I. General Considerations and Scope

The previous guideline for the use of echocardiography was published in March 1997. Since that time, there have been significant advances in the technology of echocardiography and growth in its clinical use and in the scientific evidence leading to recommendations for its proper use.

Each section has been reviewed and updated in evidence tables, and where appropriate, changes have been made in this document.
recommendations. A new section on the use of intraoperative transesophageal echocardiography (TEE) is being added to update the guidelines published by the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists. There are extensive revisions, especially of the sections on ischemic heart disease; congestive heart failure, cardiomyopathy, and assessment of left ventricular (LV) function; and screening and echocardiography in the critically ill. There are new tables of evidence and extensive revisions in the ischemic heart disease evidence tables.

Because of space limitations, only those sections and evidence tables with new recommendations will be printed in this summary article. Where there are minimal changes in a recommendation grouping, such as a change from Class IIa to Class I, only that change will be printed, not the entire set of recommendations. Advances for which the clinical applications are still being investigated, such as the use of myocardial contrast agents and three-dimensional echocardiography, will not be discussed.

The original recommendations of the 1997 guideline are based on a Medline search of the English literature from 1990 to May 1995. The original search yielded more than 3000 references, which the committee reviewed. For this guideline update, literature searching was conducted in Medline, EMBASE, Best Evidence, and the Cochrane Library for English-language meta-analyses and systematic reviews from 1995 through September 2001. Further searching was conducted for new clinical trials on the following topics: echocardiography in adult congenital heart disease, echocardiography for evaluation of chest pain in the emergency department, and intraoperative echocardiography. The new searches yielded more than 1000 references that were reviewed by the writing committee.

This document includes recommendations for the use of echocardiography in both adult and pediatric patients. The pediatric guidelines also include recommendations for fetal echocardiography, an increasingly important field. The guidelines include recommendations for the use of echocardiography in both specific cardiovascular disorders and the evaluation of patients with frequently observed cardiovascular symptoms and signs, common presenting complaints, or findings of dyspnea, chest discomfort, and cardiac murmur. In this way, the guidelines will provide assistance to physicians regarding the use of echocardiographic techniques in the evaluation of such common clinical problems.

The recommendations concerning the use of echocardiography follow the indication classification system (eg, Class I, II, and III) used in other American College of Cardiology/American Heart Association (ACC/AHA) guidelines:

**Class I:** Conditions for which there is evidence and/or general agreement that a given procedure or treatment is useful and effective.

**Class II:** Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment.

**IIa:** Weight of evidence/opinion is in favor of usefulness/efficacy.

**IIb:** Usefulness/efficacy is less well established by evidence/opinion.

**Class III:** Conditions for which there is evidence and/or general agreement that the procedure/treatment is not useful/effective and in some cases may be harmful.

Evaluation of the clinical utility of a diagnostic test such as echocardiography is far more difficult than assessment of the efficacy of a therapeutic intervention because the diagnostic test can never have the same direct impact on patient survival or recovery. Nevertheless, a series of hierarchical criteria are generally accepted as a scale by which to judge worth.1-3

**Hierarchical Levels of Echocardiography Assessment**

- Technical capacity
- Diagnostic performance
- Impact on diagnostic and prognostic thinking
- Therapeutic impact
- Health-related outcomes

Because there are essentially no randomized trials assessing health outcomes for diagnostic tests, the committee has not ranked the available scientific evidence in an A, B, and C fashion (as in other ACC/AHA documents) but rather has compiled the evidence in tables. The evidence tables have been extensively revised and updated. All recommendations are thus based on either this evidence from observational studies or on the expert consensus of the committee.

The definition of echocardiography used in this document incorporates Doppler analysis, M-mode echocardiography, two-dimensional transthoracic echocardiography (TTE), and, when indicated, TEE. Intravascular ultrasound is not considered but is reviewed in the ACC/AHA Guidelines for Percutaneous Coronary Intervention4 (available at http://www.acc.org/clinical/guidelines/percutaneous/dirIndex.htm) and the Clinical Expert Consensus Document on intravascular ultrasound5 (available at http://www.acc.org/clinical/consensus/standards/standard12.htm). Echocardiography for evaluating the patient with cardiovascular disease for noncardiac surgery is considered in the ACC/AHA Guidelines for Perioperative Cardiovascular Evaluation for Noncardiac Surgery.6 The techniques of three-dimensional echocardiography are still in the developmental stages and are not considered here. New techniques that are still rapidly evolving and improvements that are purely technological in echo-Doppler instrumentation, such as color Doppler imaging and digital echocardiography, are not going to be separately discussed in the clinical recommendations addressed in this document. Tissue Doppler imaging, both pulsed and color, which detects low Doppler shift frequencies of high energy generated by the contracting myocardium and consequent wall motion, are proving very useful in evaluating systolic and diastolic myocardial function. However, these technological advances will also not be separately discussed in the clinical recommendations.6,7 Echocardiographic-contrast injections designed to assess myocardial perfusion to quantify myocardium at risk and perfusion beds also were not addressed.

These guidelines address recommendations about the frequency with which an echocardiographic study is repeated. If
the frequency with which studies are repeated could be
decreased without adversely affecting the quality of care, the
economic savings realized would likely be significant. With a
noninvasive diagnostic study and no known complications,
the potential for repeating the study unnecessarily exists. It is
easier to state when a repeat echocardiogram is not needed
then when and how often it should be repeated, because no
studies in the literature address this question. How often an
echocardiogram should be done depends on the individual
patient and must be left to the judgment of the physician until
evidence-based data addressing this issue are available.

The ACC/AHA/ASE 2003 Guideline Update for the Clinical
Application of Echocardiography includes several signif-
icant changes in the recommendations and in the supporting
narrative portion. In this summary, we list the updated
recommendations, as well as commentary on some of the
changes. All new or revised language in recommendations
appears in boldface type. Only the references supporting the
new recommendations are included in this article. The reader
is referred to the full-text version of the guidelines posted on
the American College of Cardiology (www.acc.org), Ameri-
can Heart Association (www.americanheart.org), and Amer-
ican Society for Echocardiography (www.asecho.org) World
Wide Web sites for a more detailed exposition of the rationale
for these changes.

Section II-B. Native Valvular Stenosis

Recommendations for Echocardiography in
Valvular Stenosis

Comment: New references.6,7

Class IIb

2. Dobutamine echocardiography for the evaluation of
patients with low-gradient aortic stenosis and ventricular
dysfunction.

Section II-C. Native Valvular Regurgitation

Recommendations for Echocardiography in Native
Valvular Regurgitation

Comment: Literature on valvular effects of anorectic drugs
and references to echocardiographic predictors of prognosis
after aortic and mitral valve surgery have been added.6–10

Class I

7. Assessment of the effects of medical therapy on the
severity of regurgitation and ventricular compensation
and function when it might change medical
management.

8. Assessment of valvular morphology and regurgita-
tion in patients with a history of anorectic drug use,
or the use of any drug or agent known to be
associated with valvular heart disease, who are
symptomatic, have cardiac murmurs, or have a
technically inadequate auscultatory examination.

Class III

2. Routine repetition of echocardiography in past users
of anorectic drugs with normal studies or known
trivial valvular abnormalities.

Section II-F. Infective Endocarditis: Native Valves

Recommendations for Echocardiography in
Infective Endocarditis: Native Valves

Comment: The Duke Criteria for the diagnosis of infective
endocarditis have been added, as well as the value of TEE in
the setting of a negative transthoracic echocardiogram when
there is high clinical suspicion or when a prosthetic valve is
involved.11,12

Class I

6. If TTE is equivocal, TEE evaluation of staphylococ-
cus bacteremia without a known source.

Class IIa

1. Evaluation of persistent nonstaphylococcus bacter-
emia without a known source.*

Class III

1. Evaluation of transient fever without evidence of
bacteremia or new murmur.

*TEE may frequently provide incremental value in addition to informa-
tion obtained by TTE. The role of TEE in first-line examination awaits
further study.

Section II-G. Prosthetic Valves

Recommendations for Echocardiography in
Valvular Heart Disease and Prosthetic Valves

Class I

3. Use of echocardiography (especially TEE) in guiding
the performance of interventional techniques and
surgery (eg, balloon valvotomy and valve repair) for
valvular disease.

Section IV-A. Acute Ischemic Syndromes

Recommendations for Echocardiography in the
Diagnosis of Acute Myocardial Ischemic
Syndromes

Comment: Movement of a recommendation from Class IIa to
Class I and minor wording change.

Recommendations for Echocardiography in Risk
Assessment, Prognosis, and Assessment of Therapy
in Acute Myocardial Ischemic Syndromes

Class I

4. Assessment of myocardial viability when required to
define potential efficacy of revascularization.*

Class IIa

2. Moved to Class I (see above).

Class IIb

1. Assessment of late prognosis (greater than or equal to 2
years after acute myocardial infarction).

*Dobutamine stress echocardiography.
Section IV-B. Chronic Ischemic Heart Disease

Recommendations for Echocardiography in Diagnosis and Prognosis of Chronic Ischemic Heart Disease

Comment: There are new sections on stress echocardiography in the detection of coronary disease in the transplanted heart and stress echocardiography in the detection of coronary disease in women. There is one new Class I recommendation and three new Class IIa recommendations. Recommendations have been renumbered for clarity.

Class I

2. Exercise echocardiography for diagnosis of myocardial ischemia in selected patients (those for whom ECG assessment is less reliable because of digoxin use, LVH or with more than 1 mm ST depression at rest on the baseline ECG, those with pre-excitation [Wolff-Parkinson-White] syndrome, complete left bundle-branch block) with an intermediate pretest likelihood of CAD.

Class IIa

1. Prognosis of myocardial ischemia in selected patients (those in whom ECG assessment is less reliable) with the following ECG abnormalities: pre-excitation (Wolff-Parkinson-White) syndrome, electronically paced ventricular rhythm, more than 1 mm of ST depression at rest, complete left bundle-branch block.*
2. Detection of coronary arteriopathy in patients who have undergone cardiac transplantation.†
3. Detection of myocardial ischemia in women with a low or intermediate pretest likelihood of CAD.*

Class IIb

1. Moved to Class IIa.

*Exercise or pharmacological stress echocardiogram.
†Dobutamine stress echocardiogram.

Recommendations for Echocardiography in Assessment of Interventions in Chronic Ischemic Heart Disease

One new Class IIa recommendation has been added.

Class IIa

1. Assessment of LV function in patients with previous myocardial infarction when needed to guide possible implantation of implantable cardioverter-defibrillator (ICD) in patients with known or suspected LV dysfunction.

Tables 1 through 6 are new tables that relate to CAD.

Section V-B. Regional LV Function

Recommendations for Echocardiography in Patients With Dyspnea, Edema, or Cardiomyopathy

Class I

1. Dyspnea with clinical signs of heart disease.

Class IIb

1. Re-evaluation of patients with established cardiomyopathy when there is no change in clinical status but when the results might change management.

Class III

2. Routine re-evaluation in clinically stable patients in whom no change in management is contemplated and for whom the results would not change management.

Section IX. Pulmonary Disease

Recommendations for Echocardiography in Pulmonary and Pulmonary Vascular Disease

Comment: One recommendation was moved from Class I to Class IIa. Class IIa recommendations have been renumbered for clarity. Evidence was added concerning the diagnosis of severe pulmonary embolism by echocardiography.122

Class I

2. Moved to Class IIa (see below).

Class IIa

1. Pulmonary emboli and suspected clots in the right atrium or ventricle or main pulmonary artery branches.*

*TEE is indicated when TTE studies are not diagnostic.

Section XII. Arrhythmias and Palpitations

Recommendations for Echocardiography in Patients With Arrhythmias and Palpitations

Comment: An additional Class IIb recommendation was made concerning the use of echocardiography in the Maze procedure.123–129

Class IIa

2. TEE or intracardiac ultrasound guidance of radiofrequency ablative procedures.

Class IIb

3. Postoperative evaluation of patients undergoing the Maze procedure to monitor atrial function.

Recommendations for Echocardiography Before Cardioversion

Class IIb

2. Patients with mitral valve disease or hypertrophic cardiomyopathy who have been on long-term anticoagulation at therapeutic levels before cardioversion unless there are other reasons for anticoagulation (eg, prior embolus or known thrombus on previous TEE).*

*TEE only.
Class III

2. Patients who have been on long-term anticoagulation at therapeutic levels and who do not have mitral valve disease or hypertrophic cardiomyopathy before cardioversion unless there are other reasons for anticoagulation (eg, prior embolus or known thrombus on previous TEE).*

*TEE only.

Section XIIa. Screening

Recommendations for Echocardiography to Screen for the Presence of Cardiovascular Disease

Comment: A section has been added on the molecular genetics work that has identified a familial basis for many forms of cardiomyopathy, including dilated congestive cardiomyopathy, hypertrophic cardiomyopathy, and right ventricular (RV) dysplasia. A possible genetic basis for these cardiomyopathies supports echocardiographic screening of first-degree relatives.130–138

Class I

5. First-degree relatives (parents, siblings, children) of patients with unexplained dilated cardiomyopathy in whom no etiology has been identified.

Class III

2. Routine screening echocardiogram for participation in competitive sports in patients with normal cardiovascular history, ECG, and examination.
### TABLE 2. Prognostic Value of Stress Echocardiography in Various Patient Populations*

<table>
<thead>
<tr>
<th>First Author, Year</th>
<th>Reference</th>
<th>Stress</th>
<th>Total Pts</th>
<th>Avg F/U, mo</th>
<th>Events</th>
<th>Ischemia</th>
<th>No Ischemia</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic ischemic heart disease</td>
<td>Picano, 1989</td>
<td>DIP†</td>
<td>539</td>
<td>36</td>
<td>D, MI</td>
<td>2.3</td>
<td>0.7</td>
<td>...</td>
</tr>
<tr>
<td>Sawada, 1990</td>
<td>NL TME</td>
<td>148</td>
<td>28.4</td>
<td>D, MI</td>
<td>...</td>
<td>...</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Mazeika, 1993</td>
<td>DSE†</td>
<td>51</td>
<td>24</td>
<td>D, MI, UA</td>
<td>16</td>
<td>3.8</td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Krivokapich, 1993</td>
<td>TME†</td>
<td>360</td>
<td>~12</td>
<td>D, MI</td>
<td>10.8</td>
<td>3.1</td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Afridi, 1994</td>
<td>DSE†</td>
<td>77</td>
<td>10</td>
<td>D, MI</td>
<td>48</td>
<td>8.9</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Poldermans, 1994</td>
<td>DSE</td>
<td>360</td>
<td>12 D, MI</td>
<td>10.8</td>
<td>3.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coletta, 1995</td>
<td>NL TME</td>
<td>268</td>
<td>16</td>
<td>D, MI</td>
<td>17.9</td>
<td>1.4</td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Mazeika, 1993</td>
<td>DSE†</td>
<td>360</td>
<td>12 D, MI</td>
<td>10.8</td>
<td>3.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williams, 1996</td>
<td>DSE†</td>
<td>108</td>
<td>8</td>
<td>D, MI, Re</td>
<td>32.6</td>
<td>7.3</td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Anthopoulos, 1996</td>
<td>DSE†</td>
<td>120</td>
<td>14</td>
<td>D, MI</td>
<td>13.6</td>
<td>0</td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Marcovitz, 1996</td>
<td>DSE†</td>
<td>291</td>
<td>15</td>
<td>D, MI</td>
<td>12.8</td>
<td>8.2</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Heupler, 1997</td>
<td>TME†</td>
<td>508w</td>
<td>41</td>
<td>D, MI, Re</td>
<td>9.2</td>
<td>1.3</td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>McCully, 1998</td>
<td>NL TME</td>
<td>1325</td>
<td>23</td>
<td>D, MI</td>
<td>...</td>
<td>...</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Chua, 1998</td>
<td>DSE†</td>
<td>860</td>
<td>24</td>
<td>D, MI</td>
<td>6.9</td>
<td>6.3</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Cortigiani, 1998</td>
<td>DSE or DIP†</td>
<td>456w</td>
<td>32</td>
<td>D, MI</td>
<td>2.9</td>
<td>0.3</td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Davar, 1999</td>
<td>NL DSE</td>
<td>72w</td>
<td>13</td>
<td>D, MI</td>
<td>...</td>
<td>...</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

After cardiac transplantation

<table>
<thead>
<tr>
<th>First Author, Year</th>
<th>Reference</th>
<th>Stress</th>
<th>Total Pts</th>
<th>Avg F/U, mo</th>
<th>Adverse Events</th>
<th>Annualized Event Rate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ciliberto, 1993</td>
<td>DIP‡</td>
<td>80</td>
<td>9.8</td>
<td>D, MI, CHF</td>
<td>26.2</td>
<td>0</td>
</tr>
<tr>
<td>Lewis, 1997</td>
<td>DSE†</td>
<td>63</td>
<td>8</td>
<td>D, MI, CHF</td>
<td>28.6</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Annualized Event Rate indicates the percentage of patients per year who developed at least 1 adverse event during follow-up, depending on whether inducible ischemia was or was not demonstrated by stress echocardiography (the annualized event rate is also tabulated for those series describing patients who had normal resting and normal stress results); Stress, stress echocardiography protocol; Total Pts, number of patients studied with stress echocardiography and subsequently followed up for the development of adverse events (including death, nonfatal myocardial infarction, revascularization, or unstable angina; in posttransplant patients, development of severe congestive heart failure was also considered an adverse event); Avg F/U, average period of follow-up after stress echocardiography; DIP, dipyridamole stress echocardiography; D, death; MI, nonfatal myocardial infarction; NL, series describing patients with normal stress echocardiography test results; TME, treadmill stress echocardiography; DSE, dobutamine stress echocardiography; UA, unstable angina; Re, revascularization necessary; w, patients in these series were all women; and CHF, development of severe congestive heart failure.

*Prognostic value of inducible ischemia, detected with different forms of stress echocardiography, in patients with chronic ischemic heart disease and patients after cardiac transplantation.

†New wall motion abnormality considered “positive” for inducible ischemia.
‡Any wall motion abnormality (at rest or with stress) considered “positive.”

### TABLE 3. Prognostic Value of Viable (Hibernating) Myocardium by LD-DSE and Influence of Revascularization

<table>
<thead>
<tr>
<th>First Author, Year</th>
<th>Ref.</th>
<th>Stress</th>
<th>Total Pts</th>
<th>Avg F/U, mo</th>
<th>Adverse Events</th>
<th>Viable, +Re</th>
<th>Viable, −Re</th>
<th>Not Viable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meluzin, 1998</td>
<td>53</td>
<td>LD-DSE</td>
<td>133</td>
<td>20</td>
<td>Death, MI</td>
<td>4.1</td>
<td>...</td>
<td>9.5</td>
</tr>
<tr>
<td>Afridi, 1998</td>
<td>54</td>
<td>LD-DSE</td>
<td>353</td>
<td>18</td>
<td>Death</td>
<td>4</td>
<td>20</td>
<td>19</td>
</tr>
</tbody>
</table>

LD-DSE indicates low-dose dobutamine stress echocardiography; Ref., reference number; Stress, stress echocardiography protocol; Total Pts, number of patients with chronic ischemic heart disease and impaired left ventricular systolic function studied with LD-DSE and subsequently followed up for the development of an adverse event (death or nonfatal myocardial infarction); Avg F/U, average period of follow-up after LD-DSE; Annualized Event Rate, percentage of patients per year who developed an adverse event during follow-up after LD-DSE; Viable, +Re, patients with viability (contractile reserve) demonstrated by LD-DSE who underwent revascularization and were then followed up; Viable, −Re, patients with viability (contractile reserve) demonstrated by LD-DSE who did not undergo revascularization and were then followed up; Not Viable, patients without contractile reserve by LD-DSE who were followed up for adverse events; and MI, nonfatal myocardial infarction.
Section XIII. Echocardiography in the Critically Ill

Recommendations for Echocardiography in the Critically Ill

Comment: This section has been revised extensively. A discussion has been added on the echocardiographic detection of pulmonary embolism and the usefulness of TEE versus TTE in the critically ill patient. A section on the value of echocardiography in blunt aortic trauma has also been added.

The evidence tables have been extensively revised and updated.\textsuperscript{139–164}

Class III

1. Suspected myocardial contusion in the hemodynamically stable patient with a normal ECG who has no abnormal cardiac/thoracic physical findings and/or lacks a mechanism of injury that suggests cardiovascular contusion.
TABLE 5. Diagnostic Accuracy of Dobutamine Stress Echocardiography in Detecting Angiographically Proved CAD (Without Correction for Referral Bias)

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Ref.</th>
<th>Protocol</th>
<th>Significant CAD</th>
<th>Total Pts</th>
<th>Sensitivity, %</th>
<th>Sens 1-VD, %</th>
<th>Sens MVD, %</th>
<th>Specificity, %</th>
<th>PPV, %</th>
<th>NPV, %</th>
<th>Accuracy, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berthe, 1986</td>
<td>88</td>
<td>DSE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>30</td>
<td>85</td>
<td>...</td>
<td>85</td>
<td>88</td>
<td>85</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Sawada, 1991</td>
<td>89</td>
<td>DSE 2.5–30</td>
<td>Greater than or equal to 50%</td>
<td>55</td>
<td>89</td>
<td>81</td>
<td>100</td>
<td>85</td>
<td>91</td>
<td>81</td>
<td>74</td>
</tr>
<tr>
<td>Sawada, 1991</td>
<td>89</td>
<td>DSE 2.5–30</td>
<td>Greater than or equal to 50%</td>
<td>41</td>
<td>81</td>
<td>...</td>
<td>81</td>
<td>87</td>
<td>91</td>
<td>72</td>
<td>87</td>
</tr>
<tr>
<td>Previtali, 1991</td>
<td>90</td>
<td>DSE 5–40</td>
<td>Greater than or equal to 70%</td>
<td>35</td>
<td>68</td>
<td>50</td>
<td>92</td>
<td>100</td>
<td>100</td>
<td>44</td>
<td>83</td>
</tr>
<tr>
<td>Cohen, 1991</td>
<td>91</td>
<td>DSE 2.5–40</td>
<td>Greater than 70%</td>
<td>70</td>
<td>86</td>
<td>69</td>
<td>94</td>
<td>95</td>
<td>98</td>
<td>72</td>
<td>89</td>
</tr>
<tr>
<td>Martin, 1992</td>
<td>92</td>
<td>DSE 10–40</td>
<td>Greater than 50%</td>
<td>30</td>
<td>85</td>
<td>...</td>
<td>...</td>
<td>44</td>
<td>79</td>
<td>40</td>
<td>68</td>
</tr>
<tr>
<td>McNeill, 1992</td>
<td>93</td>
<td>DASE 10–40</td>
<td>Greater than or equal to 50%</td>
<td>28</td>
<td>71</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>71</td>
</tr>
<tr>
<td>Segar, 1992</td>
<td>94</td>
<td>DSE 5–30</td>
<td>Greater than or equal to 50%</td>
<td>88</td>
<td>95</td>
<td>...</td>
<td>82</td>
<td>94</td>
<td>86</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Mazioka, 1992</td>
<td>95</td>
<td>DSE 5–20</td>
<td>Greater than or equal to 70%</td>
<td>50</td>
<td>78</td>
<td>50</td>
<td>92</td>
<td>93</td>
<td>97</td>
<td>62</td>
<td>82</td>
</tr>
<tr>
<td>Marcovitz, 1992</td>
<td>96</td>
<td>DSE 5–30</td>
<td>Greater than or equal to 50%</td>
<td>141</td>
<td>96</td>
<td>95</td>
<td>98</td>
<td>66</td>
<td>91</td>
<td>84</td>
<td>89</td>
</tr>
<tr>
<td>McNeill, 1992</td>
<td>97</td>
<td>DASE 10–40</td>
<td>Greater than 50%</td>
<td>30</td>
<td>85</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>78</td>
</tr>
<tr>
<td>Gutal, 1993</td>
<td>98</td>
<td>DSE 5–60</td>
<td>Greater than or equal to 50%</td>
<td>46</td>
<td>79</td>
<td>...</td>
<td>...</td>
<td>78</td>
<td>85</td>
<td>70</td>
<td>78</td>
</tr>
<tr>
<td>Marwick, 1993</td>
<td>97</td>
<td>DSE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>97</td>
<td>85</td>
<td>84</td>
<td>86</td>
<td>82</td>
<td>88</td>
<td>78</td>
<td>84</td>
</tr>
<tr>
<td>Forster, 1993</td>
<td>100</td>
<td>DASE 10–40</td>
<td>Greater than 50%</td>
<td>21</td>
<td>75</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>71</td>
</tr>
<tr>
<td>Gunalp, 1993</td>
<td>101</td>
<td>DSE 5–30</td>
<td>Greater than 50%</td>
<td>27</td>
<td>83</td>
<td>78</td>
<td>89</td>
<td>89</td>
<td>94</td>
<td>73</td>
<td>85</td>
</tr>
<tr>
<td>Marwick, 1993</td>
<td>102</td>
<td>DSE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>217</td>
<td>72</td>
<td>66</td>
<td>77</td>
<td>83</td>
<td>89</td>
<td>61</td>
<td>76</td>
</tr>
<tr>
<td>Hoffmann, 1993</td>
<td>72</td>
<td>DASE 5–40</td>
<td>Greater than 70%</td>
<td>64</td>
<td>79</td>
<td>78</td>
<td>81</td>
<td>81</td>
<td>93</td>
<td>57</td>
<td>80</td>
</tr>
<tr>
<td>Previtali, 1993</td>
<td>103</td>
<td>DSE 5–40</td>
<td>Greater than 50%</td>
<td>80</td>
<td>79</td>
<td>69</td>
<td>91</td>
<td>83</td>
<td>92</td>
<td>61</td>
<td>80</td>
</tr>
<tr>
<td>Takeuchi, 1993</td>
<td>104</td>
<td>DSE 5–30</td>
<td>Greater than or equal to 50%</td>
<td>120</td>
<td>85</td>
<td>73</td>
<td>97</td>
<td>93</td>
<td>95</td>
<td>80</td>
<td>88</td>
</tr>
<tr>
<td>Cohen, 1993</td>
<td>73</td>
<td>DSE 2.5–40</td>
<td>Greater than 70%</td>
<td>52</td>
<td>86</td>
<td>75</td>
<td>95</td>
<td>87</td>
<td>94</td>
<td>72</td>
<td>87</td>
</tr>
<tr>
<td>Ostojic, 1994</td>
<td>105</td>
<td>DSE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>150</td>
<td>75</td>
<td>74</td>
<td>81</td>
<td>79</td>
<td>96</td>
<td>31</td>
<td>75</td>
</tr>
<tr>
<td>Marwick, 1994</td>
<td>74</td>
<td>DSE 5–40</td>
<td>Greater than 50%</td>
<td>86</td>
<td>54</td>
<td>36</td>
<td>65</td>
<td>83</td>
<td>86</td>
<td>49</td>
<td>64</td>
</tr>
<tr>
<td>Beleslin, 1994</td>
<td>77</td>
<td>DSE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>136</td>
<td>82</td>
<td>82</td>
<td>82</td>
<td>76</td>
<td>96</td>
<td>38</td>
<td>82</td>
</tr>
<tr>
<td>Sharp, 1994</td>
<td>106</td>
<td>DSE 5–50</td>
<td>Greater than 50%</td>
<td>54</td>
<td>83</td>
<td>69</td>
<td>89</td>
<td>71</td>
<td>89</td>
<td>59</td>
<td>80</td>
</tr>
<tr>
<td>Pelikka, 1995</td>
<td>107</td>
<td>DSE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>67</td>
<td>98</td>
<td>...</td>
<td>...</td>
<td>65</td>
<td>84</td>
<td>94</td>
<td>87</td>
</tr>
<tr>
<td>Ho, 1995</td>
<td>108</td>
<td>DSE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>54</td>
<td>93</td>
<td>100</td>
<td>92</td>
<td>73</td>
<td>93</td>
<td>73</td>
<td>89</td>
</tr>
<tr>
<td>Daoud, 1995</td>
<td>109</td>
<td>DSE 5–30</td>
<td>Greater than or equal to 50%</td>
<td>76</td>
<td>92</td>
<td>91</td>
<td>93</td>
<td>73</td>
<td>95</td>
<td>62</td>
<td>89</td>
</tr>
<tr>
<td>Dagianti, 1995</td>
<td>80</td>
<td>DSE 5–50</td>
<td>Greater than or equal to 70%</td>
<td>60</td>
<td>72</td>
<td>60</td>
<td>80</td>
<td>97</td>
<td>95</td>
<td>83</td>
<td>87</td>
</tr>
<tr>
<td>Pingitore, 1996</td>
<td>110</td>
<td>DASE 5–40</td>
<td>Greater than 50%</td>
<td>110</td>
<td>84</td>
<td>78</td>
<td>88</td>
<td>89</td>
<td>97</td>
<td>52</td>
<td>85</td>
</tr>
<tr>
<td>Schroder, 1996</td>
<td>111</td>
<td>DSE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>46</td>
<td>76</td>
<td>71</td>
<td>90</td>
<td>88</td>
<td>97</td>
<td>44</td>
<td>78</td>
</tr>
<tr>
<td>Anthopoulos, 1996</td>
<td>44</td>
<td>DASE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>120</td>
<td>87</td>
<td>74</td>
<td>90</td>
<td>84</td>
<td>94</td>
<td>68</td>
<td>86</td>
</tr>
<tr>
<td>Ling, 1996</td>
<td>112</td>
<td>DASE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>183</td>
<td>93</td>
<td>...</td>
<td>...</td>
<td>62</td>
<td>95</td>
<td>54</td>
<td>90</td>
</tr>
<tr>
<td>Takeuchi, 1996</td>
<td>113</td>
<td>DASE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>70</td>
<td>75</td>
<td>78</td>
<td>73</td>
<td>92</td>
<td>79</td>
<td>90</td>
<td>87</td>
</tr>
<tr>
<td>Minardi, 1997</td>
<td>114</td>
<td>DASE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>47</td>
<td>75</td>
<td>81</td>
<td>67</td>
<td>67</td>
<td>97</td>
<td>15</td>
<td>74</td>
</tr>
<tr>
<td>Dionisopouliou, 1997</td>
<td>115</td>
<td>DASE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>288</td>
<td>87</td>
<td>80</td>
<td>91</td>
<td>89</td>
<td>95</td>
<td>71</td>
<td>87</td>
</tr>
<tr>
<td>Elhendy, 1997</td>
<td>116</td>
<td>DASE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>306</td>
<td>74</td>
<td>59</td>
<td>83</td>
<td>85</td>
<td>94</td>
<td>50</td>
<td>76</td>
</tr>
<tr>
<td>Ho, 1998</td>
<td>117</td>
<td>DSE 5–40</td>
<td>Greater than or equal to 50%</td>
<td>51</td>
<td>93</td>
<td>89</td>
<td>95</td>
<td>82</td>
<td>87</td>
<td>90</td>
<td>88</td>
</tr>
</tbody>
</table>

CAD indicates coronary artery disease; Ref., reference number; Protocol, dobutamine stress protocol, including initial and peak infusion rates (expressed in micrograms per kilogram per minute); Significant CAD, % coronary luminal diameter narrowing, demonstrated by selective coronary angiography, considered to represent significant CAD; Total Pts, number of patients in each series undergoing selective coronary angiography in whom dobutamine stress echocardiographic studies and wall motion analysis were also performed; Sens 1-VD, test results positive in patients with single-vessel CAD; Sens MVD, test results positive in patients with multivessel CAD; PPV, positive predictive value (likelihood of angiographically significant CAD in patients with inducible wall motion abnormalities by pharmacological stress echocardiography); NPV, negative predictive value (likelihood of absence of angiographically significant CAD in patients without inducible wall motion abnormalities by pharmacological stress echocardiography); DSE, dobutamine stress echocardiography; and DASE, dobutamine/atropine stress echocardiography.

A new or worsening regional wall motion abnormality induced by stress generally was considered a “positive” result.
TABLE 6. Diagnostic Accuracy of Stress Echocardiography in Detecting Angiographically Proved CAD in Women (Generally Without Correction for Referral Bias)

<table>
<thead>
<tr>
<th>First Author, Year</th>
<th>Ref.</th>
<th>Protocol</th>
<th>Significant CAD</th>
<th>Total Pts</th>
<th>Sensitivity, %</th>
<th>Sens 1-VD, %</th>
<th>Sens MVD, %</th>
<th>Specificity, %</th>
<th>PPV, %</th>
<th>NPV, %</th>
<th>Accuracy, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masini, 1988</td>
<td>118</td>
<td>DIP</td>
<td>Greater than or equal to 70%</td>
<td>83</td>
<td>79</td>
<td>...</td>
<td>...</td>
<td>93</td>
<td>91</td>
<td>84</td>
<td>87</td>
</tr>
<tr>
<td>Sawada, 1989</td>
<td>60</td>
<td>TME or UBE</td>
<td>Greater than or equal to 50%</td>
<td>57</td>
<td>86</td>
<td>88</td>
<td>82</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>Severi, 1994</td>
<td>119</td>
<td>DIP</td>
<td>Greater than or equal to 75%</td>
<td>122</td>
<td>68</td>
<td>...</td>
<td>...</td>
<td>96</td>
<td>90</td>
<td>86</td>
<td>87</td>
</tr>
<tr>
<td>Williams, 1994</td>
<td>78</td>
<td>UBE</td>
<td>Greater than 50%</td>
<td>70</td>
<td>88</td>
<td>89</td>
<td>86</td>
<td>84</td>
<td>83</td>
<td>89</td>
<td>86</td>
</tr>
<tr>
<td>Marwick, 1995</td>
<td>81</td>
<td>TME or UBE</td>
<td>Greater than or equal to 50%</td>
<td>161</td>
<td>80</td>
<td>75</td>
<td>85</td>
<td>81</td>
<td>71</td>
<td>87</td>
<td>81</td>
</tr>
<tr>
<td>Takeuchi, 1996</td>
<td>113</td>
<td>DASE</td>
<td>Greater than or equal to 50%</td>
<td>70</td>
<td>75</td>
<td>78</td>
<td>73</td>
<td>92</td>
<td>79</td>
<td>90</td>
<td>87</td>
</tr>
<tr>
<td>Roger, 1997</td>
<td>87</td>
<td>TME or UBE</td>
<td>Greater than or equal to 50%</td>
<td>96</td>
<td>79</td>
<td>...</td>
<td>...</td>
<td>37</td>
<td>66</td>
<td>54</td>
<td>63</td>
</tr>
<tr>
<td>Dionisopoulos, 1997</td>
<td>115</td>
<td>DASE</td>
<td>Greater than or equal to 50%</td>
<td>101</td>
<td>90</td>
<td>79</td>
<td>94</td>
<td>79</td>
<td>90</td>
<td>79</td>
<td>86</td>
</tr>
<tr>
<td>Laurento, 1997</td>
<td>120</td>
<td>DS-TEE</td>
<td>Greater than or equal to 70%</td>
<td>84</td>
<td>82</td>
<td>...</td>
<td>...</td>
<td>100</td>
<td>100</td>
<td>94</td>
<td>95</td>
</tr>
<tr>
<td>Ethely, 1997</td>
<td>116</td>
<td>DASE</td>
<td>Greater than or equal to 50%</td>
<td>96</td>
<td>76</td>
<td>64</td>
<td>92</td>
<td>94</td>
<td>96</td>
<td>68</td>
<td>82</td>
</tr>
<tr>
<td>Ho, 1998</td>
<td>117</td>
<td>DSE</td>
<td>Greater than or equal to 50%</td>
<td>51</td>
<td>93</td>
<td>89</td>
<td>95</td>
<td>82</td>
<td>87</td>
<td>90</td>
<td>88</td>
</tr>
</tbody>
</table>

Studies accounting for referral bias

<table>
<thead>
<tr>
<th>Lewis, 1999 (by design)</th>
<th>121</th>
<th>DSE</th>
<th>Greater than or equal to 50%</th>
<th>92</th>
<th>40</th>
<th>40</th>
<th>60*</th>
<th>81</th>
<th>71</th>
<th>84</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roger, 1997 (by adjustment)</td>
<td>87</td>
<td>TME</td>
<td>Greater than or equal to 50%</td>
<td>1714</td>
<td>32</td>
<td>24</td>
<td>31 (2V)</td>
<td>43 (3V)</td>
<td>86</td>
<td>66</td>
<td></td>
</tr>
</tbody>
</table>

CAD indicates coronary artery disease; Ref., reference number; Protocol, exercise or pharmacological protocol used in conjunction with transthoracic echocardiographic imaging; Significant CAD, % coronary luminal diameter narrowing, documented by selective coronary angiography, considered to represent significant CAD; Total Pts, number of women in each series undergoing selective coronary angiography in whom stress echocardiographic studies and wall motion analysis were also performed; Sens 1-VD, test results positive in patients with single-vessel CAD; Sens MVD, test results positive in patients with multivessel CAD; PPV, positive predictive value (likelihood of angiographically significant CAD in patients with inducible wall motion abnormalities by stress echocardiography); NPV, negative predictive value (likelihood of absence of angiographically significant CAD in patients without inducible wall motion abnormalities by stress echocardiography); DIP, dipyridamole stress echocardiography; TME, treadmill stress echocardiography; UBE, upright bicycle stress echocardiography; DASE, dobutamine/atropine stress echocardiography; DS-TEE, dobutamine stress transesophageal echocardiography; and DSE, dobutamine stress echocardiography.

A new or worsening regional wall motion abnormality induced by stress generally was considered a “positive” result.

*Including all patients.
†Excluding patients with indeterminate studies.

Section XIV. Two-Dimensional Echocardiography in the Adult Patient With Congenital Heart Disease

Recommendations for Echocardiography in the Adult Patient With Congenital Heart Disease

Comment: A section has been added on the accuracy of echocardiography to allow surgery to proceed without catheterization in some congenital heart lesions. Echocardiography is useful in the performance of interventional therapeutic procedures.165–177

Class I

5. Patients with known congenital heart disease in whom it is important that pulmonary artery pressure be monitored (eg, patients with hemodynamically important, moderate, or large ventricular septal defects, atrial septal defects, single ventricle, or any of the above with an additional risk factor for pulmonary hypertension).

6. Periodic echocardiography in patients with repaired (or palliated) congenital heart disease with the following: change in clinical condition or clinical suspicion of residual defects, obstruction of conduits and baffles, or LV or RV function that must be monitored, or when there is a possibility of hemodynamic progression or a history of pulmonary hypertension.

8. Identification of site of origin and initial course of coronary arteries (TEE may be indicated in some patients).*

*TEE may be necessary to image both coronary origins in adults.

Section XV-E. Acquired Cardiovascular Disease in the Neonate

Recommendations for Neonatal Echocardiography

Comment: Only minor changes have been made in this section. Two new Class I recommendations and one Class III recommendation have been added.177–194 One recommendation has moved from Class IIb to Class IIa. Class I recommendations have been renumbered for clarity.

Class I

12. Re-evaluation after initiation or termination of medical therapy for pulmonary artery hypertension.
13. Re-evaluation during initiation or withdrawal of extracorporeal cardiopulmonary support.

Class IIa

3. Presence of a syndrome associated with a high incidence of congenital heart disease for which there are no abnormal cardiac findings and no urgency of management decisions.
Section XV-H. Acquired Cardiovascular Disease

Recommendations for Echocardiography in Pediatric Acquired Cardiovascular Disease
Comment: The leading cause of death after the first posttransplant year is transplant-related CAD. There is evidence that stress echocardiography identifies subclinical ischemia.204–213

Class I

3. Baseline and re-evaluation examinations of patients receiving cardiotoxic chemotherapy agents.
5. Patients with severe renal disease and/or systemic hypertension.

Class III

1. Routine screening echocardiogram for participation in competitive sports in patients with normal cardiovascular examination.

Section XV-I. Pediatric Acquired Cardiopulmonary Disease

Recommendations for Echocardiography in Pediatric Acquired Cardiopulmonary Disease
Comment: Echocardiography provides documentation of pulmonary artery hypertension and estimation of severity by the presence of RV dilation and/or hypertrophy, the presence of tricuspid or pulmonic valvular regurgitation, and Doppler estimation of RV systolic pressure.214,215

Class I

2. Re-evaluation after surgical intervention or initiation of oral and/or parenteral vasodilator therapy for pulmonary artery hypertension.
3. Re-evaluation during withdrawal of extracorporeal cardiopulmonary support.

Section XV-K. Transesophageal Echocardiography

Recommendations for TEE in Pediatric Patients
Comment: TEE has become particularly helpful in guiding placement of catheter-deployed devices used in closing atrial septal defects. It is essential in ensuring proper positioning of the device in the defect and assessing for residual shunts and abnormal device occlusion of venous inflow into the atria or encroachment on the atroventricular valves. Likewise, placement of catheters for radiofrequency ablation of arrhythmogenic pathways can be facilitated by TEE when there are intracardiac abnormalities.216–222

Class I

2. Monitoring and guidance during cardiothoracic surgical procedures.
8. Patients with right atrial to pulmonary artery Fontan connection, for identification of atrial thrombus.

Class IIa

1. Patients with lateral tunnel Fontan palliation.
Section XVI. Intraoperative Echocardiography

Recommendations for Intraoperative Echocardiography

Comment: This section is new. In 1996, a task force of the American Society of Anesthesiologists/Society of Cardiovascular Anesthesiologists (ASA/SCA) published practice guidelines for perioperative TEE. The guidelines were evidence based and focused on the effectiveness of perioperative TEE in improving clinical outcomes. A literature search conducted at that time retrieved 1844 articles, of which 588 were considered relevant to the perioperative setting. A more recent literature search identified an additional 118 articles related to the intraoperative use of echocardiography. The current text makes reference only to the latter. However, the indications for intraoperative echocardiography that are provided in these guidelines are based on both the initial ASA/SCA guidelines and the newer information.

For a detailed discussion of this topic, please see the full-text version of the guidelines posted on the ACC, AHA, and American Society of Echocardiography (ASE) World Wide Web sites.

Class I

1. Evaluation of acute, persistent, and life-threatening hemodynamic disturbances in which ventricular function and its determinants are uncertain and have not responded to treatment.
2. Surgical repair of valvular lesions, hypertrophic obstructive cardiomyopathy, and aortic dissection with possible aortic valve involvement.
3. Evaluation of complex valve replacements requiring homografts or coronary reimplantation, such as the Ross procedure.
4. Surgical repair of most congenital heart lesions that require cardiopulmonary bypass.
5. Surgical intervention for endocarditis when preoperative testing was inadequate or extension to perivalvular tissue is suspected.
6. Placement of intracardiac devices and monitoring of their position during port-access and other cardiac surgical interventions.
7. Evaluation of pericardial window procedures in patients with posterior or loculated pericardial effusions.

Class IIA

1. Surgical procedures in patients at increased risk of myocardial ischemia, myocardial infarction, or hemodynamic disturbances.
2. Evaluation of valve replacement, aortic atheromatous disease, the Maze procedure, cardiac aneurysm repair, removal of cardiac tumors, intracardiac thrombectomy, and pulmonary embolectomy.
3. Detection of air emboli during cardiectomy, heart transplant operations, and upright neurosurgical procedures.

Class IIB

1. Evaluation of suspected cardiac trauma, repair of acute thoracic aortic dissection without valvular involvement, and anastomotic sites during heart and/or lung transplantation.
2. Evaluation of regional myocardial function during and after off-pump coronary artery bypass graft procedures.
4. Evaluation of myocardial perfusion, coronary anatomy, or graft patency.
5. Dobutamine stress testing to detect inducible demand ischemia or to predict functional changes after myocardial revascularization.
6. Assessment of residual duct flow after interruption of patent ductus arteriosus.

Class III

1. Surgical repair of uncomplicated secundum atrial septal defect.

References


**KEY WORDS:** ACC/AHA Guidelines | echocardiography | imaging


Circulation. 2003;108:1146-1162
doi: 10.1161/01.CIR.0000073597.57414.A9

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2003 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/108/9/1146

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/