Cardiac Pacing

CHAPTER 10

Learning outcomes

To understand:

- **The indications for cardiac pacing in the peri-arrest setting**
- **How to perform percussion pacing**
- **How to apply non-invasive, transcutaneous electrical pacing**
- **The problems associated with temporary transvenous pacing and how to correct them**
- **How to manage patients with implanted permanent pacemakers and cardioverter defibrillators in the setting of cardiac arrest and in the peri-arrest setting**

Introduction

In some cardiac arrest or peri-arrest settings, appropriate use of cardiac pacing can be life-saving. Non-invasive pacing may be used to maintain cardiac output temporarily while expert help to deliver longer-term treatment is obtained. Non-invasive pacing can be established rapidly and is well within the capabilities of an ALS provider.

The ALS provider does not need to have a detailed technical knowledge of permanent cardiac pacemakers and implanted cardioverter defibrillators (ICDs) but needs to be able to recognise when one of these devices is present, when they are failing, and how the presence of an implanted device may influence the management of a cardiac arrest.

The cardiac impulse - its formation and its failure

The electrical activity that stimulates each normal heartbeat arises in the sino-atrial (SA) node. This depolarises spontaneously and regularly without any external stimulus. Such behaviour is termed automaticity, and any cardiac tissue that possesses it is capable of initiating a heartbeat and behaving as the heart's natural pacemaker. Different parts of the conducting system depolarise spontaneously at different rates (Figure 10.1). The fastest pacemaker will provide the cardiac rhythm and slower natural pacemakers will only take over if the faster ones fail. Examples may be seen in sinus arrest or extreme sinus bradycardia when the atrioventricular (AV) node may take over and provide a junctional escape rhythm, and in complete atrioventricular block (complete heart block - CHB) when the escape rhythm arises from the ventricular myocardium or from conducting tissue below the atrioventricular node.

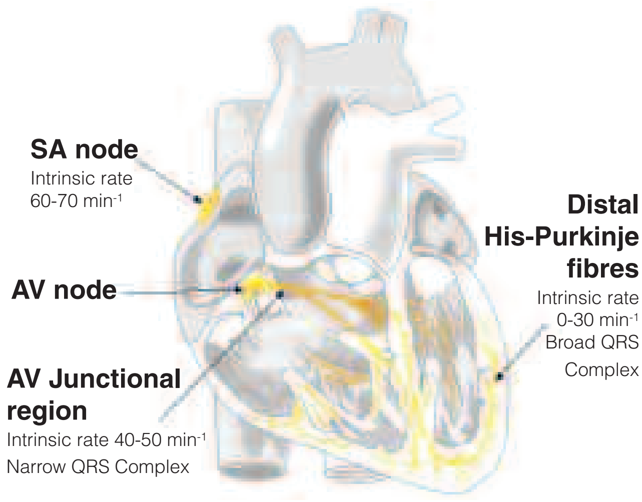

Figure 10.1 Cardiac conducting system

When CHB occurs at the level of the AV node, the most rapid automatic activity arises from cells immediately below the block and these become the new pacemaker. The intrinsic rate of these cells is relatively fast (often about 50 min^{-1}). The resulting escape rhythm is usually relatively stable and unlikely to fail and cause asystole.

The QRS complexes resulting from this type of block are narrow because the impulse is transmitted to the ventricles rapidly through an intact His-Purkinje system. This situation may be seen complicating acute inferior myocardial infarction. In this setting, narrow-complex CHB may not require pacing because the heart rate is often not especially slow and the risk of asystole is usually low.

Complete heart block can occur lower in the conducting system, for example, when all the fibres of the bundle branches are involved following anteroseptal myocardial infarction, or as a result of other disease including degenerative fibrosis and valve disease. Any automatic activity arising below this block in the distal Purkinje fibres is likely to be slow and unreliable. In this situation, the resulting QRS complexes will be broad, since the impulse passes slowly through ventricular muscle rather then rapidly through the His-Purkinje system. The unreliable escape rhythm may fail briefly, leading to syncope (Stokes-Adams attack), or completely, causing ventricular standstill and cardiac arrest. Broad-complex CHB requires cardiac pacing, and the occurrence of significant ventricular pauses makes this urgent, as this implies a risk of asystole. The possible risk of more severe AV block and asystole should always be considered in a patient who has presented with syncope and has any ECG evidence of conduction delay (e.g. long PR interval or bundle branch block). Such patients require at least cardiac monitoring and expert assessment.

In the peri-arrest setting, artificial pacemakers are used when the cardiac rhythm is unduly slow or unreliable and not responding to the treatment described in the peri-arrest algorithm for bradycardia (Chapter 11). However, pacing will be successful only if the heart is able to respond to the pacing stimulus. In the setting of cardiac arrest the continued presence of P waves makes this more likely.

Pacing is rarely successful in asystole in the absence of P waves and should not be attempted routinely in this situation.

The stimulus to the myocardium may be either mechanical, as in percussion pacing, or electrical as in transcutaneous and transvenous pacing.

If a pacing stimulus induces an immediate QRS complex this is referred to as 'capture'. Always check that electrical activity seen on the ECG is accompanied by mechanical activity producing a palpable pulse.

Methods of pacing

Methods of pacing are classified as:

Non-invasive

- Percussion pacing ('fist pacing')
- Transcutaneous pacing

Invasive

- Temporary transvenous pacing
- Permanent pacing with an implanted pacemaker

Implanted devices that deliver pacing include pacemakers implanted for the treatment of bradycardia, biventricular pacemakers implanted for the treatment of heart failure (cardiac resynchronisation therapy) and implanted cardioverter defibrillators (ICDs) that also have a pacemaker function.

Non-invasive pacing

Percussion pacing

When bradycardia is so profound that it causes clinical cardiac arrest, percussion pacing can be used in preference to CPR because it is capable of producing an adequate cardiac output with minimal trauma to the patient. It is more likely to be successful when ventricular standstill is accompanied by continuing P wave activity (Chapter 8).

How to perform percussion pacing

- With the side of a closed fist deliver repeated firm blows to the precordium lateral to the lower left sternal edge.
- Raise the hand about 10 cm above the chest for each blow.
- If initial blows do not produce a QRS complex try using slightly harder blows and try moving the point of contact around the precordium until a site is found that produces repeated ventricular stimulation.

Percussion pacing is not as reliable as electrical pacing in stimulating QRS complexes. If percussion does not produce a pulsed rhythm promptly, regardless of whether or not it stimulates QRS complexes, start CPR immediately.

Like CPR, percussion pacing is an emergency measure that is used to try to maintain circulation to vital organs and enable either recovery of a spontaneous cardiac rhythm or transcutaneous or transvenous pacing.

Transcutaneous pacing

Compared with transvenous pacing, non-invasive transcutaneous pacing has the following advantages:

- it can be established very quickly;
- it is easy to perform and requires a minimum of training;
- it can be initiated by nurses, paramedics and doctors, while waiting for expert help to establish transvenous pacing.

The major disadvantage of transcutaneous pacing in the conscious patient is discomfort. The pacing impulse stimulates painful contraction of chest wall muscles as well as causing some direct discomfort. Many defibrillators incorporate a facility for transcutaneous pacing and the availability of multifunction, adhesive electrode pads capable of ECG monitoring, pacing, cardioversion, and defibrillation have made these units particularly versatile. Stand-alone non-invasive pacing devices may also be available in some hospital departments.

Most modern transcutaneous pacing systems are capable of demand pacing: intrinsic QRS complexes are sensed and pacing stimuli delivered only when needed.

How to perform transcutaneous pacing

- Avoid any unnecessary delay in starting pacing, but pay careful attention to technique to increase the chance of success.
- Using scissors or a razor, quickly remove excess chest hair from the skin where the electrode pad is to be applied.
- Make sure that the skin is dry.
- Attach ECG monitoring electrodes and leads if necessary - these are needed with some transcutaneous pacing devices.
- Position the electrode pads in the conventional right pectoral-apical positions if possible (Figure 10.2a). If this is prevented (e.g. by chest trauma) anterior-posterior (A-P) positions can be used (Figure 10.2b-d).
- If you are using a pacing device that is not capable of defibrillation, use A-P positions for the pacing electrodes so that defibrillator pads can still be used in the 'conventional' right pectoral and apical positions if cardiac arrest occurs.
- For right pectoral-apical positions place one electrode over the right pectoral muscle, just below the clavicle. Place the apical pad in the mid-axillary line, overlying the V6 ECG electrode position. It is important that this electrode is placed sufficiently laterally. Apply this pad to the chest wall, not over any breast tissue.

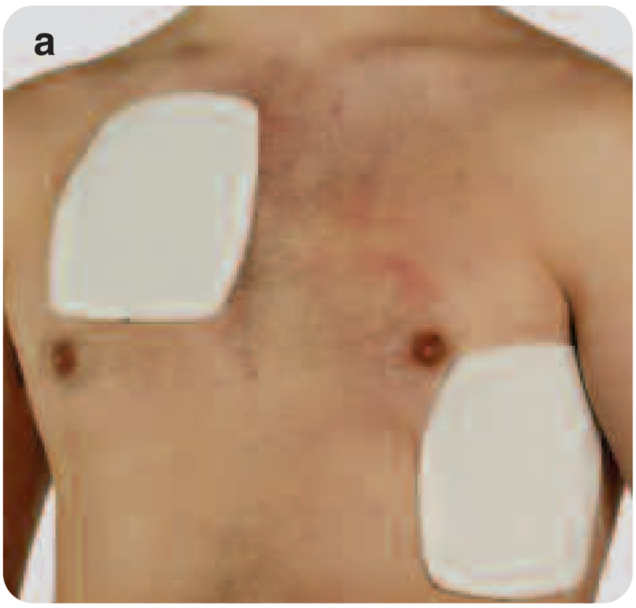

Figure 10.2a Pectoral-apical pad positions for external pacing

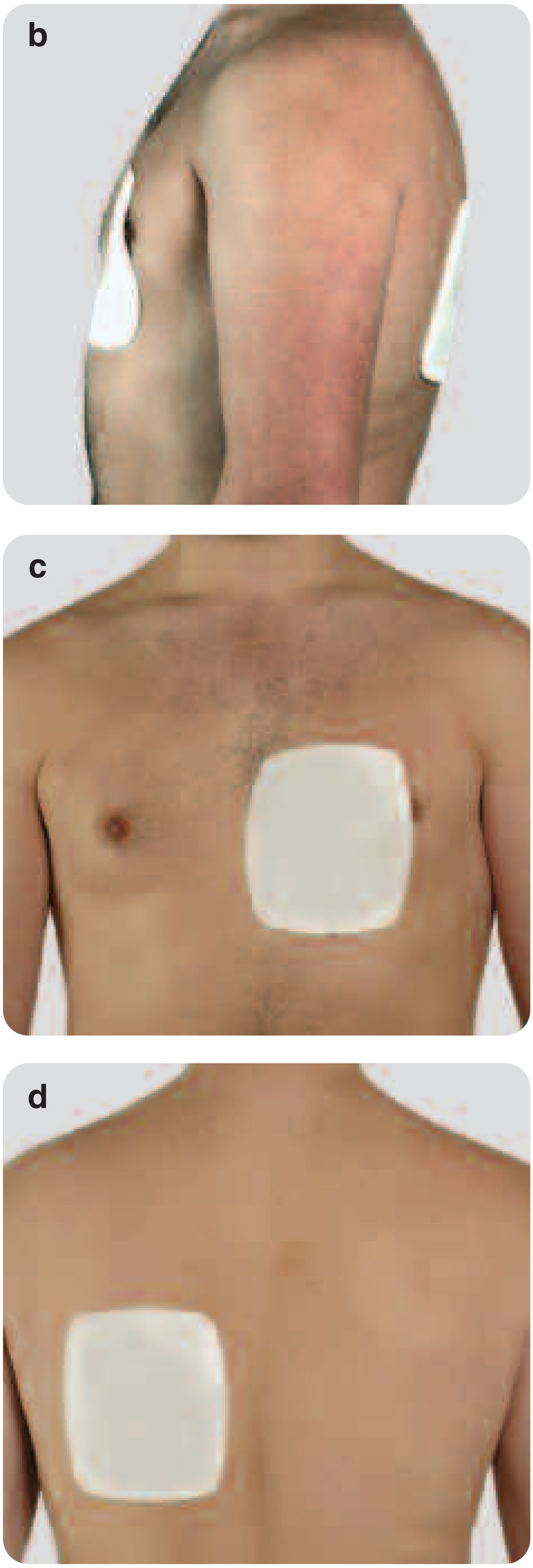

Figure 10.2b - d. Anterior-posterior (AP) pad positions for external pacing.

- For A-P positions place the anterior electrode on the left anterior chest wall, beside the sternum, overlying the V2 and V3 ECG electrode positions. Place the posterior electrode between the lower part of the left scapula and the spine, at the same horizontal level on the trunk as the anterior electrode.

- Different transcutaneous pacing devices have different properties. For example some require the operator to increase the current delivered with each pacing stimulus until electrical capture is achieved, whilst others use a constant current that cannot be adjusted and longer pulse duration (duration of the pacing stimulus) than other devices. Make sure that you are familiar with the operation of the device that you are using.

- Most transcutaneous pacing devices offer pacing in demand mode; the pacemaker will be inhibited if it detects a spontaneous QRS complex. However, if there is a lot of movement artefact on the ECG this may inhibit the pacemaker. Avoid movement artefact as far as possible. If artefact still appears to be inhibiting the pacemaker, switch to fixed-rate pacing mode.

- Select an appropriate pacing rate. This will usually be in the range of 60 - 90 min^{-1} for adults, but in some circumstances (for example complete AV block with an idioventricular rhythm at 50 min^{-1}) a slower pacing rate of 40 or even 30 min^{-1} may be appropriate to deliver pacing only during sudden ventricular standstill or more extreme bradycardia.

- If the pacing device has an adjustable energy output set this at its lowest value and turn on the pacemaker. Gradually increase the output while observing the patient and the ECG. As the current is increased the muscles of the chest wall will contract with each impulse and a pacing spike will appear on the ECG (Figure 10.3a). Increase the current until each pacing spike is followed immediately by a QRS complex, indicating electrical capture (typically with a current of 50 - 100 mA using a device with adjustable output). This means that the pacing stimuli are causing depolarisation of the ventricles (Figure 10.3b).

- Check that the apparent QRS complex is followed by a T wave. Occasionally, artefact generated by the pacing current travelling through the chest may be mistaken for a QRS complex, but such artefact will not be followed by a T wave (Figure 10.3a).

- If the highest current setting is reached and electrical capture has not occurred, try changing the electrode positions. Continued failure to achieve electrical capture may indicate non-viable myocardium, but other conditions (e.g. hyperkalaemia) may prevent successful pacing.

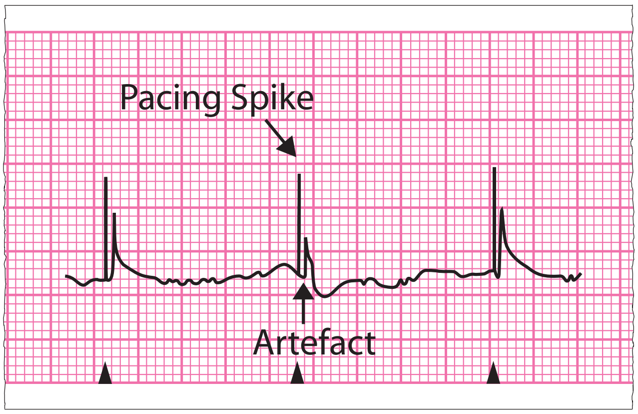

Figure 10.3a Transcutaneous pacing. Appearance of pacing spikes on ECG

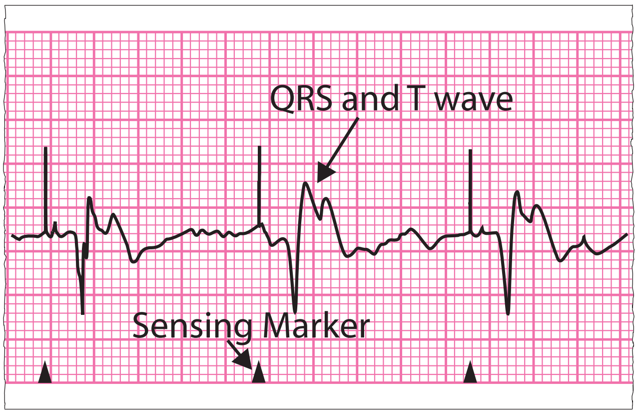

Figure 10.3b. Transcutaneous pacing. ECG shows ventricular capture after each pacing spike

Having achieved electrical capture with the pacemaker, check for a pulse. A palpable pulse confirms the presence of a mechanical response of the heart to the paced QRS complex (i.e. contraction of the myocardium). Absence of a pulse in the presence of good electrical capture constitutes pulseless electrical activity (PEA). The most likely cause is severe myocardial failure but consider other possible causes of PEA in these circumstances.

Conscious patients usually experience considerable discomfort during transcutaneous pacing. Warn patients in advance that this may happen. They will often require intravenous analgesia and/or sedation if prolonged transcutaneous pacing is necessary. If sedation is used, reassess the patient frequently (ABCDE) because sedative drugs may suppress respiratory effort.

When defibrillating a patient who has pacing-only electrode pads in place, apply the defibrillator paddles at least 2 - 3 cm from the pacing electrodes to prevent arcing of the defibrillation current.

Chest compressions can be given and other manual contact with the patient maintained as necessary with transcutaneous electrodes in place. There is no hazard from transcutaneous pacing to other people who are in contact with the patient. However, there is no benefit in trying to deliver transcutaneous pacing during chest compressions, so it is best to turn off the pacemaker whilst CPR is in progress.

When transcutaneous pacing produces an adequate cardiac output seek expert help immediately to insert a transvenous pacing lead.

Invasive pacing

Temporary transvenous pacing

It is rare to have to attempt to insert a transvenous pacing wire during a cardiac arrest. In this setting, use non-invasive pacing to attempt to establish a cardiac output, and then seek expert help to establish transvenous pacing.

Failure of an existing temporary transvenous pacing system may cause cardiac arrest, particularly when the patient is pacing-dependent. Temporary transvenous pacing systems can fail in three ways:

1. High threshold

When a temporary pacing lead is inserted the usual aim is to position its tip in the apex of the right ventricle, where it is least likely to be displaced. After positioning the lead, it is used to pace the heart and the voltage delivered by the pacemaker is decreased and increased to determine the minimum voltage needed to stimulate the ventricle. This is termed the pacing threshold and the usual aim is to achieve a threshold of < 1 V at the time of lead insertion. Higher thresholds suggest that the electrode is not making satisfactory contact with the myocardium, and the lead may need to be repositioned.

It is usual to pace the heart with a 3 - 4 V stimulus, well above the initial pacing threshold. Over the first days and weeks after insertion of a pacing lead (temporary or permanent) a rise in the threshold can be expected.

Check the threshold on temporary pacing leads at least daily to make sure that the output of the pacemaker is well above the threshold. If not, loss of capture may occur. This is seen on the ECG as a pacing spike without a subsequent QRS complex. Loss of capture may be intermittent, so any apparent 'missed beat' of this nature should prompt a repeat check of the pacing threshold.

If loss of capture occurs because of a high threshold, increase the output of the pacemaker immediately to well above the threshold. A sudden increase in pacing threshold may be caused by lead displacement, so obtain prompt expert help, as repositioning of the lead may be required.

2. Loss of electrical continuity

Modern temporary transvenous pacing leads are bipolar. One electrode is at the tip of the lead and the second is about 1 cm proximal to the tip. Each electrode is connected by the lead to separate connectors at the other end, outside the patient. These are usually inserted into sockets at one end of a connecting cable that in turn is connected to the terminals of the pacemaker.

Make sure that all connections between the lead and the pacemaker are making good secure contact that is unlikely to be lost easily, for example by minor movement of the lead or cable.

Loss of contact at any point will stop delivery of the pacing stimulus to the heart, seen on the ECG as absence of a pacing spike. This may be intermittent and symptomless, or may be sudden and total and may cause syncope or cardiac arrest in asystole. When pacing failure is accompanied by loss of the pacing spike on the ECG, check all connections immediately; check that the pacemaker has not been turned off inadvertently and check that its batteries are not depleted. If no such cause is present another possible explanation is a fracture of a wire within its insulation. This usually causes intermittent pacing failure and the fracture is more likely to be in the connecting cable than in the pacing lead. If this is suspected change the connecting cable immediately.

3. Electrode displacement

The tip of an endocardial transvenous pacing lead is usually positioned in the apex of the right ventricle. There should be enough slack in the lead as it passes through the right atrium to allow for changes in posture and deep inspiration, but not so much as to encourage displacement of the lead tip.

The tip of a pacing lead may also perforate the wall of the right ventricle and enter the pericardium with little or no apparent change in position on chest X-ray. Very rarely, this may cause pericardial tamponade, so consider this possibility if a patient with a recently implanted pacing lead suffers cardiac arrest with pulseless electrical activity.

When displacement or perforation occurs, the ECG will still show a pacing spike, but there is likely to be intermittent or complete loss of capture of the pacing stimulus, so the pacing spikes are not followed consistently by QRS complexes. When a pacing lead displaces but remains in the right ventricle it may trigger ventricular extrasystoles or more serious ventricular arrhythmia, including VT and VF. When transvenous pacing fails, there is a risk of ventricular standstill. This may be relatively short-lived and cause syncope, or prolonged and cause cardiac arrest in asystole. In this situation use non-invasive pacing until effective transvenous pacing has been re-established.

Implanted permanent pacing systems

Problems with permanent pacing systems are rare, because the connections between pacing electrodes and the pacemaker are much more secure. Occasional fracture of a permanent pacing lead may occur, usually following trauma such as a fall on to an outstretched arm on the side of the pacemaker. This may cause permanent or intermittent loss of the pacing spike.

When assessing a patient using the ABCDE approach check (during 'E') for the presence of an implanted device. These devices are usually implanted below the clavicle, often but not always on the left side. If a device is identified consider whether it is a pacemaker or an ICD and in the case of a pacemaker try to establish whether it was implanted as treatment for bradyarrhythmia or as treatment for heart failure.

If a patient with an implanted pacemaker or ICD has a cardiac arrest or requires cardioversion, place defibrillation pads at least 8 cm from the device. Devices that are implanted below the left clavicle usually present no problem with the use of standard defibrillator paddle positions. If a device has been implanted below the right clavicle, use A-P positions for defibrillation or cardioversion if possible. This is most easily and safely achieved using self-adhesive electrode pads rather than hand-held defibrillator paddles.

Biventricular pacing systems

Until relatively recently, the usual reason for implantation of a permanent pacemaker has been the treatment of bradycardia, caused mostly by malfunction of the sino-atrial node or atrioventricular conduction. In recent years there has been increasing use of biventricular pacemakers as 'cardiac resynchronisation therapy' in patients with heart failure. Most of these patients do not require pacing for bradycardia. Pacing the apex of the right ventricle and the lateral wall of the left ventricle simultaneously improves the co-ordination of left ventricular contraction. These pacemakers require the same precautions during defibrillation and cardioversion as any other pacemaker, but failure of a pacemaker that has been inserted for this purpose will not usually cause any major change in heart rate or any dangerous rhythm abnormality.

Implantable cardioverter-defibrillators

These devices resemble large implanted pacemakers. Many of them can function as demand pacemakers in the event of bradycardia and some will also deliver biventricular pacing for heart failure, as well as delivering defibrillation if required. National and international guidelines define indications for the implantation of an ICD, but accumulating evidence for improved survival after major myocardial infarction and in patients with heart failure has increased the use of these devices. Unlike a simple pacemaker, the primary function of an ICD is to terminate a life-threatening tachyarrhythmia. A 'simple' ICD can deliver a defibrillatory shock when it detects VF or very fast VT. More sophisticated devices can be programmed also to deliver critically timed pacing stimuli to attempt to terminate VT that is not especially fast and is unlikely to cause cardiac arrest, resorting to defibrillation only if the VT accelerates or degenerates into VF.

ICDs are implanted usually in the pectoral region in a similar position to pacemakers. Though these devices may seem complex, the means by which they sense changes in cardiac rhythm is relatively simple, depending mainly upon detection of rapid heart rates. Consequently, ICDs will occasionally misdiagnose an arrhythmia, or misinterpret other electrical signals, and deliver inappropriate shocks, which are very unpleasant for a conscious patient. Implantable cardioverter defibrillators can be disabled temporarily by holding or taping a magnet on the skin over the device. Seek expert help if ICD malfunction is suspected, as it may require reprogramming.

If a patient with an ICD has a cardiac arrest that is not terminated by the ICD, deliver CPR in the usual way. Until recently, it was thought that chest compressions could be undertaken without risk to the rescuer, even if the ICD delivers an internal shock to the patient during chest compression. However, there have been rare reports of rescuers receiving shocks from an ICD. This risk is minimised by wearing gloves. If a shockable cardiac arrest rhythm is present and is not terminated by the ICD, use external defibrillation in a standard fashion, taking the same precautions with choice of defibrillator paddle positions as in a patient with an implanted pacemaker.

Consider the possible requirement for ICD implantation in any patient who has been resuscitated from cardiac arrest in a shockable rhythm outside the context of proven acute ST segment elevation myocardial infarction. All such patients should be referred before discharge from hospital for assessment by a cardiologist with expertise in heart rhythm disorders.

Key learning points

- Non-invasive pacing can be delivered by any ALS provider and is the immediate treatment for bradyarrhythmia that is a potential risk to the patient who does not respond to initial drug treatment.
- Non-invasive pacing is a temporary measure to be used until either a stable and effective spontaneous rhythm returns, or a competent person establishes transvenous pacing.
- Special precautions are necessary during resuscitation attempts in patients with implanted pacemakers and ICDs.
- The possible need for an ICD should be considered in patients resuscitated from cardiac arrest in VT or VF, in whom there is a possible risk of recurrence.

Further reading

Deakin CD, Nolan JP, Sunde K, Koster RW. European Resuscitation Council Guidelines for Resuscitation 2010. Section 3. Electrical Therapies: Automated External Defibrillators, Defibrillation, Cardioversion and Pacing. Resuscitation 2010;81:e32-40.

National Institute for Clinical Health & Excellence 2006. Technology Appraisal 95. Implantable cardioverter defibrillators for arrhythmias. Review of Technology Appraisal 11. www.nice.org.uk