A pacemaker is a device placed inside a patient’s chest that sends small electrical signals to the heart, via leads placed in the heart and is used to treat clinically significant bradyarrhythmias. This article is the first of a two-part series introducing the concept of pacemaker therapy and outlining the clinical indications for its use. Placement, different modes of use and potential complications are also covered. Part 2 will focus on specific aspects of pacemakers and their role in improving patient quality of life.

History of pacemakers
Implantable pacemaker therapy was introduced in 1958. However, initially the batteries did not last very long and the patient was required to undergo many device changes throughout their lifetime. In 1972, pacemakers entered the modern era when the first lithium battery was introduced. First-generation pacemakers were only able to pace in the ventricle at a continuous rate with no variation. Later, more-sophisticated devices were introduced that could sense the patient’s intrinsic ventricular rhythm and provide a pacing stimulus only when needed. This enabled a more
appropriate physiological response and was called a ‘demand’ pacemaker.

Despite this significant technological advancement, the intrinsic activity of the atria was not considered. In the late 1970s, further advances included the introduction of a second lead to enable the atria and ventricles to communicate with each other.

**Indications**

There are many indications for permanent pacemaker therapy. The most common are:
- SAN dysfunction – the SAN fails to initiate a stimulus for a period of time;
- High-grade AV block – the AV node is unable to allow conductive signals through to the ventricles.

The American College of Cardiology, the American Heart Association and the Heart Rhythm Society produced joint guidelines on a wide array of pacing indications. These guidelines – by Kusumoto et al (2019) – divide permanent pacemaker implant indications into three classifications:
- Class I – includes rhythms for which pacemaker implantation is considered necessary and advantageous for the patient because the benefits will be greater than the risks (for example, in cases of complete heart block);
- Class II – includes rhythms for which pacemaker implantation is indicated, but there is conflicting evidence and difference of opinion:
  - Class IIa – evidence supports implantation and benefits outweigh risks (for example, second-degree AV block with associated symptoms);
  - Class IIb – benefit to patients is not as well supported as for class IIa, and the balance of risks and benefits are less clear;
- Class III – includes rhythms for which permanent pacemaker therapy is not recommended and may be considered potentially harmful to the patient, with risks outweighing benefits (for example, asymptomatic sinus bradycardia).

**Position of device**

The pacemaker is usually positioned on the left side of the patient (Fig. 2). This is mainly due to most people being right-handed and because, in the first four to six weeks after implantation, patients may have limited movement near the pacemaker site to allow the leads to embed. Left-handed patients can have the pacemaker positioned on their right side. The pacemaker sits in a pocket between the pectoral muscle and layer of fatty tissue underneath the collar bone.

**Fig 1. Cardiac conduction system**

The pacemaker is usually positioned on their right side. The pacemaker sits in a pocket between the pectoral muscle and layer of fatty tissue underneath the collar bone.

**Mode selection**

Pacemakers have several pacing modes. To select the most appropriate mode for a patient, it is vital to understand what each letter in each mode represents. The North American Society for Pacing and Electrophysiology (NASPE) and then-named British Pacing and Electrophysiology Group (BPEG) developed the NBG (NASPE/BPEG Generic) coding system. A simplified version of this is outlined in Box 1, but more detail is given below:

- Column I – this refers to the chamber(s) in the heart that are to be paced when required. Pacing can occur in either the atrium (A) or ventricle (V), or may be programmed to ‘dual’ so both are paced;
- Column II – this refers to the chamber(s) in the heart where sensing is to take place. The letter codes are the same as for column I, but the additional letter ‘O’ is an option for no sensing;
- Column III – this refers to the response of the pacemaker to a sensed event. ‘I’ indicates that, when an intrinsic sensed event occurs, no pacing stimulus will be sent by the pacemaker. If the patient’s underlying rhythm is satisfactory, the pacemaker will sense this, and no pacing is needed. ‘T’ is used when the pacemaker is required to trigger a response after an intrinsic sensed event – for example, if a sensed event occurs in the atrium, this can trigger a response to pace in the ventricle. ‘D’ enables the device to both inhibit and trigger when an intrinsic sensed event occurs – for example, if there is an intrinsic sensed event in the atrium, the device will sense this and inhibit any response from the device to pace the atrium, but will still have the ability to trigger a response in the ventricle if required. ‘O’ indicates there is to be no response to sensing and can be used for pacing modes when continuous pacing is necessary – for example, if a patient is considered dependent on the pacemaker to maintain their heart rate due to no underlying rhythm;
- Column IV – this refers to a special algorithm pacemakers can use to enable a patient’s heart rate to have some form of variation to meet the body’s demands. This can be programmed as on (‘K’) or off (‘O’) (Bernstein et al, 2002). More detail on rate modulation/adaptive algorithms will be included in part 2 of this series.

When deciding the most appropriate mode for a patient, many factors should be considered; the main one is the patient’s indication for pacemaker therapy. Other factors often considered by a multidisciplinary team include the patient’s age, other comorbidities and exercise capacity.

Two of the most common pacing modes routinely used in clinical practice are:
- VVI – this enables the pacemaker to pace, sense and inhibit any pacing output if an intrinsic ventricular event is sensed. This mode is mainly for patients with permanent atrial fibrillation with a slow ventricular rate (Park et al, 2013); it helps the patient maintain an adequate heart rate and prevents episodes of bradycardia. As it only focuses on the action of the ventricle, patients experiencing other rhythm abnormalities (such as sinus node dysfunction) will not benefit due to a loss of AV synchrony. This loss of

**Box 1. NBG coding system for pacemaker mode**

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamber(s) paced</td>
<td>Chamber(s) sensed</td>
<td>Response to sensing</td>
<td>Rate modulation</td>
</tr>
<tr>
<td>A = atrium</td>
<td>O = none</td>
<td>O = none</td>
<td>O = none</td>
</tr>
<tr>
<td>V = ventricle</td>
<td>A = atrium</td>
<td>I = inhibited</td>
<td>R = rate adaptive</td>
</tr>
<tr>
<td>D = dual</td>
<td>V = ventricle</td>
<td>T = triggered</td>
<td>D = dual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NBG = NASPE (North American Society for Pacing and Electrophysiology) and BPEG (British Pacing and Electrophysiology Group) Generic</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
synchrony could potentially lead to pacemaker syndrome (Link et al, 2004), in which a patient feels symptomatically worse after pacemaker placement; • DDD – the most commonly used pacing mode in clinical practice, this can pace and sense in both the atrium and ventricle, and has the capacity to inhibit pacing when intrinsic events occur while triggering a response if needed. The two main rhythm abnormalities indicated for this pacing mode are SAN dysfunction and AV nodal blocks (Ouali et al, 2010). Timing intervals in this mode can be adjusted to suit the specific underlying rhythm and will be discussed in part 2 of this series.

Position of leads
The number of leads required depends on the pacing mode the patient needs – for example, if the pacing mode is to be VVI, a single pacing lead is implanted in the ventricle; however, if DDD is selected, an additional lead is placed in the atrium (Fig 2). The leads for a typical system are screwed into the pacemaker at one end, with their tips placed at the apex of the right ventricle and against the right atrial appendage (in the superior right border of the heart). There are two main structures of pacing leads – active and passive – and many factors are considered when deciding which are needed (Hai-Bo et al, 2013). The leads are inserted into the right side of the heart using a transfemoral approach via the subclavian vein, the cephalic vein or the axillary vein.

Possible complications
Pacemaker implantation is considered minimally invasive but complications can occur. These can be acute (during or immediately post procedure) or chronic.

Acute complications
• Perforation of the myocardium (heart muscle) – this is a rare but very important complication. Positioning the lead in the ventricle can result in it being forced through the heart muscle; this mainly occurs at the apex of the right ventricle as the muscle wall here is often much thinner than elsewhere in the ventricle. If the pacing lead perforates the right ventricular apex, the patient can experience chest pain and dyspnoea associated with pericardial tamponade. To diagnose a perforation, imaging investigations, such as X-ray and echocardiogram, are needed to help visualise the lead placement;
• Pocket haematoma – this complication happens as a result of blood pooling in the pacemaker pocket and coagulating. Research has shown this can occur in up to 7.5% of pacemaker implantations and can significantly increase the risk of infection (Haug et al, 2011). Patients may present with pain at the pacemaker site or significant swelling. To minimise occurrence of this complication, a pressure dressing may be used;
• Pneumothorax (air in the pleural space) – mainly caused during venous access if using a particular method, such as the subclavicular puncture technique, in which a needle is inserted directly into the vein and can pass into the lung. To provide a complete diagnosis, a chest X-ray is often requested that would clearly show a shadow on the lung.

Chronic complications
• Pocket erosion – occurs when the pacemaker is recognised as a foreign body by the patient’s immune system, which causes the body to reject the device and try to evacuate it. This is obvious when it presents, as it looks as though the device is escaping from the body. This does not tend to have an effect on its function, but the patient may experience severe discomfort. If patients present with this, it should be escalated immediately;
• Lead fracture or insulation failure - this can happen even though pacing leads are designed to withstand pressure and movement exerted by the heart. Each lead contains a coil coated with polyurethane insulation to allow for a certain degree of flexibility. Specialists in pacemaker therapy can identify this complication by interrogating a patient’s device and with possible visualisation via X-ray.

This complication can have a clinically significant effect on the function of the device and the patient may experience syncopal episodes (fainting); • Venous thrombosis – this can happen a few days, or even a few years, after pacemaker implantation and, on rare occasions, may lead to a life-threatening pulmonary embolism. One possible explanation is the pacing lead producing a foreign-body type reaction, and subsequent inflammation and fibrosis along the course of the lead. Some of the most common signs include oedema, cyanotic discoloration of the affected arm, pain and venous prominence.

Conclusion
This article has outlined the indications for, and importance of, pacemaker therapy. Part 2 focuses on unique algorithms associated with pacemakers, and how they can be adapted to meet patients’ needs and improve their quality of life. NT

References