Edward K. Chung

Ambulatory Electrocardiography

Holter Monitor Electrocardiography

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Holter Monitor Electrocardiography

With 152 Electrocardiograms

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To my wife, Lisa,
and my children,
Linda and Christopher

Preface

Ambulatory (Holter monitor) electrocardiography has been one of the most essential and most useful noninvasive diagnostic tools in the field of cardiovascular disease in the past decade.

The primary indication for ambulatory (Holter monitor) electrocardiography is to document any cardiac arrhythmia, particularly when the rhythm disturbance occurs transiently or intermittently. The Holter monitor electrocardiography has an equally important role in the evaluation of various symptoms, such as dizziness, syncope, chest pain, and palpitations, which may be related to cardiac rhythm disturbances. In addition, the Holter monitor electrocardiography provides useful information for the diagnosis of transient myocardial ischemia and the evaluation of anti-arrhythmic drug therapy as well as artificial pacemaker function.

The purpose of this book is to provide practical information regarding Holter monitor electrocardiography to assist the physician in diagnosing and treating cardiac patients.

This book presents 100 cases that illustrate various cardiac rhythm problems. The actual case histories, with the Holter monitor electrocardiograms in the many different clinical circumstances that are frequently encountered in daily practice, are discussed. In many cases, 12-lead electrocardiograms are included with the Holter monitor ECG tracings to better understand the clinical situation. Diagrams and tables considered to be clinically pertinent are also shown. In some instances, the clinically important electrocardiographic rhythm strips obtained in our Emergency Room and Cardiac Clinic are illustrated. The exercise electrocardiograms (treadmill stress ECG testing) are included in cases in which they are clinically useful.

In *General Considerations*, indications, the proper approach to interpretation, and technical aspects, as well as lead systems of the Holter monitor electrocardiography, are discussed. The value of Holter monitor electrocardiography is compared with that of the exercise (stress) ECG test. The Appendix summarizes the material by way of 11 tables.

This book will be of particular value to all primary physicians, including family physicians, emergency room physicians, internists, cardiologists, cardiology fellows, and medical residents, as well as medical students and coronary care unit nurses.

The most valuable and cheerful assistance of my personal secretary, Theresa McAnally, in the preparation of this book is sincerely appreciated.

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King of Prussia, Pa.

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Abbreviations

AF:	Atrial fibrillation
AF1:	Atrial flutter
AMI:	Anterior myocardial infarction
APCs:	Atrial premature contractions
APIVR:	Artificial pacemaker-induced ventricular rhythm
ASMI:	Anteroseptal myocardial infarction
AVC:	Aberrant ventricular conduction
BBBB:	Bilateral bundle branch block
BFB:	Bifascicular block
BTS:	Brady-tachyarrhythmia syndrome
COPD:	Chronic obstructive pulmonary disease
DC shock:	Direct current shock
DMI:	Diaphragmatic myocardial infarction
LAH:	Left atrial hypertrophy
LAHB:	Left anterior hemiblock
LBBB:	Left bundle branch block
LPHB:	Left posterior hemiblock
LVH:	Left ventricular hypertrophy
MAT:	Multifocal atrial tachycardia
MI:	Myocardial infarction
MVPS:	Mitral valve prolapse syndrome
PAT:	Paroxysmal atrial tachycardia
PVT:	Paroxysmal ventricular tachycardia
RBBB:	Right bundle branch block
RVH:	Right ventricular hypertrophy
SSS:	Sick sinus syndrome
TFB:	Trifascicular block
VF:	Ventricular fibrillation
VPCs:	Ventricular premature contractions
VT:	Ventricular tachycardia
WPW syndrome:	Wolff–Parkinson–White syndrome

General Considerations

INTRODUCTION

The clinical application of ambulatory electrocardiography was proposed as early as 1949 by Norman J. Holter, an experimental physicist from Helena, Montana. He applied his technique and the data of radiotelemetry to electroencephalography as well as electrocardiography in humans. In the latter, the patient wears an 85-lb transmitter strapped to his back, while the electrocardiogram (ECG) signals are transmitted to a receiver. He reported this investigative work at the Montana State Medical Association Meeting in August, 1949.

In 1957, major improvements in these techniques were made, and currently, the patient carries a miniaturized radiotransmitter, and data are recorded on a magnetic tape for 24 hr, with the newer models.

When a physician wishes to evaluate a patient's cardiac rhythm during the patient's usual daily activities, he can utilize the technique of ambulatory (Holter monitor) electrocardiography. The Holter monitor ECG has a precordial lead system, which is connected to a portable electrocardiographic monitor. The ECG signal is recorded on magnetic tape, which may record for 10, 12, or 24 hr. This system is sensitive enough to detect not only the various cardiac arrhythmias but also changes in conduction pattern and the S-T segment and T wave abnormalities.

The tape from the Holter recorder is played back on a scanner. This equipment can be used by a trained technician to scan a 10-hr tape recording in about 20 min. The 12- and 24-hr recordings require a proportionally longer time to scan. This rapid scanning is performed by utilizing four basic aids to recognize cardiac rhythm and conduction abnormalities. It has been reported that it takes only 12 min to scan 24-hr recordings using a new scanner manufactured by the Avionics Company.

With this scanner, the ECG wave forms are rapidly superimposed on an oscilloscope. The scanning technician readily recognizes alteration in wave form and can then play back representative strips of the ECG. In addition to wave-form superimposition, the scanner has an audible, built-in tone, which varies with changes in heart rate and wave form. By sensing the tone change, the technician is alerted to recognize the ECG changes. Another visual tool is a line display of rate and beat-to-beat interval spacing changes, which also serves to alert the scanner to record representative strips. A most important part of the Holter monitor system is the patient's diary (Table 1). The patient keeps a record of his activities, when these activities are taking place, and the presence of symptoms and when they occur. The time the monitor is turned on is recorded and the tape runs at a constant speed for 10, 12, and 24 hr, respectively, depending upon the capacity of the equipment. Therefore, it is possible to correlate the ECG rhythm strips with the time of symptoms by using a clock synchronized to the monitor. When the actual ECG is reproduced from recorded tape, the physician can correlate the detailed rhythm and wave form with the patient's activities during the period monitored (see Table 1).

Indications for the use of Holter monitor electrocardiography are included in Table 2. The technique can be used to confirm such diagnoses as paroxysmal tachyarrhythmias, bradyarrhythmias, or A-V block. The recorder can be used to identify episodes of angina or an anginal equivalent by the S-T segment and T wave alteration. The recorder can also be used to evaluate the incidence of extrasystoles and whether they occur as group beats or with R-on-T phenomenon. Another important use of the Holter monitor ECG is in the evaluation of anti-arrhythmic drug therapy. By determining whether the incidence of arrhythmia is decreased or abolished by a given drug dose, the physician is able to assess the efficacy of his therapy. During digitalis therapy, the Holter monitor can identify digitalis-induced arrhythmias and also indicate ventricular rate control, especially in atrial fibrillation during various activities. For patients with artificial pacemakers, the technique is used to evaluate the status of pacemaker function. It can also indicate the period of time a demand pacemaker is actually pacing. This can be used to predict the pacemaker's life-span. Even in an early stage, a malfunctioning pacemaker can be detected on the Holter monitor ECG.

To obtain the recording, the patient is first instructed as to the nature of the examination. He is told what activities to include and to exclude during the monitoring period. In gen-

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eral, the patient must be advised to keep the electrodes on the recorder dry and not to touch or displace the electrodes during the recording period, since this may produce a recording artifact. The patient must also be given instructions on how to remove the electrodes at the end of the recording period. The patient is given a patient's diary and instructed to keep a careful record of his activities and his symptoms and their time of occurrence. He should be reminded not to forget to return the diary when he returns the recorder. The patient is also given a list of types of activities to record; these include exercising, walking up and down stairs, arguing, smoking, defecating, urinating, eating, making love and sleeping. More daily activity than usual should be clearly indicated in the diary. He should also record the kind and amount of medication taken, and when it was taken.

INDICATIONS FOR THE USE OF HOLTER MONITOR ELECTROCARDIOGRAPHY

Table 2 summarizes the indications for the use of ambulatory (Holter monitor) electrocardiography. The primary indication for its use is, needless to say, the detection of a transient or an occult cardiac arrhythmia, since such arrhythmias are usually not detected on a conventional 12-lead electrocardiogram. When an arrhythmia is detected on a Holter recording, it can be evaluated relative to the patient's activity or presenting symptoms, such as syncope or chest pain. Conversely, many ill-defined or unexplainable symptoms, such as dizziness or weakness, can be evaluated by Holter monitor electrocardiography to determine whether a given symptom is produced by a certain cardiac arrhythmia. It should be noted, however, that there are many factors that can produce similar, if not identical symptoms (e.g., dizziness, syncope), and cardiac arrhythmia may or may not underly a given symptom in a given individual.

The efficacy or toxicity of various drugs can be evaluated in conjunction with cardiac rhythm disturbances. Thus, all digitalis-induced arrhythmias can be detected even when they are transient or intermittent. Also, the status of digitalization in a patient with chronic atrial fibrillation can be assessed by evaluating the ventricular response, particularly during physical activity.

When the patient suffers anginal pain, the ischemic episode can be identified on the Holter moniter ECG by identifying the S-T segment and/or T wave abnormalities when the pain occurs. Furthermore, myocardial ischemic changes can be corrected with the patient's activity even when the patient fails to recognize the angina.

For the patient with angina pectoris, the efficacy of anti-anginal drug therapy can be evaluated by the S-T segment and/or T wave changes during physical activity with or without cardiac arrhythmia.

Another very important role of Holter monitor electrocardiography is the evaluation of artificial pacemaker function. Early stage of malfunctioning pacemaker can be detected by Holter monitor recording by recognizing acceleration (runaway pacemaker) or slowing of pacemaker, irregular pacing, and a failure of sensing and/or cardiac capture by the pacemaker.

VALUE OF HOLTER MONITOR VERSUS EXERCISE ELECTROCARDIOGRAPHY

Table 3 compares the Holter monitor ECG with the exercise ECG.

The ECG obtained with the Holter monitor as well as the exercise ECG provide valuable information for the detection and evaluation of cardiac arrhythmias and myocardial ischemia; the evaluation of such symptoms as chest pain, dizziness, syncope, or palpitations; and the evaluation of the efficacy of different cardiac drugs.

For example, Holter monitor electrocardiography is much more useful in detecting cardiac arrhythmias than is the exercise ECG test. Myocardial ischemia, however, is evaluated by the exercise ECG test in more depth than by the Holter monitor. In the evaluation of various symptoms, Holter monitor electrocardiography and the ECG test will be utilized, depending upon the nature of a given symptom.

The exercise ECG test, of course, cannot be

used to evaluate artificial pacemaker function, but the Holter monitor can. There is a slight morbidity and mortality involved with the exercise ECG, but the Holter monitor is safe. The cost of these two tests is almost the same, although it may be slightly higher for the Holter monitor ECG at some institutions.

INTERPRETATION OF THE HOLTER MONITOR ELECTROCARDIOGRAPHY

Table 4 summarizes interpretations in ambulatory (Holter monitor) electrocardiography. The Holter Monitor ECG must be interpreted by a well-trained cardiologist, in particular, a physician who is quite familiar with every known cardiac arrhythmia.

A definite procedure should be followed, for best results:

1. First, the basic underlying cardiac rhythm is described (e.g., normal sinus rhythm, atrial fibrillation).
2. When any cardiac arrhythmia is found, its precise rhythm should be described. Broad descriptions, in which extrasystoles, tachyarrhythmias, bradyarrhythmias, etc., are mentioned without a precise rhythm being specified are of little or no use in diagnosis.
3. When a particular arrhythmia is found, its occurrence and the patient's activity or complaints (shown on the patient's diary card, see Table 1) should be evaluated. When the underlying cardiac rhythm changes from time to time, the change should be correlated with the patient's activity and/or symptom.
4. In cases of clinically significant cardiac arrhythmias, such as ventricular tachycardia, sick sinus syndrome, or complete A-V block, the arrhythmias must be carefully evaluated in conjunction with the patient's symptoms, such as palpitations, dizziness, syncope, shortness of breath, and chest pain.
5. In addition to the various cardiac arrhythmias, S-T segment alterations (depression or elevation) and T wave changes (inversion, flattening, etc.) should be recorded. The S-T segment and/or T wave abnormalities must be correlated with the patient's physical activity and/or symptom, particularly during an angina episode.
6. After these steps are followed, the clinical significance of a given arrhythmia should be indicated.

When the patient is under any anti-arrhythmic therapy, its efficacy and toxicity can be evaluated. During anti-arrhythmic therapy, any occurrence of arrhythmia should be correlated with the administration of the anti-arrhythmic agent. Digitalis-induced arrhythmias especially should be carefully evaluated. The efficacy of digitalis in the patient with chronic atrial fibrillation can be determined by observing the ventricular response during physical activity. The efficacy of other anti-arrhythmic agents (e.g., quinidine, procaine amide) can be easily assessed by comparing the frequency under medication with the preexisting ectopic beats or rhythm.

In patients with artificial pacemakers, the Holter monitor recording can distinguish between normal function and a malfunction. When malfunction of the pacemaker is manifested, the ECG finding should be precisely described (e.g., acceleration or slowing of pacing, irregular pacing, or failure of sensing and/or cardiac capture). When artificial pacemaker spikes or rhythm are not detected in patients with a demand pacemaker, this should be mentioned, and the reason for their absence described.

Other findings may be included in the interpretation of the Holter monitor ECG. When the patient has ill-defined or unexplainable symptoms, such as dizziness, weakness, or syncope, these symptoms should be evaluated in terms of a possible cardiac rhythm disturbance. The efficacy of the anti-anginal drug therapy can be evaluated by recognizing the S-T segment and/or T wave alterations, as noted above.

ELECTRODE PLACEMENT

The Holter monitor has a bipolar electrode system. This consists of three electrodes: the exploring (usually red), indifferent (white), and ground (green) electrodes. Two basic electrode positioning systems are used, although any

suitable modification is acceptable. The general application is a bipolar modification of lead V_4 or V_5. This usually allows good analyses of P waves, QRS complexes, the S-T segment, and T wave abnormalities. The QRS complex is upright in most cases when this lead placement is used. In this system, the exploring electrode is placed over the fifth rib in the left mid-clavicular line. The indifferent electrode is placed high over the sternum, and the ground electrode is placed over the fifth rib in the right mid-clavicular line. Placement over the bone minimizes muscle motion and artifact. The other basic lead placement is a modified V_1 lead, which is used primarily for the cardiac rhythm analysis, though it can record S-T and T wave changes. The lead V_1 position usually records a prominent P wave and also facilitates differentiation between right bundle branch block (RBBB) and left bundle branch block (LBBB) configurations. In this position the exploring electrode is placed over the lower sternum, the indifferent electrode over the upper sternum, and the ground electrode over the fifth rib in the right mid-clavicular line. Before the electrodes are attached, the skin should be shaved and defatted with acetone, and antiperspirant should be applied and allowed to dry. After the leads are securely fixed, loops of the connecting wire from each lead should be taped to the patient's skin to prevent a sudden tension on the wire from disconnecting a lead. The lead system should then be connected to a conventional ECG to verify the lead morphology and the base-line steadiness. Control recordings should be made in the supine, sitting, and standing positions, since the configuration of the P wave, the QRS complex and S-T segment, and/or the T waves may change depending upon the patient's position. The lead system is then connected to the monitor, which should be checked to confirm that the unit contains fresh batteries and a blank magnetic tape. The time the monitor is activated is recorded on the patient's diary and the patient can then be dismissed. The monitor may be carried over the shoulder or connected to a belt, depending on the make and model instrument used.

The most commonly used lead is lead V_5, with single channel equipment. When two-channel equipment is available, leads V_1 and V_5 are the most useful Holter monitor leads. The newer Holter monitor system can record and scan two channels (leads) simultaneously.

THE HOLTER MONITOR RECORDER

The Holter monitor recorder (Electrocardiocorder Model 445, Del Mar Avionics Dynamic Instrumentation) has the following features:

1. Simultaneous monitoring of two ECG leads
2. Digital clock display with event marker for precise time–event–symptom correlation
3. Patient activation of event marker to provide standardization pulses and automatic ECG strip during playback
4. Smaller size (43 in.^{3}) (recorder fits into an inside coat pocket)
5. Weight of recorder 1.6 lb, including batteries and recording tape
6. Extended battery life for 32-hr recording capability
7. Increased timing accuracy better than 1/20 of 1% over 26 hr
8. Provision for 26-hr monitoring (designed for the usual 24-hr recording)

THE HOLTER MONITOR SCANNER

The Holter monitor scanner (Electrocardioscanner Model 660A, Del Mar Avionics Dynamic Instrumentation) has the following features:

1. A two-lead ECG scope display and time-documented paper write-out
2. Displays the number of ventricular and supraventricular ectopic beats per hour
3. Displays the number of pacemaker beats per hour
4. Displays the total number of heart beats per hour
5. A visual display of each R-R interval
6. A digital time display with a precise time–event–symptom correlation better than 5-sec accuracy
7. Summary report of all heart rate, S-T segment, and ectopic beats, related to time
8. A 24-hr tape scan in 12 min

9. Initiation of automatic real time ECG write-out by a single ventricular premature beat
10. Initiation of automatic real time ECG write-out by three or more ventricular or supraventricular premature beats in any 10-sec period
11. Time printed on all ECG write-outs for precise time–event–symptom correlation

DIARY CARD

Table 1 is a photograph of an actual diary card. The patient should be instructed to write down any unusual or significant symptoms, such as palpitations, chest discomfort, skipped heart beats, shortness of breath, dizziness, or indigestion, noting the precise time and activity. Other pertinent information includes the patient's name, age, sex, and date; the physician's name and the starting time for the recording should be filled in by the technician.

FACTORS INFLUENCING THE THERAPEUTIC APPROACH

Various factors influence the therapeutic approach (see Table 5).

Physician's philosophy, medical background, and experience: Obviously, the therapeutic approach will vary greatly depending upon the physician's philosophy, medical background, and experience. For example, the therapeutic approach will differ between physicians with an aggressive and those with a conservative approach. Similarly, a physician with a good medical background will be able to provide more appropriate, scientific treatment than an inexperienced physician. Needless to say, proper management cannot be expected when the diagnosis of a cardiac arrhythmia is in error.

Symptomatic versus asymptomatic conditions: In most cases, such asymptomatic cardiac arrhythmias as ventricular premature contractions (VPCs) or transient supraventricular tachyarrhythmias are unlikely to require active treatment. On the other hand, any arrhythmia that produces significant symptoms (e.g., palpitations, dizziness, near-syncope, syncope, dyspnea, chest pain) should be treated. Even when the ECG reveals an identical finding, the symptomatic finding requires treatment, whereas the asymptomatic one is unlikely to need therapy in most clinical situations.

Clinical circumstances: The clinical circumstances definitely influence the therapeutic approach. For instance, ventricular arrhythmias during an early phase of acute myocardial infarction should be aggressively treated. Ventricular premature contractions in healthy individuals, however, usually require no active treatment other than eliminating or modifying any possible etiologic factors (e.g., the excessive use of coffee, tea, Coca-Cola, tobacco). For digitalis-induced cardiac arrhythmias, of course, digitalis must be discontinued immediately.

Mechanisms of arrhythmias: The mechanism underlying the cardiac arrhythmia determines the therapeutic approach. For example, paroxysmal ventricular tachycardia (PVT) requires immediate treatment, whereas nonparoxysmal ventricular (idioventricular) tachycardia (accelerated idioventricular rhythm) is usually self limiting. Similarly, ordinary VPCs often require active treatment, whereas parasystole is considered benign in most cases.

Acute versus chronic arrhythmias: By and large, cardiac arrhythmias with acute onset require active treatment, whereas chronic arrhythmias often do not. The best example is an acute arrhythmia in a patient with an acute myocardial infarction, which usually requires immediate and aggressive treatment. In addition, any cardiac arrhythmia with acute onset is, as a rule, symptomatic.

THE THERAPEUTIC APPROACH TO CARDIAC ARRHYTHMIAS

Table 6 summarizes the therapeutic approach to cardiac arrhythmias.

Eliminate the cause if possible: The first therapeutic approach is to eliminate any pos-

sible etiologic factor responsible for a given cardiac arrhythmia. For example, various cardiac arrhythmias, particularly VPCs, paroxysmal supraventricular tachycardia, etc., encountered in healthy individuals can be successfully treated by eliminating or modifying the use of all stimulants (e.g., coffee, tea, Coca-Cola, tobacco). Again digitalis-induced arrhythmias are best treated by discontinuation of the drug, and cardiac arrhythmias induced by electrolyte imbalance are best managed by correcting the electrolyte imbalance.

Anti-arrhythmic drug therapy: Many drugs are available for the treatment of various cardiac arrhythmias. Depending upon the mechanism(s), the direct cause of a given arrhythmia and underlying cardiac disease, the anti-arrhythmic drug of choice will vary. For instance, the drug of choice for paroxysmal atrial fibrillation with rapid ventricular response is digitalis in most clinical situations. Ventricular tachyarrhythmas seen in the Emergency Room will best be treated by an intravenous injection of lidocaine (Xylocaine), especially in patients with coronary artery disease. Similarly, intravenous lidocaine has been shown to be very effective in various supraventricular tachyarrhythmias, especially atrial fibrillation (AF) with anomalous A-V conduction in the Wolff–Parkinson–White (WPW) syndrome. On the other hand, propranolol (Inderal) is considered to be the drug of choice for reciprocating tachycardia with normal QRS complexes in the WPW syndrome and in most exercise-induced cardiac arrhythmias. Propranolol is also considered the drug of choice for cardiac arrhythmias with or without chest discomfort in patients with mitral valve prolapse syndrome (MVPS). Procaine amide (Pronestyl) is primarily used in long-term oral therapy for chronic ventricular arrhythmias. Parenteral administration of procaine amide is now much less common because lidocaine has been found to be more effective for acute or serious ventricular tachyarrhythmias.

Diphenylhydantoin (Dilantin) is the drug of choice for various digitalis-induced tachyarrhythmias, particularly those that are ventricular in origin. The main role of quinidine is the prevention of atrial fibrillation (AF) following restoration of sinus rhythm by direct current (DC) shock, digitalis, and/or quinidine. Parenteral administration of quinidine is only rarely indicated.

A new drug, disopyramide phosphate (Norpace) has recently been introduced into clinical medicine; it is primarily used to treat VPCs. The long-term efficacy of Norpace compared to the older anti-arrhythmic drugs requires further investigation. Various sedatives or mild tranquilizers (e.g. Valium or Librium) may be valuable in anxiety-induced cardiac arrhythmias.

Direct current shock: In clinical emergencies, particularly ventricular tachycardia (VT) or ventricular fibrillation (VF), DC shock is often a life-saving measure. Direct current shock may be considered an elective procedure when restoration of sinus rhythm from various chronic ectopic tachyarrhythmias is considered, especially in chronic AF. It is best to apply DC shock in the Coronary Care Unit or in a room with similar facilities where continuous monitoring is available.

Artificial pacemakers: The use of an artificial pacemaker is primarily indicated for patients with symptomatic second-degree or complete A-V block, sick sinus syndrome (SSS), and symptomatic bilateral bundle branch block (BBBB). Permanent pacing is definitely indicated for Mobitz type II A-V block and all A-V blocks due to an infra-nodal block as well as advanced SSS. Holter monitor electrocardiography is of great value in diagnosing SSS and intermittent advanced A-V block. In addition, an artificial pacemaker is occasionally indicated for drug-resistant ectopic tachyarrhythmias, particularly VT.

Surgery: In selected patients with refractory tachyarrhythmias, surgical intervention should be considered. For example, refractory tachyarrhythmias in the WPW syndrome may be treated by ligating a bypass tract. Certain refractory ventricular tachycardia may be abolished by coronary bypass surgery, ventricular aneurysmectomy, etc.

Any combination of the above: Not uncommonly, many cardiac arrhythmias require a combined therapeutic approach. For example,

many patients require one anti-arrhythmic drug or more to prevent the recurrence of arrhythmia following restoration of sinus rhythm by DC shock. Another example is the brady-tachyarrhythmia syndrome (BTS), which often requires one anti-arrhythmic drug or more even after artificial pacing.

CARDIAC ARRHYTHMIAS REQUIRING TREATMENT

Table 7 summarizes the cardiac arrhythmias that require treatment.

Symptomatic arrhythmias: As a rule, symptomatic cardiac arrhythmias require treatment regardless of the underlying disorder. Common symptoms due to cardiac arrhythmias may include palpitations, dizziness, near-syncope, syncope, dyspnea, and chest pain. Even when the ECG findings are identical, symptomatic arrhythmias often require treatment, whereas asymptomatic arrhythmias usually do not.

Malignant ventricular arrhythmias: The term "malignant ventricular arrhythmias" is used to designate the clinically serious ventricular arrhythmias that require active treatment, whereas clinically insignificant ventricular arrhythmias are often designated "benign ventricular arrhythmias." Malignant versus benign ventricular arrhythmias are described in detail later (see Tables 8 and 11).

Sick sinus syndrome and brady-tachyarrhythmia syndrome: The SSS is characterized by an inadequate impulse formation in the sinus node, which leads to a marked and persistent sinus bradycardia followed by a variety of ECG abnormalities. In other words, the SSS is analogous to the failure of a generator, and the result of the syndrome is hypoperfusion of vital organs, particularly the brain and the heart. The SSS commonly produces dizziness, near-syncope, syncope, congestive heart failure, palpitations, and angina pectoris. Sudden death may occur in this syndrome. The term, "brady-tachyarrhythmia syndrome" (BTS) is used when the cardiac arrhythmia consists of a bradycardia component as well as a tachyarrhythmia component, and it is often a late manifestation of the SSS.

The most common indication for permanent artificial pacing is the SSS, and drug therapy alone has been found to be unsatisfactory. Various electrocardiographic manifestations of the SSS will be discussed later (see Table 9).

Symptomatic bilateral bundle branch block (bifascicular and trifascicular block): In symptomatic BBBB, there are episodes of intermittent second-degree, advanced, or complete A-V block in the presence of a number of ECG abnormalities characteristic of bifascicular or trifascicular block. Under these circumstances, a permanent pacemaker is definitely indicated. Bilateral bundle branch block will be discussed later (see Table 10).

Infra-nodal A-V block: In general, A-V block is divided into two major types according to the site of the A-V block; these include intra-nodal (A-V nodal) block and infra-nodal block. Intra-nodal (A-V nodal) A-V block is usually transient in nature and reversible, and it is commonly produced by acute diaphragmatic (inferior) myocardial infarction (MI), digitalis intoxication, and infectious heart disease, such as myocarditis. Infra-nodal A-V block is usually due to permanent damage of the Purkinje fibers, and it is not uncommon in acute anterior MI. In addition, infra-nodal A-V block is often designated "idiopathic," and degenerative-sclerotic changes in the Purkinje system are implicated. Infra-nodal A-V block, however, is irreversible and a permanent pacemaker is definitely indicated. The Mobitz type II A-V block is an expression of incomplete trifascicular block (TFB); while ventricular escape (idioventricular) rhythm, due to complete A-V block, is the end result of complete TFB. Permanent pacing is indicated in every case of Mobitz type II A-V block or complete TFB.

Persisting, exercise-induced arrhythmias: Various cardiac arrhythmias may be induced or abolished by physical exercise in healthy individuals as well as in cardiac patients. But ventricular arrhythmias induced by mild exercise with less than 70% of the maximal predicted heart rate usually indicate significant coronary heart disease. Persisting exercise-

induced arrhythmias should be thoroughly investigated to determine their underlying cause. When any form of cardiac arrhythmia is constantly induced by ordinary daily activities, active treatment may be indicated in addition to a full investigation. By and large, propranolol (Inderal) is considered the drug of choice for the various exercise-induced cardiac arrhythmias.

MALIGNANT VENTRICULAR PREMATURE CONTRACTIONS

Table 8 summarizes the types of malignant VPCs. "Malignant ventricular premature contractions" here is used to designate a clinically serious arrhythmia that requires prompt recognition and treatment.

Symptomatic: As a rule, symptomatic VPCs require some form of treatment whatever their etiology. For example, in frequent VPCs that cause palpitations or chest discomfort, the arrhythmia should be suppressed. Digitalis-induced VPCs may be abolished by simply withholding digitalis, and when VPCs are thought to be induced by the excessive use of coffee, tea, Coca-Cola or tobacco, the causative agent should be eliminated. More seriously, if VPCs cause significant symptoms, such as dizziness or signs of heart failure, it must be more aggressively treated.

In acute myocardial infarction: By and large, VPCs in patients with acute myocardial infarction or significant angina pectoris should be suppressed because VPCs under these circumstances may frequently lead to more serious ventricular arrhythmias, such as VT or VF. Ventricular premature contractions during an early phase (the first 72 hr) of an acute MI usually exhibit other forms of malignancy, such as the R-on-T phenomenon, in which a VPC with a short coupling interval interrupts the T wave of the preceding beat, which is the vulnerable period of the ventricles. Other malignancies include multifocal or grouped VPCs.

In digitalis toxicity: In the mild form of digitalis-induced VPCs, discontinuation of the drug alone is sufficient. Otherwise, treatment with diphenylhydantoin (Dilantin) or potassium may be indicated.

With the R-on-T phenomenon: As described earlier, the incidence of VF is greater when the VPCs show a very short coupling interval (the interval from the ectopic beat to the QRS complex of the preceding beat of the basic rhythm), which is designated the R-on-T phenomenon. This is more commonly observed during an early phase of acute MI. Thus, VPCs with the R-on-T phenomenon should be aggressively treated. The treatment of choice here is intravenous injection of lidocaine (Xylocaine) followed by intravenous infusion.

Multifocal: Multifocal VPCs should be actively treated because more serious ventricular tachyarrhythmias can easily be provoked. Multifocal VPCs usually occur in patients with significant underlying organic heart disease, particularly coronary artery disease, and/or digitalis toxicity.

Grouped: Similarly, grouped VPCs (two or more consecutively occurring VPCs) should be treated because there is a greater chance of VT or even VF developing, particularly in patients with coronary artery disease.

Induced by mild exercise with less than seventy percent of the maximal heart rate: It has been shown that VPCs provoked by mild exercise with less than 70% of the maximal heart rate are often indicative of significant coronary artery disease. In addition to VPCs, marked S-T segment depression is usually observed during and/or after exercise. Mild, exercise-induced VPCs are, therefore, usually considered to be serious clinically and they should be treated.

Persisting exercise-induced ventricular premature contractions: When VPCs are constantly induced by ordinary daily physical activity, the underlying cause must be determined. Persisting exercise-induced VPCs, as a rule, require treatment in addition to an appropriate medical workup. Propranolol (Inderal) is the drug of choice for exercise-induced arrhythmias in most cases.

Frequent: When VPCs occur at a rate of more than 30 beats per hour, the term "fre-

quent" VPCs is used. Although there is controversy as to whether frequent VPCs should be treated, many physicians still treat them regardless of the etiologic process.

ELECTROCARDIOGRAPHIC MANIFESTATIONS OF THE SICK SINUS SYNDROME

The SSS may be manifested by a variety of ECG abnormalities (see Table 9). The earliest, and commonest, ECG finding of the SSS is marked and persisting sinus bradycardia (rate below 45 beats per minute), which is often followed by an intermittent sinus arrest or a sinoatrial (S-A) block. The sinus bradycardia in SSS is drug (atropine or isoproterenol) resistant, but *not* drug induced.

In the SSS, a long pause often follows an atrial premature contraction (APC) because the sinus node is abnormally suppressed by the atrial ectopic impulse. In advanced SSS, the cardiac rhythm is commonly AF, which may be chronic or recurrent. In many cases of SSS, the AF shows a slow ventricular rate because of advanced A-V block, and the AF is often preceded or followed by a marked sinus bradycardia with or without a first-degree A-V block (P-R interval $\geqq$ 0.28 sec). The atrial tachyarrhythmia component is most commonly AF, but it may be atrial flutter (AF1) or atrial tachycardia (AT).

When the diagnosis of SSS is equivocal, provocative tests such as rapid atrial pacing are performed to determine the sinus node recovery time. That is, the interval from the last pacing spike to the first sinus P wave—the sinus node recovery time—is measured upon abrupt termination of atrial pacing. The atrial pacing rate may be started with 120 beats per minute and the rate may be increased progressively by 10 beats per minute up to a pacing rate of 150 beats per minute. The duration of the atrial pacing is usually 2 to 4 min, and the most practical pacing mode is coronary sinus pacing. When the sinus node recovery time is over 1500 msec, the presence of the SSS is confirmed. Concealed A-V conduction disturbance will be unmasked by rapid atrial pacing, and Wenckebach (Mobitz type I) A-V block is also commonly produced. Coexisting A-V block and/or intraventricular conduction disturbances are relatively common in the SSS. In these cases, the bifocal demand pacemaker is the ideal mode of pacing. Practically, however, the demand ventricular pacemaker is the most commonly used pacing mode in the treatment of the SSS.

In advanced cases of SSS, the cardiac rhythm frequently exhibits A-V junctional escape rhythm with or without slow and unstable sinus activity. The BTS is commonly a manifestation of advanced SSS. When the patient develops BTS, one or more anti-arrhythmic drugs may be required to suppress the tachyarrhythmia component, in addition to the use of artificial pacing. The tachyarrhythmia component in the BTS is commonly atrial tachyarrhythmia (e.g., AF, AF1, or atrial tachycardia), but it may be frequent VPCs or even VT. In advanced cases of the SSS, various ECG manifestations (described in Table 9) may occur in the same ECG.

DIAGNOSTIC CRITERIA OF BILATERAL BUNDLE BRANCH BLOCK

Bilteral bundle branch block includes BFB as well as TFB; the diagnostic criteria of BBBB are summarized in Table 10.

The most common form of BBBB is a combination of RBBB and left anterior hemiblock (LAHB) to cause BFB. A less common form of BFB is the combination of RBBB and LPHB. Needless to say, BFB is a manifestation of an incomplete BBBB, and in many cases, the BBBB is incomplete. When the BBBB is complete, the end result is, of course, complete A-V block (complete TFB), which produces ventricular escape (idioventricular) rhythm.

Alternating LBBB and RBBB is a rare maninfestation of BBBB. But not uncommonly, one may find LBBB on one occasion and RBBB on another in the same individual as a manifestation of BBBB, and LBBB or RBBB associated with first- or second-degree A-V block may be due to incomplete BBBB. When dealing with a Mobitz type II A-V block, the diagnosis of incomplete BBBB is confirmed, and the QRS

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complexes nearly always exhibit RBBB, LBBB, hemiblock, or BFB.

It has been proposed that the presence of BBBB is confirmed when the H-V interval (the interval from the His bundle potential to the first component of the ventricular deflection on the His bundle electrogram) is 70 msec or more in the presence of RBBB or LBBB. In many cases of incomplete BBBB, various ECG abnormalities may coexist, as described in Table 10.

BENIGN VENTRICULAR ARRHYTHMIAS

In contrast to malignant ventricular arrhythmias, some ventricular arrhythmias are benign and self limiting. Benign ventricular arrhythmias are summarized in Table 11.

Occasional unifocal ventricular premature contractions: When VPCs occur at a rate of less than 30 beats per hour, and when they are unifocal in origin, they are usually considered benign. No treatment is indicated in most cases.

Asymptomatic ventricular premature contractions: Asymptomatic VPCs are unlikely to cause any significant alterations in hemodynamics, and they are usually found in individuals without demonstrable heart disease.

Right ventricular premature contractions: Although there is no uniform agreement among cardiologists, VPCs encountered in healthy individuals nearly always arise from the right ventricle. Right VPCs can be diagnosed by recognizing the negative (downward) QRS complex in the right precordial leads and positive (upright) QRS complex of the ectopic beats in the left precordial leads. Thus, right VPCs are considered benign in most cases.

Conversely, the VPCs found in a diseased heart and/or in digitalis intoxication commonly originate from the left ventricle or the ventricular septum. The QRS complex of the left VPCs is positive (upright) in the right precordial leads and negative (downward) in the left precordial leads. The septal VPCs produce a positive (upright) QRS complex in both the right and the left precordial leads.

Ventricular parasystole and parasystolic ventricular tachycardia: Although ventricular parasystole and parasystolic VT are not uncommonly encountered in patients with organic heart disease, these arrhythmias are found to be self limiting in most cases. The usual rate of the parasystolic VT ranges from 70 to 130 beats per minute. No treatment is indicated.

Non-paroxysmal ventricular tachycardia (accelerated idioventricular rhythm): Similarly, non-paroxysmal VT (accelerated idioventricular rhythm) is also considered to be benign, since the arrhythmia is self limiting in most cases. The usual rate range is between 70 and 130 beats per minute, as it is in parasystolic VT. Both non-paroxysmal VT and parasystolic VT are relatively common in the first 72 hr of acute MI.

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Case Histories

Appendix

Table 1
DYNAMIC ELECTROCARDIOGRAPHY®

PATIENT ACTIVITY DIARY

☐ 10 Hr. ☐ 12 Hr. ☒ 24 Hr. ☐ 26 Hr.

Patient's Name: John Smith

Patient's Address: 123 Main Street
Philadelphia, Pa. 19101

Age: 57 Sex: M Phone: 555-1212

Medication: Inderal

Doctor: Chung Phone: 928-6220

Hospital: G. J. U. Room: 5611

Date of Recording: 7/1/78 Started: 10:00 AM PM

Connected by: P. Jones

TIME	ACTIVITY	SYMPTOMS
10:00 A.M.	START RECORDING	
10:30 A.M.	Walking in street	Fluttering feeling in chest
11:00 A.M.	Resting on bench	None
Noon	Eating lunch	Feeling of indigestion
1:15 P.M.	Walking steps to office	Shortness of breath
1:30 P.M.	Sitting in office	Shortness of breath gone
2:00 P.M.	Business meeting	Chest discomfort
2:30 P.M.	Took nitroglycerin	Feeling better
4:30 P.M.	Driving home	Anxiety
5:45 P.M.	Eating dinner	Feeling fine
7:00 P.M.	Watching T-V	None
8:30 P.M.	Got up to go bathroom	Lightheaded
8:45 P.M.	Resting	None
9:30 P.M.	Reading newspaper	Feels O.K.
10:30 P.M.	Go to bed	None
10:00 A.M.	Monitor off	

Table 2 *Indications for the Use of the Ambulatory (Holter Monitor) ECG*

1. Diagnosis of cardiac arrhythmias
2. Evaluation of symptoms (e.g., dizziness, fainting, palpitation) to correlate with actual arrhythmias
3. Diagnosis of myocardial ischemia
4. Evaluation of anti-arrhythmic drug therapy
5. Evaluation of artificial pacemaker function

Table 3 *Value of the Holter Monitor ECG versus the Exercise ECG*

	Holter Monitor ECG	Exercise ECG
Cardiac arrhythmias	+++	+
Myocardial ischemia	+	+++
Evaluation of symptoms	+++ (dizziness, fainting, palpitations)	+++ (chest pain)
Evaluation of drug efficacy	+	++
Evaluation of artificial pacemaker	+	–
Morbidity and mortality	–	+
Cost ($)	100–150	100–125

Key: +++, extremely useful;
++, significantly useful;
+, moderately useful;
–, no value.

Table 4 *Interpretations of the Ambulatory (Holter Monitor) ECG*

1. Describe the basic cardiac rhythm
2. Describe any cardiac arrhythmias
3. Describe the relationship between the arrhythmia and physical activity or complaints
4. Evaluate the symptoms (e.g., palpitation, dizziness) and correlate them with the actual arrhythmias
5. Describe the ischemic ECG change and correlate them with physical activity and chest pain
6. Conclusion (e.g., clinically significant versus clinically insignificant)

Table 5 *Factors Influencing the Therapeutic Approach*

1. Physician's philosophy, medical background, and experience
2. Symptomatic arrhythmias versus asymptomatic arrhythmias
3. Clinical circumstances (e.g., myocardial ischemia, health of individual, digitalis intoxification)
4. Mechanisms of arrhythmias
5. Acute arrhythmias versus chronic arrhythmias

Table 6 *The Therapeutic Approach to Cardiac Arrhythmias*

1. Eliminate the cause if possible
2. Anti-arrhythmic drug therapy
   - Digitalis
   - Lidocaine (Xylocaine)
   - Pronestyl (procaine amide)
   - Quinidine
   - Inderal (propranolol)
   - Norpace (disopyramide phosphate)
   - Dilantin (diphenylhydantoin)
   - Sedatives
3. Direct current shock
4. Artificial pacemaker
5. Surgery
6. Any combination of the above

Table 7 *Cardiac Arrhythmias Requiring Treatment*

1. Symptomatic arrhythmias (e.g., dizziness, syncope, palpitations)
2. Malignant ventricular arrhythmias
3. Sick sinus syndrome and brady-tachyarrhythmia syndrome
4. Symptomatic bilateral bundle branch block (bifascicular or trifascicular block)
5. Infra-nodal A-V block (Mobitz type II and complete trifascicular block)
6. Persisting, exercise-induced arrhythmias

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Table 8 *Malignant Ventricular Premature Contractions*

1. Symptomatic
2. In acute myocardial infarction
3. In digitalis toxicity
4. Ventricular premature contractions with the R-on-T phenomenon
5. Multifocal ventricular premature contractions
6. Grouped ventricular premature contractions
7. Ventricular premature contractions induced by mild exercise (less than 70% of maximal heart rate)
8. Persisting, exercise-induced ventricular premature contractions
9. Frequent (over 30 beats per hour) ventricular premature contractions

Table 9 *Electrocardiographic Manifestations of the Sick Sinus Syndrome*

1. Marked sinus bradycardia, sinus arrest, S-A block
2. Drug (atropine, Isuprel)-resistant sinus bradyarrhythmias
3. Long pause following an atrial premature contraction
4. Long sinus node recovery time by atrial pacing (>1500 msec)
5. Atrial fibrillation
   a) with slow ventricular rate
   b) preceded or followed by sinus bradycardia and/or first-degree A-V block
6. First-degree A-V block (P-R interval ≧ 0.28 sec)
7. A-V junctional escape rhythm (with or without slow, unstable sinus activity)
8. Brady-tachyarrhythmia syndrome
9. Any combination of the above

Table 10 *Diagnostic Criteria of Bilateral Bundle Branch Block*

1. Right bundle branch block with left anterior hemiblock
2. Right bundle branch block with left posterior hemiblock
3. Alternating left and right bundle branch block
4. Left or right bundle branch block with first-degree or second-degree A-V block
5. Left or right bundle branch block with a prolonged H-V interval (>70 msec)
6. Left bundle branch block on one occasion, right bundle branch block on another
7. Mobitz type II A-V block
8. Any combination of the above
9. Complete A-V block with ventricular escape rhythm

Table 11 *Benign Ventricular Arrhythmias*

1. Occasional unifocal ventricular premature contractions (<30 beats per hour)
2. Asymptomatic ventricular premature contractions in healthy individuals
3. Right ventricular premature contractions
4. Ventricular parasystole and parasystolic ventricular tachycardia
5. Non-paroxysmal ventricular tachycardia (accelerated idioventricular rhythm)

Conclusion

Holter monitor electrocardiography (ambulatory electrocardiography) is one of the most commonly used noninvasive diagnostic methods in the field of cardiology. The uses of Holter monitor electrocardiography can be summarized as follows:

1. Assessment of transient or paroxysmal cardiac arrhythmias.
2. Evaluation of various symptoms (e.g., dizziness, syncope, palpitations); correlation with actual arrhythmias.
3. Diagnosis of transient myocardial ischemia; evaluation of anti-arrhythmic drug therapy and artificial pacemaker function.
4. In interpretation of the Holter monitor ECG, the basic cardiac rhythm should be first described.
5. Any cardiac arrhythmia detected by the Holter monitor ECG should be described in relation to the patient's symptoms and physical activities.
6. When any ischemic change occurs on the Holter monitor ECG, the ECG finding should be correlated with the patient's complaint (particularly chest pain) and physical activities.
7. When any cardiac arrhythmia is detected on the Holter monitor ECG, it should be mentioned whether a given arrhythmia is clinically significant or insignificant.
8. At present, the Holter monitor ECG equipment has the capability to record the ECG for 24 hours, but the old models can record only 10 or 12 hours.
9. A diary card must be completed by the patient, and detailed descriptions regarding symptoms in relation to the physical activities must be given. A recording of the precise time of each event is essential.
10. Newer models have a capability of recording 2 channels (2 ECG leads) but older models can record only one ECG lead.
11. The Holter monitor ECG is particularly useful for the diagnosis of sick sinus syndrome (SSS).
12. The most common complaints which require the Holter monitor ECG are dizziness or episodes of fainting spells.
13. The common manifestations of SSS include periods of marked sinus bradycardia, sinus arrest, S-A block, A-V junctional escape rhythm and atrial flutter or fibrillation with advanced A-V block.
14. At present, the most common indication for permanent artificial pacemaker implantation is SSS.
15. Holter monitor ECG is extremely important to document advanced bilateral bundle branch block (BBBB) in order to determine the indication vs. non-indication of permanent artificial pacemaker.
16. Brady-tachyarrhythmia syndrome (BTS) is often documented by the Holter monitor ECG, and BTS almost always requires permanent pacemaker implantation.
17. SSS is the most common underlying disorder to produce BTS.
18. Holter monitor ECG is very essential to document paroxysmal tachyarrhythmia in the Wolff–Parkinson–White (WPW) syndrome, because the rapid heart action in this syndrome is often transient.
19. The efficacy of digitalis for atrial fibrillation is best evaluated by the Holter monitor ECG to correlate with the patient's activity, because well-controlled ventricular rate at rest may accelerate markedly during various physical activities. Under this circumstance, the dosage of digitalis may be increased or additional drug such as propranolol (Inderal) may be prescribed.
20. Various artifacts must be carefully searched in order to avoid possible misinterpretation of the artifact-induced ECG findings as true cardiac arrhythmias.

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