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ACC/AHA PRACTICE GUIDELINES

ACC/AHA Guidelines for the Clinical Application of Echocardiography: Executive Summary

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Clinical Application of Echocardiography)

Developed in Collaboration With the American Society of Echocardiography

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Executive Summary and Recommendations

I. Introduction

This document is a revision of the "Guidelines for the Clinical Application of Echocardiography" published in December 1990. This executive summary and recommendations appears in the March 15, 1997, issue of the *Journal of the American College of Cardiology.* The guidelines in their entirety, including the ACC/AHA Class I, II, and III recommendations, are published in the March 18, 1997, issue of *Circulation.* Reprints of both the full text and the executive summary and recommendations are available from both organizations.

With advances in technology, the development of Doppler echocardiography, color Doppler, stress Doppler echocardiography, and transesophageal echocardiography (TEE), there has been an increase in the clinical application of echocardiography in the diagnosis of all forms of heart disease. The Committee on Clinical Application of Echocardiography, which is composed of experts in the field of echocardiography, senior clinical cardiologists, and generalists, conducted a systematic search of the literature and reviewed the indications

"ACC/AHA Guidelines for the Clinical Application of Echocardiography" was approved by the American College of Cardiology Board of Trustees in October 1996 and by the American Heart Association Science Advisory and Coordinating Committee in December 1996. These guidelines have been endorsed by the American Society of Echocardiography.

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A single reprint of the executive summary and recommendations is available by calling 800-253-4636 (US only) or by writing the American College of Cardiology, Educational Services, 9111 Old Georgetown Road, Bethesda, MD 20814-1699. Ask for reprint No. 71-0103. To obtain a reprint of the full text published in the March 18 issue of *Circulation,* ask for reprint No. 71-0102. To purchase additional reprints (specify version and reprint number): up to 999 copies, call 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@amhrt.org.

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for the use of Doppler echocardiography in the diagnosis and evaluation of cardiovascular disease. Through a Medline search the committee obtained and considered more than 3000 references from 1990 to 1995. The guidelines include recommendations for the use of Doppler echocardiography in both specific cardiovascular diseases and in the evaluation of patients with frequently observed cardiovascular symptoms and signs such as dyspnea, chest discomfort, and cardiac murmurs.

The recommendations concerning the use of Doppler echocardiography follow the classification system used in other 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.

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

Class 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 cannot have the same direct effect on patient survival or recovery. Furthermore, there are no double-blind randomized studies to prove the usefulness of the technique in a given situation. When studies assessing the sensitivity, specificity, and diagnostic accuracy of the technique were found in the literature, the strength of that evidence was weighed by the committee and designated Class I, II, or III.

With a noninvasive diagnostic study that has no known complications, the potential exists for repeating the study unnecessarily. It is easier to state when a repeat echocardiogram is not needed than when and how often it should be repeated, because no studies in the literature address this question. An attempt by expert consensus has been made to indicate when and whether a study should be repeated.

II. Murmurs and Valvular Heart Disease

The basic indispensable evaluation of the patient with suspected valvular disease remains the cardiovascular history and physical examination. Echocardiography is extremely useful, however, in assessing the patient with a murmur. In the evaluation of heart murmurs, an echocardiogram is used to

- Define the primary lesion, its etiology, and estimated severity.
- Define the hemodynamics.
- Detect coexisting abnormalities.
- Detect lesions secondary to the primary lesion.
- Evaluate cardiac size and function.
- Establish a reference point for future observation.
- Reevaluate the patient after an intervention.

Indications for Echocardiography in the Evaluation of Heart Murmurs	*Class*
1. A murmur in a patient with cardiorespiratory symptoms.	**I**
2. A murmur in an asymptomatic patient if the clinical features indicate at least a moderate probability that the murmur is reflective of structural heart disease.	**I**
3. A murmur in an asymptomatic patient in whom there is a low probability of heart disease but in whom the diagnosis of heart disease cannot be reasonably excluded by the standard cardiovascular clinical evaluation.	**IIa**
4. In an adult, an asymptomatic heart murmur that has been identified by an experienced observer as functional or innocent.	**III**

Native Valvular Stenosis

Two-dimensional Doppler echocardiography correctly assesses stenotic lesions of both native and prosthetic valves. When the acoustic windows for transthoracic echocardiography (TTE) are limited, TEE is effective.

Indications for Echocardiography in Valvular Stenosis	*Class*
1. Diagnosis; assessment of hemodynamic severity.	**I**
2. Assessment of left ventricular (LV) and right ventricular (RV) size, function, and/or hemodynamics.	**I**
3. Reevaluation of patients with known valvular stenosis with changing symptoms or signs.	**I**
4. Assessment of changes in hemodynamic severity and ventricular compensation in patients with known valvular stenosis during pregnancy.	**I**
5. Reevaluation of asymptomatic patients with severe stenosis.	**I**
6. Assessment of the hemodynamic significance of mild to moderate valvular stenosis by stress Doppler echocardiography.	**IIa**
7. Reevaluation of patients with mild to moderate aortic stenosis with LV dysfunction or hypertrophy even without clinical symptoms.	**IIa**
8. Reevaluation of patients with mild to moderate aortic valvular stenosis with stable signs and symptoms.	**IIb**
9. Routine reevaluation of asymptomatic adult patients with mild aortic stenosis having stable physical signs and normal LV size and function.	**III**

10. Routine reevaluation of asymptomatic patients with mild to moderate mitral stenosis and stable physical signs.	**III**

(See also "Indications for Echocardiography in Interventions for Valvular Heart Disease and Prosthetic Valves.")

Native Valvular Regurgitation

Doppler echocardiography is the most sensitive technique for detection of native valvular regurgitation. However, care must be taken to distinguish physiological phenomena from pathological lesions. Although significant valvular regurgitation can be silent on auscultation, it is most often seen in symptomatic, even hemodynamically unstable patients. Silent valvular regurgitation discovered only by Doppler echocardiography is usually found in normal subjects and if trivial is considered to be within the range of normal. It is therefore not indicated to use echocardiography "to exclude valvular heart disease" in an asymptomatic patient with a normal physical examination.

Because there is no accepted gold standard for assessing the severity of valvular regurgitation—not even angiocardiography—it is difficult to assess precisely the severity of the regurgitant lesion. Nonetheless, a number of Doppler echocardiography findings are useful in assessing severity.

Echocardiography is the best choice for following patients with hemodynamically significant valvular disease to determine the timing of operative intervention. TEE has been valuable in assessing the possibility of valve repair versus replacement in mitral regurgitation.

The question of whether or how often to repeat the echocardiogram depends on the severity of the lesion. In general, in the absence of a change in clinical condition, repeat echocardiography is not indicated in lesions of mild hemodynamic severity. In patients with moderate to severe hemodynamic valvular regurgitation, Doppler echocardiography should be repeated if there is a change in the physical condition. Without a change it is appropriate to repeat the echocardiogram once a year.

Indications for Echocardiography in Native Valvular Regurgitation	*Class*
1. Diagnosis; assessment of hemodynamic severity.	**I**
2. Initial assessment and reevaluation (when indicated) of LV and RV size, function, and/or hemodynamics.	**I**
3. Reevaluation of patients with mild to moderate valvular regurgitation with changing symptoms.	**I**
4. Reevaluation of asymptomatic patients with severe regurgitation.	**I**
5. Assessment of changes in hemodynamic severity and ventricular compensation in patients with known valvular regurgitation during pregnancy.	**I**
6. Reevaluation of patients with mild to moderate regurgitation with ventricular dilation without clinical symptoms.	**I**
7. Assessment of the effects of medical therapy on the severity of regurgitation and ventricular compensation and function.	**I**
8. Reevaluation of patients with mild to moderate mitral regurgitation without chamber dilation and without clinical symptoms.	**IIb**
9. Reevaluation of patients with moderate aortic regurgitation without chamber dilation and without clinical symptoms.	**IIb**
10. Routine reevaluation in asymptomatic patients with mild valvular regurgitation having stable physical signs and normal LV size and function.	**III**

(See also "Indications for Echocardiography in Interventions for Valvular Heart Disease and Prosthetic Valves.")

Mitral Valve Prolapse

The physical examination remains the optimal method for detecting the presence of mitral valve prolapse (MVP), and in the absence of physical findings in the supine, sitting, and standing positions, echocardiography is of little use as the primary means of diagnosing MVP unless there is supportive clinical evidence of structural heart disease or a family history of myxomatous valve disease. In patients with a nonejection click and/or murmur, an echocardiogram is useful for diagnosis and risk stratification, particularly by identifying leaflet thickening and LV dilatation.

Indications for Echocardiography in Mitral Valve Prolapse	*Class*
1. Diagnosis; assessment of hemodynamic severity, leaflet morphology, and/or ventricular compensation in patients with physical signs of MVP.	**I**
2. To exclude MVP in patients who have been diagnosed but without clinical evidence to support the diagnosis.	**IIa**
3. To exclude MVP in patients with first-degree relatives with known myxomatous valve disease.	**IIa**
4. Risk stratification in patients with physical signs of MVP or known MVP.	**IIa**
5. Exclusion of MVP in patients with ill-defined symptoms in the absence of a constellation of clinical symptoms or physical findings suggestive of MVP or a positive family history.	**III**
6. Routine repetition of echocardiography in patients with MVP with no or mild regurgitation and no changes in clinical signs or symptoms.	**III**

Infective Endocarditis in Native Valves

Echocardiography is useful for detection and characterization of the hemodynamic and pathological consequences of infection, including valvular vegetations, regurgitant lesions, ventricular function, presence of ring abscesses, shunts, and ruptured chordae. TEE is more sensitive in detecting vegetations than TTE, but because of false-positive studies associated with rheumatic or myxomatous valves, Lambl's excrescences, etc, echocardiography does not supplant clinical and microbiological diagnosis. Echocardiography is useful when there is a strong clinical suspicion of infective endocarditis with negative blood cultures or in patients with persistent unexplained bacteremia.

Controversy remains as to whether echocardiographic characteristics of vegetations are useful in risk stratification; ie, predicting complications and mortality in the patient with infective endocarditis. In general, TEE is not indicated as the initial examination in the diagnosis of native valve infective endocarditis. TEE is indicated where TTE does not adequately visualize the valve or answer hemodynamic questions.

Indications for Echocardiography in Infective Endocarditis: Native Valves	*Class*
1. [illegible]tion and characterization of valvular [illegible] their hemodynamic severity, and/or [illegible]ular compensation.*	I
2. [illegible]n of vegetations and characterizations of lesions in patients with congenital heart disease suspected of having infective endocarditis.	I
3. Detection of associated abnormalities (eg, abscesses, shunts, etc).*	I
4. Reevaluation studies in complex endocarditis (eg, virulent organism, severe hemodynamic lesion, aortic valve involvement, persistent fever or bacteremia, clinical change, or symptomatic deterioration).	I
5. Evaluation of patients with high clinical suspicion of culture-negative endocarditis.*	I
6. Evaluation of bacteremia without a known source.*	IIa
7. Risk stratification in established endocarditis.*	IIa
8. Routine reevaluation in uncomplicated endocarditis during antibiotic therapy.	IIb
9. Evaluation of fever and nonpathological murmur without evidence of bacteremia.	III

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

Prosthetic Valves

Prosthetic valves are subject to valvular degeneration, development of valvular regurgitation and stenosis, thrombus, and endocarditis. It is valuable to have a baseline postoperative study for further comparison if a suspected problem arises, especially for evaluation of changes in ventricular function and hemodynamics after recovery from surgery.

Indications for Echocardiography in Interventions for Valvular Heart Disease and Prosthetic Valves	*Class*
1. Assessment of the timing of valvular intervention based on ventricular compensation, function, and/or severity of primary and secondary lesions.	I
2. Selection of alternative therapies for mitral valve disease (such as balloon valvuloplasty, operative valve repair, valve replacement).*	I
3. Use of echocardiography (especially TEE) in performing interventional techniques (eg, balloon valvotomy) for valvular disease.	I
4. Postintervention baseline studies for valve function (early) and ventricular remodeling (late).	I
5. Reevaluation of patients with valve replacement with changing clinical signs and symptoms; suspected prosthetic dysfunction (stenosis, regurgitation) or thrombosis.*	I
6. Routine reevaluation study after baseline studies of patients with valve replacements with mild to moderate ventricular dysfunction without changing clinical signs or symptoms.	IIa
7. Routine reevaluation at the time of increased failure rate of a bioprosthesis without clinical evidence of prosthetic dysfunction.	IIb
8. Routine reevaluation of patients with valve replacements without suspicion of valvular dysfunction and unchanged clinical signs and symptoms.	III
9. Patients whose clinical status precludes therapeutic interventions.	III

*TEE may provide incremental value in addition to information obtained by TTE.

Indications for Echocardiography in Infective Endocarditis: Prosthetic Valves	*Class*
1. Detection and characterization of valvular lesions, their hemodynamic severity, and/or ventricular compensation.*	I
2. Detection of associated abnormalities (eg, abscesses, shunts, etc).*	I
3. Reevaluation in complex endocarditis (eg, virulent organism, severe hemodynamic lesion, aortic valve involvement, persistent fever or bacteremia, clinical change, or symptomatic deterioration).*	I
4. Evaluation of suspected endocarditis and negative cultures.*	I

5. Evaluation of bacteremia without known source.*	**I**
6. Evaluation of persistent fever without evidence of bacteremia or new murmur.*	**IIa**
7. Routine reevaluation in uncomplicated endocarditis during antibiotic therapy.*	**IIb**
8. Evaluation of transient fever without evidence of bacteremia or new murmur.	**III**

***TEE may provide incremental value in addition to that obtained by TTE.**

III. Chest Pain

Chest pain can result from cardiac and noncardiac causes. The most common clinical cardiac disorder presenting as chest pain is myocardial ischemia from coronary artery disease. Other cardiovascular disorders such as pericarditis, dissection of the aorta, and hypertrophic cardiomyopathy produce echocardiographic findings that distinguish them from ischemic heart disease and are described elsewhere in these guidelines. The role of echocardiography has increased over the last 5 years where the character of chest pain or its association with risk factors raises concern about coronary artery disease as the cause. Echocardiography can confirm the presence of wall motion abnormalities, which suggest myocardial ischemia and/or prior infarction, but does not always distinguish among these other possible cardiovascular disorders. In a patient with persistent chest pain, normal wall motion makes acute transmural myocardial infarction less likely.

Indications for Echocardiography in Patients With Chest Pain	*Class*
1. Diagnosis of underlying cardiac disease in patients with chest pain and clinical evidence of valvular, pericardial, or primary myocardial disease (see sections II, IV through VI, VIII, and IX).	**I**
2. Evaluation of chest pain in patients with suspected acute myocardial ischemia, when baseline ECG is nondiagnostic and when study can be obtained during pain or soon after its abatement (see section IV).	**I**
3. Evaluation of chest pain in patients with suspected aortic dissection (see section VIII).	**I**
4. Chest pain in patients with severe hemodynamic instability (see section XIII).	**I**
5. Evaluation of chest pain for which a noncardiac etiology is apparent.	**III**
6. Diagnosis of chest pain in a patient with electrocardiographic changes diagnostic of myocardial ischemia/infarction.	**III**

IV. Ischemic Heart Disease

Echocardiography is a powerful tool for diagnosing the presence of coronary artery disease, assessing the amount of myocardium involved, and reaching a prognosis. Echocardiography can identify mechanical complications of acute myocardial infarction and differentiate causes of decreased cardiac output and blood pressure, such as extensive LV infarction versus hypovolemia, thus guiding therapy. Stress echocardiography by either exercise or pharmacological stress testing can be used in detection of the presence, location, and severity of inducible myocardial ischemia as well as for risk stratification and prognosis.

Acute Ischemic Syndromes (Acute Myocardial Infarction and Unstable Angina)

Echocardiography is most helpful in the diagnosis of acute ischemic syndromes when the clinical history and electrocardiographic findings are nondiagnostic. Segmental LV wall motion abnormalities are characteristic of myocardial infarction. However, regional wall motion abnormalities are seen in transient myocardial ischemia and chronic ischemia (hibernating myocardium) as well as scar tissue. Segmental wall motion abnormalities are also seen in myocarditis and cardiomyopathy. In patients with prolonged chest pain, segmental LV wall abnormalities predict a high likelihood of acute myocardial infarction. In such patients the absence of segmental wall abnormalities or the presence of diffuse wall motion abnormalities has a high negative predictive value. Acute ischemia cannot be distinguished from acute myocardial necrosis. In patients with unstable angina, atypical clinical history, and a normal or nonspecific ECG, an echocardiogram recorded during chest pain may demonstrate reversible segmental wall abnormalities and confirm the diagnosis of unstable angina.

Echocardiography, performed at the bedside if necessary, can evaluate all complications of an acute myocardial infarction, such as acute mitral regurgitation, free wall rupture, ventricular septal rupture, intracardiac thrombosis, RV infarction, LV aneurysm formation, and pericardial effusion.

By aiding in the early identification of acute myocardial infarction, its effect on LV function, and its complications, echocardiography may facilitate the prompt initiation of appropriate therapy.

Indications for Echocardiography in the Diagnosis of Acute Myocardial Ischemic Syndromes	*Class*
1. Diagnosis of suspected acute ischemia or infarction not evident by standard means.	**I**
2. Measurement of baseline LV function.	**I**
3. Patients with inferior myocardial infarction and bedside evidence suggesting possible RV infarction.	**I**
4. Assessment of mechanical complications and mural thrombus.*	**I**
5. Identification of location/severity of disease in patients with ongoing ischemia.	**IIa**
6. Diagnosis of acute myocardial infarction already evident by standard means.	**III**

***TEE is indicated when TTE studies are not diagnostic.**

Predischarge Evaluation Using Stress Echocardiography

Graded intravenous dobutamine stress echocardiography can be helpful in assessing myocardial viability and distinguish nonviable myocardium from stunned myocardium when performed 2 to 10 days after an acute myocardial infarction. Stunned and hibernating myocardium can respond to inotropic stimulation, and this response distinguishes viable from infarcted myocardium. Myocardial segments with initial improvement during low-dose dobutamine infusion but deterioration of function with higher doses are supplied by arteries with significant stenoses. Augmentation of systolic wall thickening with higher doses of dobutamine denotes preserved viability and implies lack of critical stenosis in the infarct-related artery.

Few late long-term event rates have been studied by predischarge stress echocardiography after acute myocardial infarction both in those who have and those who have not had thrombolysis or other reperfusion therapy. Nevertheless, when patients cannot exercise for a variety of reasons, pharmacological stress echocardiography is a valuable alternative for evaluation of residual myocardium at risk.

In patients with unstable angina and an ECG that is normal or shows nonspecific changes, echocardiography can reveal reversible segmental wall motion abnormalities during pain that are characteristic of transient ischemia and can also show the coronary territory involved and the size of the area at risk.

Indications for Echocardiography in Risk Assessment, Prognosis, and Assessment of Therapy in Acute Myocardial Ischemic Syndromes	*Class*
1. Assessment of infarct size and/or extent of jeopardized myocardium.	**I**
2. In-hospital assessment of ventricular function when the results are used to guide therapy.	
3. In-hospital or early postdischarge assessment of the presence/extent of inducible ischemia whenever baseline abnormalities are expected to compromise electrocardiographic interpretation.*	**I**
4. In-hospital or early postdischarge assessment of the presence/extent of inducible ischemia in the absence of baseline abnormalities expected to compromise ECG interpretation.*	**IIa**
5. Assessment of myocardial viability when required to define potential efficacy of revascularization.†	**IIa**
6. Reevaluation of ventricular function during recovery when results are used to guide therapy.	**IIa**
7. Assessment of ventricular function after revascularization.	**IIa**
8. Assessment of long-term prognosis (≥2 years after acute myocardial infarction).	**IIb**
9. Routine reevaluation in the absence of any change in clinical status.	**III**

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

Chronic Ischemic Heart Disease

In patients with chronic ischemic heart disease, echocardiography is useful in diagnosis, risk stratification, and clinical management decisions. Echocardiographic imaging and Doppler techniques can assess LV systolic function, the most important determinant of prognosis, as well as diastolic function of the left ventricle. Resting echocardiography can detect and estimate the severity of long-term structural and functional alterations seen in patients with coronary artery disease such as mitral regurgitation or LV aneurysm and in differentiating true aneurysm from false.

Stress echocardiography by either exercise or pharmacological challenge (using vasodilators or dobutamine) is both sensitive and specific for detecting inducible myocardial ischemia in patients with intermediate to high pretest probability of coronary artery disease. Dobutamine stress echocardiography has a higher sensitivity than vasodilator stress echocardiography for detecting coronary artery stenosis. Stress echocardiography, as with other noninvasive methods, has a higher sensitivity in patients with multivessel disease than in patients with one-vessel disease, in patients with prior myocardial infarction, and in those with >70% stenosis compared with lesser degrees of coronary obstruction. In patients with moderate to high clinical suspicion of coronary artery disease, stress echocardiography, like other noninvasive techniques, is appropriate when standard exercise ECG testing is likely to be nondiagnostic, eg, in patients with resting ST-T wave changes, left bundle branch block, ventricular paced rhythms, LV hypertrophy, and taking digitalis, etc. Stress echocardiography is not recommended for screening asymptomatic patients for the presence of coronary artery disease because of the low pretest likelihood of disease.

Indications for Echocardiography in Diagnosis and Prognosis of Chronic Ischemic Heart Disease	*Class*
1. Diagnosis of myocardial ischemia in symptomatic individuals.*	**I**
2. Assessment of global ventricular function at rest.	**I**
3. Assessment of myocardial viability (hibernating myocardium) for planning revascularization.†	**I**
4. Assessment of functional significance of coronary lesions (if not already known) in planning percutaneous transluminal coronary angioplasty.*	**I**
5. Diagnosis of myocardial ischemia in selected patients with an intermediate or high pretest likelihood of coronary artery disease.*	**IIb**
6. Assessment of an asymptomatic patient with positive results from a screening treadmill test.	**IIb**
7. Assessment of global ventricular function with exercise.*	**IIb**
8. Screening of asymptomatic persons with a low likelihood of coronary artery disease.	**III**
9. Routine periodic reassessment of stable patients for whom no change in therapy is contemplated.	**III**

JACC Vol. 29, No. 4
March 15, 1997:862–79

10. Routine substitution for treadmill exercise testing in patients for whom ECG analysis is expected to suffice.	**III**

***Exercise or pharmacological stress echocardiogram.**
†Dobutamine stress echocardiogram.
Other: **Risk stratification before noncardiac surgery. (See Eagle KA, Brundage BH, Chaitman BR, et al. ACC/AHA guidelines for perioperative cardiovascular evaluation for noncardiac surgery. J Am Coll Cardiol 1996;27:910–48.)**

Myocardial Viability in Chronic Coronary Artery Disease

In patients with chronic coronary artery disease, myocardial contractile function can be impaired because of irreversible necrosis or scar tissue or as a result of "hibernating" myocardium that can improve with revascularization. Improvement of segmental function during dobutamine stress echocardiography indicates contractile reserve and viability and predicts the likelihood of improved ventricular function after revascularization. The lack of contractile reserve during dobutamine infusion denotes a low likelihood of improvement after revascularization. To detect hibernating myocardium in patients with chronic LV dysfunction, larger studies using dobutamine stress echocardiography are needed. Patients would then undergo revascularization to confirm the predictive value of test results.

Echocardiographic Assessment Before and After Revascularization

Echocardiography can be helpful in planning for revascularization procedures by demonstrating the functional significance of a given coronary stenosis. This is especially important in determining the need for catheter-based revascularization. Stress echocardiography is useful for detecting restenosis in patients who become symptomatic after catheter revascularization and can be used when standard exercise tests are not possible because of deconditioning, physical disability, or difficulty interpreting the ECG. After surgical or catheter revascularization, routine follow-up testing is generally not necessary in the asymptomatic patient.

Indications for Echocardiography in Assessment of Interventions in Chronic Ischemic Heart Disease	*Class*
1. Assessment of LV function when needed to guide institution and modification of drug therapy in patients with known or suspected LV dysfunction.	**I**
2. Assessment for restenosis after revascularization in patients with atypical recurrent symptoms.*	**I**
3. Assessment for restenosis after revascularization in patients with typical recurrent symptoms.*	**IIa**
4. Routine assessment of asymptomatic patients after revascularization.	**III**

***Exercise or pharmacological stress echocardiography.**

V. Cardiomyopathy and Assessment of Left Ventricular Function: Echocardiographic Parameters

Left Ventricular Size, Wall Thickness, Mass, and Systolic Function

Evaluation of LV systolic function is among the most common reasons for requesting echocardiography. LV shortening fraction, systolic and diastolic volumes, and LV mass can be accurately assessed by two-dimensional echocardiography. Septal and posterior LV thicknesses can be accurately measured by M-mode echocardiography. There is extensive and excellent support for these measurements in the literature.

LV ejection fraction can be assessed with two-dimensional echocardiography. The algorithms used vary in complexity. In general, all are suitable for normally shaped and normally contracting left ventricles. More complex approaches are needed to assess deformed left ventricles with regional wall motion abnormalities. Visual estimation of ejection fraction from two-dimensional echocardiography is common and accurate when the reader is experienced, but it is subjective and therefore less reproducible than quantitative methods. Echocardiography is well-suited for the qualitative assessment of regional LV contractile function.

Edema and Dyspnea

Peripheral edema has numerous causes, both cardiac and noncardiac. Peripheral edema results from any cardiac or pericardial disease that causes an elevation in central venous pressure. Echocardiography generally provides the diagnosis. The overlapping features of constrictive pericarditis and restrictive cardiomyopathy may make definite diagnosis by echocardiography difficult. In the absence of an elevation in central venous pressure, a cardiac or pericardial reason for peripheral edema is usually not present, and echocardiography is not recommended.

Dyspnea, one of the cardinal symptoms of heart failure, is often related to elevation of pulmonary venous pressure. Dyspnea can also be due to noncardiac causes, such as neuromuscular disease, pulmonary disease, central nervous system disease, and anemia. Echocardiography can help identify cardiac causes of dyspnea by identifying valvular, coronary, myocardial, or pericardial disease.

Dilated Cardiomyopathy

Echocardiography demonstrates dilated ventricular chambers, usually with normal wall thickness and varying degrees of depressed systolic function in patients with dilated cardiomyopathy. Doppler techniques reveal the presence and magnitude of associated valvular regurgitation, allow estimation of pulmonary artery pressures, and offer insight into the diastolic function of the left ventricle. Echocardiography is valuable in following therapy with drugs known to depress LV function, such as doxorubicin.

Hypertrophic Cardiomyopathy

Echocardiography provides a definitive diagnosis of hypertrophic cardiomyopathy by revealing ventricular hypertrophy without other primary causes. It also permits assessment of the distribution of hypertrophy, the presence and magnitude of obstructive gradients across the LV outflow tract, the presence and severity of mitral regurgitation, and the evaluation of diastolic filling. It can be useful for assessing the effects of both medical and surgical therapy.

Restrictive Cardiomyopathy

Echocardiography usually reveals normal ventricular size and systolic function with atrial enlargement in patients with restricted cardiomyopathy. Doppler studies demonstrate characteristic inflow velocity profiles. Intense echocardiography reflectance gives a characteristic stippled appearance in some cases of amyloidosis abnormalities.

Heart Failure With Normal Systolic Function (Diastolic Dysfunction)

Diastolic dysfunction is thought to be present when a patient with heart failure has an LV ejection fraction >40%. Because treatment and prognosis for heart failure due to predominant diastolic dysfunction may differ from that of heart failure due to systolic dysfunction, the proper diagnosis is critical. Because of the effect of heart rate and loading characteristics on diastolic function and the inability to apply the Doppler indexes in atrial fibrillation and other rhythm and conduction disturbances, echocardiographic indexes of diastolic function must be interpreted in the context of all potential confounding clinical variables.

Evaluation of the Right Ventricle

Quantitation of RV size and volume are more problematic than comparable measurements of the left ventricle due to the complex shape of the right ventricle, its heavy trabecular pattern, and difficulty obtaining standardized imaging planes. Assessment of the size and function of the right ventricle is therefore usually performed in a qualitative fashion. Echocardiographic methods of evaluating RV diastolic function are less validated.

Indications for Echocardiography in Patients With Dyspnea, Edema, or Cardiomyopathy	*Class*
1. Assessment of LV size and function in patients with suspected cardiomyopathy or clinical diagnosis of heart failure.*	**I**
2. Edema with clinical signs of elevated central venous pressure when a potential cardiac etiology is suspected or when central venous pressure cannot be estimated with confidence and clinical suspicion of heart disease is high.*	**I**
3. Dyspnea with clinical signs of heart disease.	**I**
4. Patients with unexplained hypotension, especially in the intensive care unit.*	**I**
5. Patients exposed to cardiotoxic agents, to determine the advisability of additional or increased dosages.	**I**
6. Reevaluation of LV function in patients with established cardiomyopathy when there has been a documented change in clinical status or to guide medical therapy.	**I**
7. Reevaluation of patients with established cardiomyopathy when there is no change in clinical status.	**IIb**
8. Reevaluation of patients with edema when a potential cardiac cause has already been demonstrated.	**IIb**
9. Evaluation of LV ejection fraction in patients with recent (contrast or radionuclide) angiographic determination of ejection fraction.	**III**
10. Routine reevaluation in clinically stable patients in whom no change in management is contemplated.	**III**
11. In patients with edema, normal venous pressure, and no evidence of heart disease.	**III**

***TEE is indicated when TTE studies are not diagnostic.**

VI. Pericardial Disease

The earliest clinical application of echocardiography was detection of pericardial effusion. Echocardiography remains the best technique for evaluating this condition.

Pericardial Effusion

The presence, amount, and distribution of pericardial fluid can be demonstrated by echocardiography. The presence of fibrous strands, tumor masses, and blood clots can also be shown. Although most pericardial effusions requiring pericardiocentesis are located anteriorly and posteriorly, loculated effusions can occur, particularly after cardiac surgery. In these cases echocardiography can define the distribution of the fluid so the safest and most effective approach can be planned for pericardiocentesis.

Cardiac Tamponade

Although the diagnosis of cardiac tamponade is based on established clinical criteria, an accurate and early diagnosis can be made by echocardiography. Right atrial collapse is sensitive, but diastolic RV collapse is a more specific sign for cardiac tamponade. Distention of the inferior vena cava that does not collapse on deep inspiration indicates an elevation in central venous pressure. Characteristic Doppler inflow patterns have been well validated.

Constrictive Pericarditis

Echocardiographic abnormalities are always present. No single echocardiographic sign is diagnostic of constrictive pericarditis. Pericardial thickening, inferior vena caval enlargement, mild atrial enlargement with normal-sized left ventricle, and abnormalities of septal motion can all be present. Doppler findings of exaggerated respiratory variation in flow velocities across the atrioventricular valves as well as LV outflow and pulmonary venous flow are highly characteristic.

Indications for Echocardiography in Pericardial Disease	*Class*
1. Patients with suspected pericardial disease, including effusion, constriction, or effusive-constrictive process.	**I**
2. Patients with suspected bleeding in the pericardial space, eg, trauma, perforation, etc.	**I**
3. Follow-up study to evaluate recurrence of effusion or to diagnose early constriction. Repeat studies may be goal directed to answer a specific clinical question.	**I**
4. Pericardial friction rub developing in acute myocardial infarction accompanied by symptoms such as persistent pain, hypotension, and nausea.	**I**
5. Follow-up studies to detect early signs of tamponade in the presence of large or rapidly accumulating effusions. A goal-directed study may be appropriate.	**IIa**
6. Echocardiographic guidance and monitoring of pericardiocentesis.	**IIa**
7. Postsurgical pericardial disease, including postpericardiotomy syndrome, with potential for hemodynamic impairment.	**IIb**
8. In the presence of a strong clinical suspicion and nondiagnostic TTE, TEE assessment of pericardial thickness to support a diagnosis of constrictive pericarditis.	**IIb**
9. Routine follow-up of small pericardial effusion in clinically stable patients.	**III**
10. Follow-up studies in patients with cancer or other terminal illness for whom management would not be influenced by echocardiographic findings.	**III**
11. Assessment of pericardial thickness in patients without clinical evidence of constrictive pericarditis.	**III**
12. Pericardial friction rub in early uncomplicated myocardial infarction or early postoperative period after cardiac surgery.	**III**

VII. Cardiac Masses and Tumors

Echocardiography is an accurate high-resolution technique for identifying masses within any of the four cardiac chambers. These masses include primary tumors of the heart (the most common of which is atrial myxoma), as well as metastatic tumors, thrombi, and valvular vegetations. Intracardiac masses should be suspected in the context of clinical presentation, eg, suspicion of valvular vegetations with underlying connective tissue diseases or clinical signs of infective endocarditis. Patients with rheumatic heart disease are predisposed to developing intracardiac masses, dilated cardiomyopathy, atrial fibrillation, and anteroapical myocardial infarction, as are patients with malignancies known to have a high incidence of cardiovascular involvement, such as hypernephroma and metastatic melanoma. In patients with peripheral embolic phenomena such as embolic stroke, an intracardiac mass should be suspected if another source is not identified.

Indications for Echocardiography in Patients With Cardiac Masses and Tumors	*Class*
1. Evaluation of patients with clinical syndromes and events suggesting an underlying cardiac mass.	**I**
2. Evaluation of patients with underlying cardiac disease known to predispose to mass formation for whom a therapeutic decision regarding surgery or anticoagulation will depend on the results of echocardiography.	**I**
3. Follow-up or surveillance studies after surgical removal of masses known to have a high likelihood of recurrence (ie, myxoma).	**I**
4. Patients with known primary malignancies when echocardiographic surveillance for cardiac involvement is part of the disease staging process.	**I**
5. Screening persons with disease states likely to result in mass formation but for whom no clinical evidence for the mass exists.	**IIb**
6. Patients for whom the results of echocardiography will have no impact on diagnosis or clinical decision making.	**III**

VIII. Diseases of the Great Vessels

TTE and TEE can effectively visualize the entire thoracic aorta, except for a small segment of the upper ascending portion adjacent to the tracheobronchial tree. The main and proximal right and left pulmonary arteries can also be visualized as well as the proximal portions of the superior vena cava, innominate vein and upper inferior vena cava, proximal segments of the hepatic veins, and pulmonary veins.

Aortic Dissection, Aneurysm, Rupture, and Thoracic Aortic Degenerative Disease

In some patients with type I and II dissection involving the proximal ascending aorta, TTE can visualize the intimal flap and determine the degree of pericardial effusion and aortic

regurgitation. However, TEE is a far more sensitive and specific diagnostic procedure. Because time is extremely important, only an abbreviated TTE is done before TEE. Biplane or multiplane TEE should be used for comprehensive and accurate visualization of the thoracic aorta.

Aneurysms of the ascending aorta can be characterized by TTE. With Doppler, rupture of an aneurysm of the sinus of Valsalva as well as the communicating cardiac chamber can be identified. TEE is often necessary to adequately visualize descending thoracic aortic aneurysms.

TEE is useful for identifying traumatic and other causes of aortic rupture. However, small tears can be overlooked.

TEE can detect atheromatous debris, clots, and other lesions capable of producing downstream embolic occlusion in thoracic aortic degenerative disease.

Indications for Echocardiography in Suspected Thoracic Aortic Disease	*Class*	
	TTE	*TEE*
1. Aortic dissection.	**IIa**	**I**
2. Aortic aneurysm.	**I***	**I**
3. Aortic rupture.	**IIb**	**I**
4. Aortic root dilatation in Marfan or other connective tissue syndromes.	**I**	**IIb**
5. Degenerative or traumatic aortic disease with clinical atheroembolism.	**IIb**	**I**
6. Follow-up of aortic dissection, especially after surgical repair without suspicion of complication or progression.	**I**	**IIa**
7. Follow-up of aortic dissection especially after surgical repair when complication or progression is suspected.	**IIa**	**I**
8. First-degree relative of a patient with Marfan syndrome or other connective tissue disorder.	**I**	**IIb**

***Especially for aortic root aneurysm.**

The Great Veins

Echocardiography is useful for visualizing the superior vena cava and diagnosing some congenital and acquired abnormalities such as persistent left superior vena cava and its connection to the coronary sinus. Together with Doppler, TTE and TEE can detect thrombi, tumors, the size and connection of the hepatic veins, superior vena cava, and pulmonary veins as well as flow dynamics in these veins.

IX. Pulmonary Disease

Patients with pulmonary disease generally are not ideal candidates for echocardiographic examination because the hyperinflated lung is a poor conductor of ultrasound. In most patients with pulmonary disease, the subxiphoid or subcostal view can visualize the heart well. Between these TTE windows and TEE, it is possible to obtain an echocardiographic image of the heart and vessels in almost all patients with primary lung disease.

Although a normal echocardiogram does not indicate a diagnosis of lung disease, the differential diagnosis of cardiac versus pulmonary symptoms often can be made on the basis of a normal echocardiogram. If lung disease is the cause of pulmonary hypertension, the echocardiogram can detect dilatation, hypertrophy, or hypokinesia of the right ventricle. If tricuspid regurgitation is present, Doppler techniques can allow an estimation of pulmonary artery systolic pressure.

Echocardiography may aid in the diagnosis of severe or massive pulmonary embolism but otherwise has low sensitivity and specificity in detecting pulmonary emboli.

Indications for Echocardiography in Pulmonary Disease	*Class*
1. Suspected pulmonary hypertension.	**I**
2. Pulmonary emboli and suspected clots in the right atrium or ventricle or main pulmonary artery branches.*	**I**
3. For distinguishing cardiac versus noncardiac etiology of dyspnea in patients in whom all clinical and laboratory clues are ambiguous.*	**I**
4. Follow-up of pulmonary artery pressures in patients with pulmonary hypertension to evaluate response to treatment.	**I**
5. Lung disease with clinical suspicion of cardiac involvement (suspected cor pulmonale).	**I**
6. Measurement of exercise pulmonary artery pressure.	**IIa**
7. Patients being considered for lung transplantation or other surgical procedure for advanced lung disease.*	**IIa**
8. Lung disease without any clinical suspicion of cardiac involvement.	**III**
9. Reevaluation studies of RV function in patients with chronic obstructive lung disease without a change in clinical status.	**III**

***TEE is indicated when TTE studies are not diagnostic.**

X. Systemic Hypertension

Echocardiography is the best procedure to evaluate the cardiac effects of systemic hypertension, the most common cause of LV hypertrophy and congestive heart failure in adults. Detection of LV hypertrophy and estimation of LV mass are more sensitive and specific with echocardiography than either radiography or echocardiography. Because echocardiographic detection of concentric hypertrophy is more sensitive than electrocardiography, and because concentric LV hypertrophy increases the risks of cardiac morbidity and mortality, a decision to initiate therapy may be based on the presence of LV hypertrophy. Therefore, in borderline hypertensive patients without evidence of LV hypertrophy on ECG, a goal-

directed echocardiogram to evaluate LV hypertrophy may be indicated.

Although a decrease in LV mass in hypertensive patients on therapy has been demonstrated by echocardiography, the value of repeat echocardiograms in asymptomatic hypertensive patients with normal LV function has not been established, because the impact of LV regression on patient morbidity and mortality is unknown.

Indications for Echocardiography in Hypertension	*Class*
1. When assessment of resting LV function, hypertrophy, or concentric remodeling is important in clinical decision making (see LV function).	**I**
2. Detection and assessment of functional significance of concomitant coronary artery disease (see coronary disease).*	**I**
3. Follow-up assessment of LV size and function in patients with LV dysfunction when there has been a documented change in clinical status or to guide medical therapy.	**I**
4. Identification of LV diastolic filling abnormalities with or without systolic abnormalities.	**IIa**
5. Assessment of LV hypertrophy in a patient with borderline hypertension without LV hypertrophy on ECG to guide decision making regarding initiation of therapy. A limited goal-directed echocardiogram may be indicated for this purpose.	**IIa**
6. Risk stratification for prognosis by determination of LV performance.	**IIb**
7. Reevaluation to guide antihypertensive therapy based on LV mass regression.	**III**
8. Reevaluation in asymptomatic patients to assess LV function.	**III**

***Stress echocardiography.**

XI. Neurological Disease and Other Cardioembolic Disease

Acute interruption of blood flow to the cerebral vasculature or a peripheral artery results in clinical syndromes such as transient ischemic attacks, cerebrovascular accidents, and acute limb ischemia. The prevalence of a cardioembolic etiology is highly variable but is the source in up to 20% of acute neurological events, with another 40% being cryptogenic and possibly cardioembolic in origin. Cause and effect is difficult to prove, with the exception of the link between an embolus in a patient with infective endocarditis and an embolus in a patient with a prosthetic valve.

The most frequently evaluated cardioembolic events in the literature are acute neurological syndromes. The level of evidence for causally linking a potential cardiac source of the embolus to the neurological event is relatively low. The likelihood of a cardioembolic source depends on the clinical setting, with sudden onset of a middle or anterior cerebral circulation defect and multiple events in peripheral territories being more likely to be embolic. Also, young patients with sudden-onset neurological events and patients with underlying atrial fibrillation, cardiomyopathy, or other cardiac disease are more likely to have a cardioembolic event as the cause of a vascular occlusive event rather than intrinsic vascular disease.

TEE is more sensitive for identifying potential cardiac sources in a patient with an embolic event than TTE. However, if a potential cardiac source is found by TTE in a patient with an embolic event, the additive cost and inconvenience of TEE is probably not warranted. Conversely TEE is uniquely suited for detection of left atrial spontaneous contrast, left atrial thrombi, atrial septal aneurysms, and aortic atheromata.

Indications for Echocardiography in Patients With Neurological Events or Other Vascular Occlusive Events	*Class*
1. Patients of any age with abrupt occlusion of a major peripheral or visceral artery.	**I**
2. Younger patients (typically <45 years) with cerebrovascular events.	**I**
3. Older patients (typically >45 years) with neurological events without evidence of cerebrovascular disease or other obvious cause.	**I**
4. Patients for whom a clinical therapeutic decision (anticoagulation, etc) will depend on the results of echocardiography.	**I**
5. Patients with suspicion of embolic disease and with cerebrovascular disease of questionable significance.	**IIa**
6. Patients with a neurological event and intrinsic cerebrovascular disease of a nature sufficient to cause the clinical event.	**IIb**
7. Patients for whom the results of echocardiography will not impact a decision to institute anticoagulant therapy or otherwise alter the approach to diagnosis or treatment.	**III**

XII. Arrhythmias and Palpitation

Arrhythmias can occur as primary electrophysiological abnormalities or as a complication of or in association with structural heart disease. The utility of echocardiography lies primarily in the identification of associated heart disease, the knowledge of which will influence treatment of the arrhythmia or provide prognostic information. Echocardiography can detect an underlying cardiac disorder in approximately 10% of patients with atrial fibrillation who have no clinically suspected cardiac disease and in 60% of those with equivocal evidence of heart disease.

In patients with benign arrhythmias such as atrial or ventricular premature beats, echocardiographic evaluation

should be reserved for those with clinical suspicion of structural heart disease. On occasion, echocardiography may be helpful in patients with a DDD pacemaker when Doppler studies are used to determine the settings at which stroke volume is optimized.

Indications for Echocardiography in Patients With Arrhythmias and Palpitations	*Class*
1. Arrhythmias with clinical suspicion of structural heart disease.	I
2. Arrhythmia in a patient with a family history of a genetically transmitted cardiac lesion associated with arrhythmia such as tuberous sclerosis, rhabdomyoma, or hypertrophic cardiomyopathy.	I
3. Evaluation of patients as a component of the workup before electrophysiological ablative procedures.	I
4. Arrhythmia requiring treatment.	IIa
5. TEE guidance of transseptal catheterization and catheter placement during ablative procedures.	IIa
6. Arrhythmias commonly associated with, but without clinical evidence of, heart disease.	IIb
7. Evaluation of patients who have undergone radiofrequency ablation in the absence of complications. (In centers with established ablation programs, a postprocedural echocardiogram may not be necessary.)	IIb
8. Palpitation without corresponding arrhythmia or other cardiac signs or symptoms.	III
9. Isolated premature ventricular contractions for which there is no clinical suspicion of heart disease.	III

Cardioversion for Patients With Atrial Fibrillation

Echocardiography can help identify patients with atrial fibrillation who are most likely to maintain sinus rhythm after cardioversion. LV dysfunction argues against long-term success. Atrial size is a more controversial prognosticator. In subjects undergoing cardioversion for atrial fibrillation, it has been reported that exclusion of intra-atrial thrombus by TEE can obviate the need for extended precardioversion anticoagulation, allowing instead the use of heparin immediately before cardioversion and continuing coumadin for several weeks afterward until mechanical function of the atrium has been restored. Large multicenter trials are still ongoing to address this issue. It is also not clear how long atrial fibrillation must be present before the thrombus can form, so that there may be no difference in the danger of thrombus formation between recent-onset and chronic atrial fibrillation.

Indications for Echocardiography Before Cardioversion	*Class*
1. Patients requiring urgent (not emergent) cardioversion for whom extended precardioversion anticoagulation is not desirable.*	I
2. Patients who have had prior cardioembolic events thought to be related to intra-atrial thrombus.*	I
3. Patients for whom anticoagulation is contraindicated and for whom a decision about cardioversion will be influenced by TEE results.*	I
4. Patients for whom intra-atrial thrombus has been demonstrated in previous TEE.*	I
5. Evaluation of patient for whom a decision concerning cardioversion will be impacted by knowledge of prognostic factors (such as LV function, coexistent mitral valve disease, etc).	I
6. Patients with atrial fibrillation of <48 hours' duration and other heart disease.*	IIa
7. Patients with atrial fibrillation of <48 hours' duration and no other heart disease.*	IIb
8. Patients with mitral valve disease or hypertrophic cardiomyopathy who have been on long-term anticoagulation at therapeutic levels before cardioversion.*	IIb
9. Patients undergoing cardioversion from atrial flutter.	IIb
10. Patients requiring emergent cardioversion.	III
11. Patients who have been on long-term anticoagulation at therapeutic levels and who do not have mitral valve disease or hypertrophic cardiomyopathy before cardioversion.	III
12. Precardioversion evaluation of patients who have undergone previous TEE and with no clinical suspicion of a significant interval change.	III

*TEE only.

Syncope

The role of echocardiography in evaluation of patients with syncope is related to its capability to diagnose and quantitate obstructive lesions and identify abnormalities such as LV dysfunction that provide a substrate for malignant arrhythmias. There is little evidence that echocardiography is needed in the workup of a patient with no clinical evidence of underlying heart disease.

Indications for Echocardiography in the Patient With Syncope	*Class*
1. Syncope in a patient with clinically suspected heart disease.	I
2. Periexertional syncope.	I
3. Syncope in a patient in a high-risk occupation (eg, pilot).	IIa

4. Syncope of occult etiology with no findings of heart disease on history or physical exam.	**IIb**
5. Recurrent syncope in a patient in whom previous echocardiographic or other testing demonstrated a cause of syncope.	**III**
6. Syncope in a patient for whom there is no clinical suspicion of heart disease.	**III**
7. Classic neurogenic syncope.	**III**

Screening

As a testing modality, echocardiography is safe, widely available, and accurate in identifying the presence of most structural heart disease. For echocardiography to be useful, the diseases screened for must be relatively frequent and when present must lead to a change in management that will favorably affect long-term outcome. Because of its cost and the many conditions echocardiography is capable of identifying, only a few conditions meet these criteria. Examples include screening for heritable diseases of the heart and great vessels in relatives of affected individuals: for instance, hypertrophic cardiomyopathy and Marfan syndrome as well as other heritable conditions such as connective tissue diseases and tuberous sclerosis.

Another indication for echocardiographic screening is in the evaluation of potential donor hearts for transplantation. Such screening can eliminate a donor's heart about 25% of the time. However, screening is not justified when asymptomatic cardiovascular disease is sought in large populations of patients at low risk for cardiovascular involvement.

Using echocardiography to screen the asymptomatic adult competitive athlete for the existence of occult heart disease is not justified due to the low prevalence of cardiac cond ons in patients without clinical evidence of heart disease.

Indications for Echocardiography to Screen for the Presence of Cardiovascular Disease	*Class*
1. Patients with a family history of genetically transmitted cardiovascular disease.	**I**
2. Potential donors for cardiac transplantation.	**I**
3. Patients with phenotypic features of Marfan syndrome or related connective tissue diseases.	**I**
4. Baseline and reevaluations of patients undergoing chemotherapy with cardiotoxic agents.	**I**
5. Patients with systemic disease that may affect the heart.	**IIb**
6. The general population.	**III**
7. Competitive athletes without clinical evidence of heart disease.	**III**

XIII. Echocardiography in the Critically Ill

Echocardiography is extremely helpful for making the differential diagnosis in the hemodynamically unstable, critically ill patient. Echocardiography is most helpful in acute ischemic syndromes, myocardial ischemic syndromes, hypotension of unknown cause, cardiac tamponade, aortic dissection, mechanical or infective complications of mechanical valves, and evaluation of the source of embolism.

Patients in the intensive care unit are frequently on mechanical ventilation, cannot be appropriately positioned, or have postoperative dressings or chest tubes preventing adequate TTE. In these cases TEE is often required. An increasing body of evidence in the literature supports the value of TEE when TTE is inadequate and documents that the findings on TEE often result in a change in treatment. Even though cardiac output can be measured by echocardiography, it is not likely to replace thermodilution-determined cardiac outputs by pulmonary artery catheterization because continuous clinical measurements are not feasible with echocardiography.

The Trauma Patient

Both TTE and TEE are useful for the severely injured patient when cardiac, pericardial, mediastinal, or major intrathoracic vascular injury has occurred. Myocardial contusion or rupture, pericardial effusion and tamponade, major vascular injury, septal defects or fistulae, and valvular regurgitation can all occur in both penetrating and nonpenetrating injury.

Unexplained hypotension is well addressed by echocardiography. TTE is very successful in identifying cardiac trauma and pericardial fluid in the patient with penetrating chest injury, thus avoiding the necessity of an exploratory thoracotomy or subxiphoid pericardiotomy. Immediate evaluation in the emergency department can result in prompt appropriate treatment, including emergency thoracotomy. With traumatic rupture of the aorta, aortography is the gold standard, but TEE is becoming the procedure of choice, depending on the expertise of the echocardiographer and immediate availability of the study.

Conditions and Settings in Which Transesophageal Echocardiography Provides the Most Definitive Diagnosis in the Critically Ill and Injured

- **The hemodynamically unstable patient with suboptimal TTE images.**
- **The hemodynamically unstable patient on a ventilator.**
- **Major trauma or postoperative patients (unable to be positioned for adequate TTE).**
- **Suspected aortic dissection.**
- **Suspected aortic injury.**
- **Other conditions in which TEE is superior (see section on valvular disease).**

Indications for Echocardiography in the Critically Ill	*Class*
1. The hemodynamically unstable patient.	I
2. Suspected aortic dissection (TEE).	I
3. The hemodynamically stable patient not expected to have cardiac disease.	III
4. Reevaluation follow-up studies on hemodynamically stable patients.	III

*Indications for Echocardiography in the Critically Injured**	*Class*
1. Serious blunt or penetrating chest trauma (suspected pericardial effusion or tamponade).	I
2. Mechanically ventilated multiple-trauma or chest trauma patient.	I
3. Suspected preexisting valvular or myocardial disease in the trauma patient.	I
4. The hemodynamically unstable multiple-injury patient without obvious chest trauma but with a mechanism of injury suggesting potential cardiac or aortic injury (deceleration or crush).	I
5. Widening of the mediastinum, postinjury suspected aortic injury (TEE).	I
6. Potential catheter, guidewire, pacer electrode, or pericardiocentesis needle injury with or without signs of tamponade.	I
7. Evaluation of hemodynamics in multiple-trauma or chest trauma patients with pulmonary artery catheter monitoring and data disparate with clinical situation.	IIa
8. Follow-up study on victims of serious blunt or penetrating trauma.	IIa
9. Suspected myocardial contusion in the hemodynamically stable patient with a normal ECG.	III

*The use of TTE or TEE includes Doppler techniques when indicated and available and with appropriately trained and experienced sonographer and interpreter.

TEE is indicated when TTE images are suboptimal. TEE often provides incremental information.

XIV. Doppler Echocardiography in the Adult Patient With Congenital Heart Disease

The adult patient with congenital heart disease is seen by the cardiologist either because the problem was not discovered in childhood or more often because the patient was previously diagnosed with inoperable congenital heart disease or has undergone one or more palliative or corrective surgical procedures. The only patients with congenital heart disease who are considered "cured" are those with repaired patent ductus arteriosus and some patients with repaired atrial septal defects; thus, most patients must be followed periodically to evaluate residual defects and detect the late complications that occur even in the patient with a condition that has been "surgically corrected."

Indications for Echocardiography in the Adult Patient With Congenital Heart Disease	*Class*
1. Patients with clinically suspected congenital heart disease, as evidenced by signs and symptoms such as a murmur, cyanosis, or unexplained arterial desaturation, and an abnormal ECG or radiograph suggesting congenital heart disease.	I
2. Patients with known congenital heart disease on follow-up when there is a change in clinical findings.	I
3. Patients with known congenital heart disease for whom there is uncertainty as to the original diagnosis or when the precise nature of the structural abnormalities or hemodynamics is unclear.	I
4. Periodic echocardiograms in patients with known congenital heart lesions and for whom ventricular function and atrioventricular valve regurgitation must be followed (eg, patients with a functionally single ventricle after Fontan procedure, transposition of the great vessels after Mustard procedure, L-transposition and ventricular inversion, and palliative shunts).	I
5. Patients with known congenital heart disease for whom following pulmonary artery pressure is important (eg, patients with moderate or ventricular septal defects, atrial septal defects, single ventricle, or any of the above with an additional risk factor for pulmonary hypertension).	I
6. Periodic echocardiography in patients with surgically repaired (or palliated) congenital heart disease with the following: change in clinical condition or clinical suspicion of residual defects, LV or RV function that must be followed, or when there is a possibility of hemodynamic progression or a history of pulmonary hypertension.	I
7. To direct interventional catheter valvotomy, radiofrequency ablation valvotomy interventions in the presence of complex cardiac anatomy.	I
8. A follow-up Doppler echocardiographic study, annually or once every 2 years, in patients with known hemodynamically significant congenital heart disease without evident change in clinical condition.	IIb
9. Multiple repeat Doppler echocardiography in patients with repaired patent ductus arteriosus, atrial septal defect, ventricular septal defect, coarctation of the aorta, or bicuspid aortic valve without change in clinical condition.	III

10. Repeat Doppler echocardiography in patients with known hemodynamically insignificant congenital heart lesions (eg, small atrial septal defect, small ventricular septal defect) without a change in clinical condition.	**III**

Late Postoperative Complications in Patients With Congenital Heart Disease

The danger of infective endocarditis is present in most patients with congenital heart disease when there is a high-velocity jet that traumatizes the endocardium. This includes patients with residual ventricular septal defects or palliative shunts or valvular stenosis or insufficiency, especially left-sided.

Residual pulmonary hypertension due to pulmonary vascular disease can remain after closure of a large atrial or ventricular septal defect, atrioventricular canal, or patent ductus arteriosus. Even after repair, pulmonary hypertension can become progressively severe. Late complications in patients with specific congenital heart lesions who have undergone surgery are discussed in the full text of the guidelines (see "Echocardiography in the Critically Ill").

XV. Echocardiography in the Pediatric Patient

Echocardiography has become the definitive diagnostic method for the recognition and assessment of congenital and acquired heart disease in the pediatric population. Reevaluation by echocardiography is frequently used to monitor cardiovascular adaptation to surgical repair or palliation and to identify recurrence of abnormalities.

Congenital structural heart disease is the most common type of cardiovascular disease in the pediatric population. However, acquired heart disease such as rheumatic heart disease, Kawasaki disease, infective endocarditis, postinfection or other etiologies of cardiomyopathy, and hypertrophic cardiomyopathy all contribute to the cardiovascular morbidity in this population.

Resource Utilization and Age

Guidelines for pediatric echocardiography must be stratified by age to accommodate the unique physiology of the neonate, the neonate's transitional circulation with its rapid changes in pulmonary resistance, closure of the ductus arteriosus, and the frequent occurrence of pulmonary disease. Perinatal physiological changes may mask the presence of hemodynamically important cardiovascular lesions. Neonates with congenital anomalies of other organs needing urgent surgery should be screened by echocardiography to rule out associated cardiac anomalies, which will facilitate decision making and therapy.

Congenital Cardiovascular Disease in the Neonate

Structural congenital cardiovascular disease. Echocardiography provides essential structural information in all forms of cardiac and great vessel disease in pediatric patients. Doppler echocardiography provides important physiological information that combined with anatomic data is sufficient to guide therapeutic management in some diagnostic categories. Reevaluation examination allows tracking of hemodynamic changes occurring in the transitional circulation of the newborn and provides information to guide medical or surgical intervention.

Cardiopulmonary disease. Premature infants may have respiratory failure due to a combination of processes: lung immaturity, hyaline membrane disease, persistence of ductus arteriosus, inflammatory disease, or congenital heart disease. Doppler echocardiography indicates the patency of the ductus arteriosus, direction and degree of shunting at the ductal level, and assessment of pulmonary artery pressure and its consequences. Differentiation of primary pulmonary hypertension from cyanotic heart disease requires echocardiography.

Indications for Neonatal Echocardiography	*Class*
1. Cyanosis, respiratory distress, congestive heart failure, or abnormal arterial pulses.	**I**
2. Chromosomal abnormality or major extracardiac abnormality associated with a high incidence of coexisting cardiac abnormality.	**I**
3. Lack of expected improvement in cardiopulmonary status in a premature infant with a clinical diagnosis of pulmonary disease.	**I**
4. Systemic maternal disease associated with neonatal comorbidity.	**I**
5. Loud or abnormal murmur or other abnormal cardiac finding in an infant.	**I**
6. Presence of a syndrome associated with cardiovascular disease and dominant inheritance or multiple affected family members.	**I**
7. Presence of a syndrome associated with heart disease, with or without abnormal cardiac findings, for which an urgent management decision is needed.	**I**
8. Cardiomegaly on chest radiograph.	**I**
9. Dextrocardia, abnormal pulmonary or visceral situs by clinical, electrocardiographic, or radiographic examination.	**I**
10. Arrhythmias or other abnormalities on standard ECG suggesting structural heart disease or peripartum myocardial injury.	**I**
11. Clinical suspicion of residual or recurrent abnormality, poor ventricular function, pulmonary artery hypertension, thrombus, sepsis, or pericardial effusion after cardiovascular surgical therapy for congenital heart disease.	**I**
12. Nonimmunologic fetal hydrops.	**I**
13. Follow-up assessment of a neonate with patent ductus arteriosus who has undergone medical or surgical intervention.	**I**

14. Short, soft murmur at the lower left sternal border in the neonate.	IIa
15. Failure to thrive in the absence of definite abnormal clinical findings.	IIa
16. 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.	IIb
17. History of nonsustained fetal ectopy in the absence of postpartum arrhythmias.	III

Congenital Cardiovascular Disease in the Infant, Child, and Adolescent

In these age groups cardiovascular disease includes anomalies of the cardiac anatomy, function, morphogenesis, and rhythm. These problems often present as an asymptomatic cardiac murmur; however, murmurs in this age group are more commonly functional than pathological. History and physical examination by a skilled observer is usually sufficient to distinguish a functional murmur from a pathological murmur and more cost-effective than a referral for an echocardiogram. Where the clinical findings are ambiguous, organic pathology can be ruled out by Doppler echocardiography.

Structural cardiovascular disease. The abnormalities found in these age groups are identical to those encountered in the neonatal period. Doppler echocardiography can fully characterize a cardiac lesion once an abnormality is suspected. Echocardiography provides important information in patients with connective tissue disorders such as Marfan syndrome and Ehlers-Danlos syndrome.

Indications for Echocardiography in the Infant, Child, and Adolescent	*Class*
1. Atypical or pathological murmur or other abnormal cardiac finding in an infant or older child.	I
2. Cardiomegaly on chest radiograph.	I
3. Dextrocardia, abnormal pulmonary or visceral situs on clinical, electrocardiographic, or radiographic examination.	I
4. Patients with a known cardiac defect to assess timing of medical or surgical therapy.	I
5. Immediate preoperative evaluation for cardiac surgery of a patient with a known cardiac defect to guide cardiac surgical management and inform the patient and family of risks of surgery.	I
6. Patient with known cardiac lesion and change in physical finding.	I
7. Postoperative congenital or acquired heart disease with clinical suspicion of residual or recurrent abnormality, poor ventricular function, pulmonary artery hypertension, thrombus, sepsis, or pericardial effusion.	I
8. Presence of a syndrome associated with cardiovascular disease and dominant inheritance or multiple affected family members.	I
9. Patients with a family history of genetically transmitted myocardial disease, with or without abnormal cardiac finding.	I
10. Phenotypic findings of Marfan syndrome or Ehlers-Danlos syndrome.	I
11. Baseline and follow-up examinations of patients with neuromuscular disorders having known myocardial involvement.	I
12. Presence of a syndrome associated with a high incidence of congenital heart disease when there are no abnormal cardiac findings.	I
13. Exercise-induced precordial chest pain or syncope.	I
14. "Atypical," "non-vasodepressor" syncope without other cause.	I
15. Failure to thrive in the absence of definite abnormal clinical findings.	IIb
16. In a child or adolescent, an asymptomatic heart murmur identified by an experienced observer as functional or an insignificant cardiovascular abnormality.	III
17. In an otherwise asymptomatic child or adolescent, chest pain identified by an experienced observer as musculoskeletal in origin.	III

Arrhythmias/conduction disturbances. Arrhythmias in the pediatric population may be associated with Ebstein's anomaly, cardiac tumor, cardiomyopathy, MVP, glycogen storage disease, or stimulation from migrated central venous catheters. Asymptomatic arrhythmias such as supraventricular premature beats or brief runs of supraventricular tachycardia are rarely associated with pathology.

Indications for Echocardiography in Pediatric Patients With Arrhythmias/Conduction Disturbances	*Class*
1. Arrhythmia in the presence of an abnormal cardiac finding.	I
2. Arrhythmia in a patient with a family history of a genetically transmitted cardiac lesion associated with arrhythmia, such as tuberous sclerosis or hypertrophic cardiomyopathy.	I
3. Complete atrioventricular block or advanced second-degree atrioventricular block.	I
4. Complete or high-degree secondary atrioventricular block.	I
5. Arrhythmia requiring treatment.	I
6. Ventricular arrhythmia in a patient referred for evaluation for competitive sports.	IIa
7. Evidence of preexcitation on ECG.	IIa
8. Preexcitation on ECG in the absence of abnormal cardiac findings.	IIb
9. Recurring arrhythmia not requiring treatment in the presence of normal findings on examination.	IIb

10. Sinus arrhythmia or isolated extrasystoles in a child with otherwise normal cardiac findings and no family history of a genetically transmitted abnormality associated with arrhythmia.	**III**

Acquired cardiovascular disease. Acquired cardiovascular disease occurs with systemic disease processes associated with inflammation, hypertension due to renal disease, cardiotoxic therapy, pulmonary disease, and post–heart transplantation. Echocardiography provides information about cardiac chamber size and function, atrioventricular and semilunar valve function, intracardiac masses, and the presence of pericardial disease. Kawasaki disease, endocarditis, rheumatic fever, human immunodeficiency viral (HIV) disease, hypertrophic cardiomyopathy, dilated cardiomyopathy, and cardiac involvement in neuromuscular disease are all seen in childhood.

Indications for Echocardiography in Pediatric Acquired Cardiovascular Disease	*Class*
1. Baseline studies and reevaluation as clinically indicated on all pediatric patients with suspected or documented Kawasaki disease, myopericarditis, HIV, or rheumatic fever.	**I**
2. Postcardiac or cardiopulmonary transplant to monitor for signs of acute or chronic rejection, thrombus, and cardiac growth.	**I**
3. Baseline and reevaluation examinations of patients receiving cardiotoxic therapeutic agents.	**I**
4. Patients with clinical evidence of myocardial disease.	**I**
5. Patients with severe renal disease and an abnormal cardiac finding.	**I**
6. Donors undergoing evaluation for cardiac transplantation.	**I**
7. An acutely ill child with suspected bacterial sepsis or rickettsial disease.	**IIa**
8. Follow-up examinations after acute rheumatic fever in patients with normal cardiac findings.	**IIb**
9. A single late follow-up study after acute pericarditis with no evidence of recurrence or chronic pericardial disease.	**IIb**
10. Long-term follow-up studies in patients with Kawasaki disease who have no coronary abnormalities during the acute phase of the disease process.	**III**

Pulmonary diseases. Children with upper airway or chronic lung disease may have pulmonary artery hypertension, the magnitude of which can be assessed by Doppler echocardiography.

Indications for Echocardiography in Pediatric Cardiopulmonary Disease	*Class*
1. Any patient with clinical findings of pulmonary artery hypertension.	**I**
2. Baseline study of patients with cystic fibrosis and no findings of cor pulmonale.	**IIa**

Thrombus/tumor. Thromboembolism, including stroke in childhood, can result from intracardiac thrombus, tumor, or vegetation. Because children have a lower incidence of vascular disease as a cause of stroke or loss of pulse, the yield of echocardiography in finding an intracardiac cause may be somewhat higher than for adults. Patients with Fontan procedures, dilated cardiomyopathy, or any other causes of severely reduced ventricular function as well as indwelling catheters are all predisposed to thrombus formation. Atrial myxoma and infective endocarditis are both causes of systemic embolization in children. Echocardiographic screening for cardiac tumor is indicated in the fetus or newborn with clinical evidence or family history of tuberous sclerosis. Repeat screening later in childhood is also warranted because these tumors can appear at any time in childhood.

Indications for Echocardiography in Pediatric Thromboembolic Disease States	*Class*
1. Thromboembolic event in an infant, child, or adolescent.	**I**
2. Finding or family history of tuberous sclerosis.	**I**
3. Appearance of sepsis, cyanosis, or right-heart failure in a patient with a long-standing indwelling catheter.	**I**
4. Systemic embolization or acute-onset hypertension in a patient with right-to-left-shunting and an indwelling catheter.	**I**
5. Superior vena caval syndrome in the presence of central venous catheter.	**I**
6. Patient with indwelling catheter and fever but without evidence of pulmonary or systemic embolization.	**IIb**
7. Routine surveillance of asymptomatic patients with indwelling catheter.	**III**

Transesophageal Echocardiography

TTE using high-frequency imaging probes offers excellent resolution of intracardiac and paracardiac structures in the infant and young child. TEE adds important information on these structures in the older pediatric patient and in subjects during and after thoracic instrumentation. TEE may be used in concert with cardiac catheterization to limit the quantity of radiographic contrast material, especially in complex cases and patients with pulmonary artery hypertension. Certain interventions such as balloon atrial septostomy, placement of intracardiac devices, and radiofrequency ablation for arrhythmias are facilitated by TEE. Because the potential for airway compro-

mise and coexistence of complex gastroesophageal anomalies is increased in smaller patients, TEE should only be performed by operators skilled in TEE and trained in the care of infants and children.

Indications for Transesophageal Echocardiography in Pediatric Patients	*Class*
1. Any patient with congenital or acquired heart disease needing echocardiography when significant diagnostic information cannot be obtained by TTE.	**I**
2. Monitoring and guidance during cardiothoracic procedures when there is a risk for residual shunting, valvular insufficiency, obstruction, or myocardial dysfunction.	**I**
3. Guidance of catheter/device placement during interventional catheterization/radiofrequency ablation in patients with congenital heart disease.	**I**
4. Study of patients with intra-atrial baffle in whom the potential for thrombus is of concern because of elevated central venous pressures, atrial chamber dilation, increasing cyanosis, or the appearance of arrhythmia.	**I**
5. Patients with long-term placement of intravascular devices in whom thrombus or vegetation is suspected.	**I**
6. Patients with a prosthetic valve in whom thrombus or vegetation is suspected.	**I**
7. Any patient with suspected endocarditis and inadequate transthoracic acoustical window.	**I**
8. Performing TEE in a patient who has not previously had careful study by TTE.	**III**
9. Patients with structural esophageal abnormality.	**III**

Fetal Echocardiography

Definition of fetal cardiac structures is currently possible at 10 to 12 weeks of gestation with the use of vaginal probes with high-resolution transducers. With current technologies, accurate segmental analysis of cardiac structures and blood flow across valves, shunts, and the ductus is possible with a conventional transabdominal approach by 16 to 18 weeks of gestation.

Patients are referred for fetal echocardiography because of an abnormality of structure or rhythm noted on ultrasound examination or because the patient is in a high-risk group for fetal heart disease. Treatment of the patient is facilitated by the early recognition of the exact nature of the cardiac problem in the fetus. The correct diagnosis may be difficult because of fetal physiology, the effect on flow across defects and valves, inability to see the fetus for orientation reference, and inability to examine the fetus for clinical findings. For these reasons, fetal echocardiography should be performed only by trained fetal echocardiographers. Such experts may be pediatric cardiologists, obstetricians, or radiologists with special training.

Indications for Fetal Echocardiography	*Class*
1. Abnormal-appearing heart on general fetal ultrasound examination.	**I**
2. Fetal tachycardia, bradycardia, or persistent irregular rhythm on clinical or screening ultrasound examination.	**I**
3. Maternal/family risk factors for cardiovascular disease, such as a parent, sibling, or first-degree relative with congenital heart disease.	**I**
4. Maternal diabetes.	**I**
5. Maternal systemic lupus erythematosus.	**I**
6. Teratogen exposure during a vulnerable period.	**I**
7. Other fetal system abnormalities (including chromosomal).	**I**
8. Performance of transplacental therapy or presence of a history of significant but intermittent arrhythmia. Reevaluation examinations are required in these conditions.	**I**
9. Fetal distress or dysfunction of unclear etiology.	**IIa**
10. Previous history of multiple fetal losses.	**IIb**
11. Multiple gestation.	**IIb**
12. Low-risk pregnancies with normal anatomic findings on ultrasound examination.	**III**
13. Occasional premature contractions without sustained tachycardia or signs of dysfunction or distress.	**III**
14. Presence of a noncardiovascular system abnormality when evaluation of the cardiovascular system will not alter either management decisions or fetal outcome.	**III**