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ACC/AHA Guideline

ACC/AHA/ASE 2003 Guideline Update for the Clinical Application of Echocardiography: Summary Article

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (ACC/AHA/ASE Committee to Update the 1997 Guidelines for the Clinical Application of Echocardiography)

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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

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The ACC/AHA Task Force on Practice Guidelines makes every effort to avoid any actual or potential conflicts of interest that might arise as a result of an outside relationship or personal interest of a member of the writing panel. Specifically, all members of the writing panel are asked to provide disclosure statements of all such relationships that might be perceived as real or potential conflicts of interest. These statements are reviewed by the parent task force, reported orally to all members of the writing panel at the first meeting, and updated as changes occur. The relationship with industry information for the writing committee members is posted on the ACC and AHA World Wide Web sites with the full-length version of the update.

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This document and the full text guideline are available on the World Wide Web sites of the American College of Cardiology (www.acc.org), the American Heart Association (www.americanheart.org), and the American Society of Echocardiography (www.asecho.org). To obtain a single copy of this summary article published in the September 3, 2003, issue of the *Journal of the American College of Cardiology*, the September 2, 2003, issue of *Circulation*, or the October, 2003, issue of the *Journal of the American Society of Echocardiography*, call 1-800-253-4636 or write to the American College of Cardiology Foundation, Resource Center, 9111 Old Georgetown Road, Bethesda, MD 20814-1699, and ask for reprint number 71-0263. To purchase additional reprints: up to 999 copies, call 1-800-611-6083 (US only) or fax 413-665-2671; 1000 or more copies, call 214-706-1466, fax 214-691-6342, or e-mail pubauth@heart.org.

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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 Intervention[1] (available at http://www.acc.org/clinical/guidelines/percutaneous/dirIndex.htm) and the Clinical Expert Consensus Document on intravascular ultrasound[2] (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.[3] 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.[4,5] 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 significant 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), American Heart Association (www.americanheart.org), and American 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 regurgitation 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 staphylococcus bacteremia without a known source.**

Class IIa

1. Evaluation of **persistent nonstaphylococcus** bacteremia 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 information 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.

TABLE 1. Evaluation of Myocardial Viability With DSE in Patients With Chronic CAD and Impaired Systolic LV Function to Detect Hibernating Myocardium

First Author, Year	Ref.	Stress	Total Patients	Criteria	Sensitivity %	Specificity %	PPV %	NPV %	Accuracy %
Marzullo, 1993	13	LD-DSE	14	Imp. WM*	82	92	95	73	85
Cigarroa, 1993	14	LD-DSE	25	Imp. WM†	82	86	82	86	84
Alfieri, 1993	15	LD-DSE	14	Imp. WM*	91	78	92	76	88
La Canna, 1994	16	LD-DSE	33	Imp. WM*	87	82	90	77	85
Charney, 1994	17	LD-DSE	17	Imp. WM*	71	93	92	74	81
Afridi, 1995	18	DSE	20	Imp. WM†	80	90	89	82	85
Perrone-Filardi, 1995	19	LD-DSE	18	Imp. WM*	88	87	91	82	87
Senior, 1995	20	LD-DSE	22	Imp. WM*	87	82	92	73	86
Haque, 1995	21	LD-DSE	26	Imp. WM*	94	80	94	80	91
Arnese, 1995	22	LD-DSE	38	Imp. WM*	74	96	85	93	91
deFilippi, 1995	23	LD-DSE	23	Imp. WM*	97	75	87	93	89
Iliceto, 1996	24	LD-DSE	16	Imp. WM*	71	88	73	87	83
Varga, 1996	25	LD-DSE	19	Imp. WM*	74	94	93	78	84
Baer, 1996	26	LD-DSE	42	Imp. WM†	92	88	92	88	90
Vanoverschelde, 1996	27	LD-DSE	73	Imp. WM†	88	77	84	82	84
Gerber, 1996	28	LD-DSE	39	Imp. WM*	71	87	89	65	77
Bax, 1996	29	LD-DSE	17	Imp. WM*	85	63	49	91	70
Perrone-Filardi, 1996	30	LD-DSE	18	Imp. WM*	79	83	92	65	81
Qureshi, 1997	31	LD-DSE	34	Imp. WM*	86	68	51	92	73
Qureshi, 1997	31	DSE	34	Biphasic resp*	74	89	72	89	85
Nagueh, 1997	32	LD-DSE	18	Imp. WM*	91	66	61	93	75
Nagueh, 1997	32	DSE	18	Biphasic resp*	68	83	70	82	77
Furukawa, 1997	33	LD-DSE	53	Imp. WM*	79	72	76	75	76
Cornel, 1997	34	LD-DSE	30	Imp. WM*	89	82	74	93	85

DSE indicates dobutamine stress echocardiography (dobutamine infused at both low and high doses); CAD, coronary artery disease; LV, left ventricular; Ref. reference number; Stress, DSE protocol used for pharmacological stress; Total Patients, number of patients with chronic CAD and LV dysfunction in whom DSE studies were analyzed; Criteria, findings on DSE considered as a "positive" indicator of viability; PPV, positive predictive value (likelihood that presence of viability by DSE is indicative of subsequent functional recovery after revascularization); NPV, negative predictive value (likelihood that absence of viability by DSE is indicative of lack of functional recovery after revascularization); LD-DSE, low dose DSE; Imp. WM, improved wall motion during dobutamine stress in a previously asynergic segment; and Biphasic resp, biphasic response, defined as improvement in wall motion during LD-DSE followed by worsening at high dose.

In these patients, percutaneous or surgical revascularization was performed after DSE testing. Those patients demonstrating improved wall motion on follow-up resting transthoracic echocardiography were considered to have had impaired LV function due to hibernating myocardium, whereas those demonstrating no improvement despite revascularization were considered to have had impaired LV function due to necrotic myocardium.

*Wall motion analyzed by segment; †wall motion analyzed by patient.

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*

First Author, Year	Reference	Stress	Total Pts	Avg F/U, mo	Events	Annualized Event Rate, %		
						Ischemia	No Ischemia	Normal
Chronic ischemic heart disease								
Picano, 1989	35	DIP†	539	36	D, MI	2.3	0.7	...
Sawada, 1990	36	NL TME	148	28.4	D, MI	...	...	0.6
Mazeika, 1993	37	DSE†	51	24	D, MI, UA	16	3.8	...
Krivokapich, 1993	38	TME†	360	≈12	D, MI	10.8	3.1	...
Afridi, 1994	39	DSE†	77	10	D, MI	48	8.9	3
Poldermans, 1994	40	DSE†	430	17	D, MI	6.6	3.4	...
Coletta, 1995	41	DIP†	268	16	D, MI	17.9	1.4	...
Kamaran, 1995	42	DSE†	210	8	D, MI	69	1	...
Williams, 1996	43	DSE†	108	16	D, MI, Re	32.6	7.3	...
Anthopoulos, 1996	44	DSE†	120	14	D, MI	13.6	0	...
Marcovitz, 1996	45	DSE†	291	15	D, MI	12.8	8.2	1.1
Heupler, 1997	46	TME†	508w	41	D, MI, Re	9.2	1.3	...
McCully, 1998	47	NL TME	1325	23	D, MI	...	...	0.5
Chuah, 1998	48	DSE‡	860	24	D, MI	6.9	6.3	1.9
Cortigiani, 1998	49	DSE or DIP†	456w	32	D, MI	2.9	0.3	...
Davar, 1999	50	NL DSE	72w	13	D, MI	...	...	0
After cardiac transplantation								
Ciliberto, 1993	51	DIP‡	80	9.8	D, MI, CHF	26.2	0	...
Lewis, 1997	52	DSE‡	63	8	D, MI, CHF	28.6	3.6	...

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 follow-up only in subjects 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

First Author, Year	Ref.	Stress	Total Pts	Avg F/U, mo	Adverse Events	Annualized Event Rate, %		
						Viable, +Re	Viable, −Re	Not Viable
Meluzin, 1998	53	LD-DSE	133	20	Death, MI	4.1	...	9.5
Afridi, 1998	54	LD-DSE	353	18	Death	4	20	19

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.

Prognostic value of contractile reserve detected with LD-DSE in patients with chronic ischemic heart disease and impaired left ventricular systolic function. The annualized rate of death or MI is tabulated in patients with viable myocardium by LD-DSE depending on whether they did or did not undergo revascularization and also in those patients without viable myocardium.

TABLE 4. Diagnostic Accuracy of Exercise Echocardiography in Detecting Angiographically Proved CAD (Without Correction for Referral Bias)

First Author, Year	Ref.	Exercise	Significant CAD	Total Pts	Sensitivity, %	Sens 1-VD, %	Sens MVD, %	Specificity, %	PPV, %	NPV, %	Accuracy, %
Limacher, 1983	55	TME	Greater than 50%	73	91	64	98	88	96	75	90
Armstrong, 1986	56	TME	Greater than or equal to 50%	95	88	...	...	87	97	57	87
Armstrong, 1987	57	TME	Greater than or equal to 50%	123	88	81	93	86	97	61	88
Ryan, 1988	58	TME	Greater than or equal to 50%	64	78	76	80	100	100	73	86
Labovitz, 1989	59	TME	Greater than or equal to 70%	56	76	...	...	100	100	74	86
Sawada, 1989	60	TME or UBE	Greater than or equal to 50%	57	86	88	82	86	86	86	86
Sheikh, 1990	61	TME	Greater than or equal to 50%	34	74	74	...	91	94	63	79
Pozzoli, 1991	62	UBE	Greater than or equal to 50%	75	71	61	94	96	97	64	80
Crouse, 1991	63	TME	Greater than or equal to 50%	228	97	92	100	64	90	87	89
Galanti, 1991	64	UBE	Greater than or equal to 70%	53	93	93	92	96	96	93	94
Marwick, 1992	65	TME	Greater than or equal to 50%	150	84	79	96	86	95	63	85
Quinones, 1992	66	TME	Greater than or equal to 50%	112	74	59	89	88	96	51	78
Salustri, 1992	67	BE	Greater than or equal to 50%	44	87	87	...	85	93	75	86
Amanullah, 1992	68	UBE	Greater than or equal to 50%	27	82	...	...	80	95	50	81
Hecht, 1993	69	SBE	Greater than or equal to 50%	180	93	84	100	86	95	79	91
Ryan, 1993	70	UBE	Greater than or equal to 50%	309	91	86	95	78	90	81	87
Mertes, 1993	71	SBE	Greater than or equal to 50%	79	84	87	89	85	91	75	85
Hoffmann, 1993	72	SBE	Greater than 70%	66	80	79	81	88	95	58	82
Cohen, 1993	73	SBE	Greater than 70%	52	78	63	90	87	94	62	81
Marwick, 1994	74	BE	Greater than 50%	86	88	82	91	80	89	77	85
Roger, 1994	75	TME	Greater than or equal to 50%	150	91	...	...	...	...	...	...
Marangelli, 1994	76	TME	Greater than or equal to 75%	80	89	76	97	91	93	86	90
Beleslin, 1994	77	TME	Greater than or equal to 50%	136	88	88	91	82	97	50	88
Williams, 1994	78	UBE	Greater than 50%	70	88	89	86	84	83	89	86
Roger, 1995	79	TME	Greater than or equal to 50%	127	88	...	...	72	93	60	...
Dagianti, 1995	80	SBE	Greater than 70%	60	76	70	80	94	90	85	87
Marwick, 1995	81	TME or UBE	Greater than or equal to 50%	161	80	75	85	81	71	91	81
Bjornstad, 1995	82	UBE	Greater than or equal to 50%	37	84	78	86	67	93	44	81
Marwick, 1995	83	TME	Greater than 50%	147	71	63	80	91	85	81	82
Tawa, 1996	84	TME	Greater than 70%	45	94	...	...	83	94	83	91
Luotolahti, 1996	85	UBE	Greater than or equal to 50%	118	94	94	93	70	97	50	92
Tian, 1996	86	TME	Greater than 50%	46	88	91	86	93	97	76	89
Roger, 1997	87	TME	Greater than or equal to 50%	340	78	...	...	41	79	40	69

CAD indicates coronary artery disease; Ref., reference number; Exercise, type of exercise testing used in conjunction with transthoracic echocardiographic imaging; 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 exercise 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 disease; PPV, positive predictive value (likelihood of angiographically significant CAD in patients with inducible wall motion abnormalities by exercise echocardiography); NPV, negative predictive value (likelihood of absence of angiographically significant CAD in patients without inducible wall motion abnormalities by exercise echocardiography); TME, treadmill exercise; UBE, upright bicycle ergometry; BE, bicycle ergometry; and SBE, supine bicycle ergometry.

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

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.[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)

Author, Year	Ref.	Protocol	Significant CAD	Total Pts	Sensitivity, %	Sens 1-VD, %	Sens MVD, %	Specificity, %	PPV, %	NPV, %	Accuracy, %
Berthe, 1986	88	DSE 5–40	Greater than or equal to 50%	30	85	...	85	88	85	88	87
Sawada, 1991	89	DSE 2.5–30	Greater than or equal to 50%	55	89	81	100	85	91	81	74
Sawada, 1991	89	DSE 2.5–30	Greater than or equal to 50%	41	81	...	81	87	91	72	87
Previtali, 1991	90	DSE 5–40	Greater than or equal to 70%	35	68	50	92	100	100	44	83
Cohen, 1991	91	DSE 2.5–40	Greater than 70%	70	86	69	94	95	98	72	89
Martin, 1992	92	DSE 10–40	Greater than 50%	34	76	...	...	44	79	40	68
McNeill, 1992	93	DASE 10–40	Greater than or equal to 50%	28	71	...	...	...	...	...	71
Segar, 1992	94	DSE 5–30	Greater than or equal to 50%	88	95	...	...	82	94	86	92
Mazeika, 1992	95	DSE 5–20	Greater than or equal to 70%	50	78	50	92	93	97	62	82
Marcovitz, 1992	96	DSE 5–30	Greater than or equal to 50%	141	96	95	98	66	91	84	89
McNeill, 1992	97	DASE 10–40	Greater than or equal to 50%	80	70	...	...	88	89	67	78
Salustri, 1992	98	DSE 5–40	Greater than or equal to 50%	46	79	...	...	78	85	70	78
Marwick, 1993	99	DSE 5–40	Greater than or equal to 50%	97	85	84	86	82	88	78	84
Forster, 1993	100	DASE 10–40	Greater than 50%	21	75	-	-	89	90	73	81
Gunalp, 1993	101	DSE 5–30	Greater than 50%	27	83	78	89	89	94	73	85
Marwick, 1993	102	DSE 5–40	Greater than or equal to 50%	217	72	66	77	83	89	61	76
Hoffmann, 1993	72	DASE 5–40	Greater than 70%	64	79	78	81	81	93	57	80
Previtali, 1993	103	DSE 5–40	Greater than 50%	80	79	63	91	83	92	61	80
Takeuchi, 1993	104	DSE 5–30	Greater than or equal to 50%	120	85	73	97	93	95	80	88
Cohen, 1993	73	DSE 2.5–40	Greater than 70%	52	86	75	95	87	94	72	87
Ostojic, 1994	105	DSE 5–40	Greater than or equal to 50%	150	75	74	81	79	96	31	75
Marwick, 1994	74	DSE 5–40	Greater than 50%	86	54	36	65	83	86	49	64
Beleslin, 1994	77	DSE 5–40	Greater than or equal to 50%	136	82	82	82	76	96	38	82
Sharp, 1994	106	DSE 5–50	Greater than or equal to 50%	54	83	69	89	71	89	59	80
Pellikka, 1995	107	DSE 5–40	Greater than or equal to 50%	67	98	...	...	65	84	94	87
Ho, 1995	108	DSE 5–40	Greater than or equal to 50%	54	93	100	92	73	93	73	89
Daoud, 1995	109	DSE 5–30	Greater than or equal to 50%	76	92	91	93	73	95	62	89
Dagianti, 1995	80	DSE 5–40	Greater than or equal to 70%	60	72	60	80	97	95	83	87
Pingitore, 1996	110	DASE 5–40	Greater than or equal to 50%	110	84	78	88	89	97	52	85
Schroder, 1996	111	DASE 10–40	Greater than or equal to 50%	46	76	71	90	88	97	44	78
Anthopoulos, 1996	44	DASE 5–40	Greater than or equal to 50%	120	87	74	90	84	94	68	86
Ling, 1996	112	DASE 5–40	Greater than or equal to 50%	183	93	...	...	62	95	54	90
Takeuchi, 1996	113	DASE 5–40	Greater than or equal to 50%	70	75	78	73	92	79	90	87
Minardi, 1997	114	DASE 5–40	Greater than or equal to 50%	47	75	81	67	67	97	15	74
Dionisopoulos, 1997	115	DASE 5–40	Greater than or equal to 50%	288	87	80	91	89	95	71	87
Elhendy, 1997	116	DASE 5–40	Greater than or equal to 50%	306	74	59	83	85	94	50	76
Ho, 1998	117	DSE 5–40	Greater than or equal to 50%	51	93	89	95	82	87	90	88

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)

First Author, Year	Ref.	Protocol	Significant CAD	Total Pts	Sensitivity, %	Sens 1-VD, %	Sens MVD, %	Specificity, %	PPV, %	NPV, %	Accuracy, %
Masini, 1988	118	DIP	Greater than or equal to 70%	83	79	. . .	. . .	93	91	84	87
Sawada, 1989	60	TME or UBE	Greater than or equal to 50%	57	86	88	82	86	86	86	86
Severi, 1994	119	DIP	Greater than or equal to 75%	122	68	. . .	. . .	96	90	86	87
Williams, 1994	78	UBE	Greater than 50%	70	88	89	86	84	83	89	86
Marwick, 1995	81	TME or UBE	Greater than or equal to 50%	161	80	75	85	81	71	87	81
Takeuchi, 1996	113	DASE	Greater than or equal to 50%	70	75	78	73	92	79	90	87
Roger, 1997	87	TME or UBE	Greater than or equal to 50%	96	79	. . .	. . .	37	66	54	63
Dionisopoulos, 1997	115	DASE	Greater than or equal to 50%	101	90	79	94	79	90	79	86
Laurienzo, 1997	120	DS-TEE	Greater than or equal to 70%	84	82	. . .	. . .	100	100	94	95
Elhendy, 1997	116	DASE	Greater than or equal to 50%	96	76	64	92	94	96	68	82
Ho, 1998	117	DSE	Greater than or equal to 50%	51	93	89	95	82	87	90	88
Studies accounting for referral bias											
Lewis, 1999 (by design)	121	DSE	Greater than or equal to 50%	92	40	40	60* 82†	81	71	84	70
Roger, 1997 (by adjustment)	87	TME	Greater than or equal to 50%	1714	32	24	31 (2V) 43 (3V)	86	66		

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.**

Class IIb

1. Moved to Class IIa (see above).

Class III

2. Acrocyanosis with normal upper- and lower-extremity pulsed oximetry oxygen saturations.

Section XV-F. Congenital Cardiovascular Disease in the Infant, Child, and Adolescent

Recommendations for Echocardiography in the Infant, Child, and Adolescent

Comment: There are two new Class I recommendations, which have been renumbered for clarity.[6,195–200]

Class I

5. Selection, placement, patency, and monitoring of endovascular devices, as well as identification of intracardiac or intravascular shunting before, during, and subsequent to interventional cardiac catheterization.
6. Immediate assessment after percutaneous interventional cardiac catheterization procedure.
10. Presence of a syndrome associated with cardiovascular disease and dominant inheritance or multiple affected family members **(eg, Marfan syndrome or Ehlers-Danlos syndrome)**.

Deleted:

Phenotypic findings of Marfan syndrome or Ehlers-Danlos syndrome.
Presence of a syndrome associated with high incidence of congenital heart disease when there are no abnormal cardiac findings.
"Atypical," "nonvasodepressor" syncope without other causes.

Section XV-G. Arrhythmias/Conduction Disturbances

Recommendations for Echocardiography in Pediatric Patients With Arrhythmias/Conduction Disturbances

Comment: Echocardiography is discretionary after radiofrequency catheter ablation. Persistent ventricular dilatation after successful ablation or effective medical control of the heart rate may indicate an arrhythmogenic primary cardiomyopathy.[201–203]

Class IIa

2. Evidence of pre-excitation on ECG **with symptoms**.

Class IIb

3. Examination immediately after radiofrequency ablation.

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 **chemo**therapeutic 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 atrioventricular 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.[223–260]

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 cardiotomy, 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.**
3. **Evaluation of pericardiectomy, pericardial effusions, and pericardial surgery.**
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.**

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