Investigation of cardiac arrhythmias

Predict, wait or provoke?

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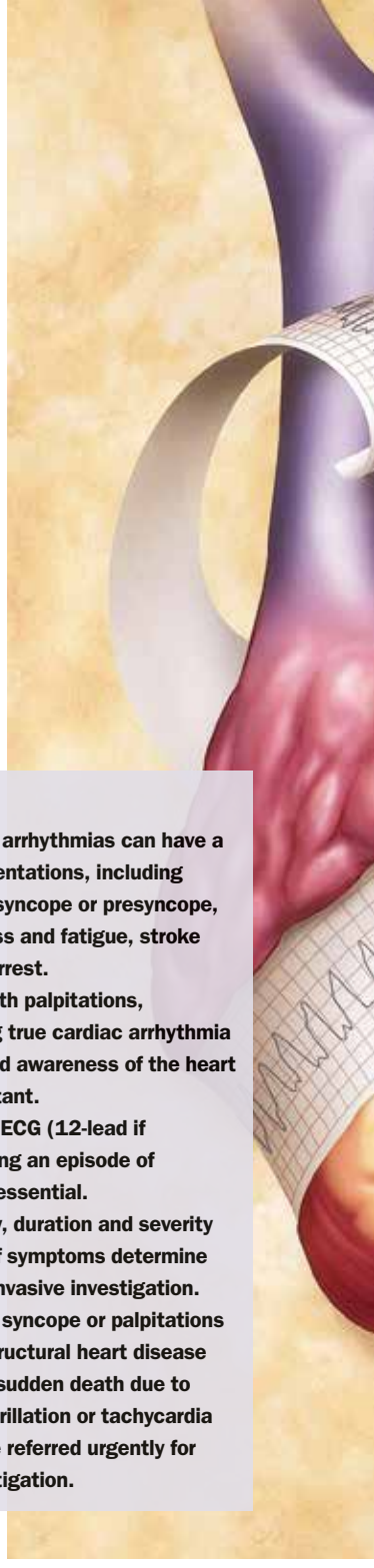
In patients with a suspected cardiac arrhythmia, the goal of investigation is to record an ECG of the arrhythmia. However, as many arrhythmias are episodic, this may be a challenge. Strategies for diagnosis include predicting the arrhythmia from the history and risk factors, waiting for an episode (e.g. ambulatory ECG monitoring) and provoking an episode (e.g. stress testing).



Key points

- **Patients with arrhythmias can have a range of presentations, including palpitations, syncope or presyncope, breathlessness and fatigue, stroke and cardiac arrest.**
- **In patients with palpitations, distinguishing true cardiac arrhythmia from increased awareness of the heart beat is important.**
- **Recording an ECG (12-lead if possible) during an episode of symptoms is essential.**
- **The frequency, duration and severity of episodes of symptoms determine the best noninvasive investigation.**
- **Patients with syncope or palpitations and known structural heart disease are at risk of sudden death due to ventricular fibrillation or tachycardia and should be referred urgently for cardiac investigation.**

Patients with cardiac arrhythmias can present with a range of symptoms that are often episodic. This can confound assessment as both examination and investigation results may be normal between episodes. The key to assessment of a patient with a potential cardiac arrhythmia relies on accurate history taking and examination and choice of an appropriate test to document the arrhythmia.

Arrhythmias likely to be encountered in patients in general practice include:

- very common – premature ventricular ectopic beats and atrial fibrillation
- common – atrial flutter, supraventricular tachycardia and atrial tachycardia
- rare but potentially life-threatening – ventricular tachycardia and fibrillation.[1]

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Presentation

Patients with cardiac arrhythmias can present with any of the following symptoms:

- palpitations
- breathlessness and fatigue
- falls or blackouts, including syncope (complete loss of consciousness) and presyncope (sensation of near blackout)
- chest pain (rarely the sole symptom)
- cardiac arrest, usually caused by ventricular fibrillation or ventricular tachycardia
- stroke and other embolic phenomena.

Cardiac arrhythmia can also be an incidental finding in patients with no apparent symptoms.

Patients with an arrhythmia may have few or no physical signs; therefore, a normal result on cardiovascular examination does not exclude arrhythmia.

Palpitations

Palpitations, defined as an unpleasant sensation of the heart beat, are a common presenting symptom of arrhythmia.[2] It is important to determine whether palpitations represent an abnormal awareness of a normal heart beat or an actual cardiac rhythm disturbance (i.e. awareness of an abnormal beat). A review of 190 patients with palpitations found the cause was cardiac in 43%, psychiatric in 31%, related to drugs or other medical conditions in 10% and unknown in 16%.[3]

Patients who present with palpitations are more likely to have a cardiac arrhythmia if:

- they have a previous history of cardiac disease
- palpitations wake the patient from sleep
- palpitations occur while they are working or with exercise
- palpitations last more than 5 minutes.[4]

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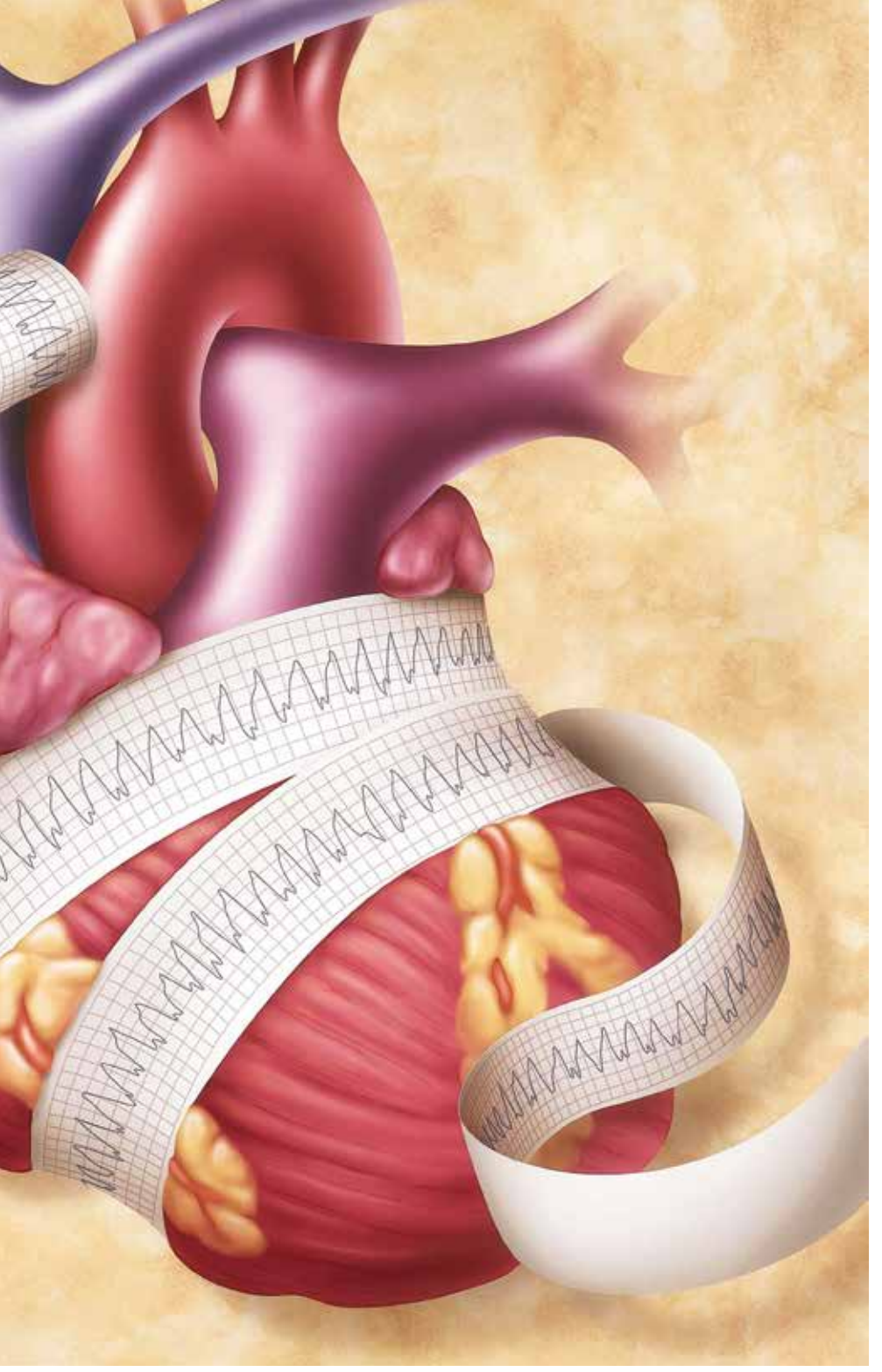

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It often helps to ask patients to tap out their heart beat to understand what they are experiencing.[2,5] Typically, palpitations are associated with tachyarrhythmias or ectopic beats rather than bradyarrhythmias.[2,6] Classic teaching describes palpitations as regular (e.g. paroxysmal supraventricular tachycardia, atrial flutter) or irregular (e.g. atrial fibrillation).[2,5] However, there are no specific patterns that reliably distinguish different arrhythmia types.

Key questions to ask a patient with palpitations are listed in Box 1.[3] Palpitations due to a pathological tachycardia often start and stop suddenly. When the palpitations have a gradual onset and offset, a benign or systemic cause (e.g. sinus arrhythmia, anaemia, thyroid disease, drugs or illicit substances) should be considered.[2]

Symptoms associated with palpitations depend on the underlying arrhythmia and the patient's premorbid condition. For example, a 20-year-old person with supraventricular tachycardia may be aware only of palpitations, whereas a 60-year-old person with atrial fibrillation associated with mitral stenosis may have severe symptoms, such as presyncope and dyspnoea. Palpitations associated with syncope or presyncope should prompt a search for a potentially serious arrhythmia.[7]

Atrial and ventricular ectopy can cause palpitations. Atrial ectopy rarely causes symptoms, although atrial runs may do so. Ventricular ectopy is more likely to cause symptoms as it disrupts normal cardiac function. Patients may notice missed beats in the pulse or a more forceful post-ectopic sinus beat, often described as a 'thump in the chest' due to increased blood volume resulting from increased filling time. Ventricular ectopy is the most common cause of palpitations, particularly in younger patients.

Infrequent ectopy leading to palpitations is generally benign.[8] However, the development of significant ectopic activity may indicate an adverse prognosis when the patient has structural heart disease or myocardial ischaemia. These patients require further investigation. In the main, a structurally normal heart will be associated with benign ectopy. If there is any doubt about the significance of ectopy then further investigation is mandatory, starting with transthoracic echocardiography to assess for structural heart disease.

Breathlessness and fatigue

Patients with tachyarrhythmias may develop breathlessness, fatigue and ultimately heart failure symptoms even in the presence of normal heart function (e.g. through the loss of 'atrial kick' in atrial fibrillation). Similarly, patients with profound bradycardia may also feel fatigued or report poor exercise capacity from poor cardiac output at low heart rates.

Some patients with cardiac arrhythmias are unaware of a change in heart rhythm and present with complications of prolonged impairment of heart function. Over time, sustained poorly controlled tachycardia or very frequent ectopic beats (e.g. more than 20% of all heart beats being ventricular

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1. Key questions for a patient with palpitations*

Questions should be asked about:

- Circumstances preceding onset of palpitations
  - Activity (rest, sleeping, during sport or normal exercise, change in posture, after exercise)
  - Position (supine or standing)
  - Predisposing factors (emotional stress, exercise, squatting or bending)
- Onset of palpitations
  - Abrupt or slowly developing
  - Preceded by other symptoms (e.g. chest pain, dyspnoea, vertigo, fatigue)
- Episode of palpitations
  - Type of palpitations (regular or not, rapid or not, permanent or not)
  - Associated symptoms (e.g. chest pain, syncope or near syncope, sweating, pulmonary oedema, anxiety, nausea, vomiting)
- End of the episode
  - Abrupt or slowly decreasing, end or perpetuation of accompanying symptoms, duration, urination
  - Spontaneous, with vagal manoeuvres, or drug administration
- Background
  - Age at first episode, number of previous episodes, frequency during the past year or month
- Previous cardiac disease
  - Prior myocardial infarction
  - Known structural/congenital heart disease
  - Longstanding systemic hypertension/diabetes/smoking
- Previous psychosomatic disorders
- Previous systemic diseases
- Previous or current thyroid dysfunction
- Family history of cardiac disease, tachycardia or sudden cardiac death
- Medications at the time of palpitations
- Drug abuse (alcohol, other drugs)
- Electrolyte imbalances

* Modified from Raviele et al. Europace 2011; 13: 920-934.[2]

ectopy) may produce global left ventricular systolic impairment.[9] Tachycardia-induced cardiomyopathy is under-recognised, as there may be a long delay between the onset of tachycardia and of cardiomyopathy.[9] However, evidence for an association comes from the frequent finding of a history of arrhythmia preceding the development of heart failure. Termination of the tachycardia and restoration of sinus rhythm often leads to progressive improvement in left ventricular performance.

Falls and syncope

Cardiac syncope is usually characterised by sudden and complete loss of consciousness, usually lasting less than 1 to 2 minutes (colloquially known as a 'blackout').[10,11] Cerebral blood flow depends on maintenance of blood pressure, which in turn is directly related to both cardiac output and peripheral vascular resistance. A drop in either may be associated with syncope, presyncope or recurrent falls. The history is crucial to diagnosis, but in some circumstances accurate details of the episode are difficult to obtain as transient loss of consciousness may result in amnesia, particularly in the elderly.

Other common causes of blackouts include vasovagal syncope and epilepsy. Features that may help to clarify whether a blackout has a cardiac cause are detailed in Box 2.[12,13] Although many patients with cardiac syncope are briefly disorientated on regaining consciousness, recovery is usually rapid and complete within a short period (usually minutes). Tonic–clonic seizures may occur in patients with cardiac syncope because of cerebral anoxia. Urinary incontinence is unusual, as is the desire to sleep afterwards. It is important to remember that syncope is more common than epilepsy.

Recurrent presyncope is common and may culminate in syncope over time because of disease progression. Presyncope is defined as a near faint and needs to be differentiated from 'dizziness', which may have many noncardiac causes, such as vertigo. Presyncope occurs commonly in situations where the native pacemaker is impaired,but the impairment does not last long enough to produce syncope (e.g. sick sinus syndrome). In some cases, symptoms may occur over many years before a diagnosis is made.

Syncope in patients with known structural heart disease, particularly those with severe left ventricular dysfunction (ejection fraction less than 35%), carries a significantly worse prognosis, with an increased risk of sudden death owing to an increased risk of ventricular fibrillation or tachycardia. These patients require urgent cardiac investigation.

Chest discomfort

Chest pain is not a typical feature of arrhythmia. Care must be taken to distinguish true chest pain from the sensation of palpitations. Angina may be a symptom of arrhythmia when there is haemodynamic compromise from increased myocardial oxygen demand (tachyarrhythmia) or decreased cardiac output (bradyarrhythmia).

Cardiac arrest

An arrhythmia can lead to cardiac arrest and sudden death. This may be the initial presentation of the arrhythmia or may occur after multiple episodes. Syncope in patients with known ischaemic heart disease, previous myocardial infarction, impaired left ventricular systolic function or a family history of premature sudden death has a significantly adverse prognosis. These patients need urgent cardiac investigation.

Other uncommon conditions that predispose to sudden arrhythmic death include hypertrophic cardiomyopathy, Brugada syndrome, Wolff–Parkinson–White syndrome, long-QT syndrome and arrhythmogenic right ventricular dysplasia. A family history of these conditions should be considered in the initial workup of patients with cardiac arrhythmia, with specific reference to a family history of premature sudden death (under the age of 40 years).

If a patient is found to have an arrhythmia with a genetic cause then their relatives should be referred for appropriate counselling and investigation. Sudden unexpected

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2. Features of the patient history that indicate a cardiac arrhythmic cause of blackout[12,13]

- Sudden-onset or unheralded loss of consciousness
- Rapid and complete recovery, with normal orientation afterwards
- Syncope when sitting or lying down
- Syncope with exercise
- Palpitations before syncope
- Personal or family history of sudden cardiac arrest or channelopathy
- Structural heart disease
- Hypertrophic cardiomyopathy
- Poor left ventricular function
- Previous myocardial infarction
- Previous cardiac surgery
- Abnormal ECG findings (see Table 1)

death without a discernible cause should prompt cardiac investigations in immediate relatives.

Stroke and other embolic phenomena

In patients who present with a transient ischaemic attack (TIA), stroke or another embolic phenomenon, atrial fibrillation should always be considered as part of the differential aetiology. Even a short episode of asymptomatic atrial fibrillation can be associated with embolic phenomena.[14] Thus, in patients who have had a stroke, an extensive search should be undertaken to exclude asymptomatic paroxysmal atrial fibrillation.

Incidental finding

A number of patients present with arrhythmia as an incidental finding, such as an irregular pulse detected during blood pressure measurement. Atrial fibrillation is the most common incidental arrhythmia in the general population and can be associated with significant complications, as described above.[15]

Investigation

The goal of investigation for any suspected arrhythmia is to capture and document the arrhythmia by electrocardiography and to establish a symptom–rhythm correlation. As discussed, most cardiac arrhythmias are episodic.

Physicians can take several approaches to identifying the cause of intermittent episodes of arrhythmia, including the following:

- predicting the arrhythmia – by identifying features present between episodes that suggest an arrhythmia
- waiting for an episode – and recording the ECG when it happens
- provoking an episode – by bringing on the arrhythmia in a controlled manner so that it can be studied.

The strategy depends on the seriousness of the patient's presentation and the frequency of the episodes.

Table 1. Electrocardiographic clues to underlying cardiac arrhythmia[2,5,11,13]

ECG abnormality	Potential arrhythmia
Short P-R interval, delta waves	Supraventricular tachycardia, Wolff–Parkinson–White syndrome
P wave abnormalities, premature atrial complexes	Atrial fibrillation
Ventricular premature complexes, left bundle branch block with positive axis	Idiopathic ventricular tachycardia, right ventricular outflow tract tachycardia
Ventricular premature complexes, right bundle-branch block with negative axis	Idiopathic ventricular tachycardia
Q waves	Previous myocardial infarction Ventricular premature complexes, non-sustained or sustained ventricular tachycardia
Long or short QT interval	Polymorphic ventricular tachycardia
Brugada syndrome	Ventricular tachycardia
Left ventricular hypertrophy	Ventricular tachycardia, atrial fibrillation
Sinus bradycardia (less than 40 beats per minute), sinus pauses longer than 3 seconds	Sick sinus syndrome
Bifascicular block (left bundle or right bundle branch block with left anterior or left posterior fascicular block)	Complete AV block
Mobitz second degree or third degree	Complete AV block
Alternating left and right bundle branch block	Complete AV block

Abbreviation: AV = atrioventricular.

Predicting the arrhythmia

A potential arrhythmia may be suggested by identifying risk factors between episodes through history taking and examination.

History

Assessment of a patient with a potential cardiac arrhythmia involves a detailed assessment of symptoms and associated features and a thorough search for high-risk features. Relevant features include:

- any history of previous cardiac ischaemia or cardiac surgery
- any history suggesting the presence of structural heart disease that increases the likelihood of arrhythmia (e.g. systemic hypertension, longstanding diabetes or previous systemic embolism or stroke)
- a family history of sudden death.

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3. High-risk features for cardiac arrhythmia requiring urgent review[5,13]

Hospitalisation required

- Features of haemodynamic compromise (e.g. heart failure or collapse)
- Suspected arrhythmias with left ventricular dysfunction or syncope
- Syncope in a patient with a pacemaker
- Recurrent shocks in a patient with an implantable cardiac defibrillator

Urgent referral to cardiologist

- Palpitations in the presence of structural heart disease
  - hypertrophic cardiomyopathy
  - myocardial ischaemia
- Syncope
- Family history of premature sudden cardiac death
- Certain occupations (e.g. aircraft pilot, train driver, truck driver)

Table 2. Duration, frequency and severity of symptom episodes as an indication for choice of investigation for suspected cardiac arrhythmia

Symptom episode duration, frequency	Investigation
Sustained episodes (hours)	
Very rare	• Observe pulse rate during symptom episode • Self-attendance at primary care clinic or hospital emergency department for 12-lead ECG
More frequent	• 12-lead ECG during symptom episode
Brief episodes	
Exercise-related	• Exercise test
Daily	• Holter (24-hour ambulatory) recorder
Infrequent (less than once per week) but tolerated	• Patient-activated recorder (up to 14 days)
Infrequent (less than once per week) but severe (either intrusive symptoms or recurrent syncope)	• Implantable loop recorder

Clinical examination

Clinical examination is typically performed when the patient is asymptomatic and should focus on seeking signs of structural heart disease, including murmur, heart failure and systemic hypertension. However, if the patient is symptomatic then assessment of the pulse and heart sounds by auscultation to assess heart rate and jugular venous pressure may provide clues to the underlying arrhythmia. Termination factors, such as vagal manoeuvres, provide further information.

Electrocardiography

Obtaining a 12-lead ECG in a symptomatic patient is the gold standard for diagnosing a cardiac arrhythmia and formulating a management strategy.[16] However, most patients do not present when symptomatic. A 12-lead ECG in an asymptomatic patient may still give clues to a potential underlying arrhythmia (Table 1).[2,5,11,13] An abnormal ECG when the patient is asymptomatic warrants a more aggressive search for an arrhythmia.[4]

Other investigations

In selected patients, further investigations for medical conditions associated with arrhythmias, such as anaemia, hyperthyroidism, hypothyroidism, electrolyte and acid–base abnormalities, pregnancy and phaeochromocytoma, and a drug screen may be warranted.[2]

An echocardiogram provides accurate information about left ventricular function and valve structure.

Who should be referred?

Most patients with a suspected arrhythmia can be managed safely in the outpatient setting. Patient at imminent risk should be referred immediately to hospital for assessment and treatment (e.g. patients with symptomatic bradycardia, who require pacemaker insertion).

Further investigations and referral to a cardiologist may be warranted for patients with frequent symptoms, especially when the initial clinical evaluation suggests a high risk of serious arrhythmia (Box 3).[2,5] In addition, in the absence of high-risk features, further investigations are also often performed because of the impact of frequent symptoms on quality of life.[1]

Waiting for an episode

Recording an ECG during an episode of symptoms is crucial to establishing the potential arrhythmia. The frequency, duration and severity of symptoms dictate the best way to obtain an ECG recording (Table 2).

A noncompromised patient with sustained palpitations requires a 12-lead ECG during an episode of symptoms wherever it can be performed promptly, such as in a hospital emergency department (ED). It is worth telling the patient that they should request an ECG immediately on arrival in the ED; providing an explanatory letter may help. Recording an ECG during an episode of symptoms can save considerable time and effort. Correlation of symptoms with an underlying arrhythmia confirms the diagnosis of cardiac arrhythmia. Conversely, symptoms that occur during normal sinus rhythm are likely to have a cause other than arrhythmia. It is prudent to give the patient a copy of their diagnostic ECG for future reference.

Patients who experience regular symptoms may be suitable for ambulatory ECG monitoring. Ambulatory ECG recorders may be continuous (e.g. Holter monitor) or intermittent (e.g. external patient-activated and implantable loop recorders); the frequency of symptoms determines the

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Table 3. Comparison of different types of ambulatory ECG monitoring[2,16]

Device type	Advantages	Disadvantages	Indications
Holter monitor	• Low cost • Able to record asymptomatic arrhythmia • Widely available • Reasonable compliance, likely to be used	• Limited to 24 to 72 hours of recording • Low yield (2 to 4% are positive) • Episodes must be frequent (more than once per day) and tolerated by patient	• Intersymptom intervals less than 1 week
External loop recorder	• Activation of the device by the patient records the ECG at that point and for a programmable period beforehand • Can be set to automatically record events (e.g. if heart rate exceeds a predetermined level)	• Electrodes may irritate the skin or come off, reducing the quality of the recording • Electrodes need to remain attached throughout continuous ECG recording, which may cause irritation • Limited to 3 to 4 weeks of recording • Can be uncomfortable for some patients	• Infrequent, fairly long-lasting, and non-incapacitating symptoms (typically weekly to monthly symptoms) • Compliant patients
Implantable loop recorder	• Long recording interval (36 months) • Ideal for very infrequent episodes • High yield in syncope • Automatic programmable recording period (asymptomatic arrhythmias) • Wireless remote monitoring	• Invasive • Expensive (cost of device is more than $3000) • Risk of complications at implantation site	• Infrequent, brief or incapacitating symptoms • Noncompliant patients • Monthly palpitations when all other investigation results are inconclusive

most appropriate method. The advantages, disadvantages and indications for the three main types of ambulatory ECG recorder are compared in Table 3.[2,16] A negative result on ambulatory ECG monitoring does not exclude an underlying arrhythmia. However, these tests can be repeated multiple times.

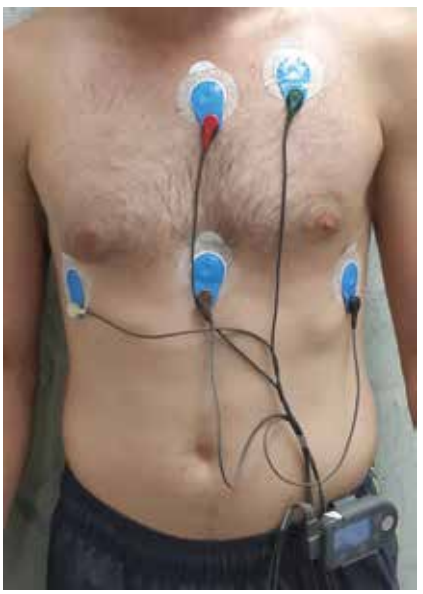

Figure 1. Ambulatory ECG monitoring with a Holter monitor, which allows continuous ECG recording for 24 to 72 hours.

Holter monitors

A Holter monitor is carried via a strap worn over the shoulder or more usually on a belt (Figure 1). Electrodes attached to the skin continuously record the electrical activity of the heart. These monitors are often used for 24-hour recording but can be used for up to 72 hours if required.

External loop recorders

The patient wears an external loop recorder around the waist and presses a button on the device to record heart activity when symptoms are experienced. Problems arise in patients with syncope, as the device requires activation to record the arrhythmia. However, modern systems have the ability to record heart activity for a programmable period (up to 7 minutes before device activation; Figure 2). Nevertheless, many patients (50% in one study) do not activate the device appropriately for a clinically significant event.[17]

Implantable loop recorders

An implantable loop recorder is inserted

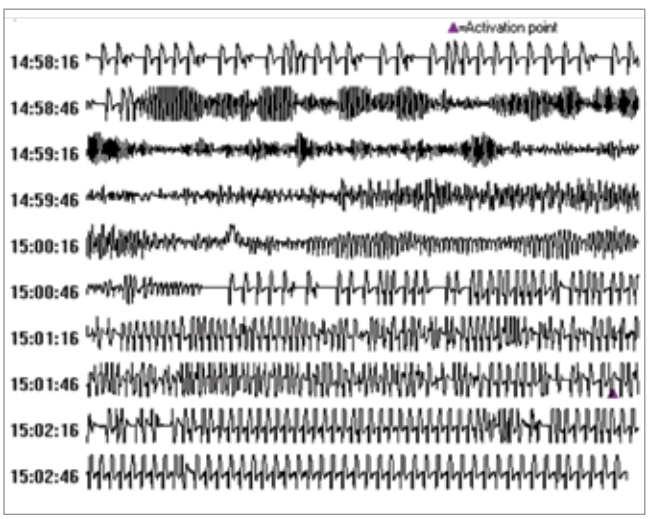

Figure 2. Patient activated ECG from an external loop recorder in a patient with syncope accompanied by brief retrograde amnesia. The ECG shows episodes of ventricular tachycardia and polymorphic ventricular tachycardia/fibrillation.

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Figure 3. Implantable loop recorder device.

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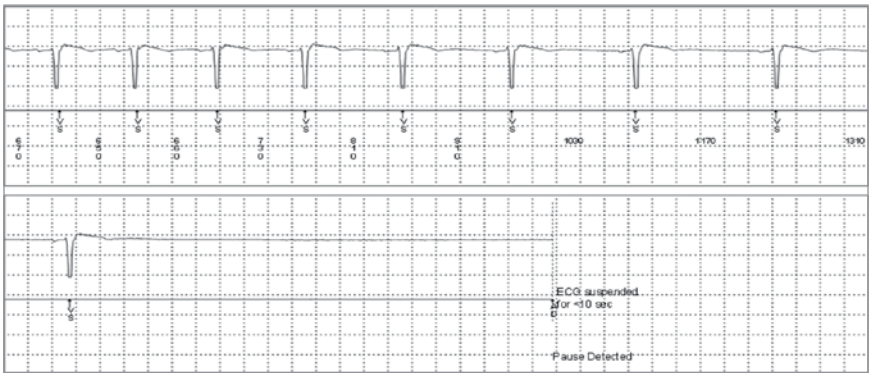

Figure 4. ECG recorded by an automatically triggered implantable loop recorder in a patient with recurrent presentations of infrequent episodes of syncope. The ECG shows sinus rhythm followed by a pause of 4 seconds.

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through a small incision (approximately 5 mm wide) in the upper left part of the chest to obtain the best signal from the heart (Figure 3). These devices have a battery life up to three years. Newer devices are auto-activated and can transmit information on clinical events even when the patient is incapacitated, allowing remote monitoring of clinically significant arrhythmias (Figure 4).[18] Implantable loop recorders are currently indicated for the investigation of recurrent syncope.

Smart phones

Recently developed hardware with compatible software capability has made it possible to record a single lead ECG on a smart phone. The increasing use of smart phones may provide an excellent opportunity to detect previously undetected arrhythmias (Figure 5).

Provoking an episode

For many patients, particularly those with severe or life-threatening arrhythmias, it is recommended that provocative procedures are used to record an ECG during an episode of arrhythmia.[15]

Treadmill exercise testing

Treadmill exercise testing can be used to evaluate arrhythmias and is a useful option before electrophysiological (EP) testing, particularly in patients who describe arrhythmias under exercise conditions.

Invasive electrophysiological studies

Most arrhythmias are re-entrant, occurring when an abnormal small circuit enters a constantly rotating loop within the heart, increasing the heart rate significantly. In this situation, a potential exists for the arrhythmia (the substrate) but a trigger is required to initiate re-entry (a random ectopic beat). By introducing extra beats into different chambers of the heart (equivalent to introducing ectopic beats), EP testing explores many triggers in a short time.

During a diagnostic EP study, pacing and recording electrodes are positioned within the heart, and painless electrical impulses are delivered through wires at different sites (usually the atrium and ventricles). The spread of these impulses through the heart defines any electrical abnormalities. The patient does not feel these impulses and is often awake during the procedure. The cardiologist then analyses the impulse as it spreads around the heart, particularly if an arrhythmia is produced. Once the electrical abnormality is defined, an ablation may be performed to target the substrate.

For arrhythmias that do not have a re-entrant mechanism and cannot usually be initiated by the extra-stimulus technique, a variety of other provocative strategies can be tried. These include administration of a sympathetic nervous system stimulant (isoprenaline or adrenaline [epinephrine]). Some arrhythmias are completely non-inducible, despite being well documented, and catheter ablation can generally not be performed in these cases.

The role of the GP

GPs are well placed to take a detailed history from patients with suspected cardiac

Figure 5. Smart phone attachments and apps are available that can record a single lead ECG to detect arrhythmia. In this example, the mobile ECG device with metal electrodes is attached to the back of a smart phone. The phone is held with the fingertips resting on the metal electrodes to record an ECG.

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4. Resources on cardiac arrhythmias for patients

- National Heart Foundation of Australia (www.heartfoundation.org.au)
- US Heart Rhythm Society (www.hrsonline.org)
- Arrhythmia Alliance - Australia (www.aa-international.org/au)
- Heart Rhythm Charity (www.heartrhythmcharity.org.uk)

arrhythmias and in particular to identify any high-risk features (Table 3). If a patient has known cardiac disease or a high-risk feature then early cardiology or EP referral is mandatory.

Many general practices can record an ECG during an episode of symptoms, which can confirm a correlation between the ECG and the symptoms. It will also avoid the frustration of chasing the underlying arrhythmia, which might otherwise require months of investigation.

Many arrhythmias are influenced by lifestyle factors. These include excess alcohol or caffeine intake, use of recreational drugs, obstructive sleep apnoea and obesity, all of which can be improved by lifestyle modification.[19,20]

Addressing underlying cardiovascular risk factors such as hypertension, heart failure, diabetes and hypercholesterolaemia is indicated for primary and secondary prevention.[2]

Patients often continue to re-present with the same symptoms after a proven benign diagnosis for those symptoms. Such patients may require ongoing reassurance about the benign nature of their condition.[2]

Useful website resources for patients with arrhythmias are listed in Box 4. 'Know your pulse' campaigns, such as the campaign publicised by the UK Arrhythmia Alliance (http://www.heartrhythmcharity.org.uk), encourage members of the public to assess their own and their relatives' pulses regularly. This campaign has increased the detection of asymptomatic atrial fibrillation in the community.[15]

Summary

Cardiac arrhythmias can present with a range of symptoms, which may be related either directly to the change in heart rate or to complications of the arrhythmia, such as stroke following atrial fibrillation. The goal is assessment and investigation of patients to document the arrhythmia with an ECG and to assess risk. Assessment of the frequency of symptoms and important red flags for referral, such as syncope, will enable appropriate and timely investigation. **CT**

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