Chapter 12
Implantable Cardiac Devices

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It is not uncommon to see patients for preoperative evaluation who have a permanent pacemaker or an implantable cardioverter-defibrillator. Perioperative management of these devices requires both knowledge of how these devices function as well as an understanding of the particular risks posed by electrocautery or other electromagnetic interference to the function of the device.

PACEMAKER AND ICD FUNCTION

Basic pacemaker function is often summarized with a three- or four-letter code, with the letters designating the chambers that are paced, the chamber(s) where sensing is performed, and the device's response to a sensed beat, as shown in Table 12.1 [1–3].

A fourth letter, "R," is often added if a rate-adaptive or rate-responsive mechanism is operational. When the activity sensor within the device determines that the patient is active, the backup (demand) pacing rate increases. Sensor options include the following [4]:

- A piezoelectric crystal that detects either muscle pressure on the device or body movement: In the operating room (OR), shaking the patient can cause increases in heart rate.
- Bioimpedance measurement within the chest to estimate minute ventilation: To make this measurement the device emits a small current between the generator and the lead. This permits an impedance measurement that reflects tidal volume, and its frequency provides the respiratory rate. The respiratory rate module of most OR/ICU monitors has similar technology and can fool the pacer/implantable cardioverter-defibrillator (ICD) into thinking the patient is active and so leads to an inappropriate paced tachycardia.

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TABLE 12.1 PACEMAKER TERMINOLOGY

First letter	Second letter	Third letter
Chamber(s) paced A = atrium; V = ventricle; D = dual (both chambers)	Chamber(s) sensed A = atrium; V = ventricle; D = dual (both chambers); O = no sensing	Response to sensing I = inhibited; T = trigger; D = dual (inhibit or trigger depending on the situation); O = nothing

- Bioimpedance measurement within the myocardium (an index of sympathetic nervous system activity): This measurement is made at the tip of the lead. No known interactions in the OR.

MOST COMMON PACING MODES

VVI: Senses and paces the ventricle.
VVIR: Same as VVI, but with rate-adaptive mechanism.
DDD: Both atrium and ventricle are sensed and paced individually.
DDDR: Same as DDD, but with rate-adaptive mechanism to alter atrial pacing.

IMPLANTABLE DEFIBRILLATORS [1, 2]

- Respond to tachyarrhythmias (typically ventricular tachycardia and fibrillation) based on detection of defined, high ventricular rates.
- Therapies include anti-tachycardia pacing, low-energy synchronized shocks, or high-energy unsynchronized shocks.
- All ICDs have pacing capability. The pacemaker component of an ICD is the same as a regular pacemaker and the four-letter code still applies. How the pacemaker component of the ICD is programmed depends on the patient's day-to-day requirement for pacemaker support.

CARDIAC RESYNCHRONIZATION THERAPY

These devices pace both the right and left ventricles in order to produce a more coordinated left ventricular contraction [1, 2]. If defibrillation capability is present, it is referred to as CRT-D. The four-letter pacing mode nomenclature can still be used to describe the pacemaker capability of the cardiac resynchronization therapy (CRT) or CRT-D device.

ELECTROMAGNETIC INTERFERENCE

Electromagnetic sources, such as electrocautery or high-frequency radio-ablation used during surgery, can interfere with implanted cardiac devices and lead to a variety of undesired events [1, 5]. Monopolar diathermy radiates far more electromagnetic interference (EMI) than bipolar, but it is impractical to substitute bipolar for monopolar cautery in almost all circumstances. Monopolar cautery can lead to the following:

- Suppression of demand pacing in the atrium, ventricle, or both.
- Inappropriate "tracking" of falsely sensed "atrial" events. Normal dual-chamber pacing mode will use a sensed atrial depolarization to initiate (trigger) a ventricular paced beat (unless inhibited by a sensed ventricular depolarization). If EMI is sensed on the atrial channel, the device can misinterpret this signal and then pace the ventricle at a high rate (up to a programmed limit).
- Activate asynchronous pacing that could result in a competing rhythm if it occurs in a patient who is not pacer dependent.
- Activation of shock therapy for falsely detecting EMI artifact as VT or VF in an ICD.
- Transient lowering of the battery voltage and device malfunction: When the device recovers, the programming returns to generic default values that may be very different from those set for the patient. This phenomenon is often referred to as "power on reset."
- Arbitrary reprogramming of the device from high-density EMI (very rare with current technology).
- Device destruction with complete loss of any pacing or shock function from very high EMI (e.g., can occur with cautery applied directly to the device).
- Myocardial burns from lead insulation failure when cautery current travels down the wire and burns the tissue at the lead tip (very rare).

PERIOPERATIVE MANAGEMENT

PREOPERATIVE CHECKLIST

Device interrogation by a programming box, if available, is the easiest and most complete method to obtain the desired preoperative information [5]. However, if this option is unavailable, the following checklist will allow any clinician to obtain considerable useful information [6].

1. *Device identification*.
   (a) Pacer or ICD? Patients may not know the distinction, but most carry a *card* with the device and lead(s) model numbers, implant dates, and managing or implanting cardiologist. The managing physician should be able to provide information regarding the patient's device type, indication for the device, special concerns, and recommendations for management of the device during the operative procedure.
   (b) A *chest X-ray* provides clear information as to the device and potential pacing capabilities. Thin wires going to the atrium, right ventricle, and possibly the left ventricle identify a patient with at least some degree of need for pacemaker function. Leads with fat, densely radio-opaque sections (usually in the superior vena cava and right ventricle) identify the device as an ICD. Of course, combinations of ICD and pacing leads may be present. Typically, pacing leads will be bipolar with the second electrode approximately 1 cm from the tip.
   (c) Careful scrutiny of the device on the chest X-ray also typically reveals a symbol and letter/number *code* identifying the manufacturer and model. One can call the manufacturer (see below) or check the Web site and quickly obtain information about the device capability including the device's *response to a magnet*, but the company will not have any patient-specific information.
2. *Contact* the physician who normally manages the device. This should be able to provide information regarding the device type, indication for the device, special concerns, and recommendations for management of the device during the operative procedure. Ideally, an interrogation should be performed within 6 months of the planned surgery. This time period can be significantly extended if the device is no more than a few years old and the patient has been doing well. If the battery is found to be near its end of life, elective surgery should generally be postponed until the device has been replaced. In this situation, risk of device malfunction increases the closer the cautery is performed to the device and leads. If you have concerns, consult your local electrophysiologist specialist.

3. Obtain a long *rhythm strip* or observe on a monitor. This will help to determine the underlying rhythm, and if the patient is pacemaker dependent. Make sure that the monitor is set to display pacing spikes. Most modern monitors found in ORs, ERs, and ICUs have electrical filters that prevent visualization of the spikes unless special circuitry is turned on.
4. If the device is a pacemaker, *place a ring magnet* over the device while observing the rhythm strip. Almost all pacemakers (but no ICDs) will then convert to asynchronous pacing. This accomplishes several goals:
   (a) Identifies the device as a pacemaker.
   (b) Provides evidence that the battery is OK because a low battery is associated with a pacing rate that is approximately 10 or more bpm below the normal magnet rate (normal is 85 bpm for Medtronic, 90 bpm for Biotronik, and 100 bpm for Guidant/Boston Scientific and St. Jude).
   (c) Documents proof (or failure) of capture when spikes stimulate the tissue in a non-refractory state.
5. Patients on diuretics or acutely ill should have their *electrolytes* checked. Pacing thresholds can be affected by electrolyte disturbances.

INTRA-OPERATIVE MANAGEMENT

For all patients, attempts should be made to *minimize EMI* [2, 5]:

- The cautery *grounding pad* should be located on the patient such that the cautery current is directed away from the device and leads.
- Some form of *pulse monitor* must be used during cautery. The pulse oximeter, routinely used during surgery, is adequate for this purpose.
- Recommendations for the use of bipolar cautery or short cautery bursts are almost always impractical and should be left to the OR personnel.

If a *programming box* and trained personnel are available to evaluate the device immediately prior to surgery, then all necessary device information is available and any necessary programming changes can be made [5]:

- For ICDs, tachycardia sensing will be disabled to prevent unwanted shocks. *Defibrillation pads* should then be placed on the patient.

- For all devices, patients dependent on the device to maintain a reasonable heart rate will typically be changed to asynchronous pacing. Even if the patient is left in demand pacing, other features may be disabled.
- A discussion with the programmer about the device is helpful as it makes the anesthesia team aware of how the device might perform during surgery.

If *interrogation is not available*, then proceeding with surgery must be a carefully weighed decision that includes the risk to the patient of EMI causing device dysfunction versus the risk to the patient not proceeding with the surgery. EMI risk increases with each of the following:

- Monopolar cautery that will be applied close (within 8 cm) to the device.
- Monopolar sensing (almost all devices use bipolar sensing but it is almost impossible to know without interrogation).
- Improper grounding pad placement.
- Device battery at end of life.

If surgery proceeds without interrogation and programming, the anesthesia team will likely perform the following [5–7]:

- For ICDs, *disable tachycardia sensing* by placing a ring magnet over the device. Defibrillation pads are not mandatory—in the event of V-tach or V-fib, simply remove the magnet. Care must be taken, however, to avoid dislodging the magnet. Some ICDs have idiosyncratic responses to the magnet such as the device will emit beeps or only result in disabled arrhythmia detection for a certain length of time: a call to the company (see contact information below) will provide this vital information.
- For pacemakers, the ring magnet will convert the device to *asynchronous pacing*. To avoid competing rhythms, especially in patients with an intrinsic rhythm, it is best to wait to observe significant inhibition of demand pacing before choosing to place a magnet. The desire to minimize the higher heart rate associated with the use of a magnet is particularly germane to some patients, for example, those with coronary artery disease or aortic stenosis.
- Worst-case scenario is a patient with an *ICD and pacemaker dependency*. Use of a magnet will prevent inadvertent shocks but nothing can be done to prevent the cautery EMI from inhibiting the demand pacing. Should demand pacing be inhibited and the patient develops an inadequate pulse or asystole, then cautery bursts will have to be of limited duration or have a temporary pacemaker placed.

- Be aware that the *rate-responsive feature* may lead to a paced tachycardia if the sensor becomes activated. Jiggling the patient can trigger the piezoelectric activity sensor, and the minute ventilation sensor can interact with the similarly designed bioimpedance method of the anesthesiologist's respiratory rate monitor. Awareness of the potential problem and knowing what the upper "sensor" rate is programmed at (the maximum heart rate that the sensor can induce) aid in the detection of the cause and institution of the correct intervention (e.g., quit wiggling the patient, turn off the anesthesia respiratory rate monitor).

POSTOPERATIVE MANAGEMENT

Device interrogation after surgery should be performed [5]:

- Prior to leaving a monitored setting, if any programming changes were made for surgery, those settings should be restored to the original values unless the clinical situation dictates different settings.
- Patients with ICDs whose tachycardia therapies were disabled for surgery must remain on a cardiac monitor with defibrillation and pacing capability until ICD shock therapy is restored.
- Other situations which should prompt interrogation include the following:
  - Monopolar cautery was performed within 8 cm of the device.
  - Cardioversion/defibrillation was performed.
  - The patient had serious hemodynamic problems intraoperatively (such as chest compressions, massive bleeding, prolonged hypotension).
  - The patient had radiofrequency ablation.
  - A central line was placed.
  - There were concerns about device function in the operating room.
- Patients who were exposed to monopolar cautery above the umbilicus, had lithotripsy or electroconvulsive therapy and were not interrogated after the procedure should see their cardiologist for an interrogation within 1 month.

COMPANY CONTACT INFORMATION

- Biotronik: (800) 547-0394
- Ela Sorin: (303) 467-6101
- Guidant/Boston Scientific: (800) 227-3422
- Medtronic: (800) 723-4636
- St. Jude: (800) 933-9956

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