ARTIFICIAL CARDIAC PACING

PRACTICAL APPROACH

Second Edition

Edward K. Chung, M.D.

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- Principles of Cardiac Arrhythmias, *Third Edition, 1983.*
- Cardiac Arrhythmias: Self Assessment (*Volume 1*), *1977.*
- Cardiac Arrhythmias: Self Assessment (*Volume 2*), *1982.*
- Artificial Cardiac Pacing: Practical Approach, *Second Edition, 1984.*
- Exercise Electrocardiography: Practical Approach, *Second Edition, 1983.*

To My Wife, Lisa,
And My Children,
Linda and Christopher

Preface to the Second Edition

Since the first edition of this book was published in 1979, a significant development has been observed in the field of artificial cardiac pacing. A general trend is more frequent use of a physiologic pacing in recent years. Thus, atrioventricular (A-V) sequential (bifocal) pacing is commonly utilized in our practice today.

In addition, various multi-programmable pacemakers have become very popular in the past several years because a variety of the pacemaker functions (e.g., the pacing rate, energy output, etc.) can easily be adjusted whenever necessary. By doing so, the most ideal pacing best suitable for a given patient's clinical circumstance may be provided non-invasively following pacemaker implantation. The multi-programmable pacing has proven to be the best pacing approach to treat advanced sick sinus syndrome. Accordingly, "Multi-Programmable Artificial Pacing" is discussed in detail (Chapter 19).

Another new chapter entitled "Automatic Implantable Defibrillator" (Chapter 20) is included in this new edition because the new device has a close relationship to over-driving artificial pacing when dealing with life-threatening ventricular tachyarrhythmias. Unfortunately, the automatic implantable defibrillator is *not* available for routine clinical use as of this writing, although this new device has been tested extensively in animals as well as humans at The Johns Hopkins University with a favorable result.

A new chapter entitled "Radiology of Cardiac Pacemakers" (Chapter 4) also has been added in view of its important contribution in the field of artificial pacing.

The whole text has been revised considerably, although its aims and the basic design are essentially unchanged. It can be said that the unique feature of this book is its practical approach with clinical applications in the diagnosis as well as the management of cardiac patients.

I am truly grateful to my wife, Lisa, and children, Linda and Christopher, for their patience and understanding during the preparation of this book.

Lastly, I will always owe a deep gratitude and appreciation to my father, Dr. Il-Chun Chung, who has always offered guidance and inspiration.

EDWARD K. CHUNG, M.D.

Preface to the First Edition

Artificial cardiac pacing is an essential and most effective way of treating various bradyarrhythmias, particularly the sick sinus syndrome and complete A-V block. In addition, artificial cardiac pacing is often a life-saving measure for refractory tachycarrhythmias, especially ventricular tachycardia.

Today, approximately 250,000 to 400,000 individuals live with artificial pacemakers, and another 25,000 to 40,000 new patients will receive permanent pacemaker implantations in the coming year in the United States of America alone. This means that every physician who takes care of cardiac patients has to be fully familiar with all aspects of artificial pacing, including indications versus non-indications, malfunctions versus pseudo-malfunctions, etc.

The intention of this book is to describe every pertinent aspect of cardiac pacing which is directly or indirectly related to the patient's care. Various aspects of cardiac electrophysiology are also included in this book in order to provide useful information for better understanding of the artificial cardiac pacing itself.

This book presents 30 chapters, including Introductory Remarks on Artificial Cardiac Pacing; The Anatomy and Histology of the Conduction System; His Bundle Electrocardiography: Contributions to Artificial Cardiac Pacing; Role of Artificial Pacing and Recording in the Understanding of Impulse Initiation in the Human Heart; Holter Monitor Electrocardiography; A-V Conduction Disturbances; Hemiblocks, Bifascicular Block and Trifascicular Block; Sick Sinus Syndrome and Brady-Tachyarrhythmia Syndrome; Techniques of Temporary Pacing; Indications of Temporary Pacing; Indications of Artificial Pacing for Tachyarrhythmias; Artificial Cardiac Pacing in Myocardial Infarction; Artificial Pacing in Children; Techniques of Permanent Pacing; Indications of Permanent Pacing; Different Modes of Artificial Cardiac Pacing; Power Sources for Implantable Artificial Pacemakers; Electrode Design and Longevity; Interferences for Artificial Cardiac Pacing; Factors Modifying Pacing Stimulatory Thresholds; Recognition of Digitalis Toxicity During Artificial Pacing; Recognition of Myocardial Infarction in Patients with Artificial Pacemakers; Hemodynamics of Artificial Pacing; Follow-up Care After Artificial Pacing; Artificial Pacemaker Clinics: Practical Value; Transtelephone Pacemaker Monitoring; Complications and Malfunctions of Artificial Cardiac Pacing; Various Electrocardiographic Findings in Patients with Artificial Pacemakers; Medico-Legal Considerations of Artificial Pacing; and Future Development of Artificial Pacing.

The contents are intended to be clinical, concise, and practical, so that this book will provide all physicians with up-to-date materials related to artificial pacing, which will assist them directly in the daily care of their cardiac patients.

The book will be particularly valuable to family physicians, emergency room physicians, practicing internists, cardiologists, cardiovascular surgeons, house staff, and cardiology fellows, along with coronary care unit nurses. In addition, medical students will also obtain a great benefit by reading this book and learning a general approach to various cardiovascular problems.

I am sincerely grateful to all authors for their valuable contributions to this book, Artificial Cardiac Pacing: Practical Approach. I also wish to thank my personal secretary, Miss Theresa McAnally, for her

devoted and cheerful secretarial assistance. She has been most valuable in handling correspondence to all contributors, in addition to typing many of my chapters for this book. It has been my pleasure to share the work to complete this valuable book with the staff of The Williams & Wilkins Company.

EDWARD K. CHUNG, M.D.

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Contents

CHAPTER 1

Introductory Remarks

EDWARD K. CHUNG, M.D., F.A.C.P., F.A.C.C.

GENERAL CONSIDERATIONS

It has been well documented that artificial (electronic) cardiac pacing is one of the most important and reliable ways to manage various cardiac arrhythmias, particularly brady-arrhythmias. Until 5–10 years ago, the primary indication for permanent artificial pacing had been in the treatment of complete A-V block. However, the most common indication for permanent artificial pacemakers at the present time is in the treatment of the sick sinus syndrome (SSS). In addition, artificial pacing with over-driving pacing rate (faster than usual pacing rate) is often a life-saving measure for refractory tachyarrhythmias. The term "brady-tachyarrhythmia syndrome" is used when the abnormal heart rhythms consist of a component of rapid rhythm as well as a slow rhythm. In this case, artificial cardiac pacing has a very important role because drug therapy alone is usually ineffective. Brady-tachyarrhythmia syndrome is usually a late manifestation of SSS (see Chapter 8).

The artificial cardiac pacemaker functions in a very similar manner to the natural pacemaker to initiate the electrical impulses generated by small batteries. The electrical impulses travel through small wires to the heart. The artificial pacemaker is timed to produce the electrical impulses (usually about 70–72 beats/min) just like the cardiac impulses initiated by the natural pacemaker (sinus node). In most cases, the heart is capable of pumping adequate amounts of blood under the control of an artificial pacemaker.

Approximately 250,000 people (500,000 according to some reports) live with artificial pacemakers in America alone, and 25,000–40,000 (100,000–110,000 according to some medical reports) new patients will require an artificial pacemaker implantation annually. Although it is difficult to know exactly how many people live with an artificial pacemaker at the present time worldwide, it is estimated to be at least 500,000 people (750,000–1,000,000 according to some reports). The total number of artificial pacemakers sold within the last 20 years is estimated to be approximately at least 1.5–2 million, possibly more. It is clearly evident that artificial cardiac pacing can provide not only the prolongation of human lives, but also the significant improvement of the quality of life. Long-term administration of various drugs (e.g., isoproterenol, atropine, epinephrine) for bradyarrhythmias is no longer necessary because of the ready availability of artificial pacemakers in most civilized countries.

The fundamental principles for the utilization of an artificial pacemaker were established as early as 1932 by Hyman, and later by Callaghan and Bigelow in 1951. External cardiac pacing was introduced into clinical medicine in 1952 by Zoll. In 1957, temporary direct myocardial stimulation in the treatment of complete A-V block was introduced by Weirich *et al*, and a transistorized, self-contained, implantable pacemaker for long-term correction of chronic complete A-V block was established in 1960 by Chardack *et al*. Until several years ago, mercury-zinc cells had been used for the energy source, but today a lithium battery has replaced the mercury-zinc battery entirely for all types of artificial pacemaker. In general, a lithium battery may last 10–12 years in most clinical circumstances. The earlier pacemakers lasted only 15–18 months, and therefore frequent replacement of the pulse generator was required. The nuclear-powered pacemaker was introduced about 20 years ago in clinical medicine, but it is not commonly used.

There are many types of artificial pacemakers on the market, but the most commonly used model is a demand ventricular pace-

maker. The demand pacemaker has a sensing device that cuts the pacemaker off if the natural heart rhythm is faster than the pre-set pacing rate. When the patient's own rhythm becomes slower than the pre-set pacing rate, the sensing device turns the artificial pacemaker on again. This is the reason the term "demand" or "standby" pacemaker is used. In other words, the demand artificial pacemaker works only when it is needed. In the past few years, multi-programmable pacemakers have been introduced in clinical medicine. In this new type of artificial pacemaker, various functions (e.g., pacing rate, energy output, sensitivity, etc.) of the pacemaker can easily be controlled and adjusted non-invasively after implantation in order to provide the best pacing for a given individual. The multi-progammable pacemakers will eventually replace all non-programmable pacemakers in the near future. The average cost of the artificial pacemaker itself ranges from $2,000 to $3,000. The total cost of implantation of an artificial pacemaker including the surgeon's fee, hospitalization, and various laboratory tests is about $6,000 to $7,000 in most hospitals.

Following implantation of an artificial pacemaker, every patient should have periodic medical check-ups and should carry out necessary daily care, because the artificial pacemaker will need care like any other mechanical device, and complications or malfunctions may occasionally occur.

A. Indications for Artificial Pacemakers

The precise criteria for the use of a temporary or a permanent pacemaker vary slightly from institution to institution, but the following conditions are generally accepted.

1. Short-Term Pacing (Temporary Pacing)
   a. Symptomatic second degree or third degree A-V block, especially during acute myocardial infarction (MI), requires temporary pacing. It should be noted that A-V block *per se* does not require artificial pacing.
   b. Symptomatic and drug-resistant sinus arrhythmias including sinus bradycardia, sinus arrest, sinoatrial (S-A) block and A-V junctional bradyarrhythmias (often manifestations of SSS).
   c. Bifascicular and incomplete trifascicular block associated with acute anterior MI usually requires short-term pacing (prophylactic pacing) because these findings are often followed by a slow ventricular escape rhythm due to complete A-V block [infra-nodal A-V block or complete bilateral bundle branch block (BBBB)].
   d. Emergency treatment for Adams-Stokes syndrome, symptomatic BBBB and SSS.
   e. Before or during implantation of a permanent pacemaker when the patient is symptomatic (e.g., syncope or near syncope).
   f. Prophylactic pacing during major surgery when Adams-Stokes syndrome and/or marked bradyarrhythmias are anticipated.
   g. Drug-resistant tachyarrhythmias by over-driving pacing rate.

At present, the most commonly used pacemaker for short-term pacing is the temporary transvenous type. In almost all situations, a demand unit is preferable to a fixed-rate unit. This is because normal A-V conduction may be present during the insertion of a pacemaker (especially when it is being used prophylactically) and because it is not uncommon to observe normal A-V conduction occurring intermittently following the development of complete A-V block. A bipolar or unipolar catheter electrode is inserted, via a jugular or arm vein, into the right ventricle, preferably in the apical region, under direct vision utilizing fluoroscopy, with an image intensifier. Otherwise, the blind float technique may be used in certain cases. In this method, the catheter electrode is advanced gently into position as the location of the tip is monitored by electrocardiogram (ECG). The usual pacing rate is around 70–72 beats/min.

When a physiologic pacing is desired, of course, A-V sequential (bifocal) pacing mode is preferable (and will be discussed later). One of the important beneficial effects of atrial pacing is its ability to suppress a variety of ectopic tachyarrhythmias, particularly those of supraventricular origin. Thus, atrial pacing, coronary sinus pacing

and A-V sequential pacing are advantageous in the treatment of brady-tachyarrhythmia syndrome or drug-resistant tachyarrhythmias. When there is significant A-V conduction disturbance under these circumstances, A-V sequential pacing (bifocal pacing) must be carried out. Indications of temporary pacing will be discussed in detail later (see Chapter 9).

2. Indication for Long-Term Pacing (Permanent Pacing)
   The decision as to whether long-term pacing is indicated or not is very serious, because the patient must live with an artificial pacemaker all his life and must observe various necessary cautions and daily care. In addition, the pulse generator should be changed every 8–12 years in most cases (every 3–6 years in older models), depending upon the model. One of the most serious problems following permanent pacemaker implantation is malfunction of the unit (see Chapter 29), which may be fatal. At times, it is difficult to judge whether a permanent artificial pacemaker is definitely required, because there is some controversy among physicians in certain clinical circumstances. In general, in the following situations, long-term pacing is considered to be indicated.
   a. Symptomatic and/or advanced SSS.
   b. Symptomatic, chronic second degree (usually Mobitz type II) or third degree (infra-nodal) A-V block.
   c. Complete A-V block in acute MI (regardless of the location of MI) lasting more than 2–3 weeks.
   d. Congenital complete A-V block.
   e. Symptomatic bilateral bundle branch block.
   f. Recurrent Adams-Stokes syndrome (usually due to Mobitz type II, advanced or complete A-V block and SSS).
   g. Recurrent drug-resistant tachyarrhythmias benefited by temporary pacing.
   h. Carotid sinus syncope (may or may not be due to SSS).
   When the indication of a permanent pacemaker has been determined, the type of pacemaker suitable for the specific patient must be determined in view of the patient's age, general condition and underlying disease. When the physiologic pacing is desired, A-V sequential (bifocal) pacing is preferable because the artificial pacing can provide almost identical hemodynamic consequences as the natural sinus rhythm so that the maximum cardiac output can be maintained. This is the reason that bifocal pacing has become the most commonly used method of artificial pacing in most clinical circumstances today. One of the major advantages of atrial pacing is its capability to suppress various ectopic tachyarrhythmias, particularly those of supraventricular origin. Drug-resistant tachyarrhythmias or brady-tachyarrhythmias are often best treated with atrial pacing, coronary sinus pacing, or A-V sequential pacing. Of course, the A-V sequential pacing has to be used when there is a significant A-V conduction disturbance under these circumstances. Fixed-rate ventricular pacemaker is seldom used today because various complications occur frequently. Most pacemaker manufacturers continuously produce the fixed-rate ventricular pacemakers primarily for foreign countries. Ordinary demand ventricular pacing is adequate in the treatment of complete A-V block when the physiologic artificial pacing is considered to be *not* essential. Indications of permanent pacing will be discussed in detail later (see Chapter 15).

3. Artificial Pacemakers in Acute Myocardial Infarction
   There is a significant controversy among physicians regarding the use of artificial pacemakers in patients with myocardial infarction. The indications of artificial pacing vary markedly depending upon the site of MI. By and large, artificial pacing is more frequently used in patients with acute anterior MI than in patients with acute diaphragmatic MI. Prophylactic artificial pacing is often indicated in acute