ACC/AHA/NASPE 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (ACC/AHA/NASPE Committee on Pacemaker Implantation)

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This document is available on the World Wide Web sites of the ACC (www.acc.org), the AHA (www.americanheart.org), and the NASPE (www.naspe.org). Copies of this document (the complete guidelines) are available for $5 each by calling 800-253-4636 (US only) or writing the American College of Cardiology, Educational Services, 9111 Old Georgetown Road, Bethesda, MD 20814-1699 (ask for No. 71-0237). To obtain a reprint of the shorter version (summary article describing the changes to the guidelines) planned for subsequent publication in *J Am Coll Cardiol* and *Circulation*, ask for reprint No. 71-0236. 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@heart.org.

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PREAMBLE

It is important that the medical profession play a significant role in critically evaluating the use of diagnostic procedures and therapies in the management or prevention of disease states. Rigorous and expert analysis of the available data documenting relative benefits and risks of those procedures and therapies can produce helpful guidelines that improve the effectiveness of care, optimize patient outcomes, and impact the overall cost of care favorably by focusing resources on the most effective strategies.

The American College of Cardiology (ACC) and the American Heart Association (AHA) have jointly engaged in the production of such guidelines in the area of cardiovascular disease since 1980. This effort is directed by the ACC/AHA Task Force on Practice Guidelines. Its charge is to develop and revise practice guidelines for important cardiovascular diseases and procedures. Experts in the subject under consideration are selected from both organizations to examine subject-specific data and write guidelines. The process includes additional representatives from other medical practitioner and specialty groups where appropriate. Writing groups are specifically charged to perform a formal literature review, weigh the strength of evidence for or against a particular treatment or procedure, and include estimates of expected health outcomes where data exist Patient-specific modifiers, comorbidities, and issues of patient preference that might influence the choice of particular tests or therapies are considered, as well as frequency of follow-up and cost-effectiveness.

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 a 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. (See Appendix for conflict of interest information for writing committee members.)

These practice guidelines are intended to assist physicians in clinical decision-making by describing a range of generally acceptable approaches for the diagnosis, management, or prevention of specific diseases or conditions. The guidelines attempt to define practices that meet the needs of most patients in most circumstances. The ultimate judgment regarding care of a particular patient must be made by the physician and patient in light of all of the circumstances presented by that patient.

The 1997 Committee on Pacemaker Implantation was chaired by Gabriel Gregoratos, MD, FACC, and included the following members: Melvin D. Cheitlin, MD, FACC; Alicia Conill, MD, FACP; Andrew E. Epstein, MD, FACC; Christopher Fellows, MD, FACC; T. Bruce Ferguson, Jr., MD, FACC; Roger A. Freedman, MD, FACC; Mark A. Hlatky, MD, FACC; Gerald V. Naccarelli, MD, FACC; Sanjeev Saksena, MD, MBBS, FACC; Robert C. Schlant, MD, FACC; and Michael J. Silka, MD, FACC. The document update used the 1997 work as its basis. The Committee to Update Guidelines on Cardiac Pacemaker Implantation and Antiarrhythmic Devices was chaired by Gabriel Gregoratos, MD, FACC, FAHA, and included the following members: Andrew E. Epstein, MD, FACC, FAHA; Roger A. Freedman, MD, FACC; David L. Hayes, MD, FACC, FAHA; Mark A. Hlatky, MD, FACC, FAHA; Richard E. Kerber, MD, FACC, FAHA; Gerald V. Naccarelli, MD, FACC, FAHA; Mark H. Schoenfeld, MD, FACC, FAHA; Michael J. Silka, MD, FACC; and Stephen L. Winters, MD, FACC.

The summary article is published in the October 15, 2002 issue of *Circulation* and in the November 6, 2002 issue of the *Journal of the American College of Cardiology*. The full text guideline is posted on the ACC, AHA, and NASPE Web sites. Copies of both the full text and the summary article are available from all three organizations.

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INTRODUCTION

This revision of the “ACC/AHA Guidelines for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices” updates the previous versions published in 1984, 1991, and 1998. Revision of the statement was deemed necessary for two reasons: the publication of major studies that have advanced our knowledge of the natural history of bradyarrhythmias and tachyarrhythmias, which may be treated optimally with device therapy, and major advances in the technology of such devices.

The committee to revise the ACC/AHA Guidelines for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices was composed of both university-affiliated and practicing physicians. It included experts in the area of device therapy and follow-up, senior clinicians skilled in cardiovascular care, a general internist, and a cardiothoracic surgeon. The committee included representatives of the American College of Physicians, NASPE, and the Society of Thoracic Surgeons. The 1998 document was reviewed by three outside reviewers nominated by the ACC, three outside reviewers nominated by the AHA, and individuals representing the American College of Physicians and NASPE. The section “Pacing in Children and Adolescents” was reviewed by additional reviewers with special expertise in pediatric electrophysiology. The 2002 update was reviewed by two outside reviewers nominated by the ACC, two outside reviewers nominated by the AHA, and two outside reviewers nominated by the NASPE. The committee thanks all the reviewers for their comments. Many of their suggestions were incorporated into the final document.

The recommendations listed in this document are, whenever possible, evidence based. Pertinent medical literature in the English language was identified through a search of library databases, and a large number of publications were reviewed by committee members during the course of their discussions. Additionally, the committee reviewed documents related to the subject matter previously published by the ACC, AHA, and NASPE. References selected and published in this document are representative and not all-inclusive.

The committee reviewed and ranked evidence supporting current recommendations with the weight of evidence ranked as level A if the data were derived from multiple *randomized* clinical trials involving a large number of individuals. The committee ranked available evidence as level B when data were derived from a limited number of trials involving a comparatively small number of patients or from well-designed data analyses of *nonrandomized* studies or *observational* data registries. Evidence was ranked as level C when the consensus of experts was the primary source of the recommendation. In the narrative portions of these guidelines, evidence is generally presented in chronological order of development. Studies are identified as *observational, randomized, prospective,* or *retrospective*. The committee emphasizes that for certain conditions for which no other therapy is available, the indications for device therapy are based on expert consensus and years of clinical experience and are thus well supported, even though the evidence was ranked as level C. An analogous example is the use of penicillin in pneumococcal pneumonia where there are no *randomized* trials and only clinical experience. When indications at level C are supported by historical clinical data, appropriate references (e.g., case reports and clinical reviews) are cited if available. When level C indications are based strictly on committee consensus, no references are cited. In areas where sparse data were available (e.g., pacing in children and adolescents), a survey of current practices of major centers in North America was conducted to determine whether there was a consensus regarding specific pacing indications.

The final recommendations for indications for device therapy are expressed in the standard ACC/AHA format as follows:

Class I: Conditions for which there is evidence and/or general agreement that a given procedure or treatment is beneficial, 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 a procedure/treatment is not useful/effective and in some cases may be harmful.

The focus of these guidelines is the appropriate use of devices (pacemakers and implantable cardioverter-defibrillators [ICDs]), not the treatment of cardiac arrhythmias. The fact that use of a device for treatment of a particular condition is listed as a Class I indication (beneficial, useful, and effective) does not preclude the use of other therapeutic modalities that may be equally effective. As with all clinical practice guidelines, the recommendations in this document focus on treatment of an average patient with a specific disorder and may be modified by patient comorbidities, limitation of life expectancy because of coexisting diseases, and other situations that only the primary treating physician may evaluate appropriately.

These guidelines include expanded sections on selection of pacemakers and ICDs; optimization of technology; cost; and follow-up of implanted devices. The follow-up section is relatively brief and is included for the sake of completeness, since in many instances, the type and frequency of follow-up examinations are device specific. The importance of adequate follow-up, however, cannot be overemphasized, because optimal results from an implanted device can be obtained only if the device is adjusted to changing clinical conditions.

The committee considered including a section on extraction of failed/unused leads, a topic of current interest, but elected not to do so in the absence of convincing evidence to support specific criteria for timing and methods of lead extraction. A policy statement on lead extraction from NASPE provides information on this topic (334). Similarly, the issue of when to discontinue long-term cardiac pacing or defibrillator therapy has not been studied sufficiently to allow formulation of appropriate guidelines despite the publication of isolated case reports (1). The committee therefore decided to defer inclusion of this topic until additional information is available.

The text accompanying the listed indications should be read carefully because it includes the rationale and supporting evidence for many of the indications, and in several instances, it includes a discussion of alternative acceptable therapies. Many of the indications are modified by the term “potentially reversible.” This term is used to indicate abnormal pathophysiology (e.g., complete heart block) that may be the result of reversible factors. Examples include complete heart block due to drug toxicity (digitalis), electrolyte abnormalities, diseases with inflammatory periatrioventricular node reaction (Lyme disease), and transient injury to the conduction system at the time of open heart surgery. When faced with a potentially reversible situation, the treating physician must decide how long a waiting period is justified before beginning device therapy. The committee recognizes that this statement does not address the issue of length of hospital stay *vis-à-vis* managed-care regulations. It is emphasized that these guidelines are not intended to address this issue, which falls strictly within the purview of the treating physician.

The term “symptomatic bradycardia” is used frequently throughout this document. Symptomatic bradycardia is defined as a documented bradyarrhythmia that is directly responsible for development of the clinical manifestations of frank syncope or near syncope, transient dizziness or lightheadedness, and confusional states resulting from cerebral hypoperfusion attributable to slow heart rate. Fatigue, exercise intolerance, and frank congestive failure may also result from bradycardia. These symptoms may occur at rest and/or with exertion. Definite correlation of symptoms with a bradyarrhythmia is required to fulfill the criteria that define symptomatic bradycardia. Caution should be exercised not to confuse physiologic sinus bradycardia (as occurs in highly trained athletes) with pathological bradyarrhythmias. Occasionally, symptoms may become apparent only in retrospect after antibradycardia pacing. Nevertheless, the universal application of pacing therapy to treat a specific heart rate cannot be recommended except in specific circumstances, as detailed subsequently.

In these guidelines, the terms “persistent,” “transient,” and “not expected to resolve” are frequently used. These terms are not specifically defined because the time element varies in different clinical conditions. The treating physician must use appropriate clinical judgment and available data in deciding when a condition is persistent or when it can be expected to be transient. Section I-C, “Pacing for Atrioventricular Block Associated With Acute Myocardial Infarction,” overlaps with the “ACC/AHA Guidelines for the Management of Patients With Acute Myocardial Infarction” (335) and includes expanded indications and stylistic changes. The statement “incidental finding at electrophysiologic study” is used several times in this document and does not mean that such a study is indicated. Appropriate indications for electrophysiologic studies have been published (3).

The section on indications for ICDs has been updated and enlarged to reflect the numerous new developments in this field and the voluminous literature related to the efficacy of these devices in the treatment of sudden cardiac death and malignant ventricular arrhythmias. Indications for ICDs are continuously changing and can be expected to change further as ongoing large-scale trials are reported. Thus, the ICD indications may require revision in the next 2 to 3 years. In this document, the term “mortality” is used to indicate all-cause mortality unless otherwise specified. The committee elected to use all-cause mortality because of the variable definition of sudden death and the developing consensus to use all-cause mortality as the most appropriate end point of clinical trials (4,5).

These guidelines are not designed to specify training or credentials required for physicians to use device therapy. Nevertheless, in view of the complexity of both cognitive and technical aspects of device therapy, only appropriately trained physicians should use device therapy. Appropriate training guidelines for physicians have been published previously (6,336).

The 2002 update reflects what the committee believes are the most relevant and significant advances in pacemaker/ICD therapy since the publication of these guidelines in the *Journal of the American College of Cardiology* and *Circulation* in 1998 (337,338). An extensive literature survey was conducted, and 113 new references have been added since the original publication of these guidelines in 1998. The new references are numbered 334 to 447 and are listed together at the end of the reference list.

In preparing this update, the committee was guided by the following principles:

1. Changes in recommendations and levels of evidence were made either because of new randomized trials or because of the accumulation of new clinical evidence and the development of clinical consensus.

2. The Committee is cognizant of the healthcare, logistic, and financial implications of recent trials and factored these considerations in arriving at the class level of certain recommendations.

3. Minor wording changes were made to render some of the original recommendations more precise.

4. The committee wishes to re-emphasize that the recommendations in this guideline apply to most patients but may require modification by existing situations that only the primary treating physician can evaluate properly.

5. All of the listed recommendations for implantation of a device presume the absence of inciting causes that may be eliminated without detriment to the patient (e.g., nonessential drug therapy).

6. The committee endeavored to maintain consistency of recommendations in this and other previously published guidelines. In the section on atrioventricular (AV) block associated with acute myocardial infarction (AMI), the recommendations follow closely those in the ACC/AHA Guidelines for the Management of Patients With Acute Myocardial Infarction (335). However, because of the rapid evolution of pacemaker/ICD science, it has not always been possible to maintain consistency with other published guidelines. An example of such a discrepancy can be found in Section I-H, where the recommendation for biventricular pacing in selected patients with heart failure has been listed as Class IIa, whereas in the ACC/AHA Guidelines for the Evaluation and Management of Chronic Heart Failure in the Adult (339), biventricular pacing is cited as an investigational procedure.

The ACC/AHA/NASPE 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices was approved for publication by the AHA Science and Advisory Coordinating Committee and the North American Society of Pacing and Electrophysiology in August 2002 and the ACC Board of Trustees in September 2002. These guidelines will be reviewed 1 year after publication and yearly thereafter and considered current unless the Task Force on Practice Guidelines revises or withdraws them from circulation.

I. INDICATIONS FOR PERMANENT PACING

A. Pacing for Acquired Atrioventricular Block in Adults

Atrioventricular (AV) block is classified as first-, second-, or third-degree (complete) block; anatomically, it is defined as supra-, intra-, or infra-His. First-degree AV block is defined as abnormal prolongation of the PR interval. Second-degree AV block is subclassified as type I and type II. Type I second-degree AV block is characterized by progressive prolongation of the PR interval before a blocked beat and is usually associated with a narrow QRS complex. Type II second-degree AV block is characterized by fixed PR intervals before and after blocked beats and is usually associated with a wide QRS complex. When AV conduction occurs in a 2:1 pattern, block cannot be unequivocally classified as type I or type II, although the width of the QRS can be suggestive as just described. *Advanced second-degree AV block* refers to the block of two or more consecutive P waves but with some conducted beats, indicating some preservation of AV conduction. Third-degree AV block (complete heart block) is defined as absence of AV conduction.

Patients with abnormalities of AV conduction may be asymptomatic or may experience serious symptoms related to bradycardia, ventricular arrhythmias, or both. Decisions regarding the need for a pacemaker are influenced importantly by the presence or absence of symptoms directly attributable to bradycardia. Furthermore, many of the indications for pacing have evolved over 40 years based on experience without the benefit of comparative *randomized* clinical trials, in part because no acceptable alternative options exist to treat most bradycardias.

Nonrandomized studies strongly suggest that permanent pacing does improve survival in patients with third-degree AV block, especially if syncope has occurred (8-13). Although there is little evidence to suggest that pacemakers improve survival in patients with isolated first-degree AV block (14), it is now recognized that marked (PR more than 300 milliseconds) first-degree AV block can lead to symptoms even in the absence of higher degrees of AV block (15). Such marked first-degree AV block may follow catheter ablation of the fast AV nodal pathway with resultant slow pathway conduction. When marked first-degree AV block for any reason causes atrial systole in close proximity to the preceding ventricular systole and produces hemodynamic consequences usually associated with retrograde (ventriculoatrial) conduction, signs and symptoms similar to the pacemaker syndrome may occur (16). With marked first-degree AV block, atrial contraction occurs before complete atrial filling, ventricular filling is compromised, and an increase in pulmonary capillary wedge pressure and a decrease in cardiac output follow. Small, uncontrolled trials have suggested some symptomatic and functional improvement by pacing of patients with PR intervals more than 0.30 seconds by decreasing the time for AV conduction (15). Finally, a long PR interval may identify a subgroup of patients with left ventricular (LV) dysfunction, some of whom may benefit from dual-chamber pacing with a short(er) AV delay (17). These same principles also may be applied to patients with type I second-degree AV block who experience hemodynamic compromise due to loss of AV synchrony, even without bradycardia. Although echocardiographic or invasive techniques may be used to assess hemodynamic improvement before permanent pacemaker implantation, such studies are not required.

Type I second-degree AV block is usually due to delay in the AV node irrespective of QRS width. Because progression to advanced AV block in this situation is uncommon (18-20), pacing is usually not indicated unless the patient is symptomatic. Nevertheless, controversy exists, and pacemaker implantation has been advocated for this finding (21-23). On the other hand, type II second-degree AV block is usually infranodal (either intra- or infra-His), especially when the QRS is wide. In these patients, symptoms are frequent, prognosis is compromised, and progression to third-degree AV block is common (18,20,24). Thus, type II second-degree AV block and a wide QRS indicate diffuse conduction system disease and constitute an indication for pacing even in the absence of symptoms. However, it is not always possible to determine the site of AV block without electrophysiologic evaluation, because type I second-degree AV block can be infranodal even when the QRS is narrow (340-342). If type I second-degree AV block with a narrow or wide QRS is found to be intra- or infra-His at electrophysiologic study, pacing should be considered.

Because it may be difficult for both patients and their physicians to attribute ambiguous symptoms such as fatigue to bradycardia, special vigilance must be exercised to acknowledge the patient's concerns that may be caused by a slow heart rate. Thus, in a patient with third-degree AV block, permanent pacing should be considered strongly even when the ventricular rate is more than 40 beats per minute (bpm), because the choice of a 40 bpm cutoff in these guidelines was not determined from clinical trial data. Indeed, it is not the escape rate that is necessarily critical for safety, but rather the site of origin of the escape rhythm (i.e., in the AV node, the His bundle, or infra-His).

AV block can sometimes be provoked by exercise. If not secondary to myocardial ischemia, AV block in this circumstance usually is due to disease in the His-Purkinje system and is associated with a poor prognosis. Thus, pacing is indicated (343,344). Conversely, long sinus pauses and AV block can occur during sleep apnea. In the absence of symptoms, these abnormalities are reversible and do not require pacing (345). If symptoms are present, pacing is indicated as in other conditions.

Recommendations for permanent pacemaker implantation in patients with AV block in AMI, congenital AV block, and AV block associated with enhanced vagal tone are discussed in separate sections. Neurocardiogenic etiologies in young patients with AV block should be assessed before proceeding with permanent pacing. Physiologic AV block in the presence of supraventricular tachyarrhythmias does not constitute an indication for pacemaker implantation except as specifically defined in the recommendations that follow.

In general, the decision regarding implantation of a pacemaker must be considered with respect to whether or not AV block will be permanent. Reversible causes of AV block, such as electrolyte abnormalities, should be corrected first. Some diseases may follow a natural history to resolution (e.g., Lyme disease), and some AV block can be expected to reverse (e.g., hypervagotonia due to recognizable and avoidable physiologic factors, perioperative AV block due to hypothermia, or inflammation near the AV conduction system after surgery in this region). Conversely, some conditions may warrant pacemaker implantation owing to the possibility of disease progression even if the AV block reverses transiently (e.g., sarcoidosis, amyloidosis, and neuromuscular diseases). Finally, permanent pacing for AV block after valve surgery follows a variable natural history, and therefore the decision for permanent pacing is at the physician's discretion (346).

Recommendations for Permanent Pacing in Acquired Atrioventricular Block in Adults

Class I

1. **Third-degree and advanced second-degree AV block at any anatomic level, associated with any one of the following conditions:**
   a. **Bradycardia with symptoms (including heart failure) presumed to be due to AV block. *(Level of Evidence: C)***
   b. **Arrhythmias and other medical conditions that require drugs that result in symptomatic bradycardia. *(Level of Evidence: C)***
   c. **Documented periods of asystole greater than or equal to 3.0 seconds (25) or any escape rate less than 40 bpm in awake, symptom-free patients (26,27). *(Level of Evidence: B, C)***
   d. **After catheter ablation of the AV junction. *(Level of Evidence: B, C)* There are no trials to assess outcome without pacing, and pacing is virtually always planned in this situation unless the operative procedure is AV junction modification (28,29).**
   e. **Postoperative AV block that is not expected to resolve after cardiac surgery. *(Level of Evidence: C)* (30,30a,346)**
   f. **Neuromuscular diseases with AV block, such as myotonic muscular dystrophy, Kearns-Sayre syndrome, Erb's dystrophy (limb-girdle), and peroneal muscular atrophy, with or without symptoms, because there may be unpredictable progression of AV conduction disease. *(Level of Evidence: B)* (31-37)**
2. **Second-degree AV block regardless of type or site of block, with associated symptomatic bradycardia. *(Level of Evidence: B)* (19)**

Class IIa

1. **Asymptomatic third-degree AV block at any anatomic site with average awake ventricular rates of 40 bpm or faster, especially if cardiomegaly or LV dysfunction is present. *(Level of Evidence: B, C)***
2. **Asymptomatic type II second-degree AV block with a narrow QRS. When type II second-degree AV block occurs with a wide QRS, pacing becomes a Class I recommendation (see next section regarding Pacing for Chronic Bifascicular and Trifascicular Block). *(Level of Evidence: B)* (21,23)**
3. **Asymptomatic type I second-degree AV block at intra- or infra-His levels found at electrophysiologic study performed for other indications. *(Level of Evidence: B)* (19,21-23)**
4. **First- or second-degree AV block with symptoms similar to those of pacemaker syndrome. *(Level of Evidence: B)* (15,16)**

Class IIb

1. **Marked first-degree AV block (more than 0.30 seconds) in patients with LV dysfunction and symptoms of congestive heart failure in whom a shorter AV interval results in hemodynamic improvement, pre-**

sumably by decreasing left atrial filling pressure. *(Level of Evidence: C)* (17)

2. **Neuromuscular diseases such as myotonic muscular dystrophy, Kearns-Sayre syndrome, Erb's dystrophy (limb-girdle), and peroneal muscular atrophy with any degree of AV block (including first-degree AV block), with or without symptoms, because there may be unpredictable progression of AV conduction disease. *(Level of Evidence: B)* (31-37)**

Class III

1. **Asymptomatic first-degree AV block. *(Level of Evidence: B)* (14) (See also "Pacing for Chronic Bifascicular and Trifascicular Block.")**
2. **Asymptomatic type I second-degree AV block at the supra-His (AV node) level or not known to be intra- or infra-Hisian. *(Level of Evidence: B, C)* (19)**
3. **AV block expected to resolve and/or unlikely to recur (38) (e.g., drug toxicity, Lyme disease, or during hypoxia in sleep apnea syndrome in absence of symptoms). *(Level of Evidence: B)***

B. Pacing for Chronic Bifascicular and Trifascicular Block

Bifascicular block refers to electrocardiographic (ECG) evidence of impaired conduction below the AV node in two fascicles of the right and left bundles. Alternating bundle-branch block (also known as bilateral bundle-branch block) refers to situations in which clear ECG evidence for block in all three fascicles is seen on successive ECGs. Examples are right bundle-branch block and left bundle-branch block on successive ECGs, or right bundle-branch block with associated left anterior fascicular block on one ECG and associated left posterior fascicular block on another ECG. A strict definition of trifascicular block is block documented in all three fascicles whether simultaneously or at different times. Alternating bundle-branch block also fulfills this criterion. This term has also been used to describe first-degree AV block in association with bifascicular block. Patients with such ECG abnormalities and symptomatic, advanced AV block have a high mortality rate and a significant incidence of sudden death (9,39). Although third-degree AV block is most often preceded by bifascicular block, there is evidence that the rate of progression of bifascicular block to third-degree AV block is slow (347). Furthermore, no single clinical or laboratory variable, including bifascicular block, identifies patients at high risk of death from a future bradyarrhythmia due to bundle-branch block (48).

Syncope is common in patients with bifascicular block. Although syncope may be recurrent, it is not associated with an increased incidence of sudden death (40-52). Although pacing relieves the transient neurological symptoms, it does not reduce the occurrence of sudden death (46). Electrophysiologic study may be helpful to evaluate and direct the treatment of inducible ventricular arrhythmias (53,54) that are common in patients with bifascicular and trifascicular block. There is convincing evidence that in the presence of permanent or transient third-degree AV block, syncope is associated with an increased incidence of sudden death regardless of the results of electrophysiologic study (9,54,55). Finally, if the cause of syncope in the presence of bifascicular or trifascicular block cannot be determined with certainty or if treatments used (such as drugs) may exacerbate AV block, prophylactic permanent pacing is indicated, especially if syncope may have been due to transient third-degree AV block (40,52).

Of the many laboratory variables, the PR and HV intervals have been identified as possible predictors of third-degree AV block and sudden death. Although PR interval prolongation is common in patients with bifascicular block, the delay is often at the level of the AV node. There is no correlation between the PR and HV intervals or between the length of the PR interval, progression to third-degree AV block, and sudden death (43,45,49). Although most patients with chronic or intermittent third-degree AV block demonstrate prolongation of the HV interval during anterograde conduction, some investigators (50,51) have suggested that asymptomatic patients with bifascicular block and a prolonged HV interval should be considered for permanent pacing, especially if the HV interval is greater than or equal to 100 milliseconds (49). The evidence indicates that although the prevalence of prolonged HV is high, the incidence of progression to third-degree AV block is low. Because HV prolongation accompanies advanced cardiac disease and is associated with increased mortality, death is often not sudden or due to AV block but rather due to the underlying heart disease itself and nonarrhythmic cardiac causes (43,46-49,51,54-56).

Atrial pacing at electrophysiologic study in asymptomatic patients as a means of identifying patients at increased risk of future high- or third-degree AV block is controversial. The probability of inducing block distal to the AV node (i.e., intra- or infra-His) with rapid atrial pacing is low (47,50,51,57-60). Failure to induce distal block cannot be taken as evidence that the patient will not develop third-degree AV block in the future. However, if atrial pacing induces nonphysiologic infra-His block, some consider this an indication for pacing (57).

Recommendations for Permanent Pacing in Chronic Bifascicular and Trifascicular Block

Class I

1. **Intermittent third-degree AV block. *(Level of Evidence: B)* (8-13,39)**
2. **Type II second-degree AV block. *(Level of Evidence: B)* (18,20,24,348)**
3. **Alternating bundle-branch block. *(Level of Evidence: C)* (349)**

Class IIa

1. **Syncope not demonstrated to be due to AV block when other likely causes have been excluded, specifi-**

cally ventricular tachycardia (VT). ***(Level of Evidence: B)*** **(40-51,53-58)**

2. **Incidental finding at electrophysiologic study of markedly prolonged HV interval (greater than or equal to 100 milliseconds) in asymptomatic patients.** ***(Level of Evidence: B)*** **(49)**
3. **Incidental finding at electrophysiologic study of pacing-induced infra-His block that is not physiologic.** ***(Level of Evidence: B)*** **(57)**

Class IIb

Neuromuscular diseases such as myotonic muscular dystrophy, Kearns-Sayre syndrome, Erb's dystrophy (limb-girdle), and peroneal muscular atrophy with any degree of fascicular block, with or without symptoms, because there may be unpredictable progression of AV conduction disease. ***(Level of Evidence: C)*** **(31-37)**

Class III

1. **Fascicular block without AV block or symptoms.** ***(Level of Evidence: B)*** **(43,45,48,49)**
2. **Fascicular block with first-degree AV block without symptoms.** ***(Level of Evidence: B)*** **(43,45,48,49)**

C. Pacing for Atrioventricular Block Associated With Acute Myocardial Infarction

Indications for permanent pacing after myocardial infarction (MI) in patients experiencing AV block are related in large measure to the presence of intraventricular conduction defects. Unlike some other indications for permanent pacing, the criteria for patients with MI and AV block do not necessarily depend on the presence of symptoms. Furthermore, the requirement for temporary pacing in AMI does not by itself constitute an indication for permanent pacing [see ACC/AHA Guidelines for Management of Patients With Acute Myocardial Infarction (335)].

The long-term prognosis for survivors of AMI who have had AV block is related primarily to the extent of myocardial injury and the character of intraventricular conduction disturbances rather than the AV block itself (11,61-64). Patients with AMI who have intraventricular conduction defects, with the exception of isolated left anterior fascicular block, have an unfavorable short- and long-term prognosis and an increased risk of sudden death (11,24,61,63). This unfavorable prognosis is not necessarily due to development of high-grade AV block, although the incidence of such block is higher in postinfarction patients with abnormal intraventricular conduction (61,65,350).

When AV or intraventricular conduction block complicates AMI, the type of conduction disturbance, location of infarction, and relation of electrical disturbance to infarction must be considered if permanent pacing is contemplated. Even with data available, the decision is not always straightforward, because the reported incidence and significance of various conduction disturbances vary widely (66). Despite the use of thrombolytic therapy and primary angioplasty, which have decreased the incidence of AV block in AMI, mortality remains high if AV block occurs (67-70).

Although more severe disturbances in conduction are in general associated with greater arrhythmic and nonarrhythmic mortality (61-66), the impact of pre-existing bundle-branch block on mortality after AMI is controversial (52,66). A particularly ominous prognosis is associated with left bundle-branch block combined with advanced second- or third-degree AV block and with right bundle-branch block combined with left anterior or left posterior fascicular block (41,52,62,64). Irrespective of whether the infarction is anterior or inferior, the development of an intraventricular conduction delay reflects extensive myocardial damage rather than an electrical problem in isolation (64). Although AV block that occurs during inferior MI can be associated with a favorable long-term clinical outcome, in-hospital survival is impaired, irrespective of temporary or permanent pacing in this situation (67,68,71,72). Furthermore, pacemakers should not be implanted if the peri-infarctional AV block is expected to resolve or to not negatively impact long-term prognosis, as in the case of inferior MI (69).

Recommendations for Permanent Pacing After the Acute Phase of Myocardial Infarction*

Class I

1. **Persistent second-degree AV block in the His-Purkinje system with bilateral bundle-branch block or third-degree AV block within or below the His-Purkinje system after AMI.** ***(Level of Evidence: B)*** **(24,61-65)**
2. **Transient advanced (second- or third-degree) infranodal AV block and associated bundle-branch block. If the site of block is uncertain, an electrophysiologic study may be necessary.** ***(Level of Evidence: B)*** **(61,62)**
3. **Persistent and symptomatic second- or third-degree AV block.** ***(Level of Evidence: C)***

Class IIb

Persistent second- or third-degree AV block at the AV node level. ***(Level of Evidence: B)*** **(23)**

Class III

1. **Transient AV block in the absence of intraventricular conduction defects.** ***(Level of Evidence: B)*** **(61)**
2. **Transient AV block in the presence of isolated left anterior fascicular block.** ***(Level of Evidence: B)*** **(63)**
3. **Acquired left anterior fascicular block in the absence of AV block.** ***(Level of Evidence: B)*** **(61)**
4. **Persistent first-degree AV block in the presence of bundle-branch block that is old or age indeterminate.** ***(Level of Evidence: B)*** **(61)***

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*These recommendations generally follow the ACC/AHA Guidelines for the Management of Patients With Acute Myocardial Infarction (335).

D. Pacing in Sinus Node Dysfunction

Sinus node dysfunction (sick sinus syndrome) constitutes a spectrum of cardiac arrhythmias, including sinus bradycardia, sinus arrest, sinoatrial block, and paroxysmal supraventricular tachyarrhythmias alternating with periods of bradycardia or even asystole. Patients with this condition may be symptomatic from paroxysmal tachycardia or bradycardia or both. Correlation of symptoms with the above arrhythmias by use of an ECG, ambulatory ECG monitoring, or an event recorder is essential. This correlation may be difficult because of the intermittent nature of the episodes. In the electrophysiology laboratory, abnormal sinus node function may be confirmed by demonstration of prolonged corrected sinus node recovery times or prolonged sinoatrial conduction times. However, utility of electrophysiologic studies for sinus node dysfunction is limited by issues of sensitivity and specificity.

Sinus node dysfunction may express itself as chronotropic incompetence in which there is an inadequate sinus response to exercise or stress. Rate-responsive pacemakers have clinically benefited patients by restoring physiologic heart rate during physical activity (73-75).

Sinus bradycardia is accepted as a physiologic finding in trained athletes, who not uncommonly have a heart rate of 40 to 50 bpm while at rest and awake and may have a sleeping rate as slow as 30 bpm, with sinus pauses or type I second-degree AV block producing asystolic intervals as long as 2.8 seconds (76-78). These findings are due to increased vagal tone.

Although sinus node dysfunction is frequently the primary indication for implantation of permanent pacemakers (73), permanent pacing in patients with sinus node dysfunction may not necessarily result in improved survival time (26,79), although symptoms related to bradycardia may be relieved (27,80) (see Section I, Selection of Pacemaker Devices). During monitoring, pauses are sometimes observed during sleep. Duration of sinus pauses and their clinical significance is uncertain. If due to sleep apnea, apnea should be treated. A small retrospective trial of atrial overdrive pacing in the treatment of sleep apnea demonstrated a decrease "in episodes of central or obstructive sleep apnea without reducing the total sleep time" (447). Although this initial trial is encouraging, it is premature to propose pacing guidelines until a larger body of data is available. Otherwise, there is not sufficient evidence to distinguish physiologic from pathologic nocturnal bradycardia.

Recommendations for Permanent Pacing in Sinus Node Dysfunction

Class I

1. **Sinus node dysfunction with documented symptomatic bradycardia, including frequent sinus pauses that produce symptoms. In some patients, bradycardia is iatrogenic and will occur as a consequence of essential long-term drug therapy of a type and dose for which there are no acceptable alternatives. *(Level of Evidence: C)* (27,73,79)**
2. **Symptomatic chronotropic incompetence. *(Level of Evidence: C)* (27,73-75,79)**

Class IIa

1. **Sinus node dysfunction occurring spontaneously or as a result of necessary drug therapy, with heart rate less than 40 bpm when a clear association between significant symptoms consistent with bradycardia and the actual presence of bradycardia has not been documented. *(Level of Evidence: C)* (26,27,73,78-80)**
2. **Syncope of unexplained origin when major abnormalities of sinus node function are discovered or provoked in electrophysiologic studies. *(Level of Evidence: C)* (351,352)**

Class IIb

In minimally symptomatic patients, chronic heart rate less than 40 bpm while awake. *(Level of Evidence: C)* (26,27,73,78-80)

Class III

1. **Sinus node dysfunction in asymptomatic patients, including those in whom substantial sinus bradycardia (heart rate less than 40 bpm) is a consequence of long-term drug treatment.**
2. **Sinus node dysfunction in patients with symptoms suggestive of bradycardia that are clearly documented as not associated with a slow heart rate.**
3. **Sinus node dysfunction with symptomatic bradycardia due to nonessential drug therapy.**

E. Prevention and Termination of Tachyarrhythmias by Pacing

Under certain circumstances, an implanted pacemaker may be useful for treating patients with recurrent symptomatic ventricular and supraventricular tachycardias (85-94). Pacing can be useful in preventing and terminating arrhythmias. Reentrant rhythms including atrial flutter, paroxysmal reentrant supraventricular tachycardia, and VT may be terminated by a variety of pacing patterns, including programmed stimulation and short bursts of rapid pacing (95,96). These antitachyarrhythmia devices may detect tachycardia and automatically activate a pacing sequence, or they may respond only to an external instruction (for example, application of a magnet).

Prevention of arrhythmias by pacing has been demonstrated in certain situations. In some patients with the long-QT syndrome, recurrent pause-dependent VT may be prevented by continuous pacing (97). A combination of pacing and beta-blockade has been reported to shorten the QT interval and help prevent sudden cardiac death (98,99). ICD therapy in combination with overdrive suppression pacing should be considered in high-risk patients.

Atrial synchronous ventricular pacing may prevent recurrences of re-entrant supraventricular tachycardia (100) although this technique is rarely used given the availability of catheter ablation and other alternative therapies. Although ventricular ectopic activity may be suppressed by such pacing in other conditions, serious or symptomatic arrhythmias are rarely prevented (101). In some patients with bradycardia-dependent atrial fibrillation, atrial pacing may be effective in reducing the frequency of recurrences (92). In the Mode Selection Trial (MOST), 2010 patients with sinus node dysfunction were randomized between DDDR and VVIR pacing. After a mean follow-up of 33 months, there was a 21% lower risk of atrial fibrillation ($p = 0.008$) in the DDDR group than in the VVVIR group (353). Other trials are under way to assess the efficacy of atrial overdrive pacing algorithms and algorithms that react to premature atrial complexes in preventing atrial fibrillation, but data to date are sparse. Dual-site right atrial pacing or alternate single-site atrial pacing from nonconventional sites (e.g., septal or Bachmann's bundle) may offer additional benefits to single-site right atrial pacing from the appendage in patients with symptomatic drug-refractory atrial fibrillation and concomitant bradyarrhythmias (93). In patients with sick sinus syndrome and intra-atrial block (P wave more than 180 milliseconds), biatrial pacing may lower recurrence rates of atrial fibrillation (94).

Potential recipients of antitachyarrhythmia devices that interrupt arrhythmias should undergo extensive testing before implantation to ensure that the devices safely and reliably terminate the ectopic mechanism without accelerating the tachycardia or inducing ventricular fibrillation (VF). Patients for whom an antitachycardia pacemaker has been prescribed have usually been unresponsive to antiarrhythmic drugs or were receiving agents that could not control their cardiac arrhythmias. When permanent antitachycardia pacemakers detect and interrupt supraventricular tachycardia, all pacing should be done in the atrium, because adverse interactions have been reported (85,102) with use of ventricular pacing to interrupt supraventricular arrhythmias. Permanent antitachycardia pacing as monotherapy for VT is not appropriate given that antitachycardia pacing algorithms are available in tiered-therapy ICDs that have the capability of cardioversion and defibrillation in cases when antitachycardia pacing is ineffective or causes acceleration of the treated tachycardia.

Recommendations for Permanent Pacemakers That Automatically Detect and Pace to Terminate Tachycardias

Class I

None.

Class IIa

Symptomatic recurrent supraventricular tachycardia that is reproducibly terminated by pacing in the unlikely event that catheter ablation and/or drugs fail to control the arrhythmia or produce intolerable side effects. *(Level of Evidence: C)* (86-88,90,91)

Class IIb

Recurrent supraventricular tachycardia or atrial flutter that is reproducibly terminated by pacing as an alternative to drug therapy or ablation. *(Level of Evidence: C)* (85-88,90,91)

Class III

1. **Tachycardias frequently accelerated or converted to fibrillation by pacing.**
2. **The presence of accessory pathways with the capacity for rapid anterograde conduction whether or not the pathways participate in the mechanism of the tachycardia.**

Pacing Recommendations to Prevent Tachycardia

Class I

Sustained pause-dependent VT, with or without prolonged QT, in which the efficacy of pacing is thoroughly documented. *(Level of Evidence: C)* (97,98)

Class IIa

High-risk patients with congenital long-QT syndrome. *(Level of Evidence: C)* (97,98)

Class IIb

1. **AV re-entrant or AV node re-entrant supraventricular tachycardia not responsive to medical or ablative therapy. *(Level of Evidence: C)* (87,88,92)**
2. **Prevention of symptomatic, drug-refractory, recurrent atrial fibrillation in patients with coexisting sinus node dysfunction. *(Level of Evidence: B)* (93,94, 354,355)**

Class III

1. **Frequent or complex ventricular ectopic activity without sustained VT in the absence of the long-QT syndrome.**
2. **Torsade de Pointes VT due to reversible causes.**

F. Pacing in Hypersensitive Carotid Sinus and Neurocardiogenic Syncope

The hypersensitive carotid sinus syndrome is defined as syncope or presyncope resulting from an extreme reflex response to carotid sinus stimulation. It is an uncommon cause of syncope. There are two components of the reflex:

1. *Cardioinhibitory*, resulting from increased parasympathetic tone and manifested by slowing of the sinus rate or prolongation of the PR interval and advanced AV block, alone or in combination.
2. *Vasodepressor*, secondary to a reduction in sympathetic activity resulting in loss of vascular tone and hypotension. This effect is independent of heart rate changes.

Before concluding that permanent pacing is clinically indicated, the physician should determine the relative contribution of the two components of carotid sinus stimulation to the individual patient's symptom complex. Hyperactive response to carotid sinus stimulation is defined as asystole due to either sinus arrest or AV block of more than 3 seconds, or a substantial symptomatic decrease in systolic blood pressure, or both (106). Pauses up to 3 seconds during carotid sinus massage are considered to be within normal limits. Such heart rate and hemodynamic responses may occur in normal subjects and patients with coronary artery disease. The cause-and-effect relation between the hypersensitive carotid sinus and the patient's symptoms must be made with great caution (107). Spontaneous syncope reproduced by carotid sinus stimulation should alert the physician to the presence of this syndrome. Minimal pressure on the carotid sinus in elderly patients or patients receiving digitalis may result in marked changes in heart rate and blood pressure yet not be of clinical significance. Permanent pacing for patients with pure excessive cardioinhibitory response to carotid stimulation is effective in relieving symptoms (108,109). Because 10% to 20% of patients with this syndrome may have an important vasodepressor component of their reflex response, it is desirable to define this component before concluding that all symptoms are related to asystole alone. Among patients whose reflex response includes both cardioinhibitory and vasodepressor components, attention to the latter is essential for effective therapy in patients undergoing pacing.

Evidence has emerged that suggests that elderly patients who have sustained otherwise unexplained falls may have carotid sinus hypersensitivity (356). In a subsequent study, 175 elderly patients who had fallen without loss of consciousness and had pauses greater than 3 seconds during carotid sinus massage (thus fulfilling the diagnosis of carotid sinus hypersensitivity) were randomized to pacing or non-pacing therapy. The paced group had a significantly lower likelihood of subsequent falling episodes during follow-up (357).

Neurocardiogenic syncope and neurocardiogenic syndromes refer to a variety of clinical scenarios in which triggering of a neural reflex results in a usually self-limited episode of systemic hypotension characterized by both bradycardia and peripheral vasodilation (110). Neurocardiogenic syncope accounts for 10% to 40% of syncope episodes. Vasovagal syncope is a term used to denote one of the most common clinical scenarios within the category of neurocardiogenic syncopal syndromes. Patients classically have a prodrome of nausea and diaphoresis (often absent in the elderly), and there may be a positive familial history of the condition. Spells may be triggered by pain, anxiety, stress, or crowded conditions. Typically, no evidence of structural heart disease is present. Other causes of syncope such as LV outflow obstruction, bradyarrhythmias, and tachyarrhythmias should be excluded. Head-up tilt-table testing may be diagnostic.

The role of permanent pacing in refractory neurocardiogenic syncope associated with significant bradycardia or asystole is controversial. Approximately 25% of patients have a predominant vasodepressor reaction without significant bradycardia (111). An additional large percentage of patients will have a mixed vasodepressor/vasoinhibitory component of their symptoms. While one group of investigators have noted some benefit of pacing in these patients (112,113), another study using a pacing rate 20% higher than the resting heart rate demonstrated that pacing did not prevent syncope any better than pharmacotherapy (106). Because most individuals with neurocardiogenic syncope have a slowing of heart rate after the fall in blood pressure, pacing may be ineffective in most patients. Dual-chamber pacing, carefully prescribed on the basis of tilt-table test results, may be effective in reducing symptoms if the patient has a significant cardioinhibitory component to the cause of their symptoms (114). Results from a *randomized trial* (358,359) in highly symptomatic patients with bradycardia demonstrated that permanent pacing increased the time to first syncopal event. In one of these trials (358), the actuarial rate of recurrent syncope at 1 year was 18.5% for pacemaker patients and 59.7% for control patients. The specific modality of pacing under these circumstances is under active investigation. One study demonstrated that DDD pacing with rate-drop response function was more effective than beta-blockade in preventing recurrent syncope in highly symptomatic patients with vasovagal syncope and relative bradycardia during tilt-table testing (360). Although spontaneous or provoked prolonged pauses are a concern in this population, the prognosis without pacing is excellent (116). Several investigators have concluded that some patients with syncope of undetermined origin may benefit from pacing if findings strongly suggestive of bradycardic etiology are discovered or provoked at electrophysiologic study (117,118,361).

The evaluation of patients with syncope of undetermined origin should take into account clinical status and not overlook other, more serious causes of syncope such as ventricular tachyarrhythmias.

Recommendations for Permanent Pacing in Hypersensitive Carotid Sinus Syndrome and Neurocardiogenic Syncope

Class I

Recurrent syncope caused by carotid sinus stimulation; minimal carotid sinus pressure induces ventricular asystole of more than 3 seconds' duration in the absence of any medication that depresses the sinus node or AV conduction. *(Level of Evidence: C)* (108,109)

Class IIa

1. **Recurrent syncope without clear, provocative events and with a hypersensitive cardioinhibitory response. *(Level of Evidence: C)* (108,109)**
2. **Significantly symptomatic and recurrent neurocardiogenic syncope associated with bradycardia docu-**

mented spontaneously or at the time of tilt-table testing. ***(Level of Evidence: B)*** **(358-360,362)**

Class III

1. **A hyperactive cardioinhibitory response to carotid sinus stimulation in the absence of symptoms or in the presence of vague symptoms such as dizziness, lightheadedness, or both.** ***(Level of Evidence: C)***
2. **Recurrent syncope, lightheadedness, or dizziness in the absence of a hyperactive cardioinhibitory response.** ***(Level of Evidence: C)***
4. **Situational vasovagal syncope in which avoidance behavior is effective.** ***(Level of Evidence: C)***

G. Pacing in Children, Adolescents, and Patients With Congenital Heart Disease

The indications for permanent cardiac pacemaker implantation in the child, adolescent, or young adult with congenital heart disease may be considered broadly as 1) symptomatic sinus bradycardia, 2) the bradycardia-tachycardia syndromes, 3) congenital third-degree AV block, and 4) advanced second- or third-degree AV block, either surgical or acquired. Although the general indications for pacemaker implantation in children are similar to those in adults, there are several important considerations in young patients. First, an increasing number of patients are surviving complex surgical procedures for congenital heart disease that result in palliation rather than correction of circulatory physiology. The residua of impaired ventricular function and abnormal physiology may result in symptomatic bradycardia at rates that do not produce symptoms in persons with normal cardiovascular physiology. Hence, the indications for pacemaker implantation in these patients need to be based on the correlation of symptoms with relative bradycardia rather than absolute heart rate criteria. Second, the clinical significance of bradycardia is age dependent; whereas a heart rate of 45 bpm may be a normal finding in an adolescent, the same rate in a newborn or infant indicates profound bradycardia.

Bradycardia and associated symptoms in children are often transient (e.g., paroxysmal AV block or sinus arrest) and difficult to document. Although sinus node dysfunction (sick sinus syndrome) is increasingly recognized in pediatric patients, it is not itself an indication for pacemaker implantation. In the young patient with sinus bradycardia, the primary criterion for a pacemaker is the concurrent observation of a symptom (e.g., syncope) with bradycardia (e.g., heart rate less than 40 bpm or asystole more than 3 seconds) (25,27,119). In general, correlation of symptoms with bradycardia is determined by 24-hour ambulatory or transtelephonic electrocardiography. Symptomatic bradycardia (as defined) is considered an indication for pacemaker implantation, provided that other causes of the symptom(s) have been excluded. Alternative causes to be considered include seizures, breath holding, apnea, or neurocardiogenic mechanisms.

The bradycardia-tachycardia syndrome (sinus bradycardia alternating with atrial flutter or re-entrant atrial tachycardia) is an increasingly frequent problem in young patients following surgery for congenital heart disease. Substantial morbidity and mortality have been observed in young patients with recurrent or chronic atrial flutter, with the loss of sinus rhythm an independent risk factor for subsequent development of atrial flutter (120,121). Thus, both long-term atrial pacing at physiologic rates as well as atrial antitachycardia pacing have been reported for treatment of sinus bradycardia and prevention or termination of recurrent episodes of tachycardia (122,123). To date, the results of pacing for the bradycardia-tachycardia syndrome in children have been equivocal and the source of considerable controversy (124,125). It is clear that long-term drug therapy (e.g., sotalol or amiodarone) deemed essential for the control of atrial flutter may result in symptomatic bradycardia in some patients, whereas the use of other antiarrhythmic agents (e.g., quinidine) may potentially increase the risk of ventricular arrhythmias or sudden death in the presence of profound bradycardia. Thus, in young patients with recurrent arrhythmias associated with the bradycardia-tachycardia syndrome, permanent pacing should be considered as an adjunctive form of therapy. As an alternative therapy to antiarrhythmic medications that result in profound bradycardia and the need for pacemaker implantation, radiofrequency catheter ablation may modify the anatomic substrate of tachycardia in select patients with congenital heart disease.

Indications for permanent pacing in young patients with congenital complete AV block continue to evolve, based on improved definition of the natural history of the disease as well as advances in pacemaker technology and diagnostic methods. In several studies it has been observed that pacemaker implantation may improve long-term survival and prevent syncopal episodes among asymptomatic patients with congenital complete AV block (126,127). Periodic evaluation of ventricular function is required in patients with congenital AV block, even after pacemaker implantation (363). Several criteria (average heart rate, pauses in the intrinsic rate, associated structural heart disease, prolonged QT interval, and exercise tolerance) must be considered in the asymptomatic patient with congenital complete AV block (128-130).

The use of cardiac pacing with beta-blockade for prevention of symptoms in patients with the congenital long-QT syndrome is supported by observational studies (98,131,364). The primary benefit of pacemaker therapy may be in patients with pause-dependent initiation of ventricular tachyarrhythmias (132) or those with sinus bradycardia or advanced AV block in association with the congenital long-QT syndrome (133,134). Although pacemaker implantation may reduce the incidence of symptoms in these patients, long-term benefit on risk of sudden cardiac arrest remains to be determined (98,131,133).

A poor prognosis has been established for patients with permanent postsurgical AV block who do not receive permanent pacemakers for rate support (135). The presence of advanced second- or third-degree AV block persisting for 7 to 14 days after cardiac surgery is considered a Class I indication for pacemaker implantation (136). The need for pacing in patients with transient advanced AV block with residual bifascicular block is less certain, whereas patients in whom AV conduction returns to normal generally have a favorable prognosis (137).

Additional details that need to be considered in pacemaker implantation in young patients include risk of paradoxic embolism due to thrombus formation on an endocardial lead system in the presence of residual intracardiac defects and the lifelong need for permanent cardiac pacing (138,139). Decisions about pacemaker implantation must also take into account implantation technique (transvenous versus epicardial) and long-term vascular access.

Recommendations for Permanent Pacing in Children, Adolescents, and Patients With Congenital Heart Disease

Class I

1. **Advanced second- or third-degree AV block associated with symptomatic bradycardia, ventricular dysfunction, or low cardiac output. *(Level of Evidence: C)***
2. **Sinus node dysfunction with correlation of symptoms during age-inappropriate bradycardia. The definition of bradycardia varies with the patient's age and expected heart rate. *(Level of Evidence: B)* (25,27,119)**
3. **Postoperative advanced second- or third-degree AV block that is not expected to resolve or persists at least 7 days after cardiac surgery. *(Level of Evidence: B, C)* (365,366)**
4. **Congenital third-degree AV block with a wide QRS escape rhythm, complex ventricular ectopy, or ventricular dysfunction. *(Level of Evidence: B)* (127,129,363)**
5. **Congenital third-degree AV block in the infant with a ventricular rate less than 50 to 55 bpm or with congenital heart disease and a ventricular rate less than 70 bpm. *(Level of Evidence: B, C)* (129,130)**
6. **Sustained pause-dependent VT, with or without prolonged QT, in which the efficacy of pacing is thoroughly documented. *(Level of Evidence: B)* (97,98,131,132)**

Class IIa

1. **Bradycardia-tachycardia syndrome with the need for long-term antiarrhythmic treatment other than digitalis. *(Level of Evidence: C)* (123,124)**
2. **Congenital third-degree AV block beyond the first year of life with an average heart rate less than 50 bpm, abrupt pauses in ventricular rate that are two or three times the basic cycle length, or associated with symptoms due to chronotropic incompetence. *(Level of Evidence: B)* (128)**
3. **Long-QT syndrome with 2:1 AV or third-degree AV block. *(Level of Evidence: B)* (133,134)**
4. **Asymptomatic sinus bradycardia in the child with complex congenital heart disease with resting heart rate less than 40 bpm or pauses in ventricular rate more than 3 seconds. *(Level of Evidence: C)***
5. **Patients with congenital heart disease and impaired hemodynamics due to sinus bradycardia or loss of AV synchrony. *(Level of Evidence: C)***

Class IIb

1. **Transient postoperative third-degree AV block that reverts to sinus rhythm with residual bifascicular block. *(Level of Evidence: C)* (137)**
2. **Congenital third-degree AV block in the asymptomatic infant, child, adolescent, or young adult with an acceptable rate, narrow QRS complex, and normal ventricular function. *(Level of Evidence: B)* (126,127)**
3. **Asymptomatic sinus bradycardia in the adolescent with congenital heart disease with resting heart rate less than 40 bpm or pauses in ventricular rate more than 3 seconds. *(Level of Evidence: C)***
4. **Neuromuscular diseases with any degree of AV block (including first-degree AV block), with or without symptoms, because there may be unpredictable progression of AV conduction disease.**

Class III

1. **Transient postoperative AV block with return of normal AV conduction. *(Level of Evidence: B)* (136,137)**
2. **Asymptomatic postoperative bifascicular block with or without first-degree AV block. *(Level of Evidence: C)***
3. **Asymptomatic type I second-degree AV block. *(Level of Evidence: C)***
4. **Asymptomatic sinus bradycardia in the adolescent with longest RR interval less than 3 seconds and minimum heart rate more than 40 bpm. *(Level of Evidence: C)* (140)**

H. Pacing in Specific Conditions

1. Hypertrophic Obstructive Cardiomyopathy

Early *nonrandomized* studies demonstrated a fall in the LV outflow gradient with dual-chamber pacing and a short AV delay and symptomatic improvement in some patients with hypertrophic obstructive cardiomyopathy (141-143,154). One long-term study (153) in eight patients supported the long-term benefit of dual-chamber pacing in this group of patients. The outflow gradient was reduced even after cessation of pacing, suggesting that some ventricular remodeling had occurred consequent to pacing. Two *randomized* trials (152,154) demonstrated subjective improvement in approximately 50% of study participants but there was no correlation with gradient reduction, and a significant placebo effect was present. A third *randomized* trial (367) failed to demonstrate any overall improvement in quality of life with pacing, although there was a suggestion that elderly patients (aged more than 65 years) may derive more benefit from pacing.

In a small group of patients with symptomatic, hypertensive cardiac hypertrophy with cavity obliteration, VDD pacing with premature excitation statistically improved exercise capacity, cardiac reserve, and clinical symptoms (368). Dual-chamber pacing may improve symptoms and LV outflow gradient in pediatric patients. However, rapid atrial rates, rapid AV conduction, and congenital mitral valve abnormalities may preclude effective pacing in some patients (155).

There are currently no data available to support the contention that pacing alters the clinical course of the disease or improves survival or quality of life. Therefore, routine implantation of dual-chamber pacemakers should not be advocated in all patients with symptomatic hypertrophic obstructive cardiomyopathy. Patients who may benefit the most are those with significant gradients (more than 30 mm Hg at rest or more than 50 mm Hg provoked (154,369-371). In highly symptomatic patients, septal myectomy or percutaneous septal alcohol ablation should be considered instead of dual-chamber pacing (372). For the patient with hypertrophic obstructive cardiomyopathy who is at high risk for sudden death and has a definite indication for pacemaker implantation, the clinician should weigh the long-term advantages of implantation instead an ICD, even if the patient's condition might not warrant an ICD implant at that point in time (see Section II-E).

Pacing Recommendations for Hypertrophic Cardiomyopathy

Class I

Class I indications for sinus node dysfunction or AV block as described previously. ***(Level of Evidence: C)***

Class IIb

Medically refractory, symptomatic hypertrophic cardiomyopathy with significant resting or provoked LV outflow obstruction. ***(Level of Evidence: A)*** **(142,145,146,152,154,367)**

Class III

1. **Patients who are asymptomatic or medically controlled.**
2. **Symptomatic patients without evidence of LV outflow obstruction.**

2. Idiopathic Dilated Cardiomyopathy

Several *observational* studies have shown limited improvement in patients who have symptomatic dilated cardiomyopathy refractory to medical therapy with dual-chamber pacing with a short AV delay (156-159). Theoretically, a short AV delay may optimize the timing of mechanical AV synchrony and ventricular filling time. In patients with prolonged PR intervals more than 200 milliseconds, diastolic filling time may be improved by dual-chamber pacing with a short AV delay (17). In one study (157), cardiac output was increased 38% by shortening AV delay when the average PR interval was 283 milliseconds before pacing. When the PR interval was shorter, no benefit of pacing was noted. Permanent pacing in symptomatic patients with drug-refractory dilated cardiomyopathy and a prolonged PR interval may be useful if short-term benefit is demonstrated in acute studies. At this time no long-term data are available, and there is no consensus for this indication. The mechanisms by which dual-chamber pacing might benefit patients with dilated cardiomyopathy are poorly understood. One hypothesis is that a well-timed atrial contraction primes the ventricles and decreases mitral regurgitation, thus augmenting stroke volume and arterial pressure.

Thirty to fifty percent of patients with congestive heart failure have intraventricular conduction defects (373,374). These conduction abnormalities progress over time, lead to discoordinated contraction of an already hemodynamically compromised ventricle, and are an independent predictor of mortality (375). Delayed activation of the LV during right ventricular pacing also leads to significant dyssynchrony in both LV contraction and relaxation. Biventricular pacing can provide a more coordinated pattern of ventricular contraction, reduce the QRS duration, and reduce intraventricular and interventricular asynchrony. Biventricular pacing was initially demonstrated to improve cardiac index acutely, decrease systemic vascular resistance and pulmonary capillary wedge pressure, increase systolic blood pressure, and lower V-wave amplitude compared with right ventricular or AAI pacing in several trials (376-378). Advances in lead design have allowed the insertion of endocardial leads into distal branches of the coronary sinus to pace the LV. These advances have led to several small and large *prospective* trials to study the efficacy of biventricular pacing in patients with congestive heart failure and intraventricular conduction defects. Auricchio et al. (379) demonstrated that pacing in the mid-lateral LV augments positive pulse pressure changes more than pacing other areas. In the Pacing Therapies for Congestive Heart Failure trial (380), increases in LV dP/dt and pulse pressure were significantly better with biventricular than with right ventricular pacing. Convincing data from several *prospective, randomized* trials (381-384) support the hemodynamic and subjective improvement that was noted in multiple previous anecdotal and smaller trials (385-387). These trials demonstrate that in patients with New York Heart Association (NYHA) class III or IV congestive heart failure, decreased ejection fraction, and prolonged QRS duration, biventricular pacing decreases QRS duration and improves 6-minute walk distance, NYHA class, and quality-of-life scores. In the Multisite Stimulation in Cardiac Insufficiency trial (381), rehospitalizations from congestive heart failure were also reduced. No data exist demonstrating that biventricular pacing improves survival, although early data suggest trends in improvement in decreasing spontaneous ventricular ectopy and ICD shocks (388-390). Ongoing studies will determine whether a combination of biventricular pacing with an ICD will result in an improvement in subjective symptoms plus improved survival.

Pacing Recommendations for Dilated Cardiomyopathy

Class I

Class I indications for sinus node dysfunction or AV block as described previously. ***(Level of Evidence: C)***

Class IIa

Biventricular pacing in medically refractory, symptomatic NYHA class III or IV patients with idiopathic dilated or ischemic cardiomyopathy, prolonged QRS interval (greater than or equal to 130 milliseconds), LV end-diastolic diameter greater than or equal to 55 mm, and ejection fraction less than or equal to 35%. ***(Level of Evidence: A)*** **(381,383)**

Class III

1. **Asymptomatic dilated cardiomyopathy.**
2. **Symptomatic dilated cardiomyopathy when patients are rendered asymptomatic by drug therapy.**
3. **Symptomatic ischemic cardiomyopathy when the ischemia is amenable to intervention.**

3. Cardiac Transplantation

The incidence of bradyarrhythmias after cardiac transplantation varies from 8% to 23% (165-167). The majority of bradyarrhythmias are associated with sinus node dysfunction. Because of symptoms and impaired recovery and rehabilitation, some transplant programs recommend more liberal use of cardiac pacing for persistent postoperative bradycardia. About 50% of patients show resolution of the bradyarrhythmia within 6 to 12 months, and long-term pacing is often unnecessary in a large number of patients (168-170). Significant bradyarrhythmias and asystole have been associated with reported cases of sudden death (171). No predictive factors have been identified to indicate which patients will develop post-transplantation bradyarrhythmias. In some patients, the need for pacing may be transient. The benefits of the atrial contribution to cardiac output and chronotropic competence may optimize the patient's functional status. Attempts to treat the bradycardia temporarily with measures such as theophylline (172) may minimize the need for pacing. Post-transplant patients who have irreversible sinus node dysfunction or AV block with previously stated Class I indications should have permanent pacemakers.

Pacing Recommendations After Cardiac Transplantation

Class I

Symptomatic bradyarrhythmias/chronotropic incompetence not expected to resolve and other Class I indications for permanent pacing. ***(Level of Evidence: C)***

Class IIb

Symptomatic bradyarrhythmias/chronotropic incompetence that, although transient, may persist for months and require intervention. ***(Level of Evidence: C)***

Class III

Asymptomatic bradyarrhythmias after cardiac transplantation.

I. Selection of Pacemaker Device

Once the decision has been made to implant a pacemaker in a given patient, the clinician must decide among a large number of available pacemaker generators and leads. Generator choices include single- versus dual-chamber devices, unipolar versus bipolar configuration, presence and type of sensor for rate response, advanced features such as automatic mode switching, size, battery capacity, and cost. Lead choices include polarity, type of insulation material, fixation mechanism (active versus passive), and presence of steroid elution, Some lead models typically show low (300-500 Ohms) and some high (greater than 1000 Ohms) pacing impedance, and this can have implications with regard to the generator's battery longevity. Other factors that importantly influence the choice of pacemaker system components include the capabilities of the pacemaker programmer, which provides the link between the pacemaker system and the physician, and local availability of technical support.

Even after selecting and implanting the pacing system, the physician has a number of options for programming the device. In modern single-chamber pacemakers, programmable features include pacing mode, lower rate, pulse width and amplitude, sensitivity, and refractory period. Dual-chamber pacemakers have the same programmable features, as well as maximum tracking rate, AV delay, and others. Rate-responsive pacemakers require programmable features to regulate the relation between sensor output and pacing rate and to limit the maximum sensor-driven pacing rate. With the advent of more sophisticated pacemaker generators, optimal programming of pacemakers has become increasingly complex and device-specific and requires specialized knowledge on the part of the physician.

Many of these considerations are beyond the scope of this document. The discussion below focuses on the most fundamental choice the clinician has with respect to the pacemaker prescription: the choice among single-chamber ventricular pacing, single-chamber atrial pacing, and dual-chamber pacing.

Table 1 gives brief guidelines on the appropriateness of different pacemakers for the most commonly encountered indications for pacing. Figure 1 is a decision tree for selecting a pacing system in a patient with AV block. Figure 2 is a decision tree for selecting a pacing system in a patient with sinus node dysfunction.

An important challenge in selecting a pacemaker system is anticipating progression of abnormalities of automaticity and conduction and selecting a system that will best accommodate these developments. Thus, it is reasonable to select a pacemaker with more extensive capabilities than needed at the time of implantation but that may prove useful in the future. Some patients with sinus node dysfunction and paroxysmal atrial fibrillation, for example, may develop AV block

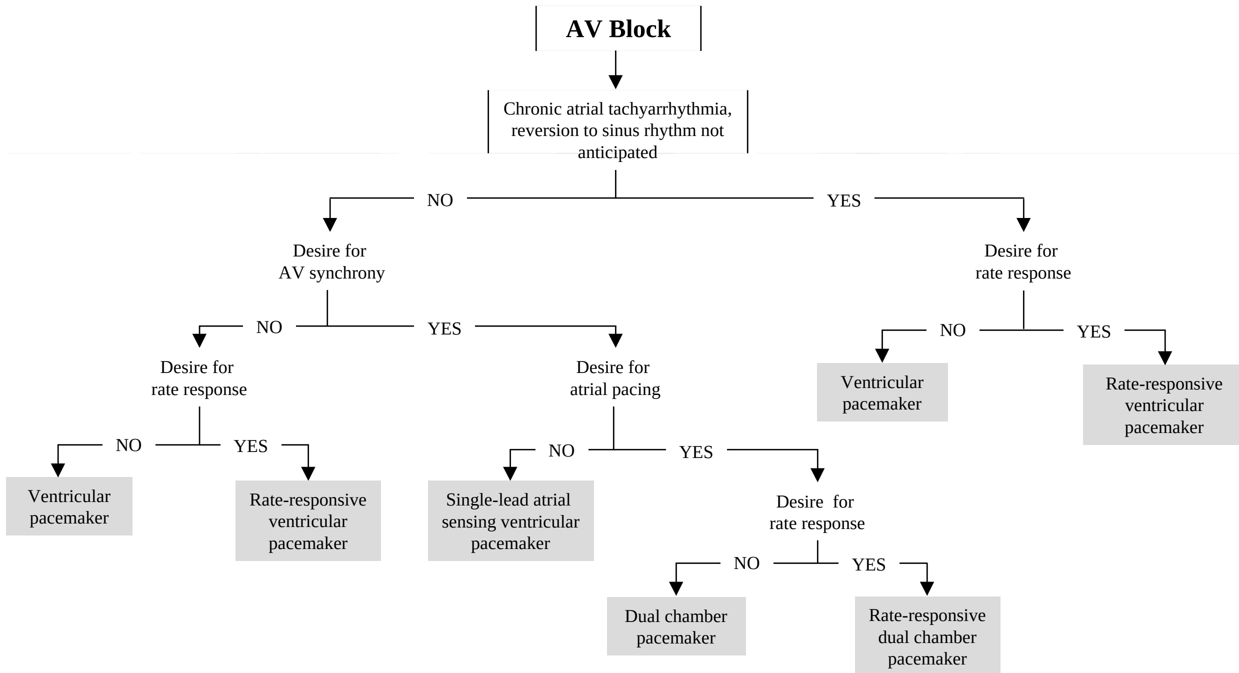

Figure 1. Selection of pacemaker systems for patients with atrioventricular (AV) block.

in the future (as a result of natural progression of disease, drug therapy, or catheter ablation) and may ultimately benefit from a dual-chamber pacemaker with mode-switching capability.

1. Newer Technical Innovations

Rate-Responsive Pacemakers

An increasing percentage of pacemakers implanted in the United States incorporate sensors to detect states of exercise and trigger accelerations in pacing rate. Approximately 97% of all generators implanted in the United States in 2000 had rate response as a programmable option (Morgan Stanley Dean Witter. Equity Research, North America. Healthcare: Pharmaceuticals, Hospital Supplies & Medical. July 26, 2000). In pacemaker patients who are chronotropically incompetent (i.e., unable to increase sinus node rate appropriately with exercise), rate-responsive pacemakers allow for increases in pacing rates with exercise and have been shown to improve exercise capacity and quality of life.

In the United States, the vast majority of sensors incorporated into rate-responsive implantable pacemakers are piezo-

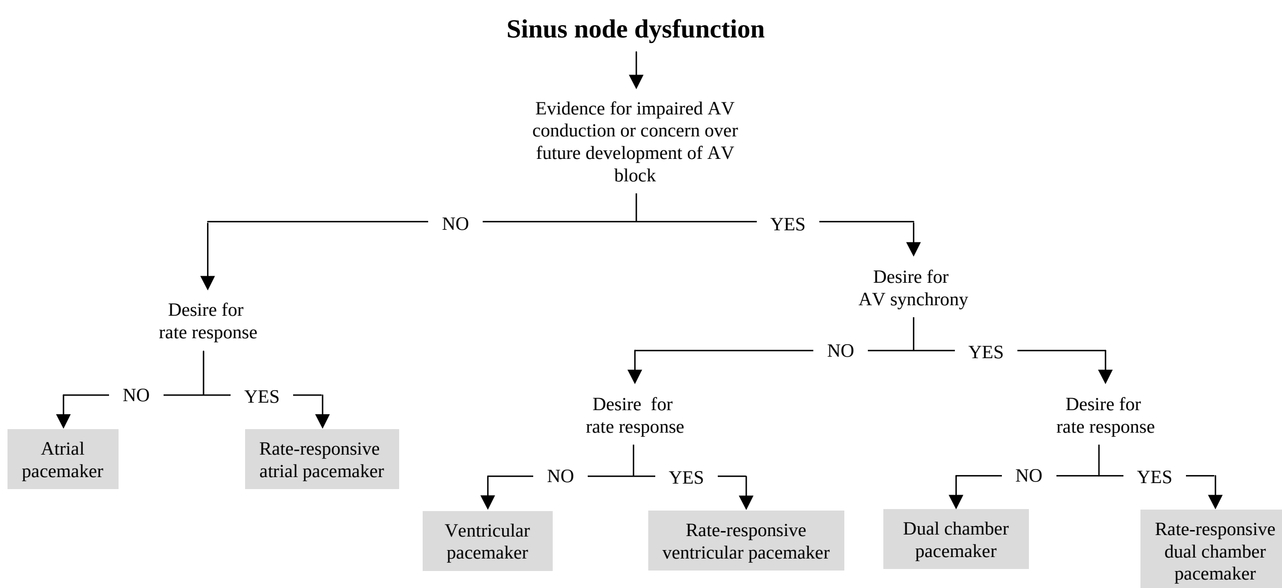

Figure 2. Selection of pacemaker systems for patients with sinus node dysfunction. AV indicates atrioventricular.

electric crystals or accelerometers that detect motion, vibration, or acceleration. Other technologies using sensors that measure minute ventilation or QT interval may provide a heart rate response more proportional to exercise than piezoelectric sensors or accelerometers. An advantage of all of these sensor technologies is that they do not require specialized pacemaker leads, although minute ventilation sensing requires a bipolar lead.

Pacemaker generators that incorporate two rate-responsive sensors are now available. These dual-sensor pacemakers incorporate one sensor that rapidly responds to exercise (i.e., piezoelectric crystal or accelerometer) and one that responds more proportionately to increasing levels of exercise (i.e., minute ventilation or QT interval). Studies have shown more appropriate rate response to various types of exercise when information from two sensors is used than when a single sensor is used (391,392). Studies are lacking that demonstrate an improvement in quality of life resulting from dual-sensor pacemakers compared with single-sensor pacemakers.

The challenge of adjusting the response of these generators to exercise appropriately in individual patients is increasingly becoming recognized. To facilitate optimal programming of rate-response capability, many current generators incorporate procedures for initial programming of rate-response parameters, subsequent automatic adjustment of these parameters, and retrievable diagnostic data (such as heart rate histograms or heart rate plots) to assess the appropriateness of the rate response.

Single-Lead VDD Pacemaker Systems

Despite advances in rate-responsive pacemakers, it is widely appreciated that the best signal to guide heart rate response to exercise (and other forms of physiologic stress) is a normally functioning sinus node. Most commonly, dual-chamber pacemakers incorporating separate atrial and ventricular leads are used to detect atrial depolarization. Single-lead transvenous pacing systems that are capable of sensing atrial depolarization are available. The distal end of the lead is positioned in the right ventricle for ventricular pacing and sensing; a pair of electrodes is incorporated in the more proximal portion of the lead body lying within the right atrial cavity for atrial sensing. With current technology, single-lead VDD* pacing systems are not capable of atrial pacing. The atrial signal sensed by single-lead VDD pacemakers has a less consistent amplitude than that typically sensed by conventional dual-chamber pacemakers and varies significantly with posture, but sensing performance is generally satisfactory (174). Single-lead VDD pacemaker systems are an alternative to dual-lead pacemakers in patients with AV block in whom atrial pacing is not required and in whom simplicity of implantation or avoidance of two leads is desired.

*This and other three- or four-letter notations conform to the NASPE/BPEG generic pacemaker code (173).

Automatic Mode Switching

When nonphysiologic atrial tachyarrhythmias, such as atrial fibrillation or flutter, occur paroxysmally in a patient with a dual-chamber pacemaker programmed to conventional DDD or DDDR mode, the tachyarrhythmia will generally be tracked near the programmed maximum tracking rate, leading to an undesirable acceleration of ventricular pacing rate. Newer dual-chamber generators incorporate algorithms for detecting rapid, nonphysiologic atrial rates and automatically switch modes to one that does not track atrial activity, such as DDI or DDIR. When the atrial tachyarrhythmia terminates, the pacemaker automatically reverts back to the DDD or DDDR mode. This automatic mode switch feature is especially helpful in patients with AV block and paroxysmal atrial fibrillation and expands the usefulness of dual-chamber pacemakers in such patients. Virtually all dual-chamber pacemakers now implanted in the United States incorporate automatic mode switching as a programmable option.

Rate-Drop Response for Neurocardiogenic Syncope

A programmable feature of some dual-pacemaker generators is automatic acceleration of pacing rate (e.g., to 100 bpm) for up to several minutes after detection of a sudden fall in intrinsic heart rate, such as would typically occur in patients with neurocardiogenic syncope. Of the two *randomized* studies showing a benefit of implanted pacemakers in patients with neurocardiogenic syncope in decreasing the recurrence of syncope in such patients, one of them (358) used pacemakers with rate-drop response, whereas the other (359) used pacemakers programmed to a more conventional hysteresis function. A large *prospective, randomized* multicenter trial is under way that will assess the specific benefit of rate-drop response in patients with neurocardiogenic syncope (393).

Pacemaker Leads

The vast majority of implanted pacemakers use transvenous endocardial leads, with the remainder using epicardial leads. Transvenous leads may be bipolar or unipolar in configuration. Bipolar configurations have the advantage of avoiding myopotential inhibition and skeletal muscle stimulation, and an increasingly important advantage is that unlike most unipolar pacing systems, they are compatible with concomitantly implanted ICDs. However, some manufacturers' bipolar leads have higher failure rates than their unipolar leads.

The insulation material used in pacemaker leads is either silicone rubber or polyurethane. Historically, some bipolar lead models with polyurethane insulation have shown unacceptably high failure rates due to degradation of the insulation. Many current polyurethane leads, using different polymers and different manufacturing processes, appear to be avoiding these unacceptably high failure rates.

Active fixation leads, in which the distal tip of the lead incorporates a small helical screw for fixation to the endocardium, are an alternative to passive fixation leads. Active fixation leads allow for more alternatives in the site of endocardial attachment. For instance, whereas a passive fixation

Table 1. Guidelines for Choice of Pacemaker Generator in Selected Indications for Pacing

	Sinus Node Dysfunction	AV Block	Neurally Mediated Syncope or Carotid Sinus Hypersensitivity
Single-chamber atrial pacemaker	• No suspected abnormality of AV conduction and not at increased risk for future AV block • Maintenance of AV synchrony during pacing desired • Rate response available if desired	• Not appropriate	• Not appropriate
Single-chamber ventricular pacemaker	• Maintenance of AV synchrony during pacing not necessary • Rate response available if desired	• Chronic atrial fibrillation or other atrial tachyarrhythmia or maintenance of AV synchrony during pacing not necessary • Rate response available if desired	• Chronic atrial fibrillation or other atrial tachyarrhythmia • Rate response available if desired
Dual-chamber pacemaker	• AV synchrony during pacing desired • Suspected abnormality of AV conduction or increased risk for future AV block • Rate response available if desired	• Rate response available if desired • AV synchrony during pacing desired • Atrial pacing desired • Rate response available if desired	• Sinus mechanism present • Rate response available if desired
Single-lead, atrial-sensing ventricular pacemaker	• Not appropriate	• Normal sinus node function and no need for atrial pacing • Desire to limit the number of pacemaker leads	• Not appropriate

AV = atrioventricular.

ventricular lead generally must be positioned in the right ventricular apex, an active fixation lead may be positioned in the apex, outflow tract, or inflow tract of the right ventricle. Active fixation leads have an additional advantage of greater ease of extraction after long-term implantation. A disadvantage of active fixation leads is that they generally have higher chronic capture thresholds than do passive fixation leads, although this difference is minimized with the incorporation of steroid elution (see below).

An important advance in pacemaker leads is the development of leads with lower capture thresholds, which result in reduced battery consumption during pacing. Steroid-eluting leads incorporate at their distal tip a small reservoir of corticosteroid that slowly elutes into the interface between the lead electrode and the endocardium, reducing the inflammation and fibrosis that normally occur at this interface. As a result, steroid-eluting leads have significantly lower long-term capture thresholds than leads not incorporating steroid. The benefit of steroid elution was originally demonstrated in passive fixation transvenous leads (175); the benefit has also been demonstrated in active fixation transvenous leads (176) and epicardial leads (177). Similar improvements in capture thresholds have been achieved with modification in electrode shape, size, and composition (394).

2. Methodology of Comparing Different Pacing Modes

Two or more pacemaker modes can be compared with respect to exercise capacity, quality of life, clinical end points (such as death, heart failure, atrial fibrillation, and stroke), and cost. For end points such as exercise capacity or quality of life, pacemaker modes can be compared using a *randomized* crossover study design, provided that the patients have pacing systems that can be programmed to each of these modes. (For example, dual-chamber, rate-responsive pacemakers can be crossed over between VVIR and DDDR pacing.)

Studies that compare clinical end points require long-term follow-up without crossover. In long-term studies, patients can be randomly assigned to receive different types of pacemakers (e.g., hardware randomization, single-chamber ventricular pacemakers versus single-chamber atrial pacemakers), or all patients may receive a single type of pacemaker system (e.g., dual-chamber, rate-responsive) and be randomly assigned to different modes (e.g., software randomization, VVIR versus DDDR).

Quality-of-life measures have been emphasized as important end points when comparing different modes of pacing, and there are important considerations in the choice of the instrument used to measure quality of life (179-181,395). Although the quality of life experienced with different modes of pacing may be compared using short-term crossover studies, long-term studies that include quality-of-life end points may reflect effects of chronic adaptation to stimulation not detectable in short-term comparisons. Several reported or ongoing long-term *randomized* comparisons of pacing modes have quality-of-life end points (83,395,396).

An important consideration in the assessment of trials that compare pacing modes is the percent of pacing among the study patients. For example, a patient who is paced only for very infrequent sinus pauses will probably have a similar outcome with ventricular pacing compared with dual-chamber pacing, regardless of the potential physiologic benefits of dual-chamber pacing. Several older studies comparing pacing modes do not include data on the frequency of pacing (84,84a,397,398), but newer studies do (355,399).

3. Pacing in Sinus Node Dysfunction

Short-Term Outcomes

Short-term crossover studies in patients with sinus node dysfunction have shown improved quality of life with atrial-based (i.e., atrial or dual chamber) pacing versus ventricular pacing, with or without rate response (180,182,395). There are conflicting data regarding any improvement in maximum exercise performance in rate-responsive atrial-based pacing compared with rate-responsive ventricular pacing in patients with sinus node dysfunction (183,395).

Long-Term Outcomes

Over the past decade, a number of *nonrandomized observational* studies have been published comparing atrial-based pacing with ventricular pacing in patients with sinus node dysfunction. These studies have been reviewed extensively (83,184,185,395,396). The incidences of atrial fibrillation, stroke, heart failure, and total mortality appear to be consistently lower in patients receiving atrial-based pacing than in those receiving ventricular pacing (395). The studies suffer from limitations common to all *nonrandomized* studies (most importantly, uncertainty as to the clinical equivalence of the patient groups). In some of these studies, the patient groups appear to be well matched, whereas in others, there is insufficient information to assess their comparability.

Andersen et al. (84,84a) published the first *randomized* study comparing pacemaker modes with long-term follow-up in patients with sinus node dysfunction. Two hundred twenty-five patients were assigned randomly to atrial and ventricular pacing. After mean follow-up of 5.5 years, the patients assigned to atrial pacing had significantly lower incidences of atrial fibrillation, thromboembolic events, heart failure, cardiovascular mortality, and total mortality compared with the ventricular paced patients.

Connolly et al. (398) published a *randomized* comparison of ventricular pacemaker implantation versus atrial-based pacemaker implantation in patients with a variety of indications for pacing. Among all patients, there was no significant difference in the combined incidence of stroke or death or in the likelihood of a heart failure hospitalization between the two treatment groups. There was, however, a statistically significant decrease in the incidence of atrial fibrillation in the patients with atrial-based pacemakers compared with ventricular pacemakers, which became apparent only after 2-year follow-up. The reduction in atrial fibrillation was seen both in patients paced for sinus node dysfunction and in those paced for AV block (345). A subgroup analysis of patients paced for sinus node dysfunction did not show any trends toward particular mortality or stroke benefit from atrial-based pacing in these patients.

The results of the MOST trial, in which 2010 patients with sinus node dysfunction were randomized between DDDR and VVIR pacing (355,395,396), have been reported (353). After mean follow-up of 33 months, there was no significant difference in the incidence of death or stroke between the two groups, but there was a 21% lower risk of atrial fibrillation ($p = 0.008$), lower heart failure scores ($p = 0.0001$), 27% lower risk of heart failure hospitalizations ($p = 0.02$), and improved quality of life in the DDDR group compared with the VVIR group. Of the patients randomized to VVIR pacing, 37.7% crossed over to DDDR, most commonly for pacemaker syndrome.

In summary, studies consistently demonstrate that in patients with sinus node dysfunction, the incidence of atrial fibrillation in patients receiving atrial or dual-chamber pacemakers is lower than in patients receiving ventricular pacemakers. Published data are mixed regarding stroke, heart failure, and mortality benefit with atrial-based pacing compared with ventricular pacing. Pacemaker syndrome is common in patients with sinus node dysfunction treated with ventricular pacing.

Role of Single-Chamber Atrial Pacemakers

Single-chamber atrial pacemakers offer the advantages of atrial-based pacing without the added complexity and cost of dual-chamber pacemakers. Such pacing systems, with rate-responsive capability if appropriate, have been advocated for patients with sinus node dysfunction but no evidence of AV block (21,179,186-188). Use of single-chamber atrial pacemakers is limited by concerns about subsequent development of AV block. The risk of developing significant AV block after atrial pacemaker implantation for sinus node dysfunction has been estimated to be 0.6% to 5.0% per year (186,188,189). Pre-existing bundle-branch block, but not AV Wenckebach rate, is predictive of a higher likelihood of subsequent development of AV block (187,190). In selected patients with sinus node dysfunction, use of single-chamber atrial pacemakers is an acceptable approach that maintains normal AV synchrony, but there is a small risk of subsequent development of AV block requiring pacemaker revision. With rate-responsive atrial pacemakers, the risk of developing hemodynamically significant first-degree AV block during rate accelerations has not been extensively studied but may be important (191).

4. Pacing in Atrioventricular Block

Short-Term Outcomes

A number of short-term crossover studies have compared pacing modes in patients with AV block with respect to quality of life and exercise capacity. These studies have been reviewed in depth (83,180,395,396). Studies comparing dual-chamber pacing with non–rate-responsive ventricular pacing have shown improved exercise capacity and symptomatology with dual-chamber pacing. Studies comparing rate-responsive ventricular pacing with non–rate-responsive ventricular pacing have shown similar advantages with rate-responsive ventricular pacing. However, studies comparing dual-chamber pacing (with or without rate response) with rate-responsive ventricular pacing have shown modest or no significant difference in exercise capacity; with respect to symptoms, most but not all of the studies have shown an advantage of dual-chamber pacing. It is likely that the symptomatic advantage of dual-chamber pacing over rate-responsive ventricular pacing is derived from the maintenance of AV association during rest and low-level activity.

Gillis et al. (399) examined atrial fibrillation recurrences in patients with paroxysmal atrial fibrillation who received pacemakers after AV ablation. Patients were crossed over between 6-month periods of DDDR pacing and VDD pacing; the principal difference between the two pacing modes was the lack of atrial pacing support and the possibility of asynchronous ventricular pacing during VDD pacing. No significant difference was seen in the time to atrial fibrillation recurrences between the two modes of pacing. However, nearly 15% of patients originally randomized to VDD pacing prematurely crossed over to DDDR pacing because of symptoms presumably related either to asynchronous ventricular pacing or atrial fibrillation.

Long-Term Outcomes

Two *nonrandomized observational* studies comparing patients with AV block who received dual-chamber pacemakers or ventricular pacemakers have shown improved survival associated with implantation of dual-chamber pacemakers among those patients with heart failure but no difference in survival between the two pacing modes among patients without heart failure (74,192). In the *randomized* studies of Connolly et al. (398) and Skanes et al. (400), the subgroup of patients implanted for AV block showed trends toward lower cardiovascular mortality or stroke and atrial fibrillation with physiologic pacing over ventricular pacing, but these did not reach statistical significance.

5. Pacing in the Elderly

More than 85% of pacemaker recipients are at least 64 years old (193). Elderly pacemaker patients are the rule, not the exception.

It has been suggested that elderly patients requiring pacing should be considered for less sophisticated devices, e.g., single-chamber ventricular pacemakers or non–rate-responsive pacemakers. However, studies in elderly patients show improved exercise capacity and alleviated symptoms with rate-responsive ventricular pacing or dual-chamber pacing compared with non–rate-responsive ventricular pacing (75,194). A *retrospective* analysis of 36,312 elderly

Medicare patients receiving pacemakers suggested that dual-chamber pacing is associated with improved survival compared with ventricular pacing, even after correction for confounding variables (195).

Lamas et al. conducted a *prospective, randomized* long-term comparison of rate-responsive ventricular pacing and rate-responsive dual-chamber pacing in elderly patients aged 65 years or older, with the principal end points being quality-of-life parameters (355). Overall, pacemaker implantation regardless of pacing mode was associated with large improvements in quality of life. In the intention-to-treat analysis, dual-chamber pacing showed modest quality-of-life advantages over ventricular pacing, primarily in the patients paced for sinus node dysfunction. However, the most striking finding of the study was that 26% of patients *randomized* to ventricular pacing crossed over to dual-chamber pacing because of symptoms of pacemaker syndrome, with improvement in quality-of-life indices after crossing over.

On the basis of these studies, dual-chamber pacing appears to offer benefits over ventricular pacing with respect to quality of life in elderly patients. It does not appear appropriate to withhold use of dual-chamber or rate-responsive pacemakers uniformly in the elderly, although such a decision may be appropriate in any patient who is extremely sedentary or has a limited life expectancy.

In an ongoing large, multicenter, *randomized* study of elderly (aged 70 years or older) patients undergoing pacemaker implantation for AV block (UKPACE, United Kingdom Pacing and Cardiovascular Events), patients are randomly assigned to receive a ventricular pacemaker or a dual-chamber pacemaker. The study's primary end point is total mortality, and secondary end points are morbidity, exercise capacity, and quality of life (83,395,396).

6. Optimizing Pacemaker Technology and Cost

The cost of a pacemaker system increases with its degree of complexity and sophistication. For example, the cost of a dual-chamber pacemaker system exceeds that of a single-chamber system with respect to the cost of the generator (additional $1000), the second lead (approximately $900), additional implantation time and supplies, and additional follow-up. The implant costs and complication rate of dual-chamber pacemakers also exceed those of single-chamber pacemakers (398). Some pacemaker models offer more extensive diagnostics than others, at a premium cost. Against these additional costs are the potential benefits of the more sophisticated systems with respect to quality of life, morbidity, and mortality. Furthermore, the additional diagnostic information available from more sophisticated generators may eliminate the need for additional diagnostic testing, such as ambulatory monitoring or exercise electrocardiography, that would otherwise be necessary occasionally in selected pacemaker patients. Several ongoing trials assessing the clinical benefits of dual-chamber pacing include economic analyses to estimate the incremental cost-effectiveness of these features (83,395,396).

Approximately 16% of pacemaker implantations are for replacement of generators; of those, 76% are replaced because their batteries have reached end of service (193). Hardware and software (i.e., programming) features of pacemaker systems that prolong useful battery longevity may improve the cost-effectiveness of pacing. Optimal programming of output voltages, pulse widths, and AV delays can markedly decrease battery drain; a study showed that expert programming of pacemaker generators can have a major impact on longevity, prolonging it by an average of 4.2 years compared with nominal settings (196). Extensive diagnostic capabilities allow for optimal programming by the experienced physician with regard to improved device longevity. Newer lead designs, such as those incorporating steroid elution or high pacing impedance, allow for less current drain. Generators that automatically determine whether a pacing impulse results in capture allow for programming outputs closer to threshold values than conventional generators, and this new technology may also have a major impact on device longevity. Although all of these features arguably should prolong generator life, there are other constraints on the useful life of a pacemaker generator, including battery drain not directly related to pulse generation and the limited life expectancy of many pacemaker recipients; rigorous studies supporting the overall cost-effectiveness of advanced pacing features are lacking.

The cost of pacemaker implantation may vary between different locations within a hospital (e.g., cardiac catheterization laboratory versus operating room); costs can be minimized by selecting the most economical site for implantation that preserves excellent patient outcome. One study comparing hospital charges for pacemaker implants in the catheterization laboratory versus the operating room within a single hospital showed a 45% lower charge for implants in the catheterization laboratory (401). There has been a trend to shorter hospital stays for pacemaker implantations, and some implantations are now being performed on an outpatient basis.

Reuse of explanted pacemakers, not currently performed to any extent in the United States, may eventually add significantly to the cost-effectiveness of cardiac pacing (197). Reports from Canada and Sweden indicate the safety and cost savings of selective pacemaker reuse (197,402).

J. Pacemaker Follow-up

After implantation of a pacemaker, careful follow-up and continuity of care are required. The committee considered the advisability of extending the scope of these guidelines to include recommendations for follow-up and device replacement but deferred this decision given other published statements and guidelines on this topic. These are listed below as a matter of information. No endorsement is implied. NASPE has published a series of reports on antibradycardia pacemaker follow-up (198-200). The Canadian Working Group in Cardiac Pacing has also published a consensus statement on pacemaker follow-up (403). In addition, the Health Care

Financing Administration (HCFA; currently the Centers for Medicare and Medicaid Services) has established guidelines for monitoring of patients covered by Medicare who have antibradycardia pacemakers (201).

Many of the same considerations are relevant to both pacemaker and ICD follow-up. Programming undertaken at implantation should be reviewed before discharge and changed accordingly at subsequent follow-up visits as indicated by interrogation, testing, and patient needs. With careful attention to programming pacing amplitude, pulse width, and diagnostic functions, battery life can be enhanced significantly without compromising patient safety. Taking advantage of programmable options also allows optimization of pacemaker function for the individual patient.

The frequency and method of follow-up is dictated by multiple factors, including other cardiovascular or medical problems managed by the physician involved, the age of the pacemaker, and geographic accessibility of the patient to medical care. Some centers may prefer to use transtelephonic monitoring (TTM) as the mainstay of follow-up, with intermittent clinic evaluations. Others may prefer to do the majority or all of the patient follow-up in clinic. Automatic features such as automatic threshold assessment have been incorporated increasingly into newer devices and facilitate follow-up for patients who live far from follow-up clinics (404). These automatic functions are not, however, universal and need not and cannot supplant the benefits of direct patient contact, particularly with regard to history taking and physical examination. Clinic follow-up usually includes assessment of the clinical status of the patient, battery status, pacing threshold and pulse width, sensing function, and lead integrity, as well as optimization of sensor-driven rate response. The schedule for clinic follow-up should be at the discretion of the caregivers providing pacemaker follow-up. As a guideline, the 1984 HCFA document suggests the following: for single-chamber pacemakers, twice in the first 6 months after implant and then once every 12 months; for dual-chamber pacemakers, twice in the first 6 months, then once every 6 months.

Guidelines for TTM of permanent pacemakers have evolved clinically based on evolution of pacemaker and transtelephonic technology. Legislation regarding TTM has not been revised since 1984 (MED-MANUAL, MED-GUIDE ¶27,201, Coverage Issue Manual §50-1 Cardiac Pacemaker Evaluation Services [effective date: October 1, 1984]). Clearly stated guidelines are necessary and should be written in such a way as to mandate TTM that achieves specific clinical goals.

Appropriate clinical goals of TTM should be divided into those pieces of information obtainable during nonmagnet (free-running) ECG assessment and assessment of the ECG tracing obtained during magnet application. The same goals should be achieved whether the service is being provided by a commercial or noncommercial monitoring service.

Goals of TTM nonmagnet ECG assessment are as follows:

- Determine whether the patient displays intrinsic rhythm or is intermittently or continuously pacing at the programmed settings.
- Characterize the patient's underlying atrial mechanism, e.g., sinus versus atrial fibrillation.
- If intrinsic rhythm is displayed, determine that normal (appropriate) sensing is present for one or both chambers depending on whether it is a single- or dual-chamber pacemaker and programmed pacing mode.

Goals of TTM ECG assessment during magnet application are as follows:

- Verify effective capture of the appropriate chamber(s) depending on whether it is a single- or dual-chamber pacemaker and programmed pacing mode.
- Assess magnet rate. Once magnet rate is determined, the value should be compared to value(s) obtained on previous transmissions to determine whether any change has occurred. The person assessing the TTM should also be aware of the magnet rate that indicates elective replacement indicators for that pacemaker.
- If the pacemaker is one in which pulse width is an indicator of elective replacement indicators, the pulse width should also be assessed and compared to previous values.
- If the pacemaker has some mechanism to allow transtelephonic assessment of threshold, i.e., Threshold Margin Test (TMT™), and that function is programmed "on," the results of this test should be demonstrated and analyzed.
- If a dual-chamber pacemaker is being assessed and magnet application results in a change in AV interval during magnet application, that change should be demonstrated and verified.

1. Amount of Time Necessary for Verification

The amount of time spent during TTM should not be specified in terms of actual seconds or minutes but in terms of verification of the above clinical parameters. Whatever length of time is necessary to verify the points listed above during "free running" and "magnet," obtained ECG assessment should be sufficient.

2. Length of Electrocardiographic Samples for Storage

It is important that the caregiver(s) providing TTM assessment be able to refer to a paper copy or computer-archived copy of the transtelephonic assessment for subsequent care. The length of the ECG sample saved should, once again, be predicated based on the clinical information that is required, i.e., the points listed above. It is the experience of personnel trained in TTM that an ECG sample of 6 to 9 seconds that is of quality and is carefully selected can demonstrate all of the points for each of the categories listed above, i.e., a 6- to 9-second strip of nonmagnet and 6- to 9-second strip of magnet-applied ECG tracing.

Historically, there may have been some reason to collect another nonmagnet ECG example after the sample had been obtained during magnet application. In very early pacemakers, it may have been that magnet application would rarely result in a "stuck" reed switch, and a subsequent nonmagnet tracing would verify that function was indeed normal. However, with contemporary pacemakers, there is no logical clinical reason to obtain another nonmagnet tracing.

3. Frequency of Transtelephonic Monitoring

The follow-up schedule for TTM varies between centers, and there is no absolute schedule that need be mandated. Regardless of any of the following schedules to which the center may adhere, TTM may be necessary at unscheduled times if, for example, the patient experiences symptoms potentially reflecting an alteration in rhythm or device function.

The majority of centers with TTM services follow the schedule allowed by HCFA. In the 1984 HCFA guidelines, there are two broad categories for follow-up (as shown in Table 2): guideline I, which was thought to apply to the majority of pacemakers in use at that time, and guideline II, which would apply to pacemaker systems for which sufficient long-term clinical information exists to ensure that they meet the standards of the Inter-Society Commission for Heart Disease Resources for longevity and end-of-life decay. The standards to which they referred are 90% cumulative survival at 5 years after implant and an end-of-life decay of less than a 50% drop of output voltage and less than a 20% deviation of magnet rate, or a drop of 5 bpm or less, over a period of 3 months or more. As of 2000, it would appear that most pacemakers would meet the specifications in guideline II.

There is no federal or clinical mandate that these TTM guidelines be followed. The ACC, AHA, and NASPE have not officially endorsed these HCFA guidelines. Nevertheless, they may be useful as a framework for TTM. An experienced center may choose to do less frequent TTM and supplement it with in-clinic evaluations as stated previously.

II. INDICATIONS FOR IMPLANTABLE CARDIOVERTER-DEFIBRILLATOR THERAPY

A. Background

ICDs were originally developed to prevent sudden cardiac death in patients who have experienced life-threatening ventricular arrhythmias such as sustained VT or VF (202-205). Epidemiological studies report high rates of recurrence of these life-threatening arrhythmias (30% to 50% in 2 years) during follow-up. Early *observational* reports documented efficacy in reversion of sustained VT and VF (103-105,202,203,205-215,405-407). Large *prospective*, *randomized* multicenter studies have established the effect of the ICD on long-term outcomes (204,216-221). Enrollment in these trials has included patients with coronary and noncoronary heart diseases with a wide range of ventricular function and coexisting disorders.

The ICD has evolved from a short-lived nonprogrammable device requiring a thoracotomy for lead insertion into a multiprogrammable antiarrhythmia device implanted almost exclusively without thoracotomy, now capable of treating bradycardia, VT, VF, and atrial tachycardia (222-224, 408,409). Clinical registries have recorded major improvements in implant risk, system longevity, symptoms associated with arrhythmia recurrences, and diagnosis and management of inappropriate device therapy (103,216-218,225-229).

Implantation, follow-up, and replacement of these devices is a complex process requiring familiarity with device capabilities, adequate case volume, continuing education, and skill in the management of ventricular arrhythmias, therefore mandating involvement of a trained electrophysiologist (230,410,411) to provide an optimal personnel team for patient safety and device management.

A substantial new body of information has emerged regarding the clinical outcome of patients with VT or VF treated with currently available antiarrhythmic therapies. There are currently three major therapeutic options to reduce or prevent VT or VF in patients at risk for these arrhythmias. These are:

1. Antiarrhythmic drug therapy.
2. For VT, ablative techniques applied at cardiac surgery or percutaneously using catheter techniques.
3. Implantation of a cardioverter-defibrillator device system.

A combination of ICD therapy with drugs or ablation is also frequently used. Currently, the largest clinical experience is with combined antiarrhythmic drug and ICD therapy.

B. Clinical Efficacy of ICD Therapy

ICD devices have been extensively evaluated in *prospective* clinical trials and device registries (103-105,202-221). Single-chamber nonthoracotomy systems can be implanted with a procedural mortality rate of 0.5% (217) to 0.8% (216). The ICD has been shown to terminate VF successfully in 98.8% (217) and 98.6% (216) of episodes. VT has been converted with antitachycardia pacing in 89.4% (216) to 91.2% (217) of episodes, with further successful conversions (98%) using shock therapy. Inappropriate therapy, typically for atrial fibrillation with a rapid ventricular response, has been noted in 5% to 11% of patients.

There has been controversy about the appropriate end point for evaluation of ICD efficacy. Many studies have used sudden death, but classification of the cause of death is often difficult and imprecise. Consequently, it is now accepted that total mortality is the appropriate primary end point for judging ICD efficacy (237). Rates of sudden death and ICD discharges provide useful information, but they should be considered as secondary end points. Total mortality varies significantly between reports due to differences in the disease status of the population under study and LV function. The presence of concomitant cardiac disease is a major determinant of survival (233,238,239). Survival of ICD recipients is influenced by LV function. Patients with reduced LV systolic function appear to benefit the most from ICD therapy (412,413). A retrospective analysis indicated that patients thought to have had a reversible cause for their life-threatening arrest were still at substantial risk of death (414).

C. Alternatives to ICD Therapy

Pharmacological options for antiarrhythmic therapy include drugs in classes I, II, and III. Therapy can be guided by Holter monitoring or serial electrophysiologic testing or given empirically. High arrhythmia recurrence rates and moderate sudden death rates are observed with Class I agents (240). By contrast, Class III agents are associated with significantly lower arrhythmia recurrences, sudden death, and total mortality (240-243).

Although the overall survival of cardiac arrest patients treated empirically with beta-blockers and Class I agents may be comparable, patients given Class I agents on serial electrophysiologic testing have a better outcome than those treated with empiric beta-blocker therapy (247). Current data do not support a significant role for monotherapy with beta-blockers in this condition.

In the post–myocardial infarction patient, empiric amiodarone therapy reduces arrhythmic mortality, but benefit with respect to total mortality in such patients has been less consistently demonstrated in individual studies (248-251). Quantitative overviews of amiodarone use in randomized trials, however, demonstrate a significant reduction in total mortality (415,416).

Long-term maintenance of effective antiarrhythmic drug therapy remains problematic. Discontinuation for drug intolerance is high for Class I agents and sotalol at initiation of therapy and during long-term administration (240). Amiodarone therapy is also frequently discontinued for adverse effects during long-term administration (243).

Ablative therapy has been most often used for patients with sustained monomorphic VT induced at cardiac surgery or electrophysiologic study and mapped to a specific ventricular site(s). Intraoperative ablation is accomplished mechanically or with physical energy sources (cryothermia or laser), whereas catheter-based energy delivery (direct-current shock, radiofrequency, microwaves, or laser) is used during electrophysiologic procedures (255-258). These methods are applicable to a select population of patients with malignant ventricular tachyarrhythmias that have reproducibly inducible monomorphic VT suitable for cardiac mapping. Intraoperative map-guided ablation—now performed infrequently—is associated with low arrhythmia recurrence (less than 10% at 2 years) and minimal sudden death rates (256-258) during long-term follow-up among patients with preserved LV function.

Catheter ablation approaches are still in technological evolution (259,260). Higher efficacy rates are observed in patients with right ventricular outflow tract tachycardia, idiopathic left septal VT, and bundle-branch re-entrant VT in whom ablation may be the preferred therapy (263-265). Although acute success rates of 71% have been reported in patients with structural heart disease, recurrence rates of 33% have subsequently occurred (417). Multiple VT morphologies, polymorphic VT, and progressive cardiomyopathy, when present, are less amenable to a favorable result with ablative intervention (255,256). Nonetheless, catheter ablation of recurrent VT associated with frequent ICD therapy may be associated with a marked reduction in the occurrence of shocks and an overall improved quality of life (418). Newer electroanatomic (419) and noncontact (420) mapping technologies may improve the outcomes of such procedures.

D. Comparison of Drug and Device Therapy for Secondary Prevention of Cardiac Arrest and Sustained Ventricular Tachycardia

A significant body of information from *prospective, randomized* trials comparing ICD and drug therapy is now available.

These trials demonstrate survival benefits with ICD therapy in this population compared with electrophysiologically guided drug therapy using Class I agents, propafenone, or sotalol (267,268). The first reported *large prospective, randomized* study comparing ICD therapy with Class III antiarrhythmic drug therapy, predominantly empiric amiodarone, in survivors of cardiac arrest and hemodynamically unstable VT revealed greater survival with ICD therapy (221). Unadjusted survival estimates for the ICD and drug therapy, respectively, were 89.3% versus 82.3% at 1 year, 81.6% versus 74.7% at 2 years, and 75.4% versus 64.1% at 3 years. Estimated relative risk reduction with ICD therapy was 39% at 1 year and 31% at 3 years. Two other reports of large *prospective* trials in similar patient groups have shown similar trends (406,407). A pooling of these three studies shows a 27% reduction in total mortality with ICD therapy (421).

E. Specific Disease States and Secondary Prevention of Cardiac Arrest or Sustained Ventricular Tachycardia

Prior guidelines do not relate the decision to implant an ICD device to the underlying cardiac disease (270). Current information suggests that the underlying disease state may have an important impact on patient prognosis and will influence the decision to implant an ICD earlier or later in the treatment algorithm.

1. Coronary Artery Disease

Patients with coronary artery disease represent the majority of patients receiving devices in most reports. Device implantation is widely accepted as improving the outcome of these patients. Patients with reduced LV function may experience greater benefit with ICD therapy than with drug therapy (208,210,267,412,413). To limit patient risk during defibrillation efficacy testing (270,271), assessment for the presence of active ischemia should precede implementation of device therapy. Furthermore, optimal anti-ischemic therapy (including, where possible, a beta-blocker) will further enhance survival. Abbreviated defibrillation threshold testing, however, may be desirable in patients with elevated pulmonary capil-

Table 2. HCFA Guidelines for Transtelephonic Monitoring (1984)

Guideline I				
	Months Pacemaker Implanted			
Single Chamber	1st Every 2 weeks	2nd to 36th Every 8 weeks	37th to Failure Every 4 weeks	
Dual Chamber	1st Every 2 weeks	2nd to 6th Every 4 weeks	7th to 36th Every 8 weeks	37th to Failure Every 4 weeks
Guideline II				
	Months Pacemaker Implanted			
Single Chamber	1st Every 2 weeks	2nd to 48th Every 12 weeks	49th to Failure Every 4 weeks	
Dual Chamber	1st Every 2 weeks	2nd to 30th Every 12 weeks	31st to 48th Every 8 weeks	49th to Failure Every 4 weeks

lary wedge pressures or severely compromised cardiac output (271).

2. Idiopathic Dilated Cardiomyopathy

Dilated cardiomyopathy is associated with a high mortality within 2 years of diagnosis, with a minority of patients surviving 5 years (272). Approximately one-half of these deaths are sudden and unexpected (273). The combination of poor LV function and frequent episodes of nonsustained VT in these patients is associated with an increased risk of sudden death (274). Moreover, although useful in patients with coronary heart disease, the value of electrophysiologic studies in patients with nonischemic cardiomyopathies is limited (275). Furthermore, the efficacy of drug therapy is low in the presence of impaired LV function and difficult to predict on the basis of invasive or noninvasive testing. ICD implantation may be preferred for treatment of patients with VT or VF and this condition. In one large *prospective* study, this population represented 10% of the study group and showed survival benefits with ICD rather than empiric amiodarone therapy similar to the entire study cohort (221).

3. Long-QT Syndrome

The long-QT syndromes represent a spectrum of electrophysiologic disorders characterized by a propensity for development of malignant ventricular arrhythmias, especially polymorphic VT (239,276-278). Because this is a primary electrical disorder, usually with no evidence of structural heart disease or LV dysfunction, the long-term prognosis is excellent if arrhythmia is controlled. Long-term treatment with beta-blockers, permanent pacing, or left cervicothoracic sympathectomy is frequently effective (277). ICD implantation is recommended for selected patients in whom recurrent syncope, sustained ventricular arrhythmias, or sudden cardiac death occurs despite drug therapy (276). Furthermore, use of the ICD as primary therapy should be considered in certain patients, such as those in whom aborted sudden cardiac death is the initial presentation of the long-QT syndrome, where there is a strong family history of sudden cardiac death, or when compliance or intolerance to drugs is a concern (276,422).

4. Idiopathic Ventricular Fibrillation

It has been estimated that in 10% of young patients resuscitated from cardiac arrest, the origin of VF is not determined despite extensive evaluation (279,280). Electrophysiologic testing in these patients with "idiopathic VF" usually reveals polymorphic VT or VF that is often suppressible by Class IA drugs administered during the electrophysiologic testing (279). However, the long-term efficacy of drug therapy remains unknown. Given the guarded prognosis even with effective drug therapy (the annual rate of sudden cardiac death is estimated to be as high as 11%), the limited clinical data available appear to support the use of ICDs in such patients (279-281).

Brugada Syndrome

Individuals with syncope and/or a family history of unexplained sudden cardiac death who have variants of right bundle-branch block QRS morphology and ST-segment elevations in leads V1 through V3 have the Brugada syndrome. Because of the high incidence of VF, ICD therapy should be recommended in such individuals (423). However, ICD therapy is not recommended in individuals with these ECG findings alone, because the specificity of this finding in the absence of the historical details noted above is very low (424).

5. Idiopathic Ventricular Tachycardia

Ventricular tachycardia may arise in structurally normal hearts from the right ventricular outflow tract or the LV. These arrhythmias should be treated pharmacologically or with catheter ablation, if amenable, before an ICD is considered for these patients (263).

6. Hypertrophic Cardiomyopathy

Hypertrophic cardiomyopathy should be suspected and is often identified as the cause of sudden death in young people, including trained athletes (239,282). Ventricular tachyarrhythmias are a common mechanism of sudden death in this condition (283). Sudden death may also be the first manifestation of the disease in a previously asymptomatic individual. Criteria to stratify these patients according to risk are not well defined. The most prominent characteristics of patients with hypertrophic cardiomyopathy who may be at high risk for experiencing sudden death include the following: 1) prior cardiac arrest or sustained VT; 2) a history of a first-degree relative who has experienced sudden cardiac death; 3) LV hypertrophy with a wall thickness greater than 30 mm (425); 4) syncope, if exertional, repetitive, or in a young patient if no other cause is documented; and 5) nonsustained VT on ECG monitoring if frequent, repetitive, and prolonged. Studies of patients resuscitated from cardiac arrest indicate that many patients will experience another event. Prophylactic pharmacological therapy in the form of beta-blockers or calcium channel antagonists has frequently been used, but efficacy in sudden death prevention has not been established. Empiric use of amiodarone has been reported to be associated with improved survival in one observational study with historical controls (282). Other data support automatic defibrillator implantation as the preferred therapy in high-risk patients with hypertrophic cardiomyopathy to decrease sudden cardiac death, in preference to or in conjunction with drug therapy (285,426).

7. Arrhythmogenic Right Ventricular Dysplasia/ Cardiomyopathy

Arrhythmogenic right ventricular dysplasia can be an important cause of congestive heart failure and ventricular arrhythmias in some patients (286). Drug therapy is often used as primary therapy but is often ineffective. Nonpharmacological options for treatment of significant arrhythmias include catheter ablation of the sites of tachycardia, surgical disarticulation of the right ventricle, and ICDs. In patients with drug-refractory malignant arrhythmias, the ICD provides prophylaxis against syncope due to hemodynamically unstable VT and sudden death (287,288).

8. Syncope With Inducible Sustained Ventricular Tachycardia

Patients with syncope of undetermined etiology in whom clinically relevant VT/VF is induced at electrophysiologic study may be candidates for ICD therapy. In these patients, the induced arrhythmia is presumed to be the cause of syncope (289-291). Cardiovascular mortality averages 20% annually, with a large proportion of it sudden. In some patients, antiarrhythmic treatment is limited by inefficacy, intolerance, or noncompliance. ICD therapy is often used in sustained VT populations with comparable results (292). In patients with hemodynamically significant and symptomatic inducible sustained VT, ICD therapy can be a primary treatment option. The documentation of appropriate ICD therapy of VT and VF from review of event counters and stored electrograms in such patients lends support to use of ICD therapy as a primary treatment option in those who have experienced syncope (414,427).

F. Pediatric Patients

Fewer than 1% of all ICD implantations are performed in pediatric patients (239,293). However, special considerations, such as the need for lifelong pharmacological therapy with its associated problems of noncompliance and side effects, make the ICD an important treatment option for young patients.

Sudden cardiac death is uncommon in childhood but is associated with three principal forms of cardiovascular disease: 1) congenital heart disease, 2) cardiomyopathy, and 3) primary electrical disease (239,294). Patients with pre-existing heart disease are more likely to experience ventricular tachyarrhythmias as the immediate cause of sudden death than are those with normal hearts (295). However, a lower percentage of children undergoing resuscitation survive to hospital discharge compared with adults (296).

Indications for ICD therapy for pediatric patients are similar to those for arrhythmias in adults. However, the data used for risk stratification in adults with coronary artery disease may have less positive predictive value in pediatric patients with a variety of underlying diseases (297). The risk of unexpected sudden death is greater in young patients with diseases such as hypertrophic cardiomyopathy or long-QT syndrome than in adults; therefore, a family history of sudden death may influence the decision to use an ICD in a pediatric patient (277,282). A limited experience with ICDs implanted in young patients with hypertrophic cardiomyopathies or long-QT syndromes after resuscitation has been encouraging (285,293,301,302,351,428).

In patients with congenital heart disease, sudden death has been estimated to occur in 1% to 2.5% of patients per decade after repair of tetralogy of Fallot (298). A higher risk has been identified for patients with transposition of the great arteries and aortic stenosis, with most cases presumed to be due to a malignant ventricular arrhythmia associated with ischemia, ventricular dysfunction, or a rapid response to atrial flutter (120,299). An ischemic substrate for arrhythmias leading to sudden cardiac death also exists in congenital coronary anomalies or after Kawasaki disease.

ICD therapy may be preferable to antiarrhythmic drugs in patients with dilated cardiomyopathy or other causes of impaired ventricular function who experience syncope or sustained ventricular arrhythmias because of concern about drug-induced proarrhythmia and myocardial depression. ICDs may also be considered as a bridge to orthotopic heart transplantation in pediatric patients, particularly given the longer times to donor procurement in younger patients (300).

G. Primary Prevention of Sudden Cardiac Death

1. Coronary Artery Disease

Nonsustained VT in patients with prior MI and LV dysfunction is associated with a 2-year mortality estimated at 30% (303,304). Approximately one-half of this is believed to be arrhythmic in origin. Antiarrhythmic drug therapy has been widely prescribed in patients after MI with and without ventricular arrhythmia, but evidence of improved survival with this approach is not forthcoming. Increased mortality in coronary disease patients with and without nonsustained VT has actually been noted with specific Class I agents (305). Empiric amiodarone therapy has shown inconsistent survival benefit in large *prospective randomized* trials (250,251), although quantitative overviews (meta-analyses) suggest total mortality may be reduced compared with other medical therapies (241,306). In this population, electrophysiologic testing has identified a subgroup with inducible sustained ventricular tachyarrhythmias that is at high risk for sudden death (307). While arrhythmia-related symptoms and repeated MIs may help identify such patients, asymptomatic persons post-MI may also be at high risk (304,307,308). In the first prospective randomized trial conducted in such a patient population, improved survival was documented after implantation of ICDs in patients with inducible and nonsuppressible ventricular tachyarrhythmias when compared with conventional drug therapy, including amiodarone (220). Results of another *prospective, randomized* trial showed reduced mortality with therapy for patients with low ejection fraction, nonsustained VT on Holter monitoring, and inducible sustained ventricular tachyarrhythmias at electrophysiologic study (405). Most of this benefit appeared to be due to ICD placement. The results of a study of 1232 patients after myocardial infarction with an LV ejection fraction of less than or equal to 30% randomized to ICD therapy or not in a 3:2 fashion without the requirement for electrophysiologic screening for inducible ventricular tachyarrhythmia were reported during this publication's review process (429). At a mean follow-up of 20 months, the mortality rate was 14.2% in the individuals who had ICDs and 19.8% in the conventionally treated group, a 5.6% absolute and 31% relative risk reduction for death. In this study, the survival curves did not begin to separate until 9 months after randomization. Of potential importance, ICD therapy was not implemented until at least 1 month after myocardial infarction and 3 months after coronary artery revascularization surgery. The cost impact, as well as a thorough analysis of the impact of other variables (e.g., risk stratification potential of programmed stimulation performed through the ICDs) has not been fully analyzed and reported. Also of note was an observed increased incidence of new or worsened heart failure in the ICD-treated patients compared with those in the conventional treatment arm. As one editorial suggested, the extent to which ICD therapy actually extends life in given patients is not fully known, and more refined screening techniques even in such patients are needed (430). Although such patients merit consideration of ICD therapy, this approach requires consideration of the patient's overall health and life expectancy. Additional risk stratification studies are needed to better define which patient subgroups will benefit more or less from ICD therapy than that demonstrated in the above-referenced population. Further preliminary data presented at the May 2002 Scientific Session of NASPE as a "late-breaking clinical trial" analyzed the effects of ICD therapy in patients stratified on the basis of various noninvasive ECG criteria. A standard ECG QRS duration longer than 0.12 seconds was found to be the strongest predictor of such patients who benefit most from ICD therapy. In the Cox proportional hazard model analysis, individuals with a QRS duration greater than 0.12 seconds had a 63% reduction in mortality relative to conventionally treated patients ($p = 0.004$). Atrial fibrillation as the baseline rhythm was the only other independent predictor of ICD therapy benefit in such patients. Whether the recommendation to implant ICDs in post–myocardial infarction patients with LV ejection fractions of 30% or less should be limited to individuals with these high-risk variables awaits further clarification.

2. After Coronary Artery Bypass Surgery

Routine ICD insertion does not improve survival in patients with coronary artery disease undergoing bypass surgery who are believed to be at high risk of sudden death based on QRS duration and severe LV dysfunction. In one *randomized* study, no benefit was noted over placebo (309) in patients with ejection fractions less than 35% and a positive signal-averaged ECG who were undergoing surgical revascularization.

3. As a Bridge to Heart Transplantation

Orthotopic heart transplantation has emerged as an acceptable therapeutic alternative for selected patients with congestive heart failure caused by severe ventricular dysfunction. About 20% of patients requiring transplantation die awaiting a donor organ, with a significant incidence of sudden death. ICDs have been associated with a lower risk of sudden death in these patients (310,311). This benefit is diluted by mortality due to heart failure in some patients (310-312).

4. Other Populations

Other high-risk populations under study for similar benefits include asymptomatic patients, from the standpoint of ventricular tachyarrhythmias, who have impaired LV systolic function and congestive heart failure (431) or idiopathic dilated cardiomyopathy (432), but no recommendations can yet be made with respect to these patients owing to insufficient data. Randomized trials of the ICD are ongoing in these populations. Patients with advanced structural heart disease and syncope of unknown origin may benefit from an ICD even if electrophysiologic evaluation is negative (433).

H. Contraindications and Limitations of ICD Therapy

ICD therapy is not recommended for patients in whom a reversible triggering factor for VT/VF can be definitely identified, such as ventricular tachyarrhythmias in evolving AMI or electrolyte abnormalities. Another population in whom ICD therapy is not routinely recommended is coronary disease patients without inducible or spontaneous VT undergoing routine coronary bypass surgery (309). Similarly, patients with Wolff-Parkinson-White syndrome presenting with VF secondary to atrial fibrillation should undergo catheter or surgical ablation if their accessory pathways are amenable to such treatment.

Patients with terminal illnesses, NYHA class IV drug-refractory congestive heart failure who are not candidates for cardiac transplantation, or with a life expectancy not exceeding 6 months are likely to obtain limited benefit—if any—from ICD therapy. Thus, ICD therapy is discouraged in such individuals. Significant behavioral disorders, including anxiety, device dependence, or social withdrawal, have been described (316,317). A history of psychiatric disorders, including uncontrolled depression and substance abuse that interfere with the meticulous care and follow-up needed by these patients, is a relative contraindication to device therapy.

Patients who have frequent tachyarrhythmias that may trigger shock therapy, such as sustained VT not responsive to antitachycardia pacing or pharmacological therapy, are not suitable candidates for a device because these events would cause frequent device activation and multiple shocks. Alternative therapies, such as combining drugs or ablation with ICD insertion, should be considered.

I. Cost-Effectiveness of ICD Therapy

Several studies have addressed the cost-effectiveness of ICD therapy. The cost-effectiveness ratio compares the total cost of ICD therapy with the total cost of an alternative management strategy such as amiodarone or guided serial drug testing. The overall costs of the ICD have been reduced as the result of nonthoracotomy implantation methods and improvements in ICD reliability and longevity that reduce cost of device replacement and modification. Significant reductions in initial costs have been realized, with newer treatment algorithms eliminating prolonged drug testing (318,319).

The early studies of ICD cost-effectiveness were based on mathematical models and relied on *nonrandomized* studies to estimate clinical efficacy and cost. These studies found cost-effectiveness ratios of $17,000 (320), $18,100 (321), and $29,200 per year of life saved (322). Another model incorporated costs of nonthoracotomy ICDs and efficacy estimates based on *randomized* trials and found ICD cost-effectiveness was between $27,300 and $54,000 per life-year gained, corresponding to risk reduction of 40% and 20%, respectively (323).

Several completed and ongoing *randomized* clinical trials have measured cost as well as clinical outcomes and thus can directly estimate ICD cost-effectiveness. The Multicenter Automatic Defibrillator Implantation Trial (MADIT) found a 54% reduction in total mortality and a cost-effectiveness ratio of $27,000 per life-year added (434). The Canadian Implantable Defibrillator Trial (CIDS), by contrast, found a 20% reduction in total mortality and a cost-effectiveness ratio of $139,000 per life-year added (406,435). The cost-effectiveness ratio from the Antiarrhythmics Versus Implantable Defibrillators (AVID) trial was $66,677 per life-year added (436). This range of results is primarily due to different estimates of the effectiveness of the ICD in reducing mortality, because all showed similar increases in the cost of care among ICD recipients. When the results of all clinical trials were used in a model that projected the full gain in life expectancy and lifetime costs (323), the cost-effectiveness of the ICD was $31,500 per life-year added, comparable to widely accepted noncardiac therapies such as renal dialysis ($30,000 to $50,000 per year of life saved). The cost-effectiveness of the ICD is more favorable in patients with an ejection fraction below 35%. In principle, the device is most cost-effective in patients at high risk of arrhythmic death and at low risk of other causes of death. Cost-effectiveness of the ICD would be improved by lowering the cost of the device itself and further improving its reliability and longevity.

J. Selection of ICD Generators

All ICDs currently marketed in the United States incorporate a number of advanced features, including multiple tachycardia zones, with rate detection criteria and tiered therapy (including low-energy cardioversion and high-energy defibrillation shocks) independently programmable for each zone. Furthermore, all devices incorporate programmable ventricular demand pacing, antitachycardia pacing, and extensive diagnostics, including stored electrograms of rhythms immediately before and after tachycardia detection and therapy. The vast majority of devices are small enough for pectoral new implantations. Larger devices suitable for abdominal implants are available primarily as replacement generators in patients with pre-existing lead systems but are being phased out by manufacturers.

Antitachycardia pacing appears to be a useful feature in the majority of patients receiving ICDs. In one study (325), antitachycardia pacing was activated in 68% of patients receiving ICDs with such a capability, despite the fact that the efficacy of antitachycardia pacing was tested with the device in only 53% of the patients in whom it was activated; in the remainder, antitachycardia pacing algorithms were programmed empirically. In the patients with activated antitachycardia pacing, 96% of all detected episodes of ventricular tachyarrhythmias were terminated with pacing (325). Acceleration of VT by antitachycardia pacing remains a concern, with most series reporting an incidence of antitachycardia pacing acceleration of an episode of VT ranging from 3% to 6% (326). Patients whose only clinical arrhythmia detected before ICD implantation was VF have a lower likelihood of having VT subsequently detected by the ICD than do patients with a prior history of VT (327). However, the incidence of subsequent VT in those with a history of only VF before device implantation is not inconsiderable [18% during 14 months of follow-up in one study (327)], so it is reasonable to assess activation of antitachycardia pacing even in such patients.

Defibrillators incorporating an atrial lead are now available. Such devices not only provide dual-chamber pacing but also use the pattern of sensed atrial depolarization to distinguish supraventricular from ventricular arrhythmias. A dual-chamber pacemaker-ventricular defibrillator device is an appropriate choice for an ICD candidate who has a concomitant need for dual-chamber pacing or a patient with supraventricular tachycardia thought likely to lead to inappropriate ICD therapies.

Early reports have documented that the time required for detection of VF during acute testing at the time of implantation is not impaired with the addition of atrial leads (437,438). However, hemodynamic benefits of dual-chamber pacing in such devices have been documented in few patients followed up for relatively short-term intervals only (439). Furthermore, data on long-term benefits of dual-chamber ICDs are lacking despite their widespread dissemination. One center's reported experience has been associated with a 2.8% complication rate in their first 95 implants. A worrisome infection rate of 8.8% was observed in patients who had previously implanted single-chamber ICDs upgraded to dual-chamber systems (440). Expected incremental benefits of the use of atrial electrograms together with ventricular electrograms to evaluate stored arrhythmic events have been documented (441). Studies are ongoing to further assess efficacy benefits that dual-chamber ICD therapy may have over single-chamber ICD therapy.

Atrial defibrillation therapy for recurrent AF has been evaluated in stand-alone implantable atrioverters (408) and in conjunction with conventional dual-chamber ICDs (409,442). Although clinically available as complementary features with some dual-chamber ICDs, the indications and role of such therapy are unclear and must await further reports and results of additional studies.

K. ICD Follow-up

All patients with ICDs require periodic and meticulous follow-up to ensure safety and optimal device performance. The goals of ICD follow-up include monitoring of device system function; optimizing performance for maximal clinical effectiveness and system longevity; minimizing complications; anticipating replacement of system components; ensuring timely intervention for clinical problems; patient tracking, education, and support; and maintenance of ICD system records. The need for device surveillance and management should be discussed *a priori* with patients before insertion of an ICD. Compliance with device follow-up is an important element in evaluating appropriate candidates for device therapy and obtaining the best long-term result. ICD follow-up is best achieved in an organized program analogous to pacemaker follow-up at outpatient clinics (198).

Institutions performing implantation of these devices should also maintain these facilities for inpatient and outpatient use. Such facilities should obtain and maintain implantation and follow-up support devices for all ICDs used at that facility. The facility should be staffed or supported by a fully trained clinical cardiac electrophysiologist (328) who may work in conjunction with trained associated professionals (198,328,329). Access to these services should be available as far as is feasible on both a regularly scheduled and emergent 24-hour-per-day basis. The implantation and/or follow-up facility should be able to locate and track patients who have received ICDs or who have entered the follow-up program.

1. Elements of ICD Follow-up

The follow-up of an ICD patient must be individualized in accordance with the patient's clinical status and conducted by a fully trained clinical cardiac electrophysiologist. In general, device programming is initiated at implantation and should be reviewed at predischarge and/or subsequent post-operative electrophysiologic testing. Devices should be followed at 1- to 4-month intervals, depending on the device model and the patient's clinical status. Manufacturer guidelines for device follow-up vary with individual models and should be available. Transtelephonic follow-up (if available) should always be supplemented by clinic visits at a minimum of 4-month intervals for patient and device evaluation (330,410).

It is often necessary to reprogram the initially selected parameters either in the outpatient clinic or by electrophysiologic testing. When device function or concomitant antiarrhythmic therapy is modified, electrophysiologic testing can be and often is required to evaluate sensing, pacing, or defibrillation functions of the device. Particular attention should be given to review of sensing parameters, programmed defibrillation and pacing therapies, device activation, and event logs. Technical elements requiring review include battery status, lead system parameters, and elective replacement indicators. Intervening evaluation of device function is often necessary. In general, in patients experiencing device activation, with or without therapy, delivery should be evaluated shortly after the event until a regular acceptable pattern of patient symptomatology and tolerance for such events is established and device behavior is deemed reliable, safe, and effective.

After insertion of a device, its performance should be reviewed, limitations on the patient's specific physical activities established, and registration accomplished. Current policies on driving advise the patient with an ICD to avoid operating a motor vehicle for 6 months after the last symptomatic arrhythmic event to determine the pattern of recurrent VT/VF (331,332). Interactions with electromagnetic interference sources, impact on employment, and prophylaxis for device infections should be discussed. ICD recipients should be encouraged to carry proper identification and information about their device at all times. Patients receiving these devices can experience transient or sustained emotional disturbances. Education and psychological support before, during, and after ICD insertion are highly desirable and can improve the patient's quality of life (316,317).

Recommendations for ICD Therapy

Class I

1. **Cardiac arrest due to VF or VT not due to a transient or reversible cause. *(Level of Evidence: A)* (103-105,202,203,205-211,216,217,219,221,238,260,267, 269,406,407)**
2. **Spontaneous sustained VT in association with structural heart disease. *(Level of Evidence: B)* (103-105,202,203,205-211,216,217,219)**
3. **Syncope of undetermined origin with clinically relevant, hemodynamically significant sustained VT or VF induced at electrophysiologic study when drug therapy is ineffective, not tolerated, or not preferred. *(Level of Evidence: B)* (204,213,215,219,227,228, 266,406)**
4. **Nonsustained VT in patients with coronary disease, prior MI, LV dysfunction, and inducible VF or sustained VT at electrophysiologic study that is not suppressible by a Class I antiarrhythmic drug. *(Level of Evidence: A)* (220,308,405)**
5. **Spontaneous sustained VT in patients without structural heart disease not amenable to other treatments. *(Level of Evidence: C)***

Class IIa

Patients with left ventricular ejection fraction of less than or equal to 30% at least 1 month post myocardial infarction and 3 months post coronary artery revascularization surgery. *(Level of Evidence: B)* (429)

Class IIb

1. **Cardiac arrest presumed to be due to VF when electrophysiologic testing is precluded by other medical conditions. *(Level of Evidence: C)* (211,218,267,276)**
2. **Severe symptoms (e.g., syncope) attributable to ventricular tachyarrhythmias in patients awaiting cardiac transplantation. *(Level of Evidence: C)* (310,311)**
3. **Familial or inherited conditions with a high risk for life-threatening ventricular tachyarrhythmias such as long-QT syndrome or hypertrophic cardiomyopathy. *(Level of Evidence: B)* (8,41,277,282,284,288,300-302)**
4. **Nonsustained VT with coronary artery disease, prior MI, LV dysfunction, and inducible sustained VT or VF at electrophysiologic study. *(Level of Evidence: B)* (103,205,212,217,220,307,308)**
5. **Recurrent syncope of undetermined origin in the presence of ventricular dysfunction and inducible ventricular arrhythmias at electrophysiologic study when other causes of syncope have been excluded. *(Level of Evidence: C)***
6. **Syncope of unexplained origin or family history of unexplained sudden cardiac death in association with typical or atypical right bundle-branch block and ST-segment elevations (Brugada syndrome). *(Level of Evidence: C)* (443,444)**
7. **Syncope in patients with advanced structural heart disease in whom thorough invasive and noninvasive investigations have failed to define a cause. *(Level of Evidence: C)***

Class III

1. **Syncope of undetermined cause in a patient without inducible ventricular tachyarrhythmias and without structural heart disease. *(Level of Evidence: C)***
2. **Incessant VT or VF. *(Level of Evidence: C)***
3. **VF or VT resulting from arrhythmias amenable to surgical or catheter ablation; for example, atrial arrhythmias associated with the Wolff-Parkinson-White syndrome, right ventricular outflow tract VT, idiopathic left ventricular tachycardia, or fascicular VT. *(Level of Evidence: C)* (259-263)**
4. **Ventricular tachyarrhythmias due to a transient or reversible disorder (e.g., AMI, electrolyte imbalance, drugs, or trauma) when correction of the disorder is considered feasible and likely to substantially reduce the risk of recurrent arrhythmia. *(Level of Evidence: B)* (414,445,446)**
5. **Significant psychiatric illnesses that may be aggravated by device implantation or may preclude systematic follow-up. *(Level of Evidence: C)* (316,317)**
6. **Terminal illnesses with projected life expectancy less than 6 months. *(Level of Evidence: C)***
7. **Patients with coronary artery disease with LV dysfunction and prolonged QRS duration in the absence of spontaneous or inducible sustained or nonsustained VT who are undergoing coronary bypass surgery. *(Level of Evidence: B)* (309)**
8. **NYHA Class IV drug-refractory congestive heart failure in patients who are not candidates for cardiac transplantation. *(Level of Evidence: C)***

APPENDIX 1

See Appendix 1 on page 31 for conflict of interest information.

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Appendix 1. ACC/AHA/NASPE Committee to Update the 1998 Guidelines for Implantation of Cardiac Pacemakers and Antiarrhythmias Devices—Conflict of Interest

Committee Member Name	Research Grant	Speakers Bureau	Stock Ownership	Committee Member	Advisory Committee	Honoraria	Consultant
Dr. Gabriel Gregoratos	None	None	None	None	None	None	None
Dr. Jonathan Abrams	None	None	None	None	None	None	None
Dr. Andrew Epstein	Biotronik Cordis-Webster Daig Guidant HMR Medtronic St. Jude	Berlex Guidant Medtronic	None	Guidant	None	None	None
Dr. Roger Freedman	Guidant St. Jude	None	None	None	None	None	None
Dr. David Hayes	None	ELA	Guidant Medtronic St. Jude	None	ELA Guidant Medtronic	Guidant Medtronic St. Jude	None
Dr. Mark Hlatky	None	None	None	None	None	None	None
Dr. Richard Kerber	Agilent	None	None	None	None	None	None
Dr. Gerald Naccarelli	Guidant Knoll Proctor & Gamble Sanofi Solvay Wyeth Ayerst	None	None	None	None	None	Berlex Guidant Knoll Medtronic Pfizer Wyeth Ayerst
Dr. Mark Schoenfeld	None	None	None	None	None	None	None
Dr. Michael Silka	None	None	None	None	None	None	None
Dr. Stephen Winters	Medtronic St. Jude Wyeth Ayerst	Berlex Pfizer	Medtronic Transneuronix	None	None	None	None

This table represents the actual or potential conflicts of committee members with industry that were reported orally at the initial writing committee meeting on November 1, 2000 and updated in conjunction with all meetings and conference calls of this writing committee. It does not reflect any actual or potential conflicts at the time of publication.

North American Society of Pacing and Electrophysiology

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