Editorial III

Implanted cardiac pacemakers and defibrillators in anaesthetic practice

There are almost 200,000 patients with implanted pacemakers and over 4000 patients with implanted cardioverter defibrillators (ICD) in the UK. The corresponding annual rates of new implants are approximately 18,000 and 1000 (A. D. Cunningham, personal communication) and ICD use is likely to increase significantly with the recent publication of guidance from the National Institute for Clinical Excellence (NICE), which recommends a threefold increase in the implant rate. It is increasingly likely that physicians in specialities other than cardiology, such as anaesthetics and accident and emergency medicine, may encounter patients with implanted devices, yet the experience of individual clinicians of device-related problems is likely to remain limited. Increased diversity and technological complexity of the devices and the emergence of new indications for their use offer ever more scope for incomplete understanding that may lead to mishaps.

New technology: modern pacemakers and ICDs

Current pacing systems include single-chamber devices for atrial or ventricular pacing and dual-chamber devices, which maintain atrioventricular (AV) synchrony and provide rate-adaptation by tracking the atrial rate during sinus rhythm. When the sinus node is diseased, a device is required which incorporates an additional sensor to detect changes in physical or physiological variables that are related to metabolic demand. This enables the pacing rate to be matched to physiological needs (rate-adaptive pacing).
Examples of such sensors include a piezoelectric crystal or accelerometer to detect physical activity and a transthoracic impedance monitor to track changes in minute ventilation. The majority of pacemakers are implanted to correct bradycardia due to sinus node disease or AV block but new indications are emerging, such as neurocardiogenic syncope and selected patients with hypertrophic cardiomyopathy or the long QT syndrome. New pacing modalities are also under investigation, including multisite pacing to prevent paroxysmal atrial fibrillation and biventricular pacing to correct interventricular dyssynchrony in patients with refractory heart failure.

The role of the ICD is now well established in the primary and secondary prevention of sudden cardiac death due to ventricular tachycardia (VT) or fibrillation (VF). The ICD incorporates algorithms for the detection of VT and VF and their termination by antitachycardia pacing or cardioversion/defibrillation. These devices also include anti-bradycardia pacing backup, either single- or dual-chamber, and patients who require both an ICD and pacing can now be treated with a single device. The most sophisticated ICDs also include the option of atrial defibrillation for patients with intermittent persistent atrial fibrillation, and standalone atrial defibrillators are also available.

Relevance to the anaesthetist
The most common scenarios that the anaesthetist will encounter are the routine management of patients in the perioperative period or in the intensive care unit and the emergency management of device-related complications. There are currently no nationally or internationally agreed guidelines for the management of patients with implanted devices in the perioperative period. Cardiologists and cardiac technicians can provide advice, but their input is not always sought until a problem has arisen. In non-specialist centres, the availability of expert help may be limited, particularly out of hours. Even when advice is available, the lack of protocols or definition of best practice may result in suboptimal care. Issues that need to be addressed include the minimum preoperative assessment, guidance on the identification of normal and abnormal device function and the recognition and avoidance of potential hazards in the medical environment.

Preoperative assessment
Preoperative assessment should aim to identify the type of device, including details of the manufacturer and model, the programmed settings (e.g. mode and rate) and the indication for the implant. A well-penetrated chest x-ray will enable the device to be identified from a radio-opaque marker within it, and the integrity and position of the lead(s) may also be confirmed. Novel methods for the identification of implanted devices are under consideration and transponder chips may be an option in the future. Baseline ECG studies with and without magnet application have been advocated. It is important to determine whether a patient is pacemaker-dependent and in case of doubt to assume that they are. Normal device function should be confirmed and battery status checked. Much of this information may be obtained by reference to the patient’s usual follow-up clinic, and patients are generally advised to carry a pacemaker/ICD ‘passport’ giving details of both the device and the clinic. If devices are under regular follow-up with good residual battery capacity when last checked [i.e. if the Elective Replacement Indicator (ERI) had not been triggered], a routine preoperative check may be unnecessary. Devices that are known to have reached ERI and those that have not been assessed recently should be checked before operation, as the time between ERI and End of Service may be difficult to predict. Similarly, any device that is beyond the nominal service lifetime indicated by the manufacturer or which is the subject of a safety advisory notice from the manufacturer or regulatory authority should be checked before operation. In patients who are pacemaker-dependent, a preoperative check may be prudent in any event, but there is no clear consensus on this or how recent a check is sufficient.

Perioperative problems
What problems may arise during surgery? Spontaneous device failure is uncommon but there are a number of potential hazards in the medical environment, the most important of which is electromagnetic interference (EMI). The use of diathermy or electrocautery during surgery is a well-recognized hazard, but there are other, less obvious sources of EMI. For example, there are reports of rate-adaptive pacemakers pacing at inappropriate rates as a result of triggering of transthoracic impedance sensors during exposure to monitoring systems. EMI due to transcutaneous nerve stimulators has also been reported. If EMI is recognized by a pacemaker, it is designed to switch to a temporary noise-reversion or interference mode with asynchronous fixed-rate pacing. If, however, EMI is not recognized, inhibition of the pacemaker may occur, which may have dire consequences for the pacemaker-dependent patient. The problem is accentuated by the fact that concurrent interference with ECG monitors may prevent its recognition in the absence of continuous haemodynamic monitoring or palpation of the pulse. In dual-chamber pacemakers, there is the potential for ventricular tracking of the interference signal, leading to high-rate pacing. High-powered sources of EMI, such as electrocautery, may cause electric reset of a pacemaker to a backup or reset mode, with either demand (VVI) or fixed-rate (VOO) ventricular pacing that will persist even after the interference has ceased. In this mode, programmed functions may be ineffective and, in some cases, the device may be unresponsive to magnet application. In extreme cases, high-powered EMI may cause
irreversible damage to the device or an increased pacing threshold due to heat injury at the point of contact of the electrode and myocardium.\textsuperscript{15} In patients with an ICD, interference from electrocautery or other sources may be detected incorrectly as VT or VF, resulting in delivery of a shock. For this reason, reprogramming to a monitoring-only mode during surgery, with disabling of antitachycardia pacing and shock therapy, is advisable. This may also be achieved by the application of a magnet. Monitoring of the ECG and haemodynamic status is once again vital, as the patient will not be protected from potentially lethal arrhythmia. Facilities for external defibrillation should be available immediately during surgery on any patient with an implanted device.

What then should be done to minimize the risk of EMI in pacemaker patients during surgery? The use and power output of electrocautery should be kept to a minimum, using short bursts, and it should be avoided in close proximity to the device. The grounding plate should be located well away from the device (usually on the thigh) and good skin contact should be ensured. Bipolar cautery is less hazardous than unipolar, although EMI may still occur.\textsuperscript{16} In the past, magnet application has been advocated as a means of temporarily reprogramming a demand pacemaker to pace asynchronously.\textsuperscript{17} However, magnet application is not without risk and its routine use is unjustified. Switching to asynchronous pacing may occasionally cause haemodynamic deterioration and there is the possibility that competitive pacing may trigger ventricular tachyarrhythmia, particularly in patients at increased risk due, for example, to myocardial ischaemia, hypoxia or electrolyte imbalance.\textsuperscript{18} Magnet application to both pacemakers and ICDs also opens the telemetry channels that are used for interrogation and programming, with the theoretical risk of ‘phantom’ reprogramming.\textsuperscript{19} The requirement for two-way exchange of coded radiofrequency signals for reprogramming makes this unlikely in practice, but if magnet application is required during surgery pacemaker function and programming should be checked before discharge.

A further potential problem with magnet application is the variability of response between different devices, as there is no universal standard. Most pacemakers will revert to asynchronous pacing at a fixed rate. This is usually higher than the basic programmed rate, in order to minimize the risk of competitive pacing. Rate-adaptation and other functions are usually disabled during magnet application. During the first 20–30 s after magnet application, some pacemakers perform a threshold margin test and others use a variable magnet rate to provide information regarding battery longevity. For the expert, these idiosyncrasies may help to identify the device and provide useful supplementary information, but for the non-specialist they are more likely to cause confusion.\textsuperscript{20} Pressed by clinicians, manufacturers have agreed to work towards universal standards for the magnet responses of pacemakers and ICD, and this work is being taken forward by the International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) Joint Working Group on Cardiac Pacing and Implantable Defibrillators.

In general, pacemakers do not require reprogramming before surgery but if electrocautery is to be used, particularly in a pacemaker-dependent patient, temporary reprogramming to an asynchronous or triggered mode should be considered. In all other cases, a programmer or magnet should be available immediately to enable asynchronous fixed-rate pacing to be activated in the event of pacemaker inhibition. It is important to note that electrocautery may still cause pacemaker failure even when the device has been switched to the asynchronous mode, and adequate monitoring remains vital.\textsuperscript{21} In patients with rate-adaptive pacemakers, consideration should be given to disabling the rate-adaptive function in order to avoid the risk of idiosyncratic rate acceleration in response to electrocautery or other stimuli.\textsuperscript{22} Ideally, when perioperative reprogramming is required, the appropriate programmer should be used. Unfortunately, programmers are manufacturer-specific as there is no common standard for the telemetry frequency or software and a hospital may have only a limited range (or none at all), reflecting the devices that they implant. Device manufacturers can provide support but this may take time and be of little use in an emergency. The case has been made\textsuperscript{23} for the development of a generic emergency intervention system, which would allow limited reprogramming of any pacemaker, but device manufacturers have shown little enthusiasm for the concept and it seems unlikely to be implemented.

What other problems may arise in the perioperative period? The pacing or defibrillation threshold may be affected by drugs, hypoxia, hypercapnia, metabolic disturbance or electrolyte imbalance.\textsuperscript{24,25} The myogenic electrical activity associated with muscle fasciculation induced by succinylcholine may result in EMI (myopotential inhibition).\textsuperscript{26} Similar responses to myoclonic movements induced by ketamine or etomidate might also be anticipated. Shivering may activate activity-sensing devices and mechanical ventilation may activate minute ventilation-sensing devices, causing rapid pacing.\textsuperscript{22} Central venous cannulation, if required, should be performed with caution because of the possibility of lead dislodgement, particularly if the pacing system has been implanted only recently. If external defibrillation is required in a patient with an implanted device, the risk of damage to the device and myocardial injury will be minimized if anteroposterior paddle positions are used. When this is not possible, the paddles should be placed at least 10–15 cm from the device. In any event, the device should always be checked after a shock has been delivered.
How frequent are problems during the perioperative period?

There is no good source of data and the reporting of incidents by clinicians is voluntary, although it is compulsory for manufacturers. In one series reported from Florida, USA, intraoperative problems were noted in relation to the pacemaker (inhibition, acceleration, change in pacing mode) in 10% of procedures.\textsuperscript{27} The Medical Devices Agency of the Department of Health is aware of two device-related perioperative deaths since 1999, one involving a pacemaker and the other an ICD. In both instances, the patient was being followed up annually by pacing clinics but neither patient had had a preoperative check. In both incidents, the device was suspected of contributing to the patient’s death but this was unconfirmed. The ICD caused inappropriate shocks to be delivered after operation on the ward and the patient died from cardiac arrest secondary to irreversible VF. The pacemaker-implanted patient failed to be resuscitated after intraoperative pacemaker failure due to battery depletion, although estimated battery longevity had been satisfactory at the last check. The importance of careful perioperative monitoring and the ready availability of emergency temporary or external pacing and external defibrillation cannot be overemphasized.

The way forward

This discussion raises several issues. There is a paucity of data regarding current practice in the management of patients with implanted devices in the perioperative and emergency settings. A survey of anaesthetists and accident and emergency physicians might usefully address this and define the need for educational initiatives and guidelines. Consideration should be given to the development of nationally agreed protocols in collaboration with expert groups, such as the British Pacing and Electrophysiology Group. These might be complemented by the establishment of national reference centres, which could provide fax, telephone or web-based support for those with inadequate access to local expertise. Manufacturers should be encouraged to develop and adopt common standards to facilitate pacemaker identification, assessment and programming in the emergency setting. In particular, the response to magnet application should be standardized. Inevitably, even if such standards are adopted, there will be a period of uncertainty whilst old and new devices coexist, during which the ready availability of expert guidance will be paramount. These initiatives should greatly assist in the perioperative and emergency management of patients with implanted devices and significantly reduce the risk of harm.

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