td>11</td>
<td>22 (39)</td>
</tr>
<tr>
<td>Detection of CAD or risk assessment, asymptomatic, moderate CHD risk (Framingham)</td>
<td>12</td>
<td>9 (16)</td>
</tr>
<tr>
<td>Detection of CAD or risk assessment, symptomatic, low pretest probability of CAD, ECG interpretable and able to exercise</td>
<td>1</td>
<td>6 (11)</td>
</tr>
<tr>
<td>Preoperative evaluation, low-risk surgery, minor or intermediate clinical risk predictors</td>
<td>28</td>
<td>5 (9)</td>
</tr>
<tr>
<td>Preoperative evaluation, intermediate-risk surgery, poor exercise tolerance (&lt;4 METs), minor or no clinical risk predictors</td>
<td>29</td>
<td>5 (9)</td>
</tr>
<tr>
<td>Postrevascularization, asymptomatic, &lt;5 years after CAGB</td>
<td>36</td>
<td>5 (9)</td>
</tr>
</tbody>
</table>

Data are presented as n (%). N=52 (of 57). CAGB indicates coronary artery bypass grafting; CHD, coronary heart disease; METs, metabolic equivalents.
Table 4. Agreement Between Appropriateness Criteria for Stress Echocardiography and SPECT MPI

<table>
<thead>
<tr>
<th>Stress Echocardiography Criteria</th>
<th>SPECT MPI Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate (n=191)</td>
<td>Uncertain (n=27)</td>
</tr>
<tr>
<td>Appropriate (n=159)</td>
<td>153*</td>
</tr>
<tr>
<td>Uncertain (n=25)</td>
<td>2</td>
</tr>
<tr>
<td>Inappropriate (n=57)</td>
<td>2†</td>
</tr>
<tr>
<td>Not Classifiable (n=57)</td>
<td>5†</td>
</tr>
<tr>
<td>Not Classifiable (n=57)</td>
<td>10†</td>
</tr>
<tr>
<td>Uncertain (n=25)</td>
<td>2*</td>
</tr>
<tr>
<td>Inappropriate (n=57)</td>
<td>12</td>
</tr>
<tr>
<td>Not Classifiable (n=28)</td>
<td>11†</td>
</tr>
<tr>
<td>Inappropriate (n=52)</td>
<td>3</td>
</tr>
<tr>
<td>Not Classifiable (n=28)</td>
<td>14‡</td>
</tr>
</tbody>
</table>

*Intercriteria agreement (κ=0.52).
†These 38 patients are described in more detail in the Results section.
‡These 25 patients are described in more detail in the Results section.

Figure. Overall classification of the 298 study patients by stress echocardiography appropriateness criteria and by SPECT MPI appropriateness criteria (P<0.001).

Discussion

Our findings demonstrate the feasibility of applying the appropriateness criteria for stress echocardiography to a patient population. In our clinical setting, it helped to have a database of patient demographics, to assign a hierarchical order to the appropriateness tables, and to make a number of assumptions a priori to facilitate what would otherwise have been a difficult process. The level of agreement between the experienced nurse abstractors was good; nonetheless, rating categories differed for 19% of the study population.

We found that 1 in 5 patients was not classifiable using the stress echocardiography criteria, which suggests substantial gaps in these criteria. In contrast, only 1 in 11 of the same patients was not classifiable by the SPECT MPI criteria. By the stress echocardiography criteria, 19% of patients were classified as inappropriate. Approximately three fourths of the patients classified as inappropriate were asymptomatic (Table 3). The clinical situations that were most often inappropriate by the stress echocardiography appropriateness criteria, such as asymptomatic patients with low-risk Framingham scores, symptomatic patients with low pretest probability of coronary artery disease, an interpretable ECG, and the ability to exercise, and patients scheduled for low-risk surgery, are instances that do not warrant screening with stress echocardiography according to existing guidelines. Efforts aimed at minimizing the overuse of stress imaging could focus on these clinical situations.

We also found that fewer patients were classified as appropriate with stress echocardiography criteria than with SPECT MPI criteria. The appropriateness criteria for stress echocardiography, although similar in many respects to the SPECT MPI criteria, are stricter. Of the 41 indications in the stress echocardiography criteria that were used in this study, 39 had identical or near-identical counterparts in the SPECT MPI appropriateness criteria. By stress echocardiography criteria, 44% of these indications are appropriate, 20% are uncertain, and 36% are inappropriate. In contrast, by SPECT MPI criteria, 54% of the same indications are appropriate, 20% are uncertain, and 26% are inappropriate. Consequently, 13 (33%) of the 39 shared indications have a different classification by stress echocardiography criteria than by SPECT MPI criteria. One of these 13 indications is stricter for SPECT MPI (uncertain versus appropriate), and 12 indications are stricter for stress echocardiography (uncertain versus appropriate for 7 indications and inappropriate versus uncertain for 5 indications).

The appropriateness criteria for stress testing were developed using a modified Delphi procedure, in which a panel of clinician experts, the “technical panel,” blended evidence-based information with clinical experience to determine the appropriateness of a test for a series of clinical situations or indications. There was a 2-part scoring process. After the first independent scoring round, the panel members met for a face-to-face discussion of the clinical situations or indications. Panel members were provided with an interim report card of their initial scores. After the meeting, the final scores for each indication were submitted by each member. The median appropriateness score, a value of 1 to 9, was calculated for each clinical situation or indication. If this score was 1 to 3, the indication was classified as inappropriate; if 4 to 6, it was classified as uncertain; and if 7 to 9, it was classified as appropriate. The median appropriateness scores ultimately assigned by the stress echocardiography technical panel were lower than those assigned previously by the SPECT MPI technical panel in 70% of the 39 shared indications; they were higher in 6%; and they were no different in 24%. As described above, these scores translated into a larger propor-
tion of indications being classified as inappropriate or uncertain by the stress echocardiography criteria compared with the SPECT MPI criteria.

As outlined in the general discussion section of the stress echocardiography appropriateness criteria document, there are several potential reasons for these discordant classifications, including rating variations by technical panel members based on their clinical experience or interpretation of data, the relative timing of the different appropriateness criteria processes, and differences in the composition of the panels for each set of appropriateness criteria. Work on a multimodality appropriateness criteria document is currently in progress (R.G. Brindis, MD, oral communication, January 9, 2009). This forthcoming publication will focus on and deal with the reasons for these differences.

Although cost-effectiveness was not included in the original definition of appropriateness, we would suggest that the cost-effectiveness of test strategies be considered by the appropriateness criteria working group when the ACCF appropriateness criteria are refined and updated in the future. Information on potential risks associated with specific imaging modalities, such as radiation exposure with SPECT MPI and microbubble contrast agent usage with stress echocardiography, could also be incorporated into future appropriateness criteria documents.

Our results suggest that increasing the number of clinical situations or indications to fill existing gaps in the appropriateness criteria will make them easier to apply to patient populations. Although the stress echocardiography appropriateness criteria were not intended to cover all patients, the addition of only a few clinical situations could result in a decrease in the proportion of stress echocardiograms that would not be classifiable to <10%. Moreover, both the SPECT MPI criteria and the stress echocardiography criteria already require revision to reflect the latest ACC and AHA guidelines for preoperative assessment for noncardiac surgery, which take a more conservative position regarding the need for noninvasive testing.

Finally, most of the classification disparities between the stress echocardiography and SPECT MPI criteria involve asymptomatic patients. Future research could focus on asymptomatic patients who are classified discordantly by these appropriateness criteria to determine which subgroups should be referred for stress testing, be it exercise electrocardiography, stress echocardiography, or stress SPECT MPI.

Study Limitations
This study was performed at a single academic medical center, and it is not known whether the proportion of patients in each appropriateness category, as determined by the stress echocardiography criteria, would apply to other stress echocardiography laboratories and practices. In applying these criteria to our patient population, we made a number of assumptions that may not be accepted by others. We studied patients who underwent stress echocardiography over a 2-week period only. The 95% confidence intervals for the estimates of appropriateness categories were, however, satisfactory. In the absence of recommendations on how to rank appropriateness criteria tables when applying them to patients, we chose a table hierarchy that we believe is a reasonable reflection of clinical thinking and clinical practice. We might have obtained different results had we used the tables in a different order. The writing groups of future appropriateness criteria documents should consider addressing the issue of how to rank the tables. This is especially important when a clinical situation meets criteria for inclusion under more than one table.

Most patient data were collected at the time of the stress echocardiogram, that is, at the “point of service.” When additional information was required, the nurse abstractors performed a retrospective review of patients’ medical records. The “point of ordering” is probably the best time for a clinician to assess the appropriateness of stress imaging. Based on the results of our first study, we constructed a flow diagram that showed that most of the inappropriate studies can be identified at the “point of ordering” by the collection of a limited number of data elements.

Conclusions
Our findings show that it is feasible to apply the appropriateness criteria for stress echocardiography to a patient population, although 20% of our patients were not classifiable. We also found that the overall classification of patients by the appropriateness criteria for stress echocardiography was significantly different compared with that by the appropriateness criteria for SPECT MPI. Future refinements to the appropriateness criteria for stress testing should include an effort to reduce gaps in the criteria and an attempt to address the disparities that exist between the stress echocardiography and SPECT MPI criteria.

Acknowledgments
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Disclosures
None.

References
We applied stress echocardiography appropriateness criteria to patients undergoing stress echocardiography at an academic medical center. The results were compared with those obtained using the single-photon computed tomography myocardial perfusion imaging criteria in the same patients. With these criteria, patient indications can be classified as appropriate, uncertain, inappropriate, or not classifiable. Applying these criteria was feasible, with good interrater agreement. One in 5 patients was not classifiable, however, suggesting significant gaps in the stress echocardiography criteria. Of the patients, 19% were classified as inappropriate, or not classifiable. Applying these criteria was feasible, with good interrater agreement. One in 5 patients was not classifiable.
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