Anesthesia teams managing pacemakers and ICDs for the perioperative period: enhanced patient safety and improved workflows

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Purpose of review
There have been both technological and philosophical advances over the last decade regarding pacemakers and implanted cardioverter defibrillators (ICDs). Collectively, these devices are currently referred to as cardiac implantable electronic devices (CIEDs). Technological advances include the introduction of leadless pacemakers, subcutaneous defibrillators and cardiac event recorders, enhancements regarding compatibility of CIEDs for MRI scanning, the ability to interrogate devices remotely, and improved programming modes that preserve battery life. Philosophical advances have been mainly in the area of perioperative management of CIED patients.

Recent findings
Current practice recommendations now acknowledge that not every patient requires a formal interrogation of their CIED before and after surgery (as was previously recommended). The response to magnet application is standardized across manufacturer's platforms, and it is known that sources of electromagnetic interference remote from the CIED and its leads do not usually cause any interference with device function.

Summary
Educated anesthesia teams can independently manage the vast majority of CIED patients perioperatively with magnet application alone. Furthermore, this portends enhanced patient safety and improved workflows in the perioperative period.

Keywords
cardiac implantable electronic device, implantable cardioverter defibrillator, pacemaker, pacemaker magnet, perioperative management

INTRODUCTION

Historically, anesthesiologists have relied on knowledgeable consultants with manufacturer-specific programming devices to ready the patient with a cardiac electronic implantable device (CIED) for the operating room. The 2005 American Society of Anesthesiologists (ASA) practice advisory for the perioperative management of patients with cardiac rhythm management devices recommended that all patients with a pacemaker or ICD should have a comprehensive interrogation of their device immediately before and after surgery [1▪▪]. Although this may have seemed in the highest level of patient safety at the time, this not only proved quite challenging to implement in all practice settings, but it was often difficult to obtain in emergency situations and off-hours, when a knowledgeable consultant may not have been immediately available to assist.

This strict recommendation for a preoperative interrogation essentially disappeared by the 2011 ASA Practice advisory for the perioperative management of patients with CIEDs [2]. This was in part because it was understood by subject-matter experts that immediate preoperative interrogations were not likely necessary in all cases where patients were compliant with routine periodic interrogations by their pacemaker physician (or at least had an

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KEY POINTS

- Pacemakers and ICDs are different devices in that pacemakers can provide only pacing, whereas ICDs can provide both pacing and antitachycardia therapies.
- Since approximately 2008–2009, across the industry, magnet application to a CIED will result in only a temporary alteration of device behavior while the magnet is in place, with magnet removal reliably returning the device to baseline settings.
- Magnet application to a pacemaker will cause the device to function in an 'asynchronous mode' that can protect the pacing-dependent patient from inhibition of pacing by intraoperative EMI from the surgical electrocautery unit or other source of electromagnetic emanations.
- Magnet application to an ICD will inhibit the delivery of antitachycardia therapies but will not affect pacing settings.
- Educated anesthesia teams can independently manage the vast majority of CIED patients perioperatively with magnet application alone, portending enhanced patient safety and improved workflows in the perioperative period.

interrogation within 6 months of the procedure). Moreover, the anesthesia team managing the patient was able to obtain the necessary information required to implement a well tolerated management plan for the patient intraoperatively. The recommendation for routine postoperative interrogation remained, however, in the 2011 advisory [2]. Certainly, baseline settings would need to be restored if the CIED had been formally reprogrammed and/or disabled preoperatively. In addition, the recommendation also took into account a few reported instances with device resets, presumed to be the result of intraoperative electromagnetic interference (EMI) [3,4].

The 2011 advisory also provided limited guidance regarding magnet use as a potential management strategy and cautioned against 'the routine use of magnets over ICDs [2]. This latter recommendation likely took into account that although industry had already standardized magnet responses in modern devices by the time of the publication, patients with older devices might still have been encountered clinically.

In contrast, the Heart Rhythm Society (HRS) also published an expert consensus statement in 2011 that proposed a radically different approach to the perioperative management of CIED patients. The HRS recommendation was that the patient's pacemaker physician would provide an actual 'prescription' for perioperative management of the device [5]. Such prescription may have recommended simple magnet application or perhaps formal reprogramming by a knowledgeable consultant. Unfortunately, the suggested approach was insurmountably challenging to implement. The HRS Consensus statement of 2011 did, however, provide guidance regarding magnet application to CIEDs as a potential perioperative management strategy, and also recommended the circumstances in which a formal postoperative interrogation is warranted.

In 2016, a series of publications aptly demonstrated why it may not be in the interest of patient safety for anesthesiologists to remain uneducated about CIEDs and instead depend on consultants to perioperatively 'manage' CIEDs for them. In these 2016 reports, routine 'radiofrequency wanding' by nursing staff for retained surgical instruments at the end of the procedures (e.g. with the Radiofrequency Assure Detection System; Radiofrequency Surgical Systems, Carlsbad, CA, USA) resulted in brief periods of asystole in four pacemaker dependent patients [6,7]. Although no permanent harm came to any of the reported patients, the FDA investigation of the reports determined that the anesthesia teams were responsible for failing to safeguard the pacing-dependent patient from inhibition of pacing during radiofrequency wanding (e.g. by placing them in a nonsensing mode that would ignore the EMI from the radiofrequency wand). Moreover, the anesthesia team (at least, in the report by Plakke *et al.*) had not apparently attended the 'in-service' on the new technology being brought in to the operating room by the nursing team [8,9]. It was confirmed in a study of 40 CIED patients and 10 patients with temporary pacing that the radiofrequency sponge detection technology can be safely used in patients appropriately placed to an asynchronous mode of pacing and/or with their ICD 'deactivated' (e.g. with a magnet or a programming device) [10].

Thus, the introduction of a new patient-safety technology in the OR brought about an unintended new threat to patient safety, reemphasizing the understanding that we, anesthesiologists, must be responsible for heartbeats in the operating room (OR). Thus, 2016 can be seen as a turning point as regards many anesthesiologists' interest in perioperative CIED management.

The recommendations of the 2020 ASA Practice Advisory are essentially identical to those of the 2011 Advisory [11]. In the new guideline, the recommendation for routine postoperative interrogation has now been downplayed, and brought into line with the 2011 HRS consensus statement recommendation. As such, a postoperative interrogation is indicated in clinical situations where significant

intraoperative EMI (or other specified circumstances) may have had a higher likelihood of affecting device function, and/or there is a suspicion that device function had been altered [11]. The 2020 Advisory continues to recommend against 'the indiscriminant use of magnets over an ICD', but the intentional temporary suspension of antitachycardia therapies for the perioperative period by magnet application to a modern device is not 'indiscriminant'.

Definition of 'adverse outcomes'

Appropriate perioperative management of the patient with a CIED is based entirely in the avoidance of adverse events during the perioperative period. According to the 2005 ASA Practice Advisory [1▪▪]:

'Adverse outcomes include (but are not limited to) damage to the device, inability of the device to deliver pacing or shocks, lead-tissue interface damage, changes in pacing behavior, electrical reset to the backup pacing mode, or inappropriate ICD therapies. Adverse clinical outcomes include (but are not limited to) hypotension, tachyarrhythmia or bradyarrhythmia, myocardial tissue damage, and myocardial ischemia or infarction. Other related outcomes may include extended hospital stay, delay, or cancellation of surgery, readmission to manage device malfunction, or additional hospital resource utilization and cost.'

To avoid adverse events, the anesthesiologist caring for the CIED patient not only needs to have a basic fund of knowledge about CIEDs in general, but also needs to proactively ascertain specific information preoperatively about their patient's device in order to devise and implement a safe plan for perioperative management.

Essential points of necessary cardiac implantable electronic device knowledge

(1) Pacemakers and ICDs are different devices. A pacemaker provides pacing, and generally, such pacing is delivered in a 'sensing mode'. The device senses what is going on and tailors its activities to provide pacing when needed with regard to, with respect for, and in sync with the patient's native underlying rhythm. Competition with an underlying perfusing rhythm could compromise optimal cardiac output and cause arrhythmias (e.g. because of R on T phenomenon).

An ICD can provide therapies to terminate tachycarrhythmias (e.g. shocks to defibrillate ventricular fibrillation, and attempted overdrive pacing and/or shocks to potentially convert supraventricular and/or ventricular tachycardias). It is important to be aware, that all ICDs also have pacemaker functionality that is generally programmed as a backup rescue in case defibrillation results in bradycardia or asystole. That said, the pacemaker functionality of an ICD can also be programmed to provide pacing all the time for patients who are dependent, but the implanted device is still an ICD (not a pacemaker).

(2) The surgical electrocautery unit and other electronic procedural equipment emit radiofrequency waves that can be interpreted by the CIED as spontaneous cardiac activity and/or interfere with sensing and detection. This can inhibit needed pacing, elicit the inappropriate delivery of antitachycardia therapies from an ICD and (if substantial and prolonged) cause a temporary or permanent alteration to device behavior, including a potential electrical 'reset'. The goal is, therefore, to protect the patient (and the CIED) from the potentially untoward effects of intraprocedural EMI, by altering the behavior of the device prior to EMI exposure.

(3) The behavior of a CIED can be temporarily altered with magnet application or permanently altered with a manufacturer-specific programming device, to prevent interference with desired device function because of EMI.

(4) Magnet application to a pacemaker inhibits sensing, causing the pacemaker to function in a 'nonsensing' asynchronous mode that will ignore any electromagnetic noise in the environment and deliver pacing at the programmed rate in whatever cardiac chamber there are leads commensurate with remaining battery life.

(5) Magnet application to an ICD inhibits 'detection', which effectively inhibits the delivery of antitachycardia therapies (e.g. shocks and/or attempts at overdrive pacing), but does not inhibit sensing, so any pacing being delivered by the ICD can still be inhibited by EMI.

(6) Magnet removal returns modern CIEDs to their baseline programmed settings.

(7) Where feasible, the anesthesiologist's use of a magnet to temporarily control the behavior of a CIED perioperatively can enhance patient safety and improve workflows by comparison to having a consultant permanently reprogram the device for the OR and back to baseline settings afterwards.

(8) If every beat on the baseline ECG (or on your monitor) is a paced beat, then it is recommended that one should assume pacemaker dependency, as this will force the creation of a safer overall plan for perioperative management.

Key information to ascertain preoperatively

(1) What device is present (pacemaker or ICD)?
(2) How is it programmed?
(3) Is the patient dependent on antibradycardia pacing?
(4) Is the device currently functioning as intended?
(5) Will there be EMI present in the perioperative period?

The advent and widespread implementation of electronic medical records in many institutions now allows for CIED information to be part of the patient's medical record, including the results of periodic remote device interrogations. In the absence of office notes from the patient's pacemaker physician or the results of a recent device interrogation, the anesthesia team can amass the necessary information from a variety of potential sources, including: manufacturer's identification cards, chest x-rays, ECGs, and direct communication with the patient's cardiologist or pacemaker clinic. There is also, now, an 'app' (available for iPhone from the App store) that can identify the device manufacturer from a picture taken of the device in the chest X-ray. In elective situations, when none of the above are available, an interrogation of the device may be needed, but this will rarely be necessary unless formal reprogramming is desired/required and/or the patient has not had a 'recent' interrogation (within 3–6 months) [11].

Devising and implementing a perioperative cardiac implantable electronic device management plan

Once the essential information has been acquired, one then has to devise a plan for perioperative management and implement any desired/necessary reprogramming of the device that ensures the highest possible level of safety for the patient. Where the risk of device interference by EMI is high, reprogramming to an asynchronous mode of pacing is recommended for pacing-dependent patients, as is disabling of the antitachyarrhythmia therapies of an ICD [11]. Stepwise algorithms based on current recommendations can be helpful to assist and guide decision-making [12] (Fig. 1). Additional information that will enable the use of such algorithms includes:

(1) if there will be EMI generated within 15–20 cm from the device and its leads (e.g. from a monopolar surgical electrocautery, a radiofrequency ablation catheter or other equipment that emits electromagnetic waves)
(2) patient positioning during the case
(3) if there will be access to the device during the case

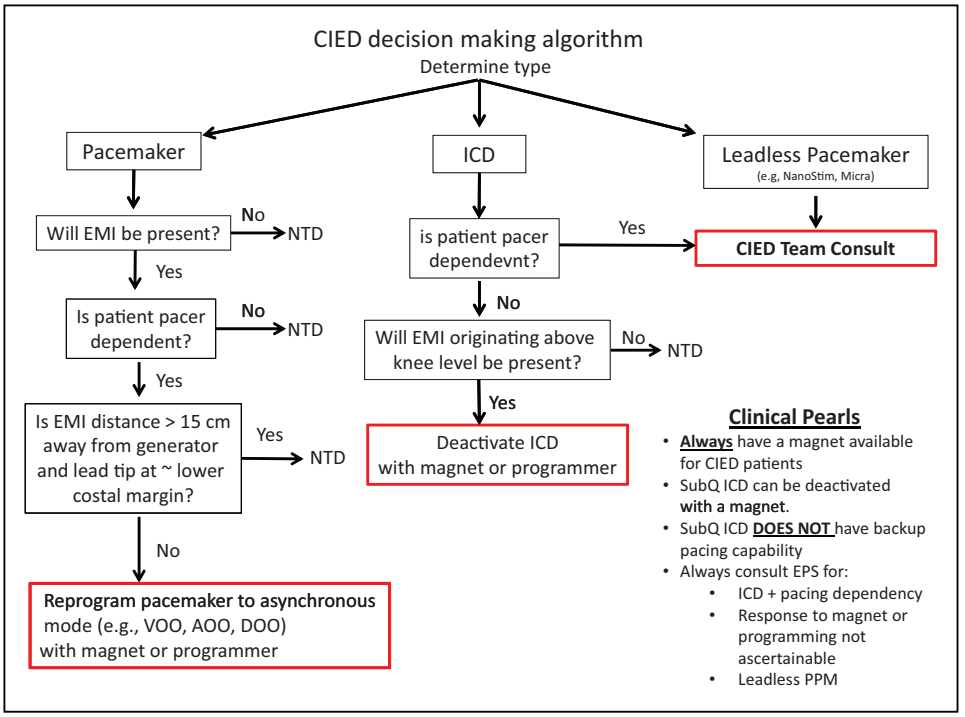

FIGURE 1. A decision-making algorithm for perioperative CIED management. 'NTD' stands for 'nothing to do', but this refers only to the likely need for specific reprogramming of a device preoperatively. As described in the text, there are further considerations intraoperatively to ensure the safety of the CIED patient intraoperatively.

Table 1. Situations in which magnet application is not feasible, not prudent and/or will not fully address the goals for perioperative CIED management

Not feasible
Magnet response is disabled
Leadless pacemaker
Not prudent
Magnet response not ascertainable
Prone patient
Device not accessible to you during the case
Magnet in surgical field?
Will not fully achieve goals
ICD + pacing dependency

(4) the disposition of the patient after the case (e.g. PACU, ICU, discharge to home, and so on)

Fortunately, since approximately 2008–2009, industry has standardized certain key aspects of CIED programming that now allow management with a magnet alone for a large percentage of CIED patients for the perioperative period. In appropriate instances, magnet application may even be 'safer' and more convenient than 'permanent reprogramming' of a device. Situations in which magnet application is not feasible, not prudent and/or will not fully address the goals for perioperative CIED management appear in Table 1. Table 2 summarizes the recommendations for periprocedural CIED management for common nonoperating room settings.

Table 2. Summary of recommendations for CIED management in nonoperative settings [4]

Extracorporeal shock wave lithotripsy
Current generation of lithotriptors appears to present low risk [13]
Avoid focusing lithotripsy beam near generator
Telemetry monitoring is prudent during the procedure
Terminate the procedure if arrhythmias develop
Disable sensing of a pacemaker if inhibition is manifest
Deactivate ICD for the procedure
Gastroenterology procedures with electrosurgery
Electrosurgery can interfere with device function
Disable ICD for the procedure
Consider disabling sensing of a pacemaker for pacemaker dependent patients
Radiofrequency ablation (RFA) above the umbilicus
Deactivate ICD
Disable sensing of a pacemaker for pacemaker dependent patients
Avoid direct contact of RFA catheter with generator/leads
Interrogate device following therapy
Electroconvulsive therapy
The brief exposure to the electrical current is not so much the issue as the significant tachycardia that may develop.
Disable ICD for the procedure
Interrogate device following therapy
Urgent/emergent cardioversion or defibrillation
Paddles/pads should not be placed directly over the device. An 'anterior-posterior' position of paddles/pads is recommended instead of the usual 'apex-base' locations.
Appropriate ACLS energy levels should be used.
Interrogate device following therapy
MRI
May cause device or lead movement, heating and thermal damage to surrounding tissues, induction of current down the leads, inappropriate function and therapies, resets and battery depletion.
MRI conditional devices and leads now exist and protocols have been developed to allow MRI scanning with close monitoring
Consideration of the risks vs. benefits must be individualized for patients, especially for patients with MRI nonconditional devices.
Disable ICD with a programming device prior to scanning
Disable sensing of a pacemaker for pacemaker dependent patients
Radiation therapy (RT)
Causes cumulative damage to device circuitry
Device should be shielded from the RT field or relocated if shielding is not possible
Interrogate device if there was significant exposure to the RT field.

Regardless of whether a patient's CIED was left at its baseline settings or was 'reprogrammed' (e.g. temporarily and reversibly with a magnet, or permanently with a programming device), intraoperative vigilance and adjunctive measures (e.g. thoughtful placement of cautery dispersal pads, minimization of EMI exposure, monitoring of a peripheral pulse and the ECG) are key intraoperative activities. In CIED patients where no specific reprogramming was enacted preoperatively, any unusual electrical activity should be presumed the result of EMI (e.g. from the surgical electrocautery) and the source of EMI should be halted temporarily to allow stabilization. Application of a magnet to a CIED can protect against the EMI as needed, as outlined above.

Postoperative management

It is in the spirit of the highest possible level of safety for patients that all device settings be returned to baseline before discharge from a monitored setting. If a magnet was used to temporarily alter the behavior of a device, magnet removal is all that will be required to restore the baseline settings. Clearly, if the device had been reprogrammed with a programmer, then one will again be needed to return the device to preoperative, baseline settings.

The vast majority of CIED patients undergoing routine, elective, noncardiothoracic procedures, where transfusion of blood was not required and where there were no significant intraoperative events do not likely require a formal interrogation of their device postoperatively. The 2011 HRS/ASA consensus statement of 2011 suggests the following specific circumstances in which one might be prudent [5]:

(1) Preoperative reprogramming that altered baseline settings or inhibited the function of the device (e.g. disabling tachycardia detection of an ICD)
(2) Intraoperative events (e.g. cardiac arrest) requiring cardiopulmonary resuscitation, cardioversion, defibrillation or temporary pacing
(3) Hemodynamically challenging surgeries involving large fluid shifts and/or blood transfusion
(4) Cardiothoracic surgery
(5) Emergent procedures where the source of EMI was in close proximity to the CIED (e.g. above the umbilicus)
(6) Procedures where the type of EMI has a higher likelihood of affecting device function (e.g. radiofrequency ablation, therapeutic radiation)
(7) 'Logistical limitations' preventing a reliable device evaluation within one month from the procedure

CONCLUSION

Appropriate perioperative management of the patient with a pacemaker or ICD is based entirely on the avoidance of problems in the perioperative period. An enhanced understanding of the technology by anesthesiologists, and their proactive engagement in perioperative CIED management whenever feasible will enhance the level of safety for CIED patients and can improve both preoperative and postoperative workflows on the day of surgery. Focused educational interventions for anesthesiologists are needed to effect culture change, and the use of validated decision-making algorithms can promote success. Appropriate consultation with cardiology and electrophysiology teams are strongly encouraged where uncertainty exists, to understand management options and to effect formal reprogramming of CIEDs when needed.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:
- ■ of special interest
- ■■ of outstanding interest

1. ■■ Practice Advisory for the Perioperative Management of Patients with Cardiac Implantable Electronic Devices. Pacemakers and Implantable Cardioverter–Defibrillators 2020: an updated report by the American Society of Anesthesiologists Task Force on perioperative management of patients with cardiac implantable electronic devices*. Anesthesiology 2020; 132:225–252.
This is the current practice advisory from the American Society of Anesthesiologists.
2. American Society of, Anesthesiologists,. Practice advisory for the perioperative management of patients with cardiac rhythm management devices: pacemakers and implantable cardioverter-defibrillators. Anesthesiology 2005; 103:186–198.
3. Practice Advisory for the Perioperative Management of Patients with Cardiac Implantable Electronic, Devices,. Pacemakers and implantable cardioverter-defibrillators an updated report by the American Society of Anesthesiologists Task Force on perioperative management of patients with cardiac implantable electronic devices. Anesthesiology 2011; 114:247–261.
4. Pili-Floury S, Farah E, Samain E, *et al.* Perioperative outcome of pacemaker patients undergoing noncardiac surgery. Eur J Anaesthesiol 2008; 25:514–516.
5. Levine PA, Balady GJ, Lazar HL, *et al.* Electrocautery and pacemakers: management of the paced patient subject to electrocautery. Ann Thorac Surg 1986; 41:313–317.
6. Crossley GH, Poole JE, Rozner MA, *et al.* The Heart Rhythm Society Expert Consensus Statement on the perioperative management of patients with implantable defibrillators, pacemakers and arrhythmia monitors: facilities and patient management. Heart Rhythm 2011; 8:e1–e18.

7. Plakke MJ, Maisonave Y, Daley SM. Radiofrequency scanning for retained surgical items can cause electromagnetic interference and pacing inhibition if an asynchronous pacing mode is not applied. A&A Case Rep 2016; 6:143–145.
8. Williams MR, Atkinson DB, Bezzerides VJ, *et al.* Pausing with the gauze: inhibition of temporary pacemakers by radiofrequency scan during cardiac surgery. Anesth Analg 2016; 123:1143–1148.
9. Rozner MA, Schultheis L, Schulman PM. The unstated Murphy's Law of the Operating Room: if something goes wrong, blame anesthesia. A&A Case Rep 2016; 6:139–141.
10. http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfmaude/detail.cfm?mdrfoi__id=3208810. [Accessed 10 October 2019]
11. Salcedo JD, Pretorius VG, Hsu JC, *et al.* Compatibility of radiofrequency surgical sponge detection technology with cardiac implantable electronic devices and temporary pacemakers. PACE 2016; 39:1254–1260.
12. Stone ME, Salter BS, Fischer A. Perioperative management of patients with cardiac implantable electronic devices. Br J Anaesth 2011; 107:16–26.
13. Platonov MA, Gillis AM, Kavanagh KM. Pacemakers, implantable cardioverter/defibrillators, and extracorporeal shockwave lithotripsy: evidence-based guidelines for the modern era [review]. J Endourol 2008; 22:243–247.