



Ambulatory Electrocardiographic Recording

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Cardiac rhythm abnormalities are common. Although many arrhythmias are not harmful, some can cause symptoms and be a signal for potential cardiac arrest or stroke. Thus, the detection and quantification of these arrhythmias are important, especially for patients who have structural heart disease caused by an event such as a prior heart attack. Arrhythmias are frequently limited in duration and occurrence and cannot be detected during physical examination and routine electrocardiography (ECG) because these procedures permit only a few seconds of observation. To diagnose arrhythmias and to assess their relationship to patient symptoms, or to assess the effectiveness of an intervention to suppress them, longer periods of ECG recording are required while the patient is pursuing his or her normal routine.

In this paper, we review the techniques and the clinical situations in which ambulatory ECG recordings are indicated.

What Kinds of Recording Devices Are Used?

The most commonly used method of extended ECG recording is a Holter monitor (named for its inventor, Nor-

man Holter) that uses a conventional tape recorder or solid-state storage system for acquiring ECG information that is later processed and displayed for physician review (Figure). Traditionally, these recordings are carried out for 24 to 48 hours via leads placed on the chest to yield 2 or 3 channels of ECG data. The patient is instructed to keep a diary of symptoms and to note the time on the Holter clock when the symptoms occur for later correlation to ECG abnormalities. For example, if the patient has a dizzy spell or rapid heart rhythm during the recording, the physician can determine if an arrhythmia, either fast or slow, was or was not responsible. These recordings are also used for measuring how often the arrhythmia occurs, determining if there are any variations by time of day, and deciphering the effectiveness of antiarrhythmic medications. The principal limitation of Holter recordings is that the sampling period is usually too short to allow capture of an infrequent arrhythmia. (It detects arrhythmias that are responsible for symptoms only 10% of the time.) There are several ways to overcome this problem. The period of observation could be extended, but because this requires serial Holter monitor recordings, it is an

impractical and costly exercise. Another potential solution is to observe patients on a telemetry unit in the hospital, but again this has severe limitations, most importantly poor patient acceptance. Mobile cardiac outpatient telemetry (MCOT) systems that permit several days of ECG monitoring via a cellular-based transmission system have been developed. Although the initial experience with this technology has been decidedly positive, it still requires validation in large, well-designed clinical trials. Nevertheless, if proven effective, MCOT's ability to capture all arrhythmia episodes and provide a link to rapid response and treatment would represent a major improvement over currently available technology.

Episodic monitors (frequently termed *event monitoring*) can also be used for extended periods to permit ECG recordings during symptoms. These devices allow the patient to record an ECG, store it for a time period, and then transmit the signal by telephone to a base station where it is decoded, recorded, and sent by fax to a physician. There have been several improvements in the technology that make it more useful today. With the older event monitors, the patient had to

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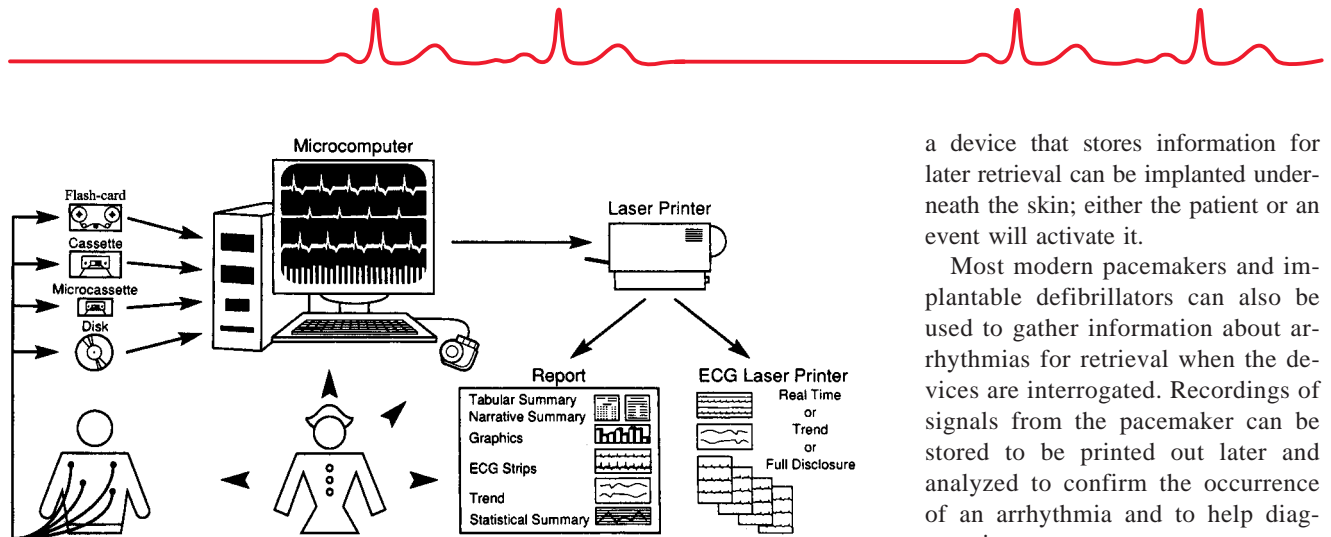
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(*Circulation*. 2003;108:e31-e33.)

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Circulation is available at <http://www.circulationaha.org>

DOI: 10.1161/01.CIR.0000082930.04238.8C



Modern conventional ambulatory electrocardiographic system. Reprinted with permission from additional resource 1 (Kennedy HL, Podrid PJ. Role of Holter monitoring and exercise testing for arrhythmia assessment and management. In: Podrid PJ, Kowey PR, eds. *Cardiac Arrhythmia*. 2nd ed. Philadelphia, Pa: Lippincott Williams & Wilkins; 2001: 168, Figure 6.1 to 6.4).

activate the device quickly to capture the ECG recording while symptoms were in progress, a difficult task for very elderly patients or for those whose arrhythmias cause functional impairment. Newer loop recorders continuously record and erase so that data gathered from 1 to 4 minutes before and then 30 to 60 seconds after the device was activated can be retained. The automatically activated

monitor is a new device that begins to record on the detection of an abnormal heart rhythm of any kind without patient activation. The key to the development of this newer device is a reliable formula for the detection of one of several different kinds of arrhythmias that may occur. Finally, in many patients, such as those who periodically lose consciousness or have very severe symptoms but have them infrequently,

a device that stores information for later retrieval can be implanted underneath the skin; either the patient or an event will activate it.

Most modern pacemakers and implantable defibrillators can also be used to gather information about arrhythmias for retrieval when the devices are interrogated. Recordings of signals from the pacemaker can be stored to be printed out later and analyzed to confirm the occurrence of an arrhythmia and to help diagnose it.

What Are the Uses of Ambulatory ECG Recordings?

ECG monitoring can be done for several purposes. For example, the presence of lower-chamber (ventricular) arrhythmias in patients with heart disease is associated with an increased risk of sudden cardiac death. Therefore, patients can be assessed for the possibility of cardiac arrest by detecting and measuring how many times these arrhythmias occurred. This is a well-established technique with great clinical utility. Unfortunately, suppressing these ventricular arrhythmias with drugs has never been shown to be beneficial. Implantable defibrillators may protect certain groups of patients, such as those who also have reduced cardiac function after myocardial infarction. Cardiac arrhythmias are a frequent cause of disturbance of consciousness, such as fainting, and ECG monitoring of patients with symptoms is common. For patients with frequent symptoms, such as palpitations or dizziness, Holter recordings may be adequate, but more infrequent arrhythmias require longer periods of observation using the methods described in the prior section. Sometimes, discovering that symptoms do not correlate with an abnormality found on ECG can be just as helpful to the physician, who can then go on to conduct a search for other nonarrhythmic causes of troublesome symptoms.

Ambulatory ECGs can be used to measure the effectiveness and safety of antiarrhythmic drugs or nonphar-

Devices and Techniques for Ambulatory ECG Recording

Device/Method	Duration	Advantage	Disadvantage
Holter monitor	1–2 days	<ul style="list-style-type: none"> ● Ease of use ● Precise quantification ● Familiarity 	<ul style="list-style-type: none"> ● Retrospective ● Short duration
Event monitor	1–30 days	<ul style="list-style-type: none"> ● Ease of use 	<ul style="list-style-type: none"> ● Patient activation ● Skin electrodes ● High failure rate
External loop monitor	1–30 days	<ul style="list-style-type: none"> ● Ease of use ● Retrograde acquisition 	<ul style="list-style-type: none"> ● Patient activation* ● Skin electrodes
Implantable loop monitor	Indefinite	<ul style="list-style-type: none"> ● Long period of observation ● No skin electrodes 	<ul style="list-style-type: none"> ● Patient activation* ● Invasive
Pacemaker	Indefinite	<ul style="list-style-type: none"> ● Continual monitoring ● No skin electrodes ● Detects pacemaker malfunction 	<ul style="list-style-type: none"> ● Limited application ● Limited storage ● Lead morphology
Hospital telemetry	1–7 days	<ul style="list-style-type: none"> ● Continual monitoring ● On-line with observation 	<ul style="list-style-type: none"> ● Costly due to need for hospitalization
Outpatient telemetry	1–30 days	<ul style="list-style-type: none"> ● Continual monitoring ● Online with observation ● Patients free-living 	<ul style="list-style-type: none"> ● Skin electrodes ● Validation in progress ● Requires cellular coverage

*Automatic activation devices are becoming available.



macological therapy. Ideally, the frequency of the arrhythmia is recorded before treatment and then after treatment to assess the effectiveness of suppression as well as the possibility of an adverse drug affect. For example, many antiarrhythmic drugs can actually cause worsening of arrhythmias, such as profound heart rate slowing, that can be detected by monitoring devices especially those (MCOT) that give continual information. Ambulatory recording of ECGs is used for a variety of other purposes, such as measurement of changes in the heart's electrical activity and recovery, shifts that could signify inadequate blood supply to the heart, or variability in heart rate caused by the part of the nervous system that controls vital functions. (In reality, clinicians seldom use these techniques in clinical practice because they do not add materially to the routine care of patients. They may be used in research projects, however.)

COMMON USES OF AMBULATORY ECG RECORDING

- Detection and measurement of rapid heart rhythm (including risk assessment)
- Detection and measurement of slow heart rhythms
- Demonstration of drug effectiveness and safety
- Diagnosis of cause for symptoms (such as palpitations or loss of consciousness)
- Detection and measurement of altered cardiac blood supply (ischemia)

Conclusions

Ambulatory ECG recording is a valuable tool in clinical medicine and is widely employed. It offers the opportunity to diagnose the cause for severe symptoms, to stratify the risk of serious events in patients with various forms of heart dis-

ease, and to assess the benefit of and the harm from several kinds of antiarrhythmic therapy. The key elements in the successful use of this technology are patient selection based on pre-test profiling, followed by optimal device selection, to arrive at an accurate diagnosis and effective treatment program as efficiently and as expeditiously as possible.

Acknowledgment

This work was supported in part by the Adolf and Rose Levis Foundation, Haverford, Pa. The authors acknowledge the help of Yvonne Wiley and Rose Marie Wells in the preparation of the manuscript.

Additional Resources

1. Kennedy HL, Podrid PJ. Role of Holter monitoring and exercise testing for arrhythmia assessment and management. In: Podrid PJ, Kowey PR, eds. *Cardiac Arrhythmia*. Philadelphia, Pa: Lippincott Williams & Wilkins; 2001: 165–193.
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