TOPICS IN REVIEW

Managing cardiac implantable electronic device patients during a health care crisis: Practical guidance

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Our world is faced with a global pandemic that threatens to overwhelm many national health care systems for a prolonged period. Consequently, the elective long-term cardiac implantable electronic device (CIED) management of millions of patients is potentially compromised, raising the likelihood of patients experiencing major adverse events owing to loss of CIED therapy. This review gives practical guidance to health care providers to help promptly recognize the requirement for expert consultation for urgent interrogation and/or surgery in CIED patients.

KEYWORDS Cardiac implantable electronic device; Health care crisis; Implantable cardioverter-defibrillator; Pacemaker; Pandemic

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Introduction

The high infectivity and fatality rates of the novel COVID-19 virus has triggered a global pandemic that is unprecedented in the modern medical era.[1] As a result, many medical and public health experts predict that a number of national health systems could be overwhelmed for an uncertain period of time.[2,3] Fortunately, many clinics and emergency departments are still able to maintain their remote cardiac implantable electronic device (CIED) monitoring capability, as off-site telecommuting is usually feasible.[4] Unfortunately, many health care providers that electively manage CIED patients are being *redirected* to assist in other areas of immediate clinical need, and elective CIED surgeries have been temporarily suspended at many medical centers.[4,5] Simultaneously, mandates for *social distancing* are leading to cancellation of ambulatory CIED outpatient appointments for those patients not enrolled in remote monitoring and, in most circumstances, absence of manufacturer field representatives for clinical support. Accordingly, recommended approaches for the long-term management of many CIED patients are potentially compromised, raising the risk of major adverse events in patients that may suffer an untimely loss of CIED therapy.

This brief review gives practical guidance to health care providers of CIED patients for appropriate identification of CIED type and manufacturer and prompt determination for expert consultation for urgent interrogation and/or surgery.

Identification of CIED

Electronic medical records will usually detail a patient's CIED type (pacemaker or implantable cardioverter-defibrillator [ICD]) and manufacturer in relevant cardiac notes. In the absence of medical records, many patients will be aware of their CIED type and manufacturer or possess a manufacturer's identification card. When prompted, some patients can at least recall the color(s) of the large bedside computer programmer used to interrogate their CIED, each of which is unique to the manufacturer. CIED and patient information (name, date of birth) is registered by manufacturers, and so confirmation of identification of appropriate CIED is available by calling the toll-free number for the relevant manufacturer. If these conventional routes fail, chest radiography can be utilized to determine the type of CIED and associated leads. Magnifying the CIED image can reveal a radiopaque logo specific to each manufacturer. If the logo proves indiscernible, the design and shape of the pacemaker or ICD generator can indicate the potential manufacturer; the recently released *"Pacemaker-ID" smart phone application*, with a reported accuracy of 94% in a US population,[6,7] can be effectively used for this purpose. The unique manufacturer characteristics and 24-hour toll-free phone numbers for the 5 largest CIED companies are summarized in Table 1 in descending order of US and global market size: Medtronic, Abbott (formerly St. Jude Medical), Boston Scientific (formerly Guidant), Biotronik, and MicroPort (formerly LivaNova and ELA/Sorin).

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KEY FINDINGS

- Cardiac implantable electronic device (CIED; pacemaker or implantable cardioverter-defibrillator [ICD]) type and manufacturer model can be identified by patient recollection, medical records, manufacturer cards, manufacturer registries, and chest radiograph utilizing the "Pacemaker-ID" smart phone application.
- A resting standard 12-lead electrocardiogram can provide data on a patient's intrinsic heart rhythm, pacing status, and efficacy. The "Rules of Ten" can help screen for pacemaker battery depletion or power-on reset in the majority of pacemaker manufacturers.
- Application of a "doughnut magnet" over the generator will maintain asynchronous pacing at a fixed rate in all pacemaker models. Magnet application will maintain inhibition of shocks in all ICD models.
- Most cardiac clinics and hospital emergency rooms have capability for remote CIED interrogation. However, CIED programming cannot be performed remotely.
- Pacemaker or ICD patients with new-onset cardiorespiratory symptoms or CIED infection (also auditory/vibratory alarms in ICD patients) warrant interrogation and potential expert consultation if programming or surgery may be required.

Pacemakers

In the absence of remote or bedside interrogation, a standard 12-lead electrocardiogram (ECG) can provide important information on pacemaker status. An absence of pacing artifact on serial ECGs usually indicates that a patient is not "pacemaker dependent." When pacing artifact is observed in a patient requiring demand pacing for bradycardia or cardiac resynchronization therapy, the ECG can be studied for evidence of malfunction owing to lack of sensing, lack of capture, and/or battery depletion.[8-10] When available, an ECG performed with a "doughnut magnet" over the pacemaker generator will yield an asynchronous mode (DOO or VOO) with a fixed pacing rate that accurately reflects the battery status for that specific manufacturer and thus can identify a pacemaker at elective replacement indication (also termed elective replacement time or recommended replacement time).[8] When power-on reset (also termed "electrical reset," "safety mode," "standby mode," and "safe program") occurs owing to a potentially critical loss of component integrity in the pacemaker's central processing unit, the ECG will demonstrate reversion to high-output back-up VVI pacing with very prominent unipolar pacing artifact at a fixed rate.[8] The manufacturer-specific characteristics seen owing to low battery status and power-on reset for the 5 largest pacemaker manufacturers are summarized in Table 2.

In lieu of remembering much of the tabulated data in Table 2 one can utilize the simple *"Rules of Ten"*: Atrial pacing at a rate *not* a multiple of 10 or *nonsynchronous* ventricular pacing at a rate *not* a multiple of 10 on a *resting ECG* likely indicates pacemaker battery depletion and/or power-on reset.[10] These easily applied prediction rules recently demonstrated a sensitivity of 79% and a specificity of 93% in a US population.[10]

If a pacemaker-dependent patient requires emergent surgery in the thoracic region (before a manufacturer programmer can be brought to the bedside), then a magnet can be secured over the pacemaker generator to ensure *asynchronous pacing* even during unipolar electrocautery application.

Table 1 Cardiac implantable electronic device manufacturer identifying characteristics and toll-free phone numbers (in the United States)

Manufacturer	Phone number	Programmers	Radiopaque logo
Medtronic	1(800) MEDTRON		 "M..." with diamond and dot inset

(*Continued*)

Table 1 (*Continued*)

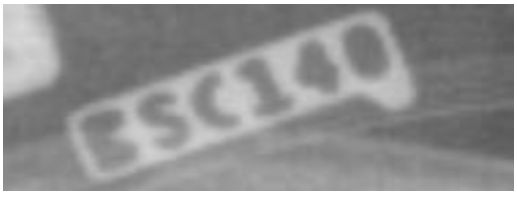
Manufacturer	Phone number	Programmers	Radiopaque logo
Abbott*	1(800) PACEICD		 "SJM..."
Boston Scientific†	1(800) CARDIAC		 "BSC..."
Biotronik	1(800) 547-0394		 Circle and inverted cross inset

Table 1 (*Continued*)

Manufacturer	Phone number	Programmers	Radiopaque logo
MicroPort‡	1(855) 877-3899		"ELA" or "S.." or "MS.."

See reference 6 for more radiographic illustrations and reference 7 for "Pacemaker-ID" phone app for all cardiac implantable electronic devices.
*Formerly St. Jude Medical.
†Formerly Guidant.
‡Formerly LivaNova and ELA/Sorin.

Implantable Cardioverter-Defibrillators

As with pacemakers, the standard 12-lead ECG can be utilized to assess pacing status in those ICD recipients that require demand pacing for bradycardia or cardiac resynchronization therapy. Of note, a doughnut magnet placed over the ICD generator will *not alter pacing mode* but will *inhibit delivery of ICD shocks* when they are deemed inappropriate or prior to emergent thoracic surgery requiring electrocautery.

Unlike pacemakers, all ICDs will emit either an *audible alarm* (Medtronic, Boston Scientific, Biotronik, MicroPort) or a *vibratory alarm* (Abbott) when a significant alert is triggered owing to low battery status, lead fracture, or ventricular tachyarrhythmia. ICD models manufactured by Abbott and Boston Scientific that are subject to recent technical advisories from the United States Food and Drug Administration warrant urgent interrogation upon alarming owing to possible premature battery depletion that may rapidly compromise delivery of ICD shock or pacing therapy.

Both chest compressions and external electrical cardioversions can be safely administered in CIED patients (preferable to avoid delivering an external shock directly over the generator to minimize risk of circuit damage).

CIED Management Algorithm

Figure 1 provides a key summary of these practical guidance tips and a stepwise algorithm for health care providers for appropriate identification of CIED type and determination for expert consultation for urgent interrogation and/or surgery.

Table 2 Manufacturer-specific automatic reprogramming of pacemakers owing to elective replacement indication, magnet rates, and power-on reset

Pacemaker characteristic	Pacemaker manufacturer				
	Medtronic	Abbott	Boston Scientific	Biotronik	MicroPort
Loss of rate response or CLS?	Yes	Yes	Yes*	Yes	Yes
Loss of A-V synchrony?	Yes (VVI)†	No	No	No	Yes (VVI)
Change in LRL?	Yes (65 bpm)	Yes (-10%)	No	Yes (-11%)	Yes (70 bpm)
Magnet rate at BOL	85 bpm	100 bpm	100 bpm	90 bpm	96 bpm
Magnet rate at ERI	≤65 bpm‡	≤86.3 bpm	≤85 bpm	≤80 bpm	≤80 bpm
Power-on reset (back-up VVI mode)	65 bpm unipolar	67.5 bpm unipolar	72.5 bpm unipolar	70 bpm unipolar	70 bpm unipolar

BOL = beginning of battery life; bpm = beats per minute; CLS = closed-loop stimulation; ERI = elective replacement indication; LRL = lower rate limit; RRT = recommended replacement time.
*Boston Scientific models manufactured prior to 2014.
†Medtronic models manufactured since 2013 preserve programmed mode at RRT 3 months prior to ERI.
‡Magnet application at RRT/ERI in Medtronic models manufactured prior to 2013 initiates a "threshold margin test" (3 paced impulses at 100 bpm with a 20% decrease in amplitude on the third impulse) followed by pacing at 65 bpm.

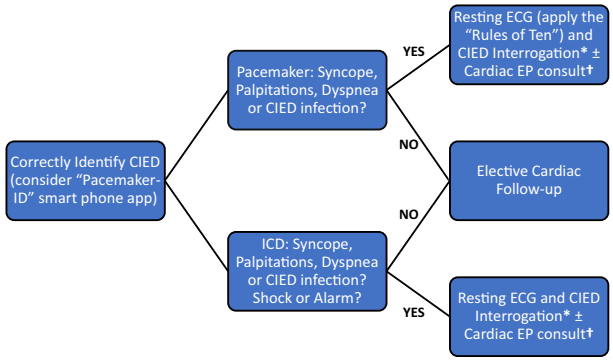


Figure 1 Cardiac implantable electronic device (CIED) management algorithm. ECG = electrocardiogram; EP = electrophysiology; ICD = implantable cardioverter-defibrillator.

Conclusion

We are now challenged with caring for CIED patients in an unprecedented public health care crisis where many routine approaches to management are less feasible. We hope that the basic practical guidance in this review will assist health care providers in promptly caring for CIED patients at greatest risk.

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