

# 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\**

Practice advisories are systematically developed reports that are intended to assist decision-making in areas of patient care. Advisories provide a synthesis of scientific literature and analysis of expert opinion, clinical feasibility data, open forum commentary, and consensus surveys. Practice advisories developed by the American Society of Anesthesiologists (ASA) are not intended as standards, guidelines, or absolute requirements, and their use cannot guarantee any specific outcome. They may be adopted, modified, or rejected according to clinical needs and constraints, and they are not intended to replace local institutional policies.

Practice advisories summarize the state of the literature and report opinions obtained from expert consultants and ASA members. They are not supported by scientific literature to the same degree as standards or guidelines because of the lack of sufficient numbers of adequately controlled studies. Practice advisories are subject to periodic revision as warranted by the evolution of medical knowledge, technology, and practice.

This document updates the 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, adopted by the ASA in 2010 and published in 2011.<sup>1</sup>

## Methodology

### Definition of Cardiac Implantable Electronic Devices

For this advisory, a cardiac implantable electronic device refers to any permanently implantable cardiac pacemaker or any implantable cardioverter–defibrillator. The term cardiac implantable electronic device also refers to any cardiac resynchronization therapy device.<sup>1</sup>

### Purposes of the Advisory

The purposes of this advisory update are to: (1) facilitate safe and effective perioperative management of the patient with a cardiac implantable electronic device and (2) reduce the incidence of adverse outcomes. Perioperative management refers to the preoperative, intraoperative, postoperative, or recovery period in any setting where an anesthesia provider will be delivering anesthesia care. Adverse outcomes associated with cardiac implantable electronic device function 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, and inappropriate implantable cardioverter–defibrillator therapies.<sup>‡</sup>

Adverse clinical outcomes include, but are not limited to, hypotension, tachyarrhythmia and bradyarrhythmia,

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A complete bibliography used to develop this updated Advisory, arranged alphabetically by author, is available as Supplemental Digital Content 1 (<http://links.lww.com/ALN/B979>).

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†Generic pacemaker and defibrillator codes are provided in tables 1 and 2. Note that every transvenous implantable cardioverter–defibrillator includes both pacing and shock therapy capabilities for the management of bradyarrhythmias and tachyarrhythmias.

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myocardial tissue damage, and myocardial ischemia and infarction. Other related adverse outcomes may include extended hospital stay, delay and cancellation of surgery, readmission to manage device malfunction, and additional hospital resource utilization and cost.

### Focus of the Advisory

This updated advisory focuses on the perioperative management of the patient who has a preexisting cardiac implantable electronic device for the treatment of bradyarrhythmia, tachyarrhythmia, or heart failure. This advisory applies to all cardiac implantable electronic device patients receiving general or regional anesthesia, sedation, or monitored anesthesia care. Both inpatient and outpatient procedures are addressed by this update.

This update does *not* address the perioperative management of the patient without a cardiac implantable electronic device, such as those (1) with only a temporary cardiac implantable electronic device; (2) with only a noncardiac implantable device (*e.g.*, neurologic or spinal cord stimulator); (3) with only an implantable mechanical cardiac assist device (*e.g.*, ventricular assist device); or (4) undergoing cardiac implantable electronic device implantation or revision. This update does not address procedures rarely involving anesthesia care (*e.g.*, radiation therapy<sup>§</sup>) or imaging modalities without known perioperative cardiac implantable electronic device concerns (*e.g.*, diagnostic radiography or ultrasonography). In addition, this update does not address patient comfort or management of pain during a procedure.

### Application of the Advisory

This updated advisory is intended for use by anesthesiologists and all other individuals who deliver or who are responsible for anesthesia care. This update may also serve as a resource for other physicians and healthcare professionals who manage patients with cardiac implantable electronic devices.

### Task Force Members and Consultants

The original advisory was developed by an ASA-appointed task force of 12 members consisting of anesthesiologists and cardiologists in private and academic practices from various geographic areas of the United States and two

methodologists from the ASA Committee on Standards and Practice Parameters. In 2017, the ASA Committee on Standards and Practice Parameters requested that the advisory be updated. This update is a revision developed by an ASA-appointed task force of five members, including three anesthesiologists and two methodologists. Conflict-of-interest documentation regarding current or potential financial and other interests pertinent to the practice guideline were disclosed by all task force members and managed.

### Process and Evaluation of Evidence

This updated advisory was developed by means of a five-step process. First, consensus was reached on the criteria for evidence. Second, original published articles from peer-reviewed journals relevant to the perioperative management of cardiac implantable electronic devices were evaluated and added to literature reported in the previous update. Third, consultants who had expertise or interest in cardiac implantable electronic devices and who practiced or worked in various settings (*e.g.*, private and academic practice) were asked to participate in opinion surveys addressing the appropriateness, completeness, and feasibility of implementation of the draft recommendations and to review and comment on a draft of the Advisory. Fourth, additional opinions were solicited from random samples of active ASA members. Fifth, all available information was used to build consensus to finalize the advisory. A summary of recommendations can be found in appendix 1.

Preparation of this updated advisory followed a rigorous methodologic process. Evidence was obtained from two principal sources: scientific evidence and opinion-based evidence. Detailed descriptions of the ASA process and methodology used in this Advisory may be found in other related publications.<sup>2-5</sup> Appendix 2 contains information on the evidence model, the literature search process, literature findings, and survey results.

Within the text of the advisory, literature classifications are reported for each intervention using the following classifications: category A, level 1: meta-analysis of randomized controlled trials; category A, level 2, multiple randomized controlled trials; category A, level 3: a single randomized controlled trial; category B, level 1: nonrandomized studies with group comparisons; category B, level 2: nonrandomized studies with associative findings; category B, level 3: nonrandomized studies with descriptive findings; and category B, level 4: case series or case reports. Outcomes are designated as either beneficial (B) or harmful (H) for the patient; statistically nonsignificant findings are designated as equivocal (E). Survey findings from task force-appointed expert consultants and a random sample of the ASA membership are fully reported in the text of these guidelines. Survey responses for each recommendation are reported using a five-point scale based on median values from “strongly agree” to “strongly disagree.”

‡Inappropriate implantable cardioverter–defibrillator therapy refers to the delivery of antitachycardia therapy (pacing or shock) in the absence of a clinically indicated tachyarrhythmia. Inappropriate implantable cardioverter–defibrillator therapy can harm a patient by inducing ischemia, worsening the arrhythmia, or causing the patient to move during a delicate procedure.

§More information about the management of patients with cardiac implantable electronic devices undergoing magnetic resonance imaging or radiation therapy may be found in the 2017 Heart Rhythm Society Expert Consensus Statement on Magnetic Resonance Imaging and Radiation Exposure in Patients with Cardiovascular Implantable Electronic Devices (<https://www.hrsonline.org/2017-hrs-expert-consensus-statement-cardiovascular-implantable-electronic-device-lead-management>; accessed August 9, 2019).

## Advisory Evidence and Recommendations

### Preoperative Evaluation

A focused preoperative evaluation of the patient with a cardiac implantable electronic device consists of the following topics: (1) determining whether a patient has a cardiac implantable electronic device; (2) determining the cardiac implantable electronic device type, manufacturer, and primary indication for placement; (3) determining whether a patient is pacing-dependent; and (4) determining the cardiac implantable electronic device's current settings and that it is functioning properly by interrogating the cardiac implantable electronic device or obtaining the most recent interrogation report.

**Literature Findings.** Although the literature is insufficient to evaluate the clinical benefit of performing a focused preoperative evaluation of patients with cardiac implantable electronic devices, case reports indicate that adverse outcomes (e.g., inappropriate shock, cardiac implantable electronic device switch to “end-of-life mode,” acute ventricular lead dysfunction, and corrupted device memory) may occur when a complete preoperative examination is not performed to determine whether the patient has a cardiac implantable electronic device (*Category B4-H evidence*).<sup>6–9</sup> The literature is insufficient to evaluate whether preoperatively determining the cardiac implantable electronic device type, manufacturer, and primary indication for placement or determining whether a patient is pacing-dependent affects perioperative outcomes. A case series reported inappropriate antitachycardia pacing or shocks, premature battery depletion, and cardiac implantable electronic device damage when the cardiac implantable electronic device's settings were not adequately assessed preoperatively (*Category B4-H evidence*).<sup>10</sup> The literature is insufficient to evaluate whether any particular time interval to determine recency for review of a previous cardiac implantable electronic device interrogation is most beneficial to the patient.

**Survey Findings.** The expert consultants and ASA members strongly agree with the recommendation that a preoperative evaluation should include determining whether a patient has a cardiac implantable electronic device, determining the cardiac implantable electronic device type (i.e., pacemaker, implantable cardioverter–defibrillator, cardiac resynchronization therapy), determining the primary indication for cardiac implantable electronic device placement, and determining whether the patient is pacing-dependent. The consultants strongly agree and ASA members agree that a preoperative evaluation should include determining the cardiac implantable electronic device manufacturer.

The consultants strongly agree and ASA members agree that a preoperative evaluation should include determining the cardiac implantable electronic device's current settings and confirming that the cardiac implantable electronic device is functioning properly (i.e., by interrogating the

cardiac implantable electronic device or obtaining the most recent interrogation report). The consultants selected preferred time spans for determining proper implantable cardioverter–defibrillator functioning before a procedure, as follows: immediately = 6% of consultants, at least 3 months before = 48% of consultants, at least 6 months before = 36% of consultants, and at least 12 months before = 6% of consultants. For a pacemaker the following time spans were selected by consultants: immediately = 3% of consultants, at least 3 months before = 39% of consultants, at least 6 months before = 30% of consultants, and at least 12 months before = 27% of consultants. The ASA members selected the following preferred time spans for determining proper functioning of an implantable cardioverter–defibrillator before the procedure: immediately = 10% of members, at least 3 months before = 39% of members, at least 6 months before = 44% of members, and at least 12 months before = 7% of members. For a pacemaker the following time spans were selected by members: immediately = 9% of members, at least 3 months before = 38%, at least 6 months before = 36%, and at least 12 months before = 18% of consultants.

### Advisory Recommendations for Preoperative Evaluation

- Determine whether a patient has a cardiac implantable electronic device
  - Conduct a focused history (e.g., interview the patient or other source, review medical record, chest x-ray, and electrocardiogram if available)
  - Perform a focused physical examination (e.g., check for scars, palpate for device)<sup>†</sup>
- Determine the cardiac implantable electronic device type, manufacturer, and primary indication for placement
  - Obtain the manufacturer's identification card from the patient or other source
  - Review the medical record
  - Obtain and review the most recent cardiac implantable electronic device interrogation report<sup>#</sup>
  - Refer to supplemental resources (e.g., manufacturer's databases, cardiac implantable electronic device clinic records)
  - Order a chest x-ray if no other data are available<sup>\*\*</sup>

†[Not all implantable electronic devices are cardiac implantable electronic devices (i.e., deep brain stimulators, spinal cord stimulators, vagal nerve stimulators, gastric stimulators, phrenic nerve stimulators, etc.). Although most cardiac implantable electronic device generators are in a pectoral position, some are in the abdomen or in an alternate position in the thorax (i.e., subcutaneous implantable cardioverter–defibrillator). Some cardiac implantable electronic devices are now implanted entirely within the heart (i.e., leadless pacemaker).

#Many cardiac implantable electronic devices now have remote interrogation and monitoring capabilities. Thus, the most recent cardiac implantable electronic device interrogation report might be from an in-office interrogation or from a remote transmission (provided the remote transmission contains all needed information).

\*\*Most cardiac implantable electronic devices have an x-ray code inscribed on the generator that can be used to identify the cardiac implantable electronic device manufacturer.

- Determine whether the patient is pacing-dependent<sup>††</sup>
  - From the focused history and medical record, assess for one or more of the following indicators:
    - Bradycardia that caused syncope or other symptoms resulting in cardiac implantable electronic device implantation
    - Successful atrioventricular nodal ablation resulting in cardiac implantable electronic device implantation
    - A cardiac implantable electronic device interrogation showing no evidence of spontaneous ventricular activity when the cardiac implantable electronic device's pacing function is temporarily programmed to a nontracking mode (*i.e.*, ventricular-only pacing and sensing) at the lowest programmable rate
- Determine the cardiac implantable electronic device's current settings, that it is functioning properly (*i.e.*, by interrogating the cardiac implantable electronic device or obtaining the most recent interrogation report), and that it is optimally programmed for the planned procedure<sup>‡‡§§</sup>
  - Reinterrogate the cardiac implantable electronic device if there is any question of proper function

### Preoperative Preparation

Preoperative preparation for patient safety and proper maintenance of the cardiac implantable electronic device during a planned procedure includes the following topics: (1) sources of electromagnetic interference; (2) preoperative reprogramming of the cardiac implantable electronic device's pacing function to an asynchronous pacing mode or disabling any special algorithms, including rate adaptive pacing functions; (3) suspending the antitachyarrhythmia functions for an implantable cardioverter–defibrillator; and (4) availability of temporary pacing and defibrillation equipment.

**Literature Findings.** The literature was evaluated for the following potential sources of electromagnetic interference: monopolar electrosurgery, bipolar electrosurgery, radiofrequency ablation, lithotripsy, external cardioversion

<sup>††</sup>A patient with an *absent* intrinsic heart rhythm is completely pacing-dependent. A patient with an *inadequate* intrinsic heart rhythm may be considered relatively or functionally pacing-dependent.

<sup>‡‡</sup>In many patients, determining proper cardiac implantable electronic device function can be accomplished by accessing the patient's most recent cardiac implantable electronic device interrogation report. Note that the majority of consultants and ASA members agree that a cardiac implantable electronic device should be interrogated within 3 to 6 months before a procedure.

<sup>§§</sup>A cardiac implantable electronic device specialist might need to be consulted to help determine key information about the cardiac implantable electronic device, whether the patient is pacing-dependent, the cardiac implantable electronic device's current settings, and that it is functioning properly.

or defibrillation, magnetic resonance imaging, radiation therapy, radiofrequency scanners, cardiac monitors, and electroconvulsive therapy.

Observational studies report that electromagnetic interference may occur during monopolar electrosurgery,<sup>11–15</sup> radiofrequency ablation,<sup>16–21</sup> magnetic resonance imaging,<sup>22–35</sup> and radiation therapy<sup>36–42</sup> (*Category B3-H evidence*). Case reports also indicate the occurrence of electromagnetic interference during monopolar electrosurgery,<sup>43–50</sup> bipolar electrosurgery,<sup>51</sup> radiofrequency ablation,<sup>52–54</sup> magnetic resonance imaging,<sup>6–9,55,56</sup> and radiation therapy<sup>57–59</sup> (*Category B4-H evidence*).

Case reports indicate that inappropriately high pacing rates may occur due to electromagnetic interference from cardiac monitoring equipment in cardiac implantable electronic devices with active minute ventilation sensors (*Category B4-H evidence*).<sup>60–62</sup> An observational study of implantable cardioverter–defibrillators in the pectoral position reports a significantly higher occurrence of electromagnetic interference when electrosurgery above the umbilicus is performed compared with electrosurgery below the umbilicus (*Category B1-H evidence*).<sup>15</sup> The literature is insufficient to evaluate the benefit of the availability of temporary pacing and defibrillation equipment during a procedure.

**Survey Findings.** The consultants and ASA members strongly agree that a preoperative evaluation should include determining whether electromagnetic interference from monopolar electrosurgery or other sources is likely to occur and strongly agree with the recommendation to alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient if monopolar electrosurgery (“bovie”) use is planned *superior* to the umbilicus. The consultants disagree and ASA members are equivocal with the recommendation to alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient if monopolar electrosurgery (bovie) use is planned *inferior* to the umbilicus. The consultants and ASA members strongly agree with the recommendation to suspend an implantable cardioverter–defibrillator's antitachycardia function, when present, if monopolar electrosurgery (bovie) use is planned *superior* to the umbilicus. The consultants agree and ASA members are equivocal with the recommendation to suspend an implantable cardioverter–defibrillator's antitachycardia function, when present, if monopolar electrosurgery (bovie) use is planned *inferior* to the umbilicus. The consultants and ASA members strongly agree with the recommendation to ensure that the patient is in a monitored environment before suspending the antitachycardia function of an implantable cardioverter–defibrillator. The consultants are equivocal and ASA members agree with the recommendation to avoid the routine use of a magnet over an implantable cardioverter–defibrillator. The consultants and ASA members strongly

agree that if needed, a specialist should be consulted to alter the pacing function of a cardiac implantable electronic device or to suspend the antitachycardia function of an implantable cardioverter–defibrillator. The consultants and ASA members strongly agree that the proceduralist should be advised to use bipolar electrosurgery or an ultrasonic scalpel when feasible. The consultants and ASA members strongly agree with the recommendation that temporary pacing and defibrillation equipment should be immediately available before, during, and after all procedures with electromagnetic interference potential. Finally, the consultants and ASA members agree with the recommendation that a cardiac implantable electronic device's active sensor for rate-responsive pacing should be suspended to prevent undesirable tachycardia.

### Advisory Recommendations for Preoperative Preparation

- Determine whether intraoperative electromagnetic interference is likely to occur
- If electromagnetic interference is likely to occur (e.g., monopolar electrosurgery [bovie] use, or radiofrequency ablation is planned superior to the umbilicus), alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient<sup>|||###</sup> and suspend an implantable cardioverter–defibrillator's antitachycardia function, if present<sup>\*\*\*</sup>
  - Before suspending the antitachycardia function, ensure that the patient is in a monitored environment
  - Avoid the indiscriminate use of a magnet over an implantable cardioverter–defibrillator

|||If electromagnetic interference is unlikely, it may be unnecessary to alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode. Altering the pacing function of a pacemaker to an asynchronous pacing mode may be accomplished by reprogramming or in many cases by applying a magnet. For most pacemakers, magnet application will initiate asynchronous pacing at a fixed pacing rate with a fixed atrioventricular delay. Some pacemakers have a programmable magnet response or no magnet response (i.e., some leadless pacemakers). Altering the pacing function of an implantable cardioverter–defibrillator to an asynchronous pacing mode must always be accomplished by reprogramming, because magnet application will never alter the pacing mode of an implantable cardioverter–defibrillator.

##If electromagnetic interference is unlikely, it may be unnecessary to suspend the antitachycardia function of an implantable cardioverter–defibrillator. Suspending the antitachycardia function of an implantable cardioverter–defibrillator may be accomplished by reprogramming or in many cases by applying a magnet. A magnet correctly applied to an implantable cardioverter–defibrillator often results in suspension of antitachycardia therapy. For most implantable cardioverter–defibrillators, there is no reliable means to confirm the magnet response. Some implantable cardioverter–defibrillators may have no magnet response. In obese patients or those with a deep generator implant (i.e., subcutaneous implantable cardioverter–defibrillator), magnet application might fail to elicit the magnet response. The antitachycardia function of some older implantable cardioverter–defibrillators can be permanently disabled by magnet application.

\*\*\*Note that the majority of consultants disagree and ASA members are equivocal regarding the recommendation to alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient if monopolar electrosurgery ("bovie") use is planned *inferior* to the umbilicus,

- If needed, consult a specialist to alter the pacing function of a cardiac implantable electronic device or to suspend the antitachycardia function of an implantable cardioverter–defibrillator
- Ensure that temporary pacing and defibrillation equipment are immediately available before, during, and after all procedures with electromagnetic interference potential
- Suspend a cardiac implantable electronic device's active sensor for rate-responsive pacing to prevent undesirable tachycardia<sup>†††</sup>

### Intraoperative Monitoring

Intraoperative monitoring topics include (1) continuous electrocardiography monitoring; (2) continuous oxygen saturation measured by pulse oximetry (SpO<sub>2</sub>) monitoring; and (3) peripheral pulse monitoring (e.g., pulse palpitation, pulse oximeter plethysmogram, or arterial line).

**Literature Findings.** Case reports indicate that continuous electrocardiography monitoring may detect electromagnetic interference-related pacemaker function abnormalities<sup>49,56,63</sup> and cardiac abnormalities<sup>64,65</sup> during a procedure (*Category B4-B evidence*). For cardiac implantable electronic device patients, the literature is insufficient to evaluate the clinical impact of continuous SpO<sub>2</sub> or perioperative peripheral pulse monitoring.

**Survey Findings.** The consultants and ASA members strongly agree with the recommendations to (1) continuously monitor and display a patient's electrocardiogram as required by ASA standards from the beginning of anesthesia until the patient is transferred out of the anesthetizing location, with additional electrocardiography monitoring in the postoperative period as indicated by the patient's medical condition; (2) perform continuous peripheral pulse monitoring for all cardiac implantable electronic device patients receiving anesthesia care; and (3) discontinue the procedure until the source of interference can be eliminated or managed if unanticipated cardiac implantable electronic device interactions occur.

### Advisory Recommendations for Intraoperative Monitoring

- Continuously monitor and display a patient's electrocardiogram and SpO<sub>2</sub> as required by ASA standards<sup>66,67</sup> from the beginning of anesthesia until the patient is transferred out of the anesthetizing location<sup>†††</sup>

†††Suspending the active rate sensor of a pacemaker may be accomplished by reprogramming or in many cases by magnet application. Suspending the active rate sensor of an implantable cardioverter–defibrillator must always be accomplished by reprogramming.

†††The term "continuous" means "prolonged without any interruption at any time" (see Standards for Basic Anesthetic Monitoring, American Society of Anesthesiologists. Approved by the ASA House of Delegates October 21, 1986, and last amended October 28, 2015).

- Perform continuous peripheral pulse monitoring for all cardiac implantable electronic device patients receiving anesthesia care<sup>§§§</sup>
- If unanticipated cardiac implantable electronic device interactions occur, temporarily suspend the procedure until the source of interference can be identified and eliminated or managed

## Managing Potential Sources of Electromagnetic Interference

Procedures using electro-surgery, radiofrequency ablation, radiofrequency identification devices, lithotripsy, magnetic resonance imaging, radiation therapy, nerve conduction studies, cardioversion, or electroconvulsive therapy may damage cardiac implantable electronic devices or interfere with cardiac implantable electronic device function, potentially resulting in severe adverse outcomes. Sources of electromagnetic interference are often unique to specific procedures, and the management of each of these potential electromagnetic interference sources is reported separately below.

### Electrosurgery

Management of potential sources of electromagnetic interference associated with electro-surgery includes the following topics: (1) positioning the electro-surgical unit's dispersive electrode so that the current pathway does not pass through or near the cardiac implantable electronic device generator and leads; (2) avoiding proximity of the electro-surgical unit's electrical current to the generator or leads; (3) using intermittent and irregular bursts of monopolar electro-surgery at the lowest feasible energy levels; (4) using bipolar electro-surgery; and (5) using ultrasonic (harmonic) scalpel.

**Literature Findings.** The literature is insufficient to evaluate whether positioning the current pathway away from the cardiac implantable electronic device generator and leads reduces the occurrence of electromagnetic interference. A case report indicates that electromagnetic interference occurred when the electro-surgical unit's electrical current was placed in proximity to the generator or leads (*Category B4-H evidence*).<sup>68</sup> An observational study reports that electromagnetic interference may occur in spite of positioning the dispersive electrode to divert the return path away from the generator and leads (*Category B3-H evidence*).<sup>15</sup> Case reports also indicate that electromagnetic interference may still occur when proximity is avoided (*Category B4-H evidence*).<sup>46,66</sup> No controlled studies were found that examine the benefit of using short intermittent bursts of electro-surgery at the lowest feasible energy levels. One case report describes pacemaker failure when short bursts of current were used with a bipolar electro-surgery system (*Category B4-H evidence*).<sup>51</sup>

Case reports indicate that cardiac arrhythmias and asystole occurred when monopolar electro-surgery was initiated,

and after changing to bipolar electro-surgery, the procedures proceeded uneventfully (*Category B4-B evidence*).<sup>46,64,65</sup> A case report indicated that dysrhythmias followed by asystole occurred when monopolar electro-surgery was initiated, and after changing to a harmonic scalpel, the procedure was completed successfully (*Category B4-B evidence*).<sup>44</sup>

**Survey Findings.** The consultants and ASA members strongly agree with the recommendations to (1) minimize the risk of electromagnetic interference by positioning the electro-surgical instrument and dispersive electrode (bovie pad) so the current pathway does not pass through or near the cardiac implantable electronic device generator or leads; (2) avoid proximity of the electro-surgery electrical field to the generator and leads, including the avoidance of waving the activated electrode over the generator; and (3) use short, intermittent, and irregular bursts of electro-surgery at the lowest feasible energy levels. The consultants agree and ASA members strongly agree with the recommendations to use bipolar electro-surgery or an ultrasonic (harmonic) scalpel, if possible.

### Radiofrequency Ablation

Management of potential sources of electromagnetic interference associated with radiofrequency ablation primarily involves keeping the radiofrequency current path (electrode tip to current return pad) as far away from the generator and leads as possible.

**Literature Findings.** The literature is insufficient to examine the benefit of avoiding direct contact between the ablation catheter and the generator and leads or of keeping the radiofrequency current path (electrode tip to current return pad) as far away from the generator and leads as possible.

**Survey Findings.** The consultants and ASA members strongly agree with the recommendations to avoid direct contact between the ablation catheter and the generator and leads and to keep the radiofrequency's current path (electrode tip to current return pad) as far away from the generator and leads as possible.

### Lithotripsy

Management of potential sources of electromagnetic interference associated with lithotripsy consists of avoiding focus of the lithotripsy beam near the generator.

**Literature Findings.** The literature is insufficient to evaluate the benefits of focusing the lithotripsy beam away from the generator.

**Survey Findings.** The consultants and ASA members strongly agree with the recommendation to avoid focusing the lithotripsy beam near the generator.

### Magnetic Resonance Imaging

Management of potential sources of electromagnetic interference associated with magnetic resonance imaging include the topics of (1) moving the patient outside of

§§§The peripheral pulse may be continuously monitored with either pulse oximetry plethysmography or an intraarterial pressure waveform.

the immediate magnetic resonance imaging area when an external defibrillator/monitor, cardiac implantable electronic device programmer, or any other magnetic resonance imaging-unsafe equipment is used; (2) interrogating the cardiac implantable electronic device before the magnetic resonance imaging scan; (3) suspending the antitachycardia function of an implantable cardioverter-defibrillator before the magnetic resonance imaging scan; (4) altering the pacing function of the cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient before the magnetic resonance imaging scan; (5) ensuring that an individual capable of programming the cardiac implantable electronic device remains in attendance for the duration of the magnetic resonance imaging scan; and (6) reinterrogating the cardiac implantable electronic device and restoring its permanent settings after the magnetic resonance imaging is completed.<sup>||||</sup>

**Literature Findings.** Observational studies evaluating the effects of suspending the antitachycardia function of an implantable cardioverter-defibrillator report that electromagnetic interference may still occur (*Category B3-E evidence*).<sup>25,30,32,33</sup> Observational studies of magnetic resonance imaging-conditional cardiac implantable electronic devices report that electromagnetic interference does not occur when a cardiac implantable electronic device is programmed to “magnetic resonance imaging mode” and the antitachycardia function is suspended (*Category B3-E evidence*).<sup>22–24</sup>

The literature is insufficient to examine the necessity of: (1) moving the patient outside of the magnetic resonance imaging area when an external defibrillator/monitor, cardiac implantable electronic device programming system, or any other magnetic resonance imaging-unsafe equipment is used; (2) interrogating a cardiac implantable electronic device before magnetic resonance imaging is performed; (3) having an individual capable of programming the cardiac implantable electronic device remain in attendance for the duration of magnetic resonance imaging; and (4) reinterrogating the cardiac implantable electronic device and restoring its permanent settings after magnetic resonance imaging is completed.

**Survey Findings.** The consultants and ASA members strongly agree with the recommendations to move the patient outside of the immediate magnetic resonance imaging area when the use of an external defibrillator/monitor, cardiac implantable electronic device programmer, or any other magnetic resonance imaging-unsafe equipment is required and to monitor the patient’s electrocardiogram and/or SpO<sub>2</sub> continuously throughout the magnetic resonance imaging. The consultants agree and ASA members are equivocal regarding the

recommendation to have an individual capable of programming the cardiac implantable electronic device remain in attendance for the duration of the magnetic resonance imaging.

For magnetic resonance imaging-conditional cardiac implantable electronic devices, the consultants strongly agree and ASA members agree with the recommendations to interrogate a cardiac implantable electronic device, program the cardiac implantable electronic device to magnetic resonance imaging mode, suspend the antitachycardia function of an implantable cardioverter-defibrillator, and alter the pacing function of the cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient before the magnetic resonance imaging. The consultants and ASA members strongly agree with the recommendation to reinterrogate the cardiac implantable electronic device and restore its permanent settings after the magnetic resonance imaging scan.

For magnetic resonance imaging nonconditional cardiac implantable electronic devices, the consultants strongly agree and ASA members agree with the recommendations to interrogate a cardiac implantable electronic device before the magnetic resonance imaging scan, alter the pacing function of the cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient, and suspend the antitachycardia function of an implantable cardioverter-defibrillator if present. The consultants and ASA members strongly agree with the recommendation to reinterrogate the cardiac implantable electronic device and restore its permanent settings after the magnetic resonance imaging scan.

### Radiofrequency Identification Devices

Radiofrequency identification devices are scanners used to detect retained surgical items. Management of potential sources of electromagnetic interference associated with radiofrequency identification devices addresses the topic of avoiding the use of these devices in close proximity to a cardiac implantable electronic device.

**Literature Findings.** The literature is insufficient to evaluate either the impact of radiofrequency identification devices as a source of electromagnetic interference or to evaluate whether electromagnetic interference depends on the distance between the radiofrequency source and cardiac implantable electronic device in the perioperative setting.

**Survey Findings.** For radiofrequency identification devices, the consultants strongly agree and ASA members agree with the recommendations to avoid using radiofrequency identification devices in close proximity to the cardiac implantable electronic device whenever possible.

### Electroconvulsive Therapy

Management of potential sources of electromagnetic interference associated with electroconvulsive therapy includes the topics of altering the pacing function of a cardiac implantable

|||||Note that some cardiac implantable electronic devices are labeled by the Food and Drug Administration as magnetic resonance imaging-conditional. Any cardiac implantable electronic device system not labeled as such by the Food and Drug Administration is considered non-magnetic resonance imaging-conditional.

electronic device to an asynchronous pacing mode in the pacing-dependent patient, suspending an implantable cardioverter-defibrillator's antitachycardia functions, and monitoring and treating ventricular arrhythmias that may occur secondary to the hemodynamic effects of electroconvulsive therapy.

**Literature Findings.** The literature is insufficient to evaluate the effects of specific management activities related to electroconvulsive therapy.

**Survey Findings.** The consultants and ASA members agree with the recommendations to alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient and to suspend an implantable cardioverter-defibrillator's antitachycardia functions, if present. The consultants and ASA members strongly agree with the recommendation to monitor for and treat ventricular arrhythmias that may occur secondary to the hemodynamic effects of electroconvulsive therapy.

### Advisory Recommendations for Managing Potential Sources of Electromagnetic Interference

#### Electrosurgery

- If monopolar electrosurgery is planned superior to the umbilicus, ensure that the pacing function of a cardiac implantable electronic device is altered to an asynchronous pacing mode in the pacing-dependent patient and suspend an implantable cardioverter-defibrillator's antitachycardia function, if present
  - Before suspending the antitachycardia function of an implantable cardioverter defibrillator, ensure that the patient is in a monitored environment
- Minimize the risk of electromagnetic interference from monopolar electrosurgery
  - Position the electrosurgical instrument and dispersive electrode (bovie pad) so the current pathway does not pass through or near the cardiac implantable electronic device generator or leads<sup>####</sup>
  - Avoid waving the activated electrode over the generator<sup>####</sup>
  - Use short, intermittent, and irregular bursts of electrosurgery at the lowest feasible energy levels
- Use bipolar electrosurgery or an ultrasonic (harmonic) scalpel, if possible

<sup>####</sup>For some cases, the electrosurgical dispersive electrode will need to be placed at a site different from the thigh. For example, in head and neck cases, the dispersive electrode may be placed on the posterior superior aspect of the shoulder contralateral to the generator position.

<sup>\*\*\*\*</sup>An underbody electrosurgery dispersive electrode that is incorporated into a pad and placed directly on the operating table is sometimes used instead of a conventional dispersive electrode. In patients with a cardiac implantable electronic device, there is insufficient evidence to determine the impact of using an underbody dispersive electrode as compared with a conventional dispersive electrode on the risk of electromagnetic interference.

<sup>+++</sup>An inhibitory effect could occur even when the active electrode of the electrosurgery instrument is not touching the patient.

#### Radiofrequency Ablation

- If radiofrequency ablation is planned superior to the umbilicus, ensure that the pacing function of a cardiac implantable electronic device is altered to an asynchronous pacing mode in the pacing-dependent patient and suspend an implantable cardioverter-defibrillator's antitachycardia function, if present
  - Before suspending the antitachycardia function, ensure that the patient is in a monitored environment
- Avoid direct contact between the ablation catheter and the generator and leads
- Keep the radiofrequency's current path (electrode tip to current return pad) as far away from the generator and leads as possible

#### Lithotripsy

- Do not focus the lithotripsy beam near the generator

#### Magnetic Resonance Imaging<sup>###</sup>

- Ensure that a standardized workflow and/or institutional protocol is in place and followed
- Move the patient outside of the immediate magnetic resonance imaging area when the use of an external defibrillator/monitor, cardiac implantable electronic device programmer, or any other magnetic resonance imaging-unsafe equipment is required
- Before the magnetic resonance imaging scan, perform the following:
  - Interrogate the cardiac implantable electronic device
  - Suspend the antitachycardia function of an implantable cardioverter-defibrillator, if present
    - For magnetic resonance imaging-conditional cardiac implantable electronic devices, adhere to all product labeling including activating magnetic resonance imaging mode to suspend the antitachycardia function of a magnetic resonance imaging-conditional implantable cardioverter-defibrillator<sup>####</sup>
    - In the pacing-dependent patient, alter the pacing function of the cardiac implantable electronic device to an asynchronous pacing mode

<sup>###</sup>More information about the management of patients with cardiac implantable electronic devices undergoing magnetic resonance imaging or radiation therapy may be found in the 2017 Heart Rhythm Society Expert Consensus Statement on Magnetic Resonance Imaging and Radiation Exposure in Patients with Cardiovascular Implantable Electronic Devices (<https://www.hrsonline.org/2017-hrs-expert-consensus-statement-cardiovascular-implantable-electronic-device-lead-management>; accessed August 7, 2019).

<sup>####</sup>Some cardiac implantable electronic devices are labeled by the Food and Drug Administration as magnetic resonance imaging-conditional. These systems have been approved for magnetic resonance imaging under specific conditions of use. Cardiac implantable electronic devices that do not meet these criteria are non-magnetic resonance imaging-conditional. In many centers, magnetic resonance imaging remains contraindicated in the presence of a magnetic resonance imaging nonconditional cardiac implantable electronic device; however, some centers have implemented specific protocols allowing patients with a nonconditional cardiac implantable electronic device to undergo magnetic resonance imaging.



- Ensure that an individual capable of performing advanced cardiac life support remains in attendance for the duration of the magnetic resonance imaging scan.
- Ensure that an individual capable of programming the cardiac implantable electronic device is readily available for consultation or remains in attendance for the duration of the magnetic resonance imaging scan whenever dictated by institutional policy
- After the magnetic resonance imaging scan is completed, reinterrogate the cardiac implantable electronic device and restore its permanent settings

### Radiofrequency Identification Devices

- Avoid using radiofrequency identification devices in close proximity to the cardiac implantable electronic device whenever possible
- Monitor for signs of electromagnetic interference and be prepared to stop using the radiofrequency identification device if interference occurs

### Electroconvulsive Therapy

- Alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient
- Suspend an implantable cardioverter–defibrillator’s antitachycardia function, if present
- Monitor for and be prepared to manage postconvulsive sinus tachycardia
- Monitor for and treat ventricular arrhythmias that may occur secondary to the hemodynamic effects of electroconvulsive therapy

### Emergency External Cardioversion or Defibrillation

During the perioperative period, the cardiac implantable electronic device patient might require emergency external defibrillation or cardioversion. In this case, a concern is to minimize the current flowing through the pulse generator and leads.

**Literature Findings.** The literature is insufficient to evaluate the effects of specific management activities related to emergency defibrillation or cardioversion.

**Survey Findings.** The consultants and ASA members agree with the recommendation that before emergently defibrillating or cardioverting a patient with an implantable cardioverter–defibrillator and magnet-disabled therapies, all sources of electromagnetic interference should be terminated, and the magnet should be removed to reenoble the implantable cardioverter–defibrillator’s antitachycardia therapies; then the patient should be observed for the delivery of appropriate antitachycardia therapy from the implantable cardioverter–defibrillator. The consultants agree and ASA members strongly agree with the

recommendation to determine whether the antitachycardia therapy of an implantable cardioverter–defibrillator should be reenoble when it has been disabled by programming. The consultants and ASA members strongly agree that if the above activities fail to restore implantable cardioverter–defibrillator antitachycardia function, emergency external defibrillation or cardioversion should be performed when needed using advanced cardiac life support guidelines for delivered energy level and pad placement. The consultants and ASA members strongly agree with the recommendation to minimize the current flowing through the generator and leads by positioning the defibrillation or cardioversion pads so they are not directly over the cardiac implantable electronic device. The consultants strongly agree and ASA members agree with the recommendation to use anterior–posterior rather than anterior–lateral pad positioning whenever possible. The consultants and ASA members strongly agree with the recommendations to use a clinically appropriate energy output regardless of the presence of the cardiac implantable electronic device and to interrogate the cardiac implantable electronic device immediately after external cardioversion or defibrillation is performed.

### Advisory Recommendations for Emergency Cardioversion or Defibrillation

- Before attempting to emergently externally cardiovert or defibrillate a patient with an implantable cardioverter–defibrillator and magnet-disabled therapies, terminate all sources of electromagnetic interference and remove the magnet to reenoble the implantable cardioverter–defibrillator’s antitachycardia therapies
  - Observe the patient for appropriate antitachycardia therapy from the implantable cardioverter–defibrillator
  - Determine the need for reenabling an implantable cardioverter–defibrillator’s antitachycardia therapy if it was disabled by programming
- If the above activities fail to restore the implantable cardioverter’s antitachycardia therapy, or if the antitachycardia therapy cannot be restored expeditiously, proceed with emergency external cardioversion or defibrillation when needed.
  - Follow advanced cardiac life support guidelines for delivered energy level and pad placement
  - Position the cardioversion and defibrillation pads so they are not directly over the cardiac implantable electronic device generator to minimize the current flowing through the generator and leads
  - Use a clinically appropriate energy output regardless of the presence of a cardiac implantable electronic device
  - Interrogate the cardiac implantable electronic device immediately after external cardioversion or defibrillation is performed

## Postoperative Management

Postoperative management of cardiac implantable electronic device patients primarily consists of interrogating and restoring cardiac implantable electronic device function.

**Literature Findings.** An observational study reports that postoperative interrogation revealed cardiac implantable electronic device malfunctions that occurred during a procedure (*Category B3-B evidence*).<sup>41</sup> Case reports also indicate that postoperative interrogation may have revealed intraoperative changes to cardiac implantable electronic device settings; subsequently the devices were reprogrammed to their original settings, except in one case where the device was damaged to the point it had to be replaced (*Category B4-B evidence*).<sup>10,52</sup> The literature is insufficient to evaluate the benefits of: (1) continuing to monitor and display a patient's electrocardiogram; (2) monitoring cardiac rate and rhythm throughout the immediate postoperative period; (3) ensuring that back-up pacing and cardioversion–defibrillation equipment are immediately available; and (4) restoring the cardiac implantable electronic device to its permanent setting before the patient is discharged from a monitored environment when the cardiac implantable electronic device has been reprogrammed pre- or intraoperatively.

**Survey Findings.** The consultants and ASA members strongly agree with the following recommendations: (1) continuously monitor cardiac rate and rhythm throughout the immediate postoperative period; (2) for a cardiac implantable electronic device that was reprogrammed pre- or intraoperatively, ensure that back-up pacing and cardioversion–defibrillation equipment is immediately available until the permanent settings are restored; (3) for a cardiac implantable electronic device that was reprogrammed pre- or intraoperatively, restore the cardiac implantable electronic device to its permanent settings before the patient is discharged from a monitored environment; (4) if interrogation determines that the cardiac implantable electronic device settings are inappropriate, then reprogram the cardiac implantable electronic device to newly appropriate settings; (5) perform a postoperative cardiac implantable electronic device interrogation if emergency surgery occurred without appropriate preoperative cardiac implantable electronic device evaluation; (6) perform a postoperative cardiac implantable electronic device interrogation if there is suspicion that antitachycardia therapy might have been disabled rather than temporarily suspended with magnet placement; (7) perform a postoperative cardiac implantable electronic device interrogation if significant electromagnetic interference occurred in close proximity to the cardiac implantable electronic device; and (8) perform a postoperative cardiac implantable electronic device interrogation if the delivery of antitachycardia therapy was observed or if there is concern for cardiac implantable electronic device malfunction. The consultants strongly agree and ASA members agree that if the cardiac implantable electronic device is not interrogated during the immediate postoperative period, interrogate it within 30 days after the procedure.

## Advisory Recommendations for Postoperative Management

- Continue to monitor and display a patient's cardiac rate and rhythm throughout the immediate postoperative period as required by ASA standards and as indicated by the patient's medical condition
- For a cardiac implantable electronic device that was reprogrammed pre- or intraoperatively:
  - Ensure that back-up pacing and cardioversion–defibrillation equipment are immediately available until the cardiac implantable electronic device's permanent settings are restored<sup>|||||</sup>
  - Ensure that the patient's cardiac rate and rhythm are continuously monitored and displayed until the cardiac implantable electronic device's permanent settings are restored<sup>####</sup>
  - Ensure that the patient remains in a monitored environment until the cardiac implantable electronic device's permanent settings are restored (*e.g.*, until the antitachycardia function of an implantable cardioverter–defibrillator is reenabled)
- Perform a postoperative cardiac implantable electronic device interrogation whenever:
  - Emergency surgery occurs without appropriate preoperative cardiac implantable electronic device evaluation
  - There is suspicion that antitachycardia therapy might have been disabled rather than temporarily suspended with magnet placement<sup>\*\*\*\*\*</sup>
  - The delivery of antitachycardia therapy was observed or suspected
  - There is concern for cardiac implantable electronic device malfunction (*i.e.*, significant electromagnetic interference occurred in close proximity to the cardiac implantable electronic device, an invasive procedure was performed in close proximity to a cardiac implantable electronic device generator or lead, or large fluid shifts occurred)
- If interrogation determines that the cardiac implantable electronic device settings are inappropriate, reprogram to newly appropriate settings<sup>++++</sup>

||||| Postoperative cardiac implantable electronic device interrogation may not be needed in low-risk situations (*e.g.*, appropriate preoperative cardiac implantable electronic device interrogation, no electromagnetic interference-generating devices used during the procedure, no perioperative reprogramming occurred, and no problems identified during the procedure).

#### In some instances, new settings may be needed.

\*\*\*\*\* Although the antitachycardia function of some older implantable cardioverter–defibrillators can be permanently disabled by magnet application, these implantable cardioverter–defibrillators are unlikely to still be encountered.

++++ If the cardiac implantable electronic device is not interrogated during the immediate postoperative period, an interrogation after the patient is discharged may be warranted. Note that the expert consultants strongly agree and ASA members agree that interrogation should occur within 30 days after a procedure.

## Appendix 1: Summary of Advisory Recommendations<sup>####</sup>

### Preoperative Evaluation

- Determine whether a patient has a cardiac implantable electronic device (cardiac implantable electronic device)
  - Conduct a focused history (*e.g.*, interview the patient or other source, review medical record, chest x-ray, and electrocardiogram if available)
  - Perform a focused physical examination (*e.g.*, check for scars, palpate for device)<sup>#####</sup>
- Determine the cardiac implantable electronic device type, manufacturer, and primary indication for placement
  - Obtain the manufacturer's identification card from the patient or other source
  - Review the medical record
  - Obtain and review the most recent cardiac implantable electronic device interrogation report<sup>#####</sup>
  - Refer to supplemental resources (*e.g.*, manufacturer's databases, cardiac implantable electronic device clinic records)
  - Order a chest x-ray if no other data are available<sup>#####</sup>
- Determine whether the patient is pacing-dependent<sup>#####</sup>
  - From the focused history and medical record, assess for one or more of the following indicators:
    - Bradycardia that caused syncope or other symptoms resulting in cardiac implantable electronic device implantation
    - Successful atrioventricular nodal ablation resulting in cardiac implantable electronic device implantation
    - A cardiac implantable electronic device interrogation showing no evidence of spontaneous ventricular activity when the cardiac implantable electronic device's pacing function is temporarily programmed to a nontracking mode (*i.e.*, ventricular-only pacing and sensing) at the lowest programmable rate

####Refer to table 3 for an example of a stepwise approach to the perioperative management of the patient with a cardiac implantable electronic device.

#####Not all implantable electronic devices are cardiac implantable electronic devices (*i.e.*, deep brain stimulators, spinal cord stimulators, vagal nerve stimulators, gastric stimulators, phrenic nerve stimulators, *etc.*). Although most cardiac implantable electronic device generators are in a pectoral position, some are in the abdomen or in an alternate position in the thorax (*i.e.*, subcutaneous implantable cardioverter–defibrillator). Some cardiac implantable electronic devices are now implanted entirely within the heart (*i.e.*, leadless pacemaker).

#####Many cardiac implantable electronic devices now have remote interrogation and monitoring capabilities. Thus, the most recent cardiac implantable electronic device interrogation report might be from an in-office interrogation or from a remote transmission (provided the remote transmission contains all needed information).

#####Most cardiac implantable electronic devices have an x-ray code inscribed on the generator that can be used to identify the cardiac implantable electronic device manufacturer.

#####A patient with an *absent* intrinsic heart rhythm is completely pacing-dependent. A patient with an *inadequate* intrinsic heart rhythm may be considered relatively or functionally pacing-dependent.

- Determine the cardiac implantable electronic device's current settings, that it is functioning properly (*i.e.*, by interrogating the cardiac implantable electronic device or obtaining the most recent interrogation report), and that it is optimally programmed for the planned procedure<sup>#####</sup>
  - Reinterrogate the cardiac implantable electronic device if there is any question of proper function

### Preoperative Preparation

- Determine whether intraoperative electromagnetic interference is likely to occur.
- If electromagnetic interference is likely to occur (*e.g.*, monopolar electrosurgery ["bovie"] use, or radiofrequency ablation is planned superior to the umbilicus), alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient<sup>#####</sup> and suspend an implantable cardioverter–defibrillator's antitachycardia function, if present<sup>#####</sup>
  - Before suspending the antitachycardia function, ensure that the patient is in a monitored environment

#####In many patients, determining proper cardiac implantable electronic device function can be accomplished by accessing the patient's most recent cardiac implantable electronic device interrogation report. Note that the majority of consultants and ASA members agree that a cardiac implantable electronic device should be interrogated within 3 to 6 months before a procedure.

#####A cardiac implantable electronic device specialist might need to be consulted to help determine key information about the cardiac implantable electronic device, whether the patient is pacing-dependent, the cardiac implantable electronic device's current settings, and that it is functioning properly.

#####If electromagnetic interference is unlikely, it may be unnecessary to alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode. Altering the pacing function of a pacemaker to an asynchronous pacing mode may be accomplished by reprogramming or in many cases by applying a magnet. For most pacemakers, magnet application will initiate asynchronous pacing at a fixed pacing rate with a fixed atrioventricular delay. Some pacemakers have a programmable magnet response or no magnet response (*i.e.*, some leadless pacemakers). Altering the pacing function of an implantable cardioverter–defibrillator to an asynchronous pacing mode must always be accomplished by reprogramming, because magnet application will never alter the pacing mode of an implantable cardioverter–defibrillator.

#####If electromagnetic interference is unlikely, it may be unnecessary to suspend the antitachycardia function of an implantable cardioverter–defibrillator. Suspending the antitachycardia function of an implantable cardioverter–defibrillator may be accomplished by reprogramming or in many cases by applying a magnet. A magnet correctly applied to an implantable cardioverter–defibrillator often results in suspension of antitachycardia therapy. For most implantable cardioverter–defibrillators, there is no reliable means to confirm the magnet response. Some implantable cardioverter–defibrillators may have no magnet response. In obese patients or those with a deep cardiac implantable electronic device implant (*i.e.*, subcutaneous implantable cardioverter–defibrillator), magnet application might fail to elicit the magnet response. The antitachycardia function of some older implantable cardioverter–defibrillators can be permanently disabled by magnet application.

#####Note that the majority of consultants disagree and ASA members are equivocal regarding the recommendation to alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient if monopolar electrosurgery ("bovie") use is planned *inferior* to the umbilicus,

- Avoid the indiscriminate use of a magnet over an implantable cardioverter–defibrillator
- If needed, consult a specialist to alter the pacing function of a cardiac implantable electronic device or to suspend the antitachycardia function of an implantable cardioverter–defibrillator
- Ensure that temporary pacing and defibrillation equipment are immediately available before, during, and after all procedures with electromagnetic interference potential
- Suspend a cardiac implantable electronic device’s active sensor for rate–responsive pacing to prevent undesirable tachycardia<sup>+++++</sup>

### Intraoperative Monitoring

- Continuously monitor and display a patient’s electrocardiogram and SpO<sub>2</sub> as required by American Society of Anesthesiologists (ASA) standards<sup>66,67</sup> from the beginning of anesthesia until the patient is transferred out of the anesthetizing location<sup>+++++</sup>
- Perform continuous peripheral pulse monitoring for all cardiac implantable electronic device patients receiving anesthesia care<sup>ssssss</sup>
- If unanticipated cardiac implantable electronic device interactions occur, temporarily suspend the procedure until the source of interference can be identified and eliminated or managed

### Managing Potential Sources of Electromagnetic Interference

#### Electrosurgery

- If monopolar electrosurgery is planned superior to the umbilicus, ensure that the pacing function of a cardiac implantable electronic device is altered to an asynchronous pacing mode in the pacing–dependent patient and suspend an implantable cardioverter–defibrillator’s antitachycardia function, if present
  - Before suspending the antitachycardia function, ensure that the patient is in a monitored environment
- Minimize the risk of electromagnetic interference from monopolar electrosurgery

+++++Suspending the active rate sensor of a pacemaker may be accomplished by reprogramming or in many cases by magnet application. Suspending the active rate sensor of an implantable cardioverter–defibrillator must always be accomplished by reprogramming.

+++++The term “continuous” means “prolonged without any interruption at any time” (see Standards for Basic Anesthetic Monitoring, American Society of Anesthesiologists; approved by the ASA House of Delegates October 21, 1986; last amended October 28, 2015).

ssssssThe peripheral pulse may be continuously monitored with either pulse oximetry plethysmography or an intraarterial pressure waveform.

- Position the electrosurgical instrument and dispersive electrode (“bovie pad”) so the current pathway does not pass through or near the cardiac implantable electronic device generator or leads<sup>+++++</sup>
- Avoid waving the activated electrode over the generator<sup>\*\*\*\*\*</sup>
- Use short, intermittent, and irregular bursts of electrosurgery at the lowest feasible energy levels
- Use bipolar electrosurgery or an ultrasonic (harmonic) scalpel, if possible

#### Radiofrequency Ablation

- If radiofrequency ablation is planned superior to the umbilicus, ensure that the pacing function of a cardiac implantable electronic device is altered to an asynchronous pacing mode in the pacing–dependent patient and suspend an implantable cardioverter–defibrillator’s antitachycardia function, if present
  - Before suspending the antitachycardia function, ensure that the patient is in a monitored environment
- Avoid direct contact between the ablation catheter and the generator and leads
- Keep the radiofrequency’s current path (electrode tip to current return pad) as far away from the generator and leads as possible

#### Lithotripsy

- Do not focus the lithotripsy beam near the generator

#### Magnetic Resonance Imaging<sup>+++++</sup>

- Ensure that a standardized workflow and/or institutional protocol is in place and followed
- Move the patient outside of the immediate magnetic resonance imaging area when the use of an external defibrillator/monitor, cardiac implantable electronic device programmer, or any other magnetic resonance imaging–unsafe equipment is required

|||||||For some cases, the electrosurgical dispersive electrode will need to be placed at a site different from the thigh. For example, in head and neck cases, the dispersive electrode may be placed on the posterior superior aspect of the shoulder contralateral to the generator position.

#####An underbody electrosurgery dispersive electrode that is incorporated into a pad and placed directly on the operating table is sometimes used instead of a conventional dispersive electrode. In patients with a cardiac implantable electronic device, there is insufficient evidence to determine the impact of using an underbody dispersive electrode as compared with a conventional dispersive electrode on the risk of electromagnetic interference.

\*\*\*\*\*An inhibitory effect could occur even when the active electrode of the electrosurgery instrument is not touching the patient.

+++++More information about the management of patients with cardiac implantable electronic devices undergoing magnetic resonance imaging or radiation therapy may be found in the 2017 Heart Rhythm Society Expert Consensus Statement on Magnetic Resonance Imaging and Radiation Exposure in Patients with Cardiovascular Implantable Electronic Devices (<https://www.hrsonline.org/2017-hrs-expert-consensus-statement-cardiovascular-implantable-electronic-device-lead-management>; accessed August 7, 2019).

- Before the magnetic resonance imaging scan, perform the following:
  - Interrogate the cardiac implantable electronic device
  - Suspend the antitachycardia function of an implantable cardioverter–defibrillator, if present
    - For magnetic resonance imaging–conditional cardiac implantable electronic devices, adhere to all product labeling including activating “magnetic resonance imaging mode” to suspend the antitachycardia function of a magnetic resonance imaging–conditional implantable cardioverter–defibrillator<sup>#####</sup>
    - In the pacing-dependent patient, alter the pacing function of the cardiac implantable electronic device to an asynchronous pacing mode
- Ensure that an individual capable of performing advanced cardiac life support remains in attendance for the duration of the magnetic resonance imaging scan
- Ensure that an individual capable of programming the cardiac implantable electronic device is readily available for consultation or remains in attendance for the duration of the magnetic resonance imaging scan whenever dictated by institutional policy
- After the magnetic resonance imaging scan is completed, reinterrogate the cardiac implantable electronic device and restore its permanent settings

### Radiofrequency Identification Devices

- Avoid using radiofrequency identification devices in close proximity to the cardiac implantable electronic device, whenever possible
- Monitor for signs of electromagnetic interference and be prepared to stop using the radiofrequency identification device if interference occurs

### Electroconvulsive Therapy

- Alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient
- Suspend an implantable cardioverter–defibrillator’s antitachycardia function, if present
- Monitor for and be prepared to manage postconvulsive sinus tachycardia

#####Some cardiac implantable electronic devices are labeled by the Food and Drug Administration as magnetic resonance imaging–conditional. These systems have been approved for magnetic resonance imaging under specific conditions of use. Cardiac implantable electronic devices that do not meet these criteria are non-magnetic resonance imaging–conditional. In many centers, magnetic resonance imaging remains contraindicated in the presence of a non-magnetic resonance imaging–conditional cardiac implantable electronic device; however, some centers have implemented specific protocols allowing patients with a nonconditional cardiac implantable electronic device to undergo magnetic resonance imaging.

- Monitor for and treat ventricular arrhythmias that may occur secondary to the hemodynamic effects of electroconvulsive therapy

### Emergency Cardioversion or Defibrillation

- Before attempting to emergently externally cardiovert or defibrillate a patient with an implantable cardioverter–defibrillator and magnet-disabled therapies, terminate all sources of electromagnetic interference and remove the magnet to reenabling the implantable cardioverter–defibrillator’s antitachycardia therapies
  - Observe the patient for appropriate antitachycardia therapy from the implantable cardioverter–defibrillator
  - Determine the need for reenabling an implantable cardioverter–defibrillator’s antitachycardia therapy if it was disabled by programming
- If the above activities fail to restore the implantable cardioverter’s antitachycardia therapy, or if the antitachycardia therapy cannot be restored expeditiously, proceed with emergency external cardioversion or defibrillation when needed.
  - Follow advanced cardiac life support guidelines for delivered energy level and pad placement
  - Position the cardioversion and defibrillation pads so they are not directly over the cardiac implantable electronic device generator to minimize the current flowing through the generator and leads
  - Use a clinically appropriate energy output regardless of the presence of a cardiac implantable electronic device
  - Interrogate the cardiac implantable electronic device immediately after external cardioversion or defibrillation is performed

### Postoperative Management

- Continue to monitor and display a patient’s cardiac rate and rhythm throughout the immediate postoperative period as required by ASA standards and as indicated by the patient’s medical condition
- For a cardiac implantable electronic device that was reprogrammed pre- or intraoperatively:
  - Ensure that back-up pacing and cardioversion–defibrillation equipment are immediately available until the cardiac implantable electronic device’s permanent settings are restored<sup>§§§§§§</sup>

§§§§§§Postoperative cardiac implantable electronic device interrogation may not be needed in low-risk situations (e.g., appropriate preoperative cardiac implantable electronic device interrogation, no electromagnetic interference-generating devices used during the procedure, no perioperative reprogramming occurred, and no problems identified during the procedure).

- Ensure the patient's cardiac rate and rhythm are continuously monitored and displayed until the cardiac implantable electronic device's permanent settings are restored
- Ensure the patient remains in a monitored environment until the cardiac implantable electronic device's permanent settings are restored (*e.g.*, until the antitachycardia function of an implantable cardioverter–defibrillator is reenabled)
- Perform a postoperative cardiac implantable electronic device interrogation whenever:
  - Emergency surgery occurred without appropriate preoperative cardiac implantable electronic device evaluation
  - There is suspicion that antitachycardia therapy might have been disabled rather than temporarily suspended with magnet placement
  - The delivery of antitachycardia therapy was observed or suspected
  - There is concern for cardiac implantable electronic device malfunction (*i.e.*, significant electromagnetic interference occurred in close proximity to the cardiac implantable electronic device, an invasive procedure was performed in close proximity to a cardiac implantable electronic device generator or lead, or large fluid shifts occurred)
- If interrogation determines that the cardiac implantable electronic device settings are inappropriate, reprogram to newly appropriate settings

## Appendix 2: Methods and Analyses

For this updated practice advisory, a systematic search and review of peer-reviewed published literature was conducted, with scientific findings summarized and reported below and in the document. Assessment of conceptual issues and the practicality and feasibility of the advisory recommendations were also evaluated, with opinion data collected from surveys and other sources. Both the systematic literature review and the opinion data are based on evidence linkages or statements regarding potential relationships between perioperative interventions and electromagnetic interference (electromagnetic interference) outcomes associated with cardiac implantable electronic devices (cardiac implantable electronic devices). The evidence linkage interventions are listed

||||| In some instances, new settings may be needed.

##### Although the antitachycardia function of some older implantable cardioverter–defibrillators can be permanently disabled by magnet application, these implantable cardioverter–defibrillators are unlikely to still be encountered.

\*\*\*\*\* If the cardiac implantable electronic device is not interrogated during the immediate postoperative period, an interrogation after the patient is discharged may be warranted. Note that the expert consultants strongly agree and ASA members agree that interrogation should occur within 30 days after a procedure.

below. The evidence model below guided the search, providing inclusion and exclusion information regarding patients, procedures, practice settings, providers, clinical interventions, and outcomes. After review of all evidentiary information, the task force placed each recommendation into one of three categories: (1) provide the intervention or treatment; (2) the intervention or treatment may be provided to the patient based on circumstances of the case and the practitioner's clinical judgment; or (3) do not provide the intervention or treatment. The American Society of Anesthesiologists (ASA) Committee on Standards and Practice Parameters reviews all practice parameters at the ASA annual meeting and determines update and revision timelines. The policy of the ASA Committee on Standards and Practice Parameters is to update practice guidelines every 5 yr.

## Evidence Model

### Patients

- Inclusion criteria:
  - Patients with permanently implanted cardiac implantable electronic device for treatment of a bradyarrhythmia, tachyarrhythmia, or heart failure
    - Implantable cardiac pacemakers
    - Implantable cardioverter–defibrillators
    - Cardiac resynchronization devices
- Exclusion criteria:
  - Patients undergoing cardiac implantable electronic device implantation or revision
  - Patients without a permanently implantable pacemaker or implantable cardioverter–defibrillator
  - Patients with a temporary cardiac implantable electronic device

### Procedures

- Inclusion criteria:
  - Inpatient procedures
  - Outpatient procedures
- Exclusion criteria:
  - Procedures without known perioperative cardiac implantable electronic device–related concerns
    - Plain radiography
    - Fluoroscopy
    - Mammography
    - Ultrasonography

### Practice Settings

- Inclusion criteria:
  - Any perioperative setting in which an anesthesia provider will be delivering anesthesia care

- Preoperative settings
- Intraoperative settings
- Postoperative settings
- Recovery settings
- Exclusion criteria:
  - Nonperioperative settings

### Providers

- Inclusion criteria:
  - Anesthesia care providers
    - Anesthesiologists
    - All other individuals who deliver or are responsible for anesthesia care
- Exclusion criteria:
  - Individuals who do not deliver or are responsible for anesthesia care

### Interventions

- Inclusion criteria:
  - Preoperative patient evaluation
    - Establish whether a patient has a cardiac implantable device
      - Conduct a focused history
      - Obtain manufacturer's identification card from patient or other source
      - Order chest x-ray if no other data are available
      - Refer to supplemental resources (*e.g.*, manufacturer's databases)
    - Determine cardiac implantable electronic device dependency
    - Determine cardiac implantable electronic device function
      - Cardiac implantable electronic device interrogation
      - Determine whether a cardiac implantable electronic device will capture when it paces
      - Contact the manufacturer
  - Preoperative preparation
    - Determine whether electromagnetic interference occurs during procedure
      - Electrosurgery
      - Radiofrequency ablation
      - Lithotripsy
      - External cardioversion or defibrillation
      - Magnetic resonance imaging
      - Electroconvulsive therapy

- Determine whether reprogramming a cardiac implantable electronic device to an asynchronous pacing mode is needed
  - Electrosurgery
  - Radiofrequency ablation
  - Lithotripsy
  - Magnetic resonance imaging
- Program antitachyarrhythmia therapy off
- Temporary pacing and cardioversion and defibrillation equipment immediately available
- Use of a bipolar electrosurgery or ultrasonic scalpel
- Intraoperative management
  - Monitor operation of the cardiovascular device
    - Electrocardiography monitoring (per ASA standard)
    - Monitor pulse wave form (*e.g.*, pulse oximeter plethysmogram, intraarterial pressure)
  - Management of potential cardiac implantable electronic device dysfunction due to electromagnetic interference
    - Electrosurgery
      - Position the dispersive electrode so that the current pathway does not pass through or near the cardiac electronic device generator and leads
      - Avoid direct contact with the generator or leads
      - Use short, intermittent, and irregular bursts at the lowest feasible energy levels
      - Use bipolar electrosurgery system or ultrasonic scalpel
      - Use an ultrasonic (harmonic) scalpel (an ultrasonic scalpel can be safely used without affecting a pacemaker or implantable cardioverter–defibrillator)
    - Radiofrequency ablation
      - Keep the current path as far away from the generator and leads as possible
      - Avoid proximity of the ablation catheter to the leads (intercardiac ablative procedures)
    - Lithotripsy
      - Avoid focusing the lithotripsy beam near the pulse generator
    - Magnetic resonance imaging
      - Move the patient outside of the immediate magnetic resonance imaging scan area when the use of an external monitor or cardioverter

defibrillator, cardiac implantable electronic device programmer, or any other magnetic resonance imaging-unsafe equipment is required

- Monitor the patient's electrocardiogram and/or SpO<sub>2</sub> continuously throughout the magnetic resonance imaging scan
- An individual capable of programming the cardiac implantable electronic device remaining in attendance for the duration of the magnetic resonance imaging scan

Magnetic resonance imaging-conditional cardiac implantable electronic devices

- Before the magnetic resonance imaging, interrogate the cardiac implantable electronic device and program to "magnetic resonance imaging mode" to suspend the antitachycardia function or an implantable cardioverter-defibrillator
- Alter the pacing function of the cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient
- After the magnetic resonance imaging scan is completed, reinterrogate the cardiac implantable electronic device and restore its permanent settings

Magnetic resonance imaging nonconditional cardiac implantable electronic devices

- Interrogate the cardiac implantable electronic device before and after the magnetic resonance imaging scan
- Reprogram the cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient
- Suspend the antitachycardia function of an implantable cardioverter-defibrillator, if present
- After the magnetic resonance imaging scan is completed, reinterrogate the cardiac implantable electronic device and restore its permanent settings
- Radiofrequency identification devices
  - Avoid using this equipment in close proximity to the cardiac implantable electronic device whenever possible
  - Monitor for signs of interference with the cardiac implantable electronic device and be prepared to stop using the radiofrequency identification device if interference occurs
- Electroconvulsive therapy
  - Alter the pacing function of a cardiac implantable electronic device to an

asynchronous pacing mode in the pacing-dependent patient

- Suspend an implantable cardioverter-defibrillator's antitachycardia therapy, if present
- Monitor for and treat ventricular arrhythmias that may occur secondary to the hemodynamic effects of electroconvulsive therapy
- Emergency cardioversion or defibrillation
  - Patients with an implantable cardioverter-defibrillator and magnet-disabled therapies:
    - Remove the magnet to reen able antitachycardia therapy
    - Terminate all sources of electromagnetic interference after magnet is removed
    - Observe the patient for appropriate cardiac implantable electronic device antitachycardia therapy
  - Patients with an implantable cardioverter-defibrillator and antitachycardia therapy that have been disabled by programming
    - Reenable antitachycardia therapy *via* programming
  - Minimize the current flowing through the generator and leads
    - Position cardioversion and defibrillation pads as far as possible from the pulse generator
    - Use anterior-posterior position
    - Use a clinically appropriate energy output
- Postoperative management
  - Confirm or restore cardiac implantable electronic device function
    - Interrogate the implantable cardiac electronic device
    - Reprogram the implantable cardiac electronic device to appropriate settings
    - Restore therapy antiarrhythmic therapies
    - Patients with disabled implantable cardioverter-defibrillator antitachycardia functions
      - Continuously monitor cardiac function
      - Keep external cardioversion and defibrillation equipment immediately available until antitachycardia function has been restored

## Outcomes

- Expected benefits:
  - Successful procedure
  - Reduced frequency/severity of adverse outcomes:



- Adverse outcomes associated with a cardiac implantable electronic device
  - Cardiac implantable electronic device damage
  - Inability to deliver pacing or shocks
  - Lead-tissue interface damage
  - Changes in pacing behavior
  - Electrical reset to the backup pacing mode
  - Inappropriate implantable cardioverter–defibrillator antitachycardia therapy
- Adverse clinical outcomes
  - Hypotension
  - Tachyarrhythmia
  - Bradyarrhythmia
  - Myocardial tissue damage

## Evidence Collection

- Literature inclusion criteria:
  - Randomized controlled trials
  - Prospective nonrandomized comparative studies (*e.g.*, quasi-experimental, cohort)
  - Retrospective comparative studies (*e.g.*, case-control)
  - Observational studies (*e.g.*, correlational or descriptive statistics)
  - Case reports, case series
- Literature exclusion criteria (except to obtain new citations):
  - Editorials
  - Literature reviews
  - Meta-analyses conducted by others
  - Abstracts
  - Unpublished studies
  - Studies in non-peer-review journals
  - Newspaper articles
- Survey evidence:
  - Expert consultant survey
  - ASA membership survey
  - Other participating organization surveys
  - Reliability survey
  - Feasibility survey

## State of the Literature

For the systematic review, potentially relevant clinical studies were identified *via* electronic and manual searches. Healthcare database searches included PubMed, EMBASE, Web of Science, Google Books, and the Cochrane Central Register of Controlled Trials. The searches covered a 9.5-yr period from January 1, 2010, through July 1, 2019. Accepted studies from the previous advisory were also rereviewed, covering the period of January 1, 1990, through July 31, 2010. Only studies containing original findings from

peer-reviewed journals were acceptable. Editorials, letters, and other articles without data were excluded. A literature search strategy and PRISMA<sup>1</sup> flow diagram are available as Supplemental Digital Content 2 (<http://links.lww.com/ALN/B980>).

In total, 1,143 new citations were identified, with 810 articles assessed for eligibility. After review, 746 were excluded, with 24 new studies meeting the above stated criteria. These studies were combined with 40 pre-2010 articles used in the previous advisory and 8 provided by task force members, resulting in a total of 72 articles accepted as evidence for these guidelines. In this document, 63 peer-reviewed articles, 2 ASA standards, and 1 ASA practice advisory are referenced, with a complete bibliography of articles used to develop these guidelines, organized by section, available as Supplemental Digital Content 3 (<http://links.lww.com/ALN/B981>).

Each pertinent outcome reported in a study was classified by evidence category and level and designated as beneficial, harmful, or equivocal. Findings were then summarized for each evidence linkage and reported in the text of the updated advisory, with evidence tables available as Supplemental Digital Content 4 (<http://links.lww.com/ALN/B982>).

Evidence categories refer specifically to the strength and quality of the research design of the studies. Category A evidence represents results obtained from randomized controlled trials, and category B evidence represents observational results obtained from nonrandomized study designs or randomized controlled trials without pertinent comparison groups. When available, category A evidence is given precedence over category B evidence for any particular outcome. These evidence categories are further divided into evidence levels. Evidence levels refer specifically to the strength and quality of the summarized study findings (*i.e.*, statistical findings, type of data, and the number of studies reporting/replicating the findings). In this document, only the highest level of evidence is included in the summary report for each intervention—outcome pair, including a directional designation of benefit, harm, or equivocality.

**Category A.** Randomized controlled trials report comparative findings between clinical interventions for specified outcomes. Statistically significant ( $P < 0.01$ ) outcomes are designated as either beneficial (B) or harmful (H) for the patient; statistically nonsignificant findings are designated as equivocal (E).

Level 1. The literature contains a sufficient number of randomized controlled trials to conduct meta-analysis<sup>2</sup> and meta-analytic findings from these aggregated studies are reported as evidence.

Level 2. The literature contains multiple randomized controlled trials, but the number of randomized controlled trials is not sufficient to conduct a viable meta-analysis for the purpose of these guidelines. Findings from these

†††††††† Preferred reporting items of systematic reviews and meta-analyses.

randomized controlled trials are reported separately as evidence.

Level 3. The literature contains a single randomized controlled trial, and findings from this study are reported as evidence.

**Category B.** Observational studies or randomized controlled trials without pertinent comparison groups may permit inference of beneficial or harmful relationships among clinical interventions and clinical outcomes. Inferred findings are given a directional designation of beneficial (B), harmful (H), or equivocal (E). For studies that report statistical findings, the threshold for significance is  $P < 0.01$ .

Level 1. The literature contains nonrandomized comparisons (e.g., quasiexperimental, cohort [prospective or retrospective], or case-control research designs) with comparative statistics between clinical interventions for a specified clinical outcome.

Level 2. The literature contains noncomparative observational studies with associative statistics (e.g., correlation, sensitivity, and specificity).

Level 3. The literature contains noncomparative observational studies with descriptive statistics (e.g., frequencies, percentages).

Level 4. The literature contains case reports.

**Insufficient Literature.** The lack of sufficient scientific evidence in the literature may occur when the evidence is either unavailable (i.e., no pertinent studies found) or inadequate. Inadequate literature cannot be used to assess relationships among clinical interventions and outcomes because a clear interpretation of findings is not obtained due to methodologic concerns (e.g., confounding of study design or implementation) or the study does not meet the criteria for content as defined in the “focus” of the guidelines.

Although interobserver agreement among task force members and two methodologists was not assessed for this update, the original guidelines reported agreement levels using a  $\kappa$  statistic for two-rater agreement pairs as follows: (1) type of study design,  $\kappa = 0.72$  to  $0.90$ ; (2) type of analysis,  $\kappa = 0.80$  to  $0.90$ ; (3) evidence linkage assignment,  $\kappa = 0.84$  to  $1.00$ ; and (4) literature inclusion for database,  $\kappa = 0.70$  to  $1.00$ . Three-rater agreement values were as follows: (1) study design,  $Sav = 0.81$ ,  $Var (Sav) = 0.010$ ; (2) type of analysis,  $Sav = 0.86$ ,  $Var (Sav) = 0.009$ ; (3) linkage assignment,  $Sav = 0.82$ ,  $Var (Sav) = 0.005$ ; and (4) literature database inclusion  $Sav = 0.78$ ,  $Var (Sav) = 0.031$ . These values represent moderate to high levels of agreement.

### Consensus-based Evidence

Validation of the concepts addressed by this advisory and subsequent recommendations proposed was obtained by

##### All meta-analyses are conducted by the ASA methodology group. Meta-analyses from other sources are reviewed but not included as evidence in this document. A minimum of five independent randomized controlled trials (i.e., sufficient for fitting a random-effects model) is required for meta-analysis.

consensus from multiple sources, including: (1) survey opinions from consultants##### who were selected based on their knowledge or expertise in perioperative management of cardiac implantable electronic devices; (2) survey opinions from randomly selected samples of active members of the ASA; (3) testimony on the original advisory from attendees of two publicly held open forums at a national anesthesia meeting and at a major cardiology meeting; and (4) internet commentary. All opinion-based evidence relevant to each topic was considered in the development of these guidelines. However, only findings obtained from formal surveys are reported in the document. Opinion surveys were developed by the task force to address each clinical intervention identified in the document. Identical surveys were distributed to expert consultants and a random sample of members of the participating organizations.

Survey responses were recorded using a five-point scale and summarized based on median values.#####

Strongly agree: Median score of 5 (at least 50% of the responses are 5)

Agree: Median score of 4 (at least 50% of the responses are 4 or 4 and 5)

Equivocal: Median score of 3 (at least 50% of the responses are 3, or no other response category or combination of similar categories contain at least 50% of the responses)

Disagree: Median score of 2 (at least 50% of responses are 2 or 1 and 2)

Strongly disagree: Median score of 1 (at least 50% of responses are 1)

The survey rate of return was 34% ( $N = 32/94$ ) for consultants, and 5% ( $N = 245/5,000$ ) for the ASA membership. The results of the surveys are reported in tables 2 and 3 and are summarized in the text of the guidelines.#####

An additional survey was sent to the consultants accompanied by a draft of the advisory asking them to indicate which, if any, of the evidence linkages would change their clinical practices if the advisory were instituted. The rate of return was 13% ( $N = 12$  of 94). The percentage of responding consultants expecting *no change* associated with each linkage were as follows: preoperative evaluation (determining whether a patient has a cardiac implantable electronic device and that it is functioning properly), 83.3%; patient preparation (determining whether electromagnetic interference is likely to occur), 83.3%; consulting a specialist when needed to alter the pacing function of a cardiac implantable electronic device, 75.0%; having temporary pacing and defibrillation equipment immediately available before, during, and after procedures with electromagnetic

##### Consultants were drawn from the following specialties where perioperative management of cardiac implantable electronic devices are a concern: anesthesiology (85% of respondents) and cardiac electrophysiology (15% of respondents).

##### When an equal number of categorically distinct responses are obtained, the median value is determined by calculating the arithmetic mean of the two middle values. Ties are calculated by a predetermined formula.

interference potential, 91.7%; continuous monitoring of electrocardiography, SpO<sub>2</sub>, and peripheral pulse, 91.7%; electrosurgery, 100%; radiofrequency ablation, 100%; lithotripsy, 91.7%; magnetic resonance imaging, 91.7%; radiation therapy, 100%; radiofrequency identification devices, 100%; electroconvulsive therapy, 100%; emergency defibrillation or cardioversion, 91.7%; postoperative management (continuing to monitor and display electrocardiogram, cardiac rate, and rhythm), 100%; postoperative management (for a cardiac implantable electronic device that was reprogrammed pre- or intraoperatively, restore the cardiac implantable electronic device to its permanent settings before the patient is discharged from a monitored environment), 83.3%; and postoperative cardiac implantable electronic device interrogation, 91.7%. In total, 67% of the respondents indicated that the advisory would have *no effect* on the amount of time spent on

##### To view a bar chart with the above findings, refer to Supplemental Digital Content 5 (<http://links.lww.com/ALN/B983>).

a typical case with the implementation of this advisory, 25% indicated that there would be an increase, and 8.3% indicated that there would be a decrease.

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## Competing Interests

The authors declare no competing interests.

**Table 1. NASPE/BPEG Generic Pacemaker Code: Revised (2002)**

Position I	Position II	Position III	Position IV	Position V
Chambers paced	Chambers sensed	Response to sensing	Rate modulation	Multisite pacing
O = None	O = None	O = None	O = None	O = None
A = Atrium	A = Atrium	T = Triggered	R = Rate modulation	A = Atrium
V = Ventricle	V = Ventricle	I = Inhibited		V = Ventricle
D = Dual (A + V)	D = Dual (A + V)	D = Dual (T+)		D = Dual (A + V)

The generic pacemaker code was developed as a joint project by the British Pacing and Electrophysiology Group (BPEG) and the North American Society of Pacing and Electrophysiology (NASPE). The five positions refer to the order of the programmed settings on the cardiac implantable electronic device (cardiac implantable electronic device). Examples of the code follow: (1) AA = atrial-only pacing and sensing. In this mode, any failure of the atrium to produce an intrinsic event within the appropriate time interval (determined by the lower rate limit) results in the emission of an atrial pacing pulse. (2) AOO = atrial-only asynchronous pacing (*i.e.*, no sensing). In this mode, an atrial pacing pulse is emitted regardless of the intrinsic cardiac rhythm. (3) DDD = dual chamber (atrial and ventricular) pacing and sensing. This mode provides dual chamber pacing and sensing, and atrial tracking. Thus, every atrial event, within programmed limits, is followed by a ventricular event. In the absence of an intrinsic atrial event, the atrium will be paced, and after any sensed or paced atrial event, an intrinsic ventricular event must occur before the expiration of the atrioventricular timer or the ventricle will be paced. (4) DDI = dual chamber (atrial and ventricular) pacing and sensing without tracking of sensed atrial events. In this mode, only paced atrial events are tracked into the ventricle, and ventricular pacing occurs when the ventricle fails to produce an intrinsic event within the appropriate time interval. (5) DOO = dual chamber (atrial and ventricular) asynchronous atrioventricular sequential pacing (*i.e.*, no sensing). In this mode, atrial and ventricular pacing pulses are emitted regardless of the intrinsic cardiac rhythm. (6) VOO = ventricular-only asynchronous pacing (*i.e.*, no sensing). In this mode, a ventricular pacing pulse is emitted regardless of the intrinsic cardiac rhythm. (7) VVI = ventricular-only pacing and sensing. In this mode, any failure of the ventricle to produce an intrinsic event within the appropriate time interval (determined by the lower rate limit) results in the emission of a ventricular pacing pulse. There is no atrial sensing and thus no atrioventricular synchrony in the absence of intrinsic atrial activity.

**Table 2. NASPE/BPEG Generic Defibrillator Code**

Position I	Position II	Position III	Position IV
Shock chambers	Antitachycardia pacing chambers	Tachycardia detection	Antibradycardia pacing chambers
O = None	O = None	E = Electrocardiogram	O = None
A = Atrium	A = Atrium	H = Hemodynamic	A = Atrium
V = Ventricle	V = Ventricle		V = Ventricle
D = Dual (A + V)	D = Dual (A + V)		D = Dual (A + V)

The generic defibrillator code was developed as a joint project by the British Pacing and Electrophysiology Group (BPEG) and the North American Society of Pacing and Electrophysiology (NASPE). The five positions refer to the order of the programmed settings on the cardiac implantable electronic device. For robust identification, position IV is expanded into its complete NASPE/BPEG Generic Pacemaker code. For example, a biventricular implantable cardioverter-defibrillator with ventricular shock and antitachycardia pacing functionality would be identified as VE-DDDRV, assuming it was programmed to pace and sense in the DDD mode with rate response.

**Table 3. Example of a Stepwise Approach to the Perioperative Management of the Patient with a Cardiac Implantable Electronic Device**

Perioperative Period	Patient/CIED Condition	Intervention	
Preoperative evaluation	Patient has CIED	Focused history Focused physical exam	
	Determine CIED type (PM, ICD, CRT)	Manufacturer's CIED Identification card Chest x-ray (no data available) Supplemental resources*	
	Determine whether patient is CIED-dependent for pacing function	Verbal history Bradycardia symptoms Atrioventricular node ablation No spontaneous ventricular activity†	
	Determine CIED function	Comprehensive CIED evaluation‡ Determine whether pacing pulses are present and generate appropriate paced beats	
Preoperative preparation	Any CIED	Suspend the CIED's active sensor for rate-responsive pacing to prevent undesirable tachycardia, if present Use bipolar electrosurgery or ultrasonic scalpel whenever possible Temporary pacing and cardioversion–defibrillation available	
	EMI unlikely (during procedure)	Additional interventions are not needed	
	EMI likely; pacemaker	Pacing-dependent patient: reprogram to asynchronous mode	
	EMI likely: ICD	Suspend antitachycardia therapy Pacing-dependent patient: reprogram to asynchronous mode	
Intraoperative management	Intraoperative physiologic changes likely (e.g., bradycardia, ischemia)	Plan for possible adverse CIED–patient interaction	
	Monitoring per ASA standards	Electrocardiogram Peripheral pulse (i.e., SpO <sub>2</sub> )	
	Electrosurgery	Direct current return path away from generator and leads Avoid proximity of electrosurgical unit to generator/leads Short bursts at lowest possible energy Use bipolar electrosurgery or ultrasonic scalpel whenever possible	
	RF catheter ablation	Avoid contact RF catheter with generator/leads RF current path far away from generator/leads Discuss these concerns with operator	
	Lithotripsy	Do not focus lithotripsy beam near generator	
	MRI	Move the patient outside of the MRI scan area when the use of an external monitor, cardioverter defibrillator, CIED CIED programmer or any other MRI-unsafe equipment is required Before the MRI, perform the following: Interrogate the CIED Suspend the antitachycardia function of an ICD, if present For MRI-conditional ICDs, program to “MRI Mode” to suspend the antitachycardia function In the pacing-dependent patient, alter the pacing function of the CIED to an asynchronous pacing mode Ensure that an individual capable of programming the CIED remains in attendance for the duration of the MRI After the MRI is completed, reinterrogate the CIED and restore its permanent settings	
	ECT	Alter the pacing function to an asynchronous pacing mode in the pacing-dependent patient Suspend an ICD's antitachycardia functions, if present Monitor for and treat ventricular arrhythmias that may occur secondary to the hemodynamic effects of ECT	
	Emergency defibrillation–cardioversion	ICD: magnet-disabled	Terminate all electromagnetic interference sources
		ICD: programming disabled	Observe for appropriate therapies
		ICD: either of above	Programming to reenable therapies or proceed directly with external cardioversion/defibrillation Minimize current flow through PG/leads PP as far as possible from PG PP perpendicular to major axis PG/leads To extent possible, PP in anterior–posterior location
	Regardless of CIED type	Use clinically appropriate cardioversion/defibrillation energy	

(Continued)

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**Table 3.** (Continued)

Perioperative Period	Patient/CIED Condition	Intervention
Postoperative management		Continue to monitor and display a patient's electrocardiogram as required by ASA standards as indicated by the patient's medical condition Continuously monitor cardiac rate and rhythm throughout the immediate postoperative period. For a CIED that was reprogrammed pre- or intraoperatively: Ensure that back-up pacing and cardioversion–defibrillation equipment are immediately available until its permanent settings are restored§ For a CIED that was reprogrammed pre- or intraoperatively, restore the CIED to its permanent settings before the patient is discharged from a monitored environment   Perform a postoperative CIED interrogation whenever emergency surgery occurred without appropriate preoperative CIED evaluation There is suspicion that antitachycardia therapy might have been disabled rather than temporarily suspended with magnet placement Significant electromagnetic interference occurred in close proximity to the CIED The delivery of antitachycardia therapy was observed There is concern for CIED malfunction If interrogation determines that the CIED settings are inappropriate, reprogram to newly appropriate settings

\*Manufacturer's databases, pacemaker clinic records, consultation with a CIED specialist. †With CIED pacing function temporarily programmed to a nontracking mode (*i.e.*, ventricular-only pacing and sensing) at the lowest programmable rate. ‡Assessed by interrogating the cardiac implantable electronic device or obtaining the most recent interrogation report. §Postoperative cardiac implantable electronic device interrogation may not be needed in low-risk situations (*e.g.*, appropriate preoperative cardiac implantable electronic interrogation, no electromagnetic interference-generating devices used during the procedure, no perioperative reprogramming took place, and no problems identified during the procedure). ||In some instances new settings may be needed.

ASA, American Society of Anesthesiologists; CIED, cardiac implantable electronic device; CRT, cardiac resynchronization therapy; ECT, electroconvulsive therapy; EMI, electromagnetic interference; ICD, implantable cardioverter–defibrillator; MRI, magnetic resonance imaging; PG, pulse generator; PP, defibrillation or cardioversion pads; RF, radiofrequency; RT, radiation therapy; SpO<sub>2</sub>, oxygen saturation measured by pulse oximetry.

**Table 4. Expert Consultant Survey Results**

Recommendations	N	Strongly Agree, %	Agree, %	Equivocal, %	Disagree, %	Strongly Disagree, %
Preoperative evaluation						
1. Determine whether a patient has a CIED	32	100*	0	0	0	0
2. Determine the CIED type ( <i>i.e.</i> , PM, ICD, CRT)	32	97*	3	0	0	0
3. Determine the CIED manufacturer	32	66*	28	6	0	0
4. Determine the primary indication for CIED placement	32	69*	28	3	0	0
5. Determine whether the patient is pacing-dependent	32	91*	9	0	0	0
Preoperative preparation						
6. Determine the CIED's current settings	32	63*	31	6	0	0
7. Confirm that the CIED is functioning properly ( <i>i.e.</i> , by interrogating the CIED or obtaining the most recent interrogation report)	32	72*	22	6	0	0
8. Determine whether intraoperative EMI from monopolar electrosurgery or other sources is likely to occur	32	81*	19	0	0	0
9. If monopolar electrosurgery ("bovie") use is planned superior to the umbilicus, alter the pacing function of a CIED to an asynchronous pacing mode in the pacing-dependent patient	32	63*	22	13	3	0
10. If monopolar electrosurgery ("bovie") use is planned inferior to the umbilicus, alter the pacing function of a CIED to an asynchronous pacing in the pacing-dependent patient	32	34	6	25	34*	28
11. If monopolar electrosurgery ("bovie") use is planned superior to the umbilicus, suspend an ICD's antitachycardia function, if present	32	78*	19	3	0	0
12. If monopolar electrosurgery ("bovie") use is planned inferior to the umbilicus, suspend an ICD's antitachycardia function, if present	31	23	29*	13	23	13
13. Before suspending the antitachycardia function of an ICD, ensure that the patient is in a monitored environment	32	75*	25	0	0	0
14. Avoid the routine use of a magnet over an ICD	32	16	31	9*	25	19
15. If needed, consult a specialist to alter the pacing function of a CIED or suspend the antitachycardia function of an ICD	32	81*	9	6	3	0
16. Advise the proceduralist to use bipolar electrosurgery or an ultrasonic scalpel when feasible	32	25	41*	31	3	0

(Continued)

**Table 4.** (Continued)

Recommendations	N	Strongly Agree, %	Agree, %	Equivocal, %	Disagree, %	Strongly Disagree, %
17. Ensure that temporary pacing and defibrillation equipment are immediately available before, during, and after all procedures with EMI potential	32	72*	25	3	0	0
18. Suspend the CIED's active sensor for rate-responsive pacing to prevent undesirable tachycardia	32	28	44*	22	6	0
Intraoperative monitoring						
19. Continuously monitor and display a patient's electrocardiogram as required by ASA standards, from the beginning of anesthesia until the patient is transferred out of the anesthetizing location, with additional electrocardiography monitoring in the postoperative period as indicated by the patient's medical condition	32	91*	9	0	0	0
20. Perform continuous peripheral pulse monitoring for all CIED patients receiving anesthesia care	32	69*	13	9	3	6
21. If unanticipated CIED interactions occur, discontinue the procedure until the source of interference can be eliminated or managed	32	56*	34	6	3	0
Intraoperative management of EMI sources: electrosurgery						
22. Minimize the risk of EMI by positioning the electrosurgical instrument and dispersive electrode ("bovie pad") so the current pathway does not pass through or near the CIED system	32	75*	25	0	0	0
23. Avoid proximity of the electrosurgery electrical field to the generator and leads, including the avoidance of waving the activated electrode over the generator	31	81*	13	6	0	0
24. Use short, intermittent, and irregular bursts of electrosurgery at the lowest feasible energy levels	32	63*	25	13	0	0
25. Use bipolar electrosurgery or an ultrasonic (harmonic) scalpel, if possible	32	41	44*	13	3	0
Intraoperative management of EMI sources: radiofrequency ablation						
26. Avoid direct contact between the ablation catheter and the generator and leads	31	65*	32	3	0	0
27. Keep the RF's current path (electrode tip to current return pad) as far away from the generator and leads as possible	31	65*	32	3	0	0
Intraoperative management of EMI sources: lithotripsy						
28. Avoid focusing the lithotripsy beam near the generator	30	63*	27	10	0	0
Intraoperative management of EMI sources: MRI						
29. Move the patient outside of the immediate MRI area when the use of an external defibrillator/monitor, CIED programming system, or any other MRI-unsafe equipment is required	31	84*	13	3	0	0
30. Monitor the patient's electrocardiogram and/or Sp <sub>o</sub> <sub>2</sub> continuously throughout the MRI	31	84*	13	3	0	0
31. An individual capable of programming the CIED should remain in attendance for the duration of the MRI	30	20	30*	33	13	3
Intraoperative management of EMI sources: MRI-conditional CIEDs						
32. Before the MRI, interrogate the CIED and program to "MRI mode" to suspend the antitachycardia function of an ICD	29	69*	24	7	0	0
33. Alter the pacing function of the CIED to an asynchronous pacing mode in the pacing-dependent patient	29	59*	28	10	3	0
34. After the MRI, reinterrogate the CIED and restore its permanent settings	29	83*	17	0	0	0
Intraoperative management of EMI sources: non-MRI-conditional CIEDs						
35. Interrogate the CIED before and after the MRI	29	62*	31	7	0	0
36. Alter the pacing function of the CIED to an asynchronous pacing mode in the pacing-dependent patient	29	66*	21	14	0	0
37. Suspend the antitachycardia function of an ICD if present	29	66*	24	10	0	0
38. After the MRI, reinterrogate the CIED and restore its permanent settings	28	82*	14	4	0	0
Intraoperative management of EMI sources: radiation therapy						
39. Avoid exposing the CIED to radiation whenever possible by positioning the CIED outside the radiation field, shielding the CIED from direct radiation, and relocating the generator to the patient's contralateral side	29	55*	17	24	3	0
40. Determine whether the manufacturer recommends verification of CIED function before and at the completion of radiation	29	59*	31	10	0	0
Intraoperative management of EMI sources: RFID						
41. Avoid using this equipment in close proximity to the CIED whenever possible	29	52*	31	14	0	3
42. Monitor for signs of interference with the CIED and be prepared to stop using the RFID if interference occurs	28	71*	21	4	0	4
Intraoperative management of EMI sources: ECT						
43. Alter the pacing function of a CIED to an asynchronous pacing mode in the pacing-dependent patient	27	33	33*	22	7	4
44. Suspend an ICD's antitachyarrhythmia functions, if present	27	48	41*	7	4	0
45. Monitor for and treat ventricular arrhythmias that may occur secondary to the hemodynamic effects of ECT	28	89*	7	4	0	0

(Continued)

**Table 4.** (Continued)

Recommendations	N	Strongly Agree, %	Agree, %	Equivocal, %	Disagree, %	Strongly Disagree, %
Intraoperative management: emergency external defibrillation or cardioversion						
46. Before performing emergency defibrillation or cardioversion of the patient with an ICD and magnet-disabled therapies, terminate all sources of EMI and remove the magnet to reenables the ICD's antitachycardia therapies; then observe the patient for the delivery of appropriate antitachycardia therapy from the ICD	28	54*	32	4	7	4
47. For the patient with an ICD and antitachycardia therapy that have been disabled by programming, determine whether the antitachycardia therapy should be reenables	28	43	32*	7	18	0
48. If the above activities fail to restore ICD function perform, emergency external defibrillation or cardioversion when needed	28	89*	7	4	0	0
49. Follow ACLS and emergency protocols to provide rapid cardioversion or defibrillation when needed	28	86*	14	0	0	0
50. Follow ACLS guidelines for delivered energy level and pad placement	28	75*	21	0	4	0
51. Attempt to minimize the current flowing through the pulse generator and leads by positioning the defibrillation or cardioversion pads so they are not directly over the CIED	28	75*	21	4	0	0
52. Use anterior–posterior rather than anterior–lateral pad positioning whenever possible	27	52*	22	22	4	0
53. Use a clinically appropriate energy output regardless of the presence of the CIED	28	79*	21	0	0	0
54. Interrogate the CIED immediately after external cardioversion or defibrillation is performed	27	67*	22	11	0	0
Postoperative management						
55. Continuously monitor cardiac rate and rhythm throughout the immediate postoperative period	28	86*	14	0	0	0
56. For a CIED that was reprogrammed pre- or intraoperatively, ensure that back-up pacing and cardioversion–defibrillation equipment are immediately available until its permanent settings are restored	28	86*	14	0	0	0
57. For a CIED that was reprogrammed pre- or intraoperatively, restore the CIED to its permanent settings before the patient is discharged from a monitored environment	28	86*	14	0	0	0
58. If interrogation determines that the CIED settings are inappropriate, then reprogram the CIED to newly appropriate settings	28	57*	43	0	0	0
59. Perform a postoperative CIED interrogation if emergency surgery occurred without appropriate preoperative CIED evaluation	28	75*	11	14	0	0
60. Perform a postoperative CIED interrogation if there is suspicion that antitachycardia therapy might have been disabled rather than temporarily suspended with magnet placement	28	68*	29	0	0	4
61. Perform a postoperative CIED interrogation if significant electromagnetic interference occurred in close proximity to the CIED	28	71*	21	4	4	0
62. Perform a postoperative CIED interrogation if the delivery of antitachycardia therapy was observed or if there is concern for CIED malfunction	28	82*	18	0	0	0
63. If the CIED is not interrogated during the immediate postoperative period, have it interrogated within 30 days after the procedure	28	50*	29	11	11	0

N = number of consultants who responded to each item.

\*Median.

ACLS, advanced cardiac life support; ASA, American Society of Anesthesiologists; CIED, cardiac implantable electronic device; CRT, cardiac resynchronization therapy; ECT, electroconvulsive therapy; EMI, electromagnetic interference; ICD, implantable cardioverter–defibrillator; MRI, magnetic resonance imaging; N, number of members who responded to each item; RF, radiofrequency; RFID, radiofrequency identification device; RT, radiation therapy; SpO<sub>2</sub>, oxygen saturation measured by pulse oximetry.

**Table 5.** ASA Member Survey Results

Recommendations	N	Strongly Agree, %	Agree, %	Equivocal, %	Disagree, %	Strongly Disagree, %
Preoperative evaluation						
1. Determine whether a patient has a CIED	245	95*	5	0	0	0
2. Determine the CIED type ( <i>i.e.</i> , PM, ICD, CRT)	243	86*	11	3	0	0
3. Determine the CIED manufacturer	244	44	35*	18	2	1
4. Determine the primary indication for CIED placement	245	79*	18	3	0	0
5. Determine whether the patient is pacing-dependent	243	85*	14	1	0	0
Preoperative preparation						
6. Determine the CIED's current settings	243	47	38*	12	2	1

(Continued)

**Table 5.** (Continued)

Recommendations	N	Strongly Agree, %	Agree, %	Equivocal, %	Disagree, %	Strongly Disagree, %
7. Confirm that the CIED is functioning properly ( <i>i.e.</i> , by interrogating the CIED or obtaining the most recent interrogation report)	243	49	28*	19	3	1
8. Determine whether intraoperative EMI from monopolar electrosurgery or other sources is likely to occur	211	80*	16	3	1	0
9. If monopolar electrosurgery (“bovie”) use is planned superior to the umbilicus, alter the pacing function of a CIED to an asynchronous pacing mode in the pacing-dependent patient	211	51*	28	12	7	1
10. If monopolar electrosurgery (“bovie”) use is planned inferior to the umbilicus, alter the pacing function of a CIED to an asynchronous pacing in the pacing-dependent patient	210	10	17	24*	40	9
11. If monopolar electrosurgery (“bovie”) use is planned superior to the umbilicus, suspend an ICD’s antitachycardia function, if present	208	55*	36	7	2	0
12. If monopolar electrosurgery (“bovie”) use is planned inferior to the umbilicus, suspend an ICD’s antitachycardia function, if present	209	19	22	24*	31	4
13. Before suspending the antitachycardia function of an ICD, ensure that the patient is in a monitored environment	210	76*	22	2	0	0
14. Avoid the routine use of a magnet over an ICD	209	23	32*	24	16	5
15. If needed, consult a specialist to alter the pacing function of a CIED or suspend the antitachycardia function of an ICD	209	54*	38	5	1	1
16. Advise the proceduralist to use bipolar electrosurgery or an ultrasonic scalpel when feasible	210	55*	37	7	1	0
17. Ensure that temporary pacing and defibrillation equipment are immediately available before, during, and after all procedures with EMI potential	209	71*	26	3	0	0
18. Suspend the CIED’s active sensor for rate-responsive pacing to prevent undesirable tachycardia	211	22	35*	37	6	0
Intraoperative monitoring						
19. Continuously monitor and display a patient’s electrocardiogram as required by ASA standards, from the beginning of anesthesia until the patient is transferred out of the anesthetizing location, with additional electrocardiography monitoring in the postoperative period as indicated by the patient’s medical condition	200	89*	10	1	0	1
20. Perform continuous peripheral pulse monitoring for all CIED patients receiving anesthesia care	201	71*	17	9	2	1
21. If unanticipated CIED interactions occur, discontinue the procedure until the source of interference can be eliminated or managed	201	53*	36	8	2	0
Intraoperative management of EMI sources: electrosurgery						
22. Minimize the risk of EMI by positioning the electrosurgical instrument and dispersive electrode (“bovie pad”) so the current pathway does not pass through or near the CIED system	193	88*	11	1	1	0
23. Avoid proximity of the electrosurgery electrical field to the generator and leads, including the avoidance of waving the activated electrode over the generator	193	64*	27	8	1	0
24. Use short, intermittent, and irregular bursts of electrosurgery at the lowest feasible energy levels	194	66*	28	5	1	0
25. Use bipolar electrosurgery or an ultrasonic (harmonic) scalpel, if possible	194	71*	25	4	1	0
Intraoperative management of EMI sources: radiofrequency ablation						
26. Avoid direct contact between the ablation catheter and the generator and leads	190	73*	22	6	0	0
27. Keep the RF’s current path (electrode tip to current return pad) as far away from the generator and leads as possible	190	73*	24	4	0	0
Intraoperative management of EMI sources: lithotripsy						
28. Avoid focusing the lithotripsy beam near the generator	187	63*	29	9	0	0
Intraoperative management of EMI sources: MRI						
29. Move the patient outside of the immediate MRI area when the use of an external defibrillator/monitor, CIED programming system, or any other MRI-unsafe equipment is required	185	75*	22	3	0	0
30. Monitor the patient’s and/or SpO <sub>2</sub> continuously throughout the MRI	185	81*	17	2	0	0
31. An individual capable of programming the CIED should remain in attendance for the duration of the MRI	185	18	17	45*	18	2
Intraoperative management of EMI sources: MRI-conditional CIEDs						
32. Before the MRI, interrogate the CIED and program to “MRI mode” to suspend the antitachycardia function of an ICD	179	48	31*	17	3	1
33. Alter the pacing function of the CIED to an asynchronous pacing mode in the pacing-dependent patient	177	32	37*	21	8	2
34. After the MRI, reinterrogate the CIED and restore its permanent settings	179	60*	30	8	1	1
Intraoperative management of EMI sources: non-MRI-conditional CIEDs						
35. Interrogate the CIED before and after the MRI	172	44	31*	22	2	1

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Table 5. (Continued)

Recommendations	N	Strongly Agree, %	Agree, %	Equivocal, %	Disagree, %	Strongly Disagree, %
36. Alter the pacing function of the CIED to an asynchronous pacing mode in the pacing-dependent patient	172	38	35*	20	5	2
37. Suspend the antitachycardia function of an ICD if present	172	41	36*	17	4	2
38. After the MRI, reinterrogate the CIED and restore its permanent settings	173	59*	28	12	1	1
Intraoperative management of EMI sources: radiation therapy						
39. Avoid exposing the CIED to radiation whenever possible by positioning the CIED outside the radiation field, shielding the CIED from direct radiation, and relocating the generator to the patient's contralateral side	165	31	35*	31	2	1
40. Determine whether the manufacturer recommends verification of CIED function before and at the completion of radiation	165	42	41*	15	1	1
Intraoperative management of EMI sources: RFID						
41. Avoid using this equipment in close proximity to the CIED whenever possible	163	40	39*	17	2	1
42. Monitor for signs of interference with the CIED and be prepared to stop using the RFID if interference occurs	163	52*	39	8	1	0
Intraoperative management of EMI sources: ECT						
43. Alter the pacing function of a CIED to an asynchronous pacing mode in the pacing-dependent patient	159	33	36*	20	9	1
44. Suspend an ICD's antitachyarrhythmia functions, if present	157	41	27*	22	10	0
45. Monitor for and treat ventricular arrhythmias that may occur secondary to the hemodynamic effects of ECT	159	70*	23	7	0	0
Intraoperative management: emergency external defibrillation or cardioversion						
46. Before performing emergency defibrillation or cardioversion of the patient with an ICD and magnet-disabled therapies, terminate all sources of EMI and remove the magnet to reenact the ICD's antitachycardia therapies; then observe the patient for the delivery of appropriate antitachycardia therapy from the ICD	147	57*	30	9	3	1
47. For the patient with an ICD and antitachycardia therapy that have been disabled by programming, determine whether the antitachycardia therapy should be reenacted	146	51*	37	8	3	1
48. If the above activities fail to restore ICD function, perform emergency external defibrillation or cardioversion when needed	146	85*	12	3	0	0
49. Follow ACLS and emergency protocols to provide rapid cardioversion or defibrillation when needed	146	88*	10	2	0	0
50. Follow ACLS guidelines for delivered energy level and pad placement	146	77*	13	9	0	1
51. Attempt to minimize the current flowing through the pulse generator and leads by positioning the defibrillation or cardioversion pads so they are not directly over the CIED	147	71*	24	4	0	1
52. Use anterior-posterior rather than anterior-lateral pad positioning whenever possible	145	48	30*	20	3	0
53. Use a clinically appropriate energy output regardless of the presence of the CIED	147	60*	33	5	1	0
54. Interrogate the CIED immediately after external cardioversion or defibrillation is performed	27	67*	22	11	0	0
Postoperative management						
55. Continuously monitor cardiac rate and rhythm throughout the immediate postoperative period	145	83*	14	2	0	0
56. For a CIED that was reprogrammed pre- or intraoperatively, ensure that back-up pacing and cardioversion-defibrillation equipment are immediately available until its permanent settings are restored	145	82*	16	2	0	0
57. For a CIED that was reprogrammed pre- or intraoperatively, restore the CIED to its permanent settings before the patient is discharged from a monitored environment	145	83*	15	2	0	0
58. If interrogation determines that the CIED settings are inappropriate, then reprogram the CIED to newly appropriate settings	145	72*	23	5	1	0
59. Perform a postoperative CIED interrogation if emergency surgery occurred without appropriate preoperative CIED evaluation	145	56*	28	16	1	0
60. Perform a postoperative CIED interrogation if there is suspicion that antitachycardia therapy might have been disabled rather than temporarily suspended with magnet placement	145	77*	21	1	0	0
61. Perform a postoperative CIED interrogation if significant EMI occurred in close proximity to the CIED	145	51*	34	14	1	0
62. Perform a postoperative CIED interrogation if the delivery of antitachycardia therapy was observed or if there is concern for CIED malfunction	145	82*	17	1	0	0
63. If the CIED is not interrogated during the immediate postoperative period, have it interrogated within 30 days after the procedure	145	42	33*	17	6	1

N = number of members who responded to each item.

\*Median.

ACLS, advanced cardiac life support; ASA, American Society of Anesthesiologists; CIED, cardiac implantable electronic device; CRT, cardiac resynchronization therapy; ECT, electroconvulsive therapy; EMI, electromagnetic interference; ICD, implantable cardioverter-defibrillator; MRI, magnetic resonance imaging; RF, radiofrequency; RFID, radiofrequency identification device; SpO<sub>2</sub>, oxygen saturation measured by pulse oximetry.

## Correspondence

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