Management of Implantable Pacemakers and Defibrillators at the Time of Noncardiac Surgery

Martin C. Burke, DO, FACC, and Bradley P. Knight, MD, FACC, Section of Cardiology, Department of Internal Medicine, University of Chicago, Chicago, Illinois

As the indications for pacemakers (PMs) and implantable cardioverter-defibrillators (ICDs) have increased, more patients undergoing noncardiac surgery will have an implanted cardiac rhythm-management device. The complexity of implantable cardiac devices has also increased so that devices now can deliver pacing therapy for bradycardia, shocks and anti-tachycardia pacing therapy for atrial and ventricular tachycardias, and cardiac resynchronization pacing therapy for heart failure. Therefore, it is important that those involved in the perioperative evaluation and management of surgical patients have both an understanding of the indications and functions of implantable cardiac devices and an organized approach to these patients. It is also important that the evaluating physician effectively communicates with the surgeon, the anesthesiologist, and either the device nurse, technician, or industry field representative.

A patient with an implantable cardiac rhythm device should have a preoperative evaluation before elective noncardiac surgery. The evaluation should include determination of the scope and location of the surgery to be performed, the potential for exposure to electromagnetic interference (EMI), the type of implantable device, and whether the patient is PM dependent. This review addresses each of these issues and offers a guide for an algorithmic approach (Figure 1).

Electromagnetic Interference

During the preoperative assessment it should be determined whether EMI is likely to occur during the procedure. Although improved internal shielding and the use of bipolar leads has significantly reduced the susceptibility of implantable cardiac devices to EMI, efforts should still be made to minimize EMI exposure to the device. A cardiac device has multiple potential temporary and permanent responses to EMI: (a) resetting to a backup, reset, or noise reversion pacing mode; (b) inhibition of PM output; (c) an increase in pacing rate due to ventricular tracking or upper sensor rate activation; (d) ICD therapy delivery due to noise; and (e) direct damage to the lead, insulation, or device semiconductor chip.

The highest potential for electrical interference in the operating room is electrocautery that uses unipolar radio-frequency energy. Techniques to minimize the effects of electrocautery include placement of the receiving dispersive cutaneous plate or pad in a location that directs the current pathway away from the cardiac device and its leads, and delivery of short bursts of cautery at the lowest effective energy level. Bipolar electrocautery effectively minimizes the electric field and, if feasible, should be recommended. An alternative to electrocautery is a harmonic (ultrasonic) scalpel. This scalpel does not create an electric field and has no adverse effect on implantable cardiac devices.

Electrocautery can generate electrocardiographic noise so that it may not be possible to determine a patient’s rhythm during electrocautery. When cautery must be delivered for a prolonged period of time and there is sufficient noise that the rhythm cannot be established, the arterial pressure waveform should be monitored. When a pressure waveform is not available, a peripheral pulse should be palpated to assure that there is adequate perfusion during prolonged cautery.

Direct cautery on the device can cause destruction of the generator, and invasion of the pocket can result in damage to the leads. Although these events are unlikely to occur during noncardiac surgery, efforts must be made to avoid contact with the device during ipsilateral shoulder or breast surgery and during central venous line placement. The option of repositioning the device preoperatively should be considered before a patient undergoes a surgical approach that is expected to interfere with the device.

Other sources of EMI include radiation therapy and magnetic resonance imaging (MRI). Therapeutic radiation that is directed into the pulse generator’s plane can corrupt the internal semiconductor and create malfunction. When therapeutic radiation is delivered to a location remote from a pulse generator, a protective lead shield should be placed over the device to prevent semiconductor corruption. However, a protective lead shield may not be effective if the path of radiation is nearby, as occurs during radiation therapy for breast cancer. In these instances the device must be repositioned before treatment if the patient is PM dependent.

Currently, MRI in a patient with an implanted cardiac device is contraindicated. Exposure of implantable cardiac devices to an MRI unit can result in any of the responses to EMI listed above, but can also result in heating of the device or electrode–endocardial interface. Heating at the tip of the PM lead can result in loss of capture. It is unlikely that a chronically placed device and lead system would move in a magnetic field, but this has not been proven in human studies. Although recent reports have suggested that MRI is safe in patients with newer-generation devices, MRI in patients with a PM or defibrillator should be avoided for now.
Emergent or elective cardioversion can be performed in the patient with a cardiac device if the paddles are placed as far away from the device implant site as possible and the current is delivered as perpendicularly as possible to the lead orientation. In most cases an anterior–posterior electrode placement is preferred.

**Pacemaker Dependence**

Pacemaker (PM) dependence implies that a patient would have no underlying rhythm or an inadequate escape rhythm without pacing. It is important to determine whether a patient with an implantable device is PM dependent preoperatively, because this will determine how important it is to reprogram the device to an asynchronous pacing mode to avoid asystole in the operating room (Figure 1). Without a PM programmer to temporarily reduce the pacing rate, it may be difficult to determine whether a patient is PM dependent or not. Medical records from the Device Clinic are important resources. When records are available preoperatively, it is usually possible to determine the indication for the PM and if the patient was PM dependent during the last interrogation.

In the absence of such records, the electrocardiogram (ECG) can offer clues regarding PM dependency. A patient who has no visible pacing stimuli on the ECG is not PM dependent and only uses the PM on demand. Because bipolar pacing results in small pacing artifact on an ECG, it is important to examine the tracing carefully to exclude pacing. When there is atrial pacing, one must assume that the patient is PM dependent and that sinus arrest would occur if pacing was stopped. When there is ventricular pacing, inspection of the QRS morphology can help determine PM dependency. If the QRS complex is wide, it should be assumed that the ventricle is being depolarized solely by the PM, that the patient has complete atrioventricular (AV) block, and that the patient is PM dependent. If the QRS complex is narrow, it is likely that there is intact AV conduction and that the pacing stimulus is causing fusion or pseudofusion. Therefore, patients who are in sinus rhythm and have a pacing stimulus that is followed by a narrow QRS complex are unlikely to be PM dependent.

**Programmable Device Features**

An understanding of the pacing mode nomenclature is helpful when deciphering the medical records. The three-position code refers to the chamber paced, the chamber sensed, and the response to sensing. For instance, DOO mode indicates dual-chamber pacing (D), no sensing (O), and thus no response to sensing. For instance, DDD mode indicates dual-chamber pacing, dual-chamber sensing, and a dual-response to sensing. A dual response to sensing includes triggering a ventricular-paced event after an atrial-sensed event to allow for AV synchrony, and inhibition of ventricular pacing if an intrinsic ventricular beat is sensed.

A PM device may have an activated feature called hysteresis, which allows a patient with a slow heart rate to not be paced until the heart rate falls significantly below the lower pacing rate (programmable to between 1 to 20 beats/min) before returning to the lower pacing rate (i.e., hysteresis rate of 50 beats/min with a lower pacing rate of 60 beats/min). A similar function is called sleep hysteresis in which a device may be programmed to decrease the pacing rate below the lower pacing rate at night. The above functions are normal but may need to be addressed before surgery or anticipated during surgery.

---

**Figure 1. Perioperative algorithm to manage the implanted cardiac device patient.**

ACC CURRENT JOURNAL REVIEW January 2005
The Implantable Device Clinic or manufacturers’ support phone lines (Table 1) are useful resources regarding specific device features. Most patients carry a card with them that identifies the manufacturer and model of the implanted leads and device.

Magnet Response by Cardiac Devices

Application of a simple donut magnet to a cardiac device is a very useful maneuver to avoid inhibition of pacing and to gain control of an inappropriately functioning cardiac device in the operating room. Sterile magnets are available when the device is in the sterile field.

For PMs, a magnet initiates an asynchronous pacing mode (AOO, VOO, and DOO) by affecting a reed switch. The PM will effectively stop sensing intrinsic heart beats and any EMI. The device will pace at a specific rate, unique to the device or manufacturer, ranging from the programmed lower rate limit to a maximum of 100 beats/min. These magnet rates are fixed in a normally functioning PM and may not be appropriate for the clinical situation in the operating room. The anesthesiologist can refer to published magnet rates to avoid clinical situations where a magnet rate may not be appropriate for the anticipated surgical condition. Unfortunately, some antitachycardia pacing devices, such as the Medtronic AT500, do not convert to an asynchronous pacing mode in the presence of a magnet.

Some PMs are rate-responsive so that the pacing rate increases when the patient needs a higher heart rate. Most rate-responsive PMs detect patient activity using a piezoelectric crystal embedded in the PM can. Vibration or repetitive movement of the PM generator during surgery can result in pacing at the upper rate of the PM when the patient is under anesthesia. Some PMs sense an increase in demand by measuring intrathoracic impedance to determine minute ventilation. Mechanical ventilation and EMI can alter intrathoracic impedance measurements and result in pacing at the upper rate of the PM. Inappropriate sensor-driven tachycardia caused by a PM should be considered in the operating room during unexplained tachycardia in a patient with a PM. Application of a magnet will terminate this behavior. Turning the rate-responsive pacing feature off is advisable in a patient who has a PM with a minute-ventilation sensor.

For ICDs, magnet application disables tachycardia therapies (including shocks) but has no effect on the pacing mode or rate. Therefore, application of a magnet to an ICD will prevent shocks triggered by EMI but will not prevent inhibition of pacing by EMI. This is important because some ICD patients are PM dependent. Although some ICDs have a noise-reversion mode so that the device asynchronously paces when it senses something that it considers EMI, defibrillators are primarily designed to sense ventricular fibrillation and usually do not permit permanent programming to an asynchronous pacing mode. Therefore, insertion of a temporary transvenous PM is occasionally necessary for an ICD patient who is PM dependent and who is expected to undergo a procedure that will be associated with a high degree of EMI. Temporary pacing of an ICD patient should only be performed in collaboration with an electrophysiologist. External defibrillation should be immediately available for a patient whose implantable defibrillator has been deactivated.

A programmable feature in some ICDs is to permanently turn off the tachycardia therapy functions of the device after a magnet is in contact for a specific amount of time. This feature may be activated in individual patients and should be managed during the preoperative and postoperative interrogation sessions. A magnet can be safely applied to a Medtronic ICD and removed without permanently deactivating the device. Because ICDs are complex devices and therapeutically dormant most of the time, a malfunction caused by EMI may not be manifest immediately. Therefore, it is important to confirm that the device is appropriately activated and programmed postoperatively, whether a magnet was applied or not.

Perioperative Algorithm

Figure 1 includes an algorithm that offers a systematic approach to a patient with a cardiac device who is undergoing noncardiac surgery. Application of the algorithm will vary depending on hospital resources and policies. When possible, the Implantable Cardiac Device Clinic staff should be notified well in advance of an elective surgery involving a patient with such a device. This will allow for a smooth device programming session during the perioperative period.

Although not every patient undergoing noncardiac surgery needs to have his or her device reprogrammed preoperatively, it is advisable to have the device interrogated preoperatively and postoperatively to confirm normal function.

Questions and Answers

1. A preoperative cardiac device evaluation should include:
   A) A device interrogation and perioperative plan
   B) Defining the type of device
   C) Determination of patient’s cardiac device dependence
   D) Plans for a postoperative cardiac device evaluation
   E) All of the above

   The answer is E.

2. The preoperative device management of a surgical patient with an ICD should:

Table 1. Phone Numbers for Cardiac Device Manufacturers’ Technical Services

<table>
<thead>
<tr>
<th>Device</th>
<th>Telephone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biotronik</td>
<td>1-800-547-0391</td>
</tr>
<tr>
<td>ELA/Sorin</td>
<td>1-800-352-6466</td>
</tr>
<tr>
<td>Guidant</td>
<td>1-800-227-3422</td>
</tr>
<tr>
<td>Medtronic</td>
<td>1-800-466-9738</td>
</tr>
<tr>
<td>St. Jude Medical</td>
<td>1-800-550-1648</td>
</tr>
</tbody>
</table>
A) Suspend all antitachyarrhythmia functions
B) Leave antitachycardia pacing programs on
C) Apply a magnet before and during surgery in all cases and send the patient home postoperatively without a device interrogation
D) Place a temporary pacemaker
The answer is A.

3. Electrocautery’s interaction with a cardiac device can cause which of the following:
   A) Temporary resetting to a noise-reversion mode
   B) Permanent resetting to a backup mode
   C) Total inhibition of pacing
   D) ICD tachycardia detection and therapy
   E) All of the above
   The answer is E.

4. Electromagnetic interference can be created by all of the following except:
   A) Magnetic resonance imaging
   B) Therapeutic radiation
   C) Radiofrequency ablation
   D) Ultrasonic (harmonic) scalpel
   The answer is D.

5. When should a magnet be placed on a cardiac device during surgery?
   A) At all times
   B) In an emergency when device interrogation is impossible
   C) Only if bipolar electrocautery is being used
   D) If pacing inhibition is noted by pulse or electrocardiogram
   E) B and D
   The answer is E.

Suggested Reading


Address correspondence and reprint requests to Martin C. Burke, DO, Section of Cardiology, Department of Internal Medicine, University of Chicago, 5758 S. Maryland Ave., MC9024, Chicago, IL 60637.