Electrophysiological investigation

Martina Muggenthaler

Razeen Gopal

Richard Schilling

Nicholas Gall

Abstract

Cardiac electrophysiology is the subspecialty of cardiology dealing with heart rhythm disorders, particularly the investigation and management of bradyarrhythmia, tachyarrhythmia and syncope, and the prevention of sudden cardiac death. Recent years have seen significant developments in our understanding of arrhythmias. Recent technological developments include ever smaller and more complex implantable pacing devices, the ability to map an arrhythmia circuit in three dimensions, potentially in one beat, and the ability safely to damage small areas of myocardium known to be critical to a particular arrhythmia, leading to permanent cure. This article focuses on the diagnostic tools that can be used to investigate these conditions and its sister article (see 'Supraventricular and ventricular arrhythmias: interventional management' in *Medicine* 2018; **46**(10)) deals with some of the treatment strategies.

Keywords Ablation; arrhythmia; ECG; electrophysiological; Holter; MRCP; palpitation

Key points

- The electrocardiogram (ECG) is key to arrhythmia management, to define the exact diagnosis, provide an idea of prognosis and plan treatment
- There are many methods of capturing the ECG at the time of symptoms, including short-term Holter monitors, hand-held mobile devices and implantable recorders for the long-term
- Choosing the appropriate monitoring technique for the frequency of arrhythmia is vital to improve cost-efficacy
- An understanding of electrophysiological mechanisms can allow more information to be accumulated according to the effects of medications, for example adenosine and ajmaline
- Tilt-testing can provide helpful information to assess blackouts but is not a first-line investigation

Non-invasive electrophysiology

Electrophysiology is the subspecialty of cardiology dealing with heart rhythm disorders; it is a growing area because of technological developments and increasing understanding of arrhythmia mechanisms. It involves the investigation and treatment of both brady- and tachyarrhythmias, including ablation and device therapy. The prediction and prevention of sudden cardiac death also constitutes a major focus. This article deals with invasive and non-invasive methods of investigation, and its sister article covers the treatment of tachyarrhythmias. Other articles in this series deal with device therapy.

Arrhythmias often present with palpitations, but they can also present non-specifically with symptoms of breathlessness, tiredness, chest pain, dizziness and syncope. The investigation of an arrhythmia needs to define whether the rhythm disturbance is relevant to the patient's symptoms, and to identify the underlying cause and electrophysiological mechanism; only then can the most suitable treatment be specified.

Martina Muggenthaler *MRCP is a Consultant Cardiologist and Cardiac Electrophysiologist, Royal Devon and Exeter Hospital, UK. Competing interests: none declared.*

Razeen Gopal *MB ChB MMed (US) is a Consultant Cardiologist and Cardiac Electrophysiologist, Cape Town AF Centre, South Africa. Competing interests: none declared.*

Richard Schilling *MD FRCP is a Professor of Cardiology and Electrophysiology, St Bartholomew's Hospital and Queen Mary University, London, UK. Competing interests: none declared.*

Nicholas Gall *MSc MD FRCP a is Consultant Cardiologist and Cardiac Electrophysiologist, King's College Hospital, and Honorary Senior Lecturer, King's College London, UK. Competing interests: none declared.*

Ambulatory electrocardiography (AECG)[1]

AECG allows the recording of an electrocardiogram (ECG) over a prolonged period of time, and is the main tool used to decide whether an arrhythmia is causing the patient's symptoms (Figure 1); it can also reveal information about the mechanism and allow selection of the best treatment. Less frequently, AECG can be used for the detection of myocardial ischaemia, risk stratification, particularly in ischaemic heart disease, monitoring of drug treatment and evaluation of pacemaker function.

Selection of recording technique

The frequency and characteristics of the patient's symptoms dictate the choice of recording technique. Continuous ECG recording can be achieved throughout the day and night for 7 days or more, depending on the digital memory of the device used. Three leads are typically recorded, but 12-lead versions are also available for 24–48-hour periods and are used in selected cases where detailed ECG morphology might be important (e.g. defining ventricular ectopic morphology to plan an ablation, investigating biventricular pacemaker function).

These continuous recording techniques are particularly useful if symptoms occur on most days or the patient is incapacitated by the symptoms, for example when an arrhythmia leads to syncope. Patients can mark events on the recording, and should always keep a diary of their symptoms and activities to allow the correlation of symptoms and heart rhythm. Some devices store the complete ECG data, whereas others are more selective, logging in particular any arrhythmia detected; the former provide a complete rhythm assessment and allow further analysis at a later date, whereas the latter require less analysis and are therefore less work-intensive.

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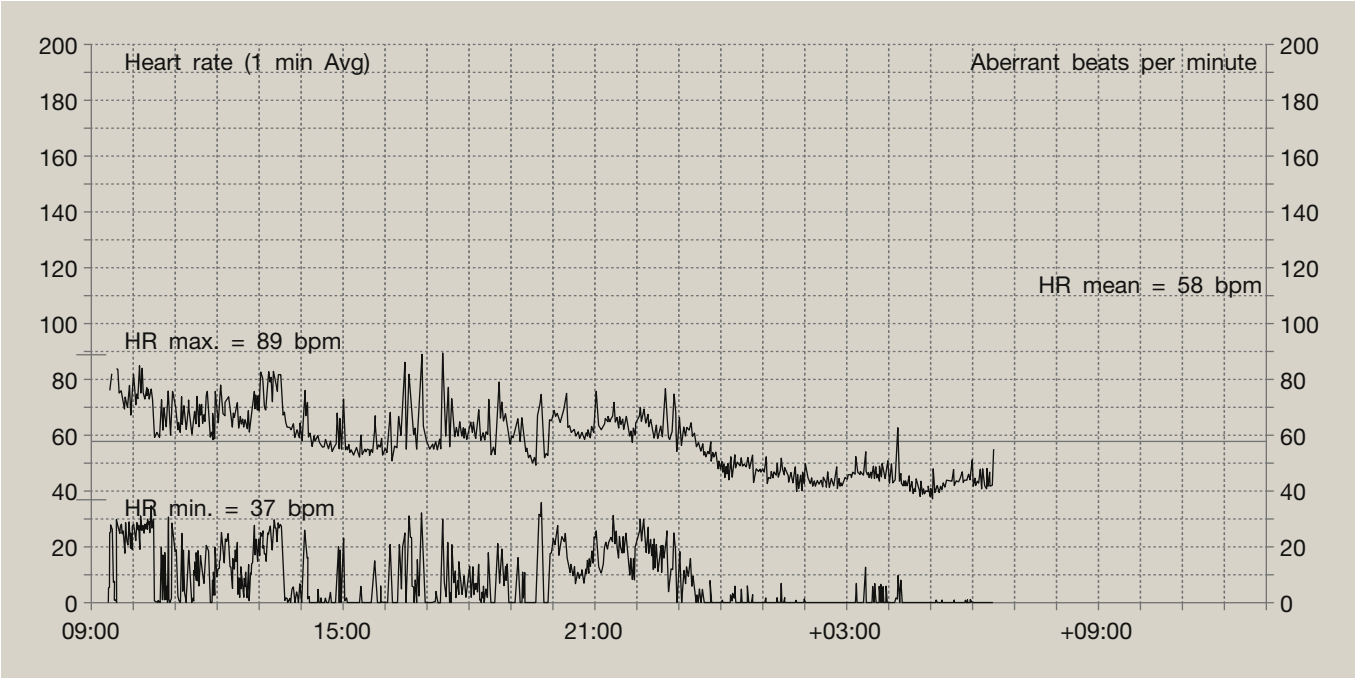

Figure 1 Holter monitors provide a considerable amount of information, including heart rate profile, frequency of ectopics beats and more complex arrhythmias in addition to allowing symptom–rhythm correlation. The heart rate trend is shown, providing information about, in this case, rate control in atrial flutter. The bottom graph gives an idea of ventricular ectopic frequency.

With less frequent symptoms, there are two alternatives. Event recorders record and store a brief period of ECG when activated by the patient. They can be attached via ECG leads or be carried in a pocket and held to the chest wall during the symptoms. These devices can be used for weeks or months at a time and are useful for patients with infrequent symptoms, providing the patient is able to activate the recorder at the time of symptoms. With recent technological advances, some smartphones can also be turned into event recorders.

Loop recorders continuously record the ECG but only store a few minutes' information, which is constantly updated. When activated, the stored ECG is fixed in a separate memory for later download; several separate events can be stored in this manner. As a rule, the ECG before and after device activation is stored to ensure that the whole event is captured, particularly where symptoms are brief or associated with incapacity. Loop recorders are either attached to the patient or can be implanted subcutaneously for prolonged monitoring. Patients activate the device in response to symptoms. Implanted devices have a battery life of up to 4 years and can also be programmed to store the ECG automatically, for example with heart rates above or below a defined cut-off. Remote monitoring allows these devices to be read at the patient's home, the data being transferred wirelessly via the internet for medical review.

Future implantable devices will have better arrhythmia detection capability and may also be able to measure other physiological variables, such as blood pressure and movement. The current generation of implantable recorders, released in 2014, are significantly reduced in size and can be injected subcutaneously away from the operating theatre/catheter laboratory environment.

Normal findings during AECG monitoring

During a 24-hour period, a healthy person's heart rate varies in response to autonomic influences, with a reduction in heart rate at night to <50 beats per minute in some people, although this is usually of little relevance when asymptomatic. Indeed, many 'abnormalities' are observed that have little significance. For instance, supraventricular and ventricular ectopics are frequently noted in healthy people; night-time atrioventricular (AV) nodal Wenckebach block is often seen in healthy individuals purely because of high vagal tone. However, very frequent ventricular ectopy or signs of higher grade AV block, particularly at times of low vagal tone (during the day), warrant further consideration.

Assessment of symptoms with AECG (Table 1)

The most common indication for the use of AECG is to correlate symptoms with a cardiac rhythm disturbance. Four different scenarios are possible:

- Characteristic symptoms correlate with the recording of a cardiac arrhythmia. This outcome is most useful in making the diagnosis and directs therapy.
- Typical symptoms occur at the time of normal rhythm. This can represent a patient's abnormal perception of a normal heart rhythm or the fact that the symptoms are not related to a cardiac arrhythmia. Some patients have an excessive sinus tachycardia caused by autonomic abnormalities, for example inappropriate sinus tachycardia/postural orthostatic tachycardia syndrome. In this rare situation, the sinus rhythm detected is the arrhythmia.
- The AECG detects an arrhythmia while the patient remains asymptomatic. This can be relevant if, for example, the recording shows a bradycardia, which might indicate that

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