

Pacemakers and implantable cardioverter defibrillators

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INTRODUCTION

As the number of indications for permanent pacemakers and implantable defibrillators have increased over recent years it has become increasingly common for anaesthetists to care for patients with these devices. Considering the growing range and complexity of these devices, it is not surprising that several surveys have shown that many anaesthetists are not comfortable managing these patients in the perioperative period.^{1,2} Placement of a magnet on these devices is rarely an appropriate manoeuvre and a more systematic and structured approach needs to be adopted. This article reviews key recommendations by the American Society of Anesthesiologists Task Force with regards to caring for patients with one of these devices.³

PERMANENT PACEMAKERS

A permanent pacemaker is an electronic device, generally placed subcutaneously, with one or several leads connected to the myocardium. Pacemakers allow both sensing of myocardial electrical activity and delivery of electrical stimulation for pacing functions.

Depending on the patient's clinical need, pacing can be delivered to single, dual, or multiple chambers (in bi-ventricular pacing), using unipolar or bipolar leads. More modern systems use bipolar leads, where the cathode and anode (the positive and negative electrodes) lie in close proximity, to reduce susceptibility to electromagnetic interference (EMI). Newer devices also incorporate a wide spectrum of programmability to allow alterations in pacing rate, energy output, sensitivity, mode of operation, and other functions.

Some pacemakers even utilize piezoelectric crystals to detect physical activity and compensate by increasing the heart rate. Other forms of sensors include: thoracic impedance, minute ventilation, temperature, QT interval, oxygen saturation, and myocardial contractility as means of detecting and adjusting to activity levels.

Classification

The function and capabilities of a pacemaker are often represented by a simple code. Since 2001, the North American Society of Pacing and Electrophysiology (NASPE)/British Pacing and Electrophysiology Group (BPEG) established a five letter generic code to describe various pacing modes. Devices are usually described using just the first three letters, but some have additional capabilities that are denoted in the final two codes. Familiarisation with this code is essential to understanding the function and management of an individual's pacemaker in the perioperative period.

The following examples illustrate how this code may be used.

AAI mode

The **Atrium** is the chamber that is paced. The **Atrium** is the chamber that is sensed and, if an electrical impulse is detected, the pacemaker will be **Inhibited** from delivering an electrical impulse. If no depolarization occurs within a certain period of time, the device will automatically initiate pacing at a pre-set rate. This mode can be used to raise the heart rate of patients with symptomatic sinus bradycardia, but normal AV conduction.

Table 1. The NSAPE/BPEG (NBG) Pacemaker Code⁴

I	II	III	IV	V
Pacing	Sensing	Response	Rate modulation	Multisite pacing
A = atrium	A = atrium	I = inhibited	R = rate modulating	V = ventricle
V = ventricle	V = ventricle	T = triggered	O = none	A = atrium
D = dual (A+V)	D = dual (A+V)	D = dual (T+I)		D = dual (A+V)
	O = none	O = none		O = none

Summary
 Conduct a focused history and full physical examination for all patients with cardiac electronic devices
 Gather important information regarding the device: its make and model, basic programming features, battery life, and the underlying rhythm
 Involve the cardiology team responsible for management of the device as early as possible in the patient's perioperative care
 Confirm the location of the operation in relation to the device and consider deactivating it if exposure to significant electromagnetic interference is expected
 Always have a backup plan in case of device malfunction
 Magnets should only be used after consultation with the cardiologist responsible for the patient's care.

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VVI mode

This is similar to AAI mode, but applied to the ventricle. The **V**entricle is the chamber that is paced, the **V**entricle is the chamber sensed for electrical activity and, if a ventricular depolarization is detected, the pacemaker will be **I**nhibited from delivering an electrical impulse. This mode is used to ensure that patients have an adequate ventricular rate in the presence of atrial fibrillation and a slow ventricular response.

DDD mode

This mode is used in a variety of clinical scenarios, sensing and triggering or inhibiting pacing of the atrium ventricle or both. **D**ual atria and ventricle are paced (requiring two pacemaker leads), **D**ual chambers are sensed and if electrical activity is detected, then pacing of that chamber is inhibited, or paced if no activity is noted. This is the **D**ual response. This mode can ensure each atrial depolarisation (spontaneous or stimulated) is followed by a ventricular depolarisation at a predetermined rate and maintain atrioventricular synchrony.

Asynchronous modes

Asynchronous modes (e.g. AOO, VOO and DOO) do not provide sensing and simply pace the designated heart chambers regardless of the underlying electrical activity. These modes are most often used in emergency situations or when triggered by placement of a magnet over the device.

Indications

There are three broad indications for cardiac pacemaker insertion: bradycardias (either persistent, intermittent or suspected); resynchronization therapy for cardiac failure; and rare conditions such as long QT syndrome and metabolic disorders. The bradyarrhythmias make up the bulk of these with the most common indications for pacemaker implantation being sinus node dysfunction with AV block. The need for permanent pacing in patients is based upon the severity of symptoms associated with their bradycardia. The most significant symptoms are: syncope, seizures, heart failure, dizziness, and confusion. The American College of Cardiology guidelines for pacemaker implantation grade the indications from Class I (strong evidence or general agreement for indication) to Class III (evidence existing against the procedure).⁵

The Class 1 indications for permanent pacing (American College of Cardiology) are:

- Symptomatic sinus bradycardia

- Symptomatic chronotropic incompetence
- Symptomatic sinus bradycardia resulting from medical drug therapy.

IMPLANTABLE CARDIOVERTER DEFIBRILLATORS

An implantable cardioverter defibrillator (ICD) resembles a pacemaker in location and lead connection to the myocardium, but differs structurally by including a pulse generator. Defibrillators usually have a sensing lead in the right ventricle to monitor electrical activity and a defibrillation lead to deliver a shock when malignant tachycardias are detected. An additional sensing lead is sometimes placed in the right atrium to help distinguish true ventricular tachycardia (VT) from conducted supraventricular tachycardia, which does not require defibrillation. Apart from the defibrillating function, ICDs may also have bipolar, anti-bradycardia and anti-tachycardia pacing capabilities. As with pacemakers, defibrillators have their own unique coding system to describe their programming and functionality (Table 2).

Indications

The main indications for insertion of an ICD are:

- secondary prevention in patients with prior sustained ventricular tachycardia (VT)
- ventricular fibrillation (VF)
- resuscitated sudden cardiac death (SCD) due to VT/VF
- primary prevention in patients at increased risk of life-threatening VT/VF.

In 2008, the American College of Cardiology/American Heart Association/Heart Rhythm Society (ACC/AHA/HRS) issued guidelines for insertion of cardiac defibrillators. The recommendations are graded from Class 1 (strong evidence for ICD therapy) to Class 3 (evidence against the procedure).⁵ Table 3 summarizes the Class 1 indications for permanent ICD therapy.

PERIOPERATIVE MANAGEMENT OF PATIENTS WITH CARDIAC IMPLANTABLE ELECTRONIC DEVICES (CIED)

Preoperative management

Safe anaesthetic management of patients with these devices should begin with a comprehensive preoperative visit and review of the clinical records. The involvement of the device managing team

Table 2. The NASPE/BPEG (NBD) code for cardiac defibrillators

I	II	III	IV
Shock chamber	Anti-tachycardia pacing chamber	Tachycardia detection	Anti-bradycardia pacing chamber
0 = none	0 = none	E = ECG	0 = none
A = atrium	A = atrium	H = haemodynamic	A = atrium
V = ventricle	V = ventricle		V = ventricle
D = dual (A+V)	D = dual (A+V)		D = dual (A+V)

Table 3. American College of Cardiology Class 1 indications for ICD therapy

- Left ventricular ejection fraction (LVEF) <35% due to prior myocardial infarction
- Minimally symptomatic VT with LVEF <40%
- VF or SCD survivors
- Nonischaemic dilated cardiomyopathy with LVEF <35%
- Spontaneous sustained VF/VT due to structural heart disease
- VT/VF causing syncope of undetermined origin.

as well as complete information about the device is vital in the perioperative management of these patients and close liaison with the cardiologists and cardiology technicians should be arranged at the earliest opportunity. Numerous case reports have shown how incomplete evaluation of a CIED has resulted in significant intraoperative problems.⁶⁻⁷

It is preferable that a pacemaker has been checked *within the last 12 months* and an ICD within the *last 6 months*, however this does not guarantee that the device will not malfunction. A specific history from the patient and a thorough physical examination may provide clues as to their dependence on the device, as well as how well it is functioning.

Preoperative tests should include: a 12-lead ECG, chest Xray, and blood electrolyte levels. ECGs can show the underlying rhythm in the absence of pacing, signs of pacemaker activity and evidence of electrical capture. Examination of the chest radiograph can often provide information about the position, type of device, lead configuration, and the presence of fractured leads.

The choice of anesthetic technique depends on the patient's comorbidities and intended procedures. Most of the commonly used anesthetic agents do not affect EICDs, but some practitioners may avoid suxamethonium due to concerns of over-sensing from muscle fasciculation. A more important perioperative concern is how capture thresholds and impedance of the leads can be altered by anaesthetic management (hypoxaemia, hypercapnia, significant acidosis, marked electrolyte disturbances, volume overload, high concentrations of local anesthetics and myocardial ischaemia).

In addition to standard monitoring, invasive arterial pressure monitoring should be considered in complex cases. If central venous access is being considered, extra care must be taken to avoid dislodging the electrodes. When practical, recommend the use of bipolar diathermy during the operation. Regardless of the type (monopolar versus bipolar), cautery use should be limited to short and irregular bursts at the lowest effective current. If unipolar diathermy is unavoidable, the diathermy and ground plate should be placed far away from the EICD as possible and the current pathway from the forceps to plate should run at a right angle to the leads.

Magnet use

Most pacemakers implanted after 2000 produce an asynchronous mode of pacing when a magnet is applied. The rate obtained depends on the programming of the device and default settings. Removal of the magnet should result in reversion to the device's baseline

programming. *Reprogramming is only recommended for pacemaker-dependent patients who will be exposed to significant EMI.* If no reprogramming is necessary, the rate modulation should still be suspended in the perioperative period.

ICDs should be deactivated preoperatively if diathermy is to be used, to avoid delivery of unnecessary shocks. This is also particularly important in patients undergoing lithotripsy, radiofrequency ablation, and electroconvulsive therapy. Application of a magnet to most modern ICDs disables the arrhythmia detection function and prevents discharge. *However, if significant EMI is expected, it is recommended that the device is reprogrammed and the defibrillation function disabled.*

The defibrillation function of the device should be instantly reactivated following the removal of the magnet, with *no subsequent reprogramming usually needed.* A magnet does not usually alter the pacemaker function of an ICD, as it should deactivate the defibrillating function only. Unfortunately, the magnet response by devices varies considerably between manufacturers. Some ICDs (Boston Scientific and St Jude) can be programmed to ignore the magnet application.⁶ With this in mind, it is recommended to contact the manufacturer/cardiologist for more information about how that particular device responds to a magnet if clarification is required.

In general, the use of a magnet should only be considered after consultation with the patient's cardiologist.

Intraoperative

The most common issue arising in the perioperative period is interference with device function from electromagnetic interference (EMI). Table 4 shows a list of common sources of EMI in the hospital setting.

EMI can potentially cause inhibition of pacing due to over-sensing or inadvertent reversion to back up pacing modes in pacemakers. With an ICD, EMI can trigger inappropriate delivery of potentially harmful defibrillatory shocks. Modern devices now incorporate bipolar leads as well as filters and insulating circuit shields to reduce EMI interference, but this is not 100% effective. Current literature advises that the potential for EMI-CIED interactions decreases when the cardiac device gets further away from the EMI source (a critical distance of 15cm has been suggested).² It is also theoretically safer if the EMI source is not in a vector parallel to that of the EICD current.

Table 4. Common sources of EMI in the hospital setting

Diathermy (monopolar > bipolar)
Magnetic resonance imaging
Electroconvulsive therapy
Radiofrequency ablation
Fasciculation
External defibrillation
Extracorporeal shock wave lithotripsy
Nerve stimulators

Contingency plans for pacing, defibrillation, or both should always be available in case of EICD malfunctioning. For pacing, this includes inotrope infusions and external transthoracic pacing pads. If these fail, transvenous and transoesophageal pacing should be considered, but both take time and experience to set up. If defibrillation is required or anticipated, patients should be attached to the external defibrillator with an anterior–posterior configuration of the pads in order to minimize exposure to the electrical current. Resuscitative measures should follow the current ACLS algorithms.

Table 5. Recommendations for interrogating CIEDs postoperatively

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- Intraoperative cardiopulmonary resuscitation and cardiac interventions
 - Significant EMI exposure during surgery
 - Haemodynamically challenging surgeries such as cardiac or high risk vascular surgery
 - EICD reprogrammed before the procedure
 - After insertion of a pulmonary artery catheter, especially in the setting of recently inserted leads (<6 weeks) or after cardiopulmonary bypass/ECMO
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After the operation

Postoperative interrogation of CIEDs is strongly recommended in certain situations (Table 5) to ensure patient safety.

CONCLUSION

Perioperative management of pacemakers and implantable cardioverter defibrillators can be challenging. All patients should be thoroughly evaluated before surgery and a plan devised for perioperative management of their device in close liaison with the patient's cardiologist. Prior to surgery, the anaesthetist should have a thorough understanding of the patient's underlying cardiac function, the status and function of the device, and its magnet response.

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