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

CME

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This document updates the "Practice Advisory for the Perioperative Management of Patients with Cardiac Rhythm Management Devices: Pacemakers and Implantable Cardioverter-Defibrillators, adopted by the ASA in 2004 and published in 2005.* Fn1

Methodology

A. Definition of Cardiac Implantable Electronic Devices

For this Advisory, a cardiac implantable electronic device (CIED) refers to any permanently implanted cardiac pacemaker or any implantable cardioverter-defibrillator (ICD). The term CIED also refers to any cardiac resynchronization device.† Fn2

B. Purposes of the Advisory

The purposes of this Advisory update are to (1) facilitate safe and effective perioperative management of the patient with a CIED and (2) reduce the incidence of adverse outcomes. Perioperative management refers to the preoperative, intraoperative, postop-

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Address correspondence to the American Society of Anesthesiologists: 520 North Northwest Highway, Park Ridge, Illinois 60068-2573. This Practice Advisory, as well as all published ASA Practice Parameters, may be obtained at no cost through the Journal Web site, www.anesthesiology.org.

* American Society of Anesthesiologists: Practice Advisory for the Perioperative Management of Patients with Cardiac Rhythm Management Devices: Pacemakers and Implantable Cardioverter-Defibrillators. ANESTHESIOLOGY 2005; 103:186–98

† Generic pacemaker and defibrillator codes are provided in appendix 1. Note that every ICD includes both pacing and shock therapies for the management of bradyarrhythmias and tachyarrhythmias.

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erative, or recovery period in any setting where an anesthesia provider will be delivering anesthesia care. Adverse outcomes associated with a CIED include, but are not limited to, damage to the device, inability of the device to deliver pacing or shocks, lead-tissue interface damage, changes in pacing behavior, electrical reset to the backup pacing mode, or inappropriate ICD therapies.‡ Adverse clinical outcomes include, but are not limited to, hypotension, tachyarrhythmia or bradyarrhythmia, myocardial tissue damage, and myocardial ischemia or infarction. Other related outcomes may include extended hospital stay, delay or cancellation of surgery, readmission to manage device malfunction, or additional hospital resource utilization and cost.

C. Focus

This updated Advisory focuses on the perioperative management of the patient who has a preexisting, permanently implanted CIED for treatment of bradyarrhythmia, tachyarrhythmia, or heart failure. Both inpatient and outpatient procedures are addressed by this update. This update does not address the perioperative management of any patient undergoing CIED implantation or revision. It is not applicable to any patient (1) without a permanently implanted pacemaker or ICD, (2) with a temporary CIED, (3) with a noncardiac implantable device (*e.g.*, neurologic or spinal cord stimulator), or (4) with an implantable mechanical cardiac assist device (*e.g.*, ventricular assist device). This updated Advisory does not address procedures where there are no known perioperative CIED concerns, such as plain radiography, fluoroscopy, mammograms, or ultrasound.

D. Application

This updated Advisory is intended for use by anesthesiologists and all other individuals who deliver or are responsible for anesthesia care. The update may also serve as a resource for other physicians and health care professionals who manage patients with CIEDs.

E. 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.

The Task Force developed the original Advisory by means of a six-step process. First, they reached consensus on the criteria for evidence. Second, original published articles from peer-reviewed journals relevant to the perioperative management of cardiac rhythm management devices were evaluated. Third, consultants who had expertise or interest in CIEDs and who practiced or worked in various settings (*e.g.*, private and academic practice) were asked to (1) participate in opinion surveys on the effectiveness of various perioperative management strategies and (2) review and comment on a draft of the Advisory developed by the Task Force. Fourth, additional opinions were solicited from random samples of active members of both the ASA and the Heart Rhythm Society (HRS).§ Fifth, the Task Force held an open forum at a national anesthesia meeting and at a major cardiology meeting to solicit input on the key concepts of this Advisory.‖ Sixth, all available information was used to build consensus within the Task Force to finalize the Advisory.

In 2009, the ASA Committee on Standards and Practice Parameters requested that scientific evidence for this Advisory be updated. The update consists of an evaluation of literature that includes new studies obtained after publication of the original Advisory.

F. Availability and Strength of Evidence

Preparation of this update used the same methodological process as used in the original Advisory to obtain new scientific evidence. Opinion-based evidence obtained from the original Advisory is reported in this update. The protocol for reporting each source of evidence is described below.

G. Scientific Evidence

Study findings from published scientific literature were aggregated and are reported in summary form by evidence category, as described below. All literature (*e.g.*, randomized controlled trials, observational studies, and case reports) relevant to each topic was considered when evaluating the findings. However, for reporting purposes in this document, only the highest level of evidence (*i.e.*, levels 1, 2, or 3 identified below) within each category (*i.e.*, A, B, or C) is included in the summary.

Category A: Supportive Literature. Randomized controlled trials report statistically significant ($P < 0.01$) differences between clinical interventions for a specified clinical outcome.

Level 1. The literature contains multiple, randomized controlled trials, and the aggregated findings are supported by meta-analysis.#

Level 2. The literature contains multiple, randomized controlled trials, but there is an insufficient number of studies to conduct a viable meta-analysis for the purpose of this Advisory.

Level 3. The literature contains a single, randomized controlled trial.

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

§ Formerly North American Society of Pacing and Electrophysiology (NASPE).

‖ International Anesthesia Research Society; 78th Clinical and Scientific Congress, March 28, 2004, in Tampa, Florida, and NASPE Heart Rhythm Society Annual Meeting, May 20, 2004, in San Francisco, California.

Practice advisories lack the support of a sufficient number of adequately controlled studies required to conduct an appropriate meta-analysis. Therefore, category A1 evidence is not reported in this document.

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Category B: Suggestive Literature. Information from observational studies permits inference of beneficial or harmful relationships among clinical interventions and clinical outcomes.

Level 1. The literature contains observational comparisons (*e.g.*, cohort, case-control research designs) of clinical interventions or conditions and indicates statistically significant differences between clinical interventions for a specified clinical outcome.

Level 2. The literature contains noncomparative observational studies with associative (*e.g.*, relative risk and correlation) or descriptive statistics.

Level 3. The literature contains case reports.

Category C: Equivocal Literature. The literature cannot determine whether there are beneficial or harmful relationships among clinical interventions and clinical outcomes.

Level 1. Meta-analysis did not find significant differences among groups or conditions.

Level 2. There is an insufficient number of studies to conduct meta-analysis, and (1) randomized controlled trials have not found significant differences among groups or conditions or (2) randomized controlled trials report inconsistent findings.

Level 3. Observational studies report inconsistent findings or do not permit inference of beneficial or harmful relationships.

Category D: Insufficient Evidence from Literature. The lack of scientific evidence in the literature is described by the following terms:

Silent. No identified studies address the specified relationships among interventions and outcomes.

Inadequate. The available literature cannot be used to assess relationships among clinical interventions and clinical outcomes. The literature either does not meet the criteria for content as defined in the Focus of the Advisory or does not permit a clear interpretation of findings because of methodological concerns (*e.g.*, confounding in study design or implementation).

H. Opinion-based Evidence

The original Advisory contained formal survey information collected from expert consultants, a random sample of members of the ASA, and a random sample of members of the HRS. Additional information was obtained from open-forum presentations and other invited and public sources. All opinion-based evidence relevant to each topic (*e.g.*, survey data, open-forum testimony, Internet-based comments, letters, and editorials) was considered in the development of the original Advisory.

Survey responses from Task Force–appointed expert consultants are reported in summary form in the text, with a listing of consultant survey responses reported in appendix 3. In addition, survey responses from active ASA and HRS members are reported in summary form in the text, with a listing of survey responses reported in appendix 3.

Advisories

I. Preoperative Evaluation

A focused preoperative evaluation of CIED patients consists of the following: (1) establishing whether a patient has a CIED, (2) defining the type of device, (3) determining whether a patient is CIED-dependent for antibradycardia pacing function, and (4) determining device function.

Although no controlled trials of the clinical impact of performing a focused preoperative evaluation for CIED patients were found, case reports suggest that incomplete preoperative examination of patients with CIEDs may lead to adverse outcomes (*e.g.*, inhibited CIED function and asystole) (*Category B3 evidence*).[1,2]

The majority of consultants, ASA members, and HRS members agree that the above four preoperative evaluation activities should be conducted.** Fn7

Advisory for Preoperative Evaluation. A focused preoperative evaluation should include establishing whether a patient has a CIED, defining the type of device, determining whether a patient is CIED-dependent for pacemaking function, and determining CIED function.

Determining whether a patient has a CIED should be based on the following: (1) a focused history including, but not limited to, the patient interview, medical records review, and review of available chest x-rays, electrocardiograms, or any available monitor or rhythm strip information; and (2) a focused physical examination (*i.e.*, checking for scars and palpating for device).

Defining the type of device is accomplished by (1) obtaining the manufacturer's identification card from the patient or other source, (2) ordering chest x-rays if no other data are available,†† or (3) referring to supplemental resources (*e.g.*, manufacturer's databases, pacemaker clinic records, and consultation with a cardiologist). Fn8

CIED dependence for pacemaking function may be determined by one or more of the following: (1) a verbal history or an indication in the medical record that the patient has experienced a bradyarrhythmia that has caused syncope or other symptoms requiring CIED implantation, (2) a history of successful atrioventricular nodal ablation that resulted in CIED placement, or (3) a CIED evaluation that shows no evidence of spontaneous ventricular activity when the pacemaking function of the CIED is programmed to VVI pacing mode at the lowest programmable rate.

CIED function is ideally assessed by a comprehensive evaluation of the device.[3] If a comprehensive evaluation is not possible, then, at a minimum, confirm whether pacing impulses are present and create a paced beat. Consultation with a cardiologist or CIED service may be necessary. Contacting the manufacturer for perioperative recommendations may be a consideration.

** Refer to appendix 3 for results of the consultants, ASA membership, and HRS membership surveys.

†† Most current CIEDs have an x-ray code that can be used to identify the manufacturer of the device.

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II. Preoperative Preparation

Preparation for patient safety and proper maintenance of the device during a procedure includes (1) determining whether electromagnetic interference (EMI) is likely to occur during the planned procedure; (2) determining whether preoperative reprogramming the CIED pacemaking function to an asynchronous pacing mode or disabling any special algorithms, including rate adaptive functions, is needed; (3) suspending antitachyarrhythmia functions if present; (4) advising the individual performing the procedure to consider use of a bipolar electrocautery system or ultrasonic (harmonic) scalpel to minimize potential adverse effects of EMI on the pulse generator or leads; (5) assuring the availability of temporary pacing and defibrillation equipment; and (6) evaluating the possible effects of anesthetic techniques on CIED function and patient-CIED interactions.

Numerous descriptive studies and case reports suggest that the following procedures are likely to be associated with EMI: (1) electrocautery,[4–10] (2) radiofrequency ablation,[11–16] and (3) magnetic resonance imaging (MRI),[17–30] (*Category B2–B3 evidence*). Studies with observational findings report the occurrence of EMI during radiation therapy,[31–33] whereas other observational studies and case reports indicate no apparent EMI effects (*Category B2–B3 evidence*).[34,35] Studies with observational findings report the occurrence of EMI during lithotripsy,[36,37] whereas other observational studies and case reports indicate no apparent EMI effects (*Category B2–B3 evidence*).[38–41] No studies were found that reported EMI during electroconvulsive therapy (ECT) (*Category D evidence*). Case reports indicate that inappropriately high pacing rates may occur as a result of EMI effects between cardiac monitoring equipment and CIEDs with active minute entilation sensors.[42–44]

No controlled trials of the clinical impact of programming the pacemaking function to an asynchronous mode for a procedure were found (*Category D evidence*). Although a case report suggests that such reprogramming may be beneficial during electrocautery,[45] other reports indicate that EMI may continue to affect reprogrammed pacemakers (*Category B3 evidence*).[46,47] The literature lacks sufficient guidance regarding the potential perioperative impact of anesthetic techniques on CIED function (*Category D evidence*).

The majority of consultants, ASA members, and HRS members agree that it should be determined whether EMI is likely to occur before a planned procedure. The majority of consultants agree that a CIED's rate-adaptive therapy should be turned off before a procedure, whereas the ASA and HRS members are equivocal. The majority of consultants and HRS members disagree that all patients' CIEDs should be programmed to an asynchronous mode before surgery, whereas the ASA members are equivocal. In addition, the majority of consultants and HRS members agree that pacemaker-dependent patients' CIEDs should be programmed to an asynchronous mode before surgery, whereas the ASA members are again equivocal. The majority of consultants, ASA members, and HRS members agree that (1) suspending antitachyarrhythmia functions if present, (2) advising the individual performing the procedure to consider use of a bipolar electrocautery system to minimize potential adverse effects of EMI on the pulse generator or leads, (3) assuring the availability of temporary pacing and defibrillation equipment, and (4) evaluating the possible effects of anesthetic techniques on CIED function and patient-CIED interactions are important steps in promoting patient safety and successfully managing patients with CIEDs. The consultants and ASA members agree, and HRS members are equivocal regarding the consideration of using an ultrasonic scalpel.

Advisory for Preoperative Preparation. Planned procedures should include a determination of whether EMI is likely to occur for either conventional pacemakers or ICDs. If EMI is likely to occur, the conventional pacing function of a CIED should be altered by changing to an asynchronous pacing mode‡‡ in pacemaker-dependent patients and suspending special algorithms, including rate-adaptive functions.§§ These alterations may be accomplished by programming or applying a magnet when applicable.|||| However, the Task Force cautions against the routine use of the magnet over an ICD.## In addition, an ICD's antitachyarrhythmia functions should be suspended if present. For the ICD patient who depends on pacing function for control of bradyarrhythmia, these functions should be altered by programming as noted above. Consultation with a cardiologist or pacemaker ICD service may be necessary. Fn9 Fn10 Fn11 Fn12

For all CIEDs, consider advising the individual performing the procedure to use a bipolar electrocautery system or an ultrasonic scalpel when applicable. Temporary pacing and defibrillation equipment should be immediately available before, during, and after a procedure.

Finally, the Task Force believes that anesthetic techniques do not influence CIED function. However, anesthetic-in-

‡‡ The VVT mode (with attention to the upper rate limit) might also be considered for a patient with ventricular ectopy where concern exists regarding R-on-T pacing during an asynchronous pacing mode. However, the upper pacing rate during VVT mode is manufacturer- and possibly generator-specific and can approach 200 beats per minute for many devices. Generally, VVT mode pacing would not be a consideration except in very rare circumstances. Before using the VVT mode, a cardiologist and the generator manufacturer should be consulted to determine the suitability of the upper pacing rate for any patient.

§§ Disabling of ICDs may not be needed in low-risk situations (*e.g.,* appropriate preoperative CIED check, no EMI, no ICD or lead issues likely to lead to inappropriate discharge, and no patient issues likely to lead to any discharge, such as an ICD placed for primary prevention).

|||| A magnet correctly applied to a pacemaker often results in asynchronous pacemaker function at a predetermined rate without rate responsiveness. The magnet rate and response vary by manufacturer. Magnet response can be affected by programming and remaining battery life. The magnet rate may be excessive for some patients. Some pacemakers may have no magnet response.

Magnet application to an ICD rarely alters bradycardia pacing rate and function. A magnet correctly applied to an ICD often results in suspension of tachyarrhythmia therapy. For most ICDs, there is no reliable means to detect appropriate magnet placement. Some ICDs may have no magnet response. Some ICDs can be permanently disabled by magnet application.

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duced physiologic changes (*i.e.*, cardiac rate, rhythm, or ischemia) in the patient may induce unexpected CIED responses or adversely affect the CIED-patient interaction.

III. Intraoperative Management

The primary activities associated with intraoperative management of a CIED include the following: (1) monitoring the operation of the device; (2) preventing potential CIED dysfunction; and (3) performing emergency defibrillation, cardioversion, or heart rate support.

Intraoperative Monitoring. Intraoperative monitoring includes continuous electrocardiography as well as monitoring of the peripheral pulse (*e.g.*, palpation of the pulse, auscultation of heart sounds, monitoring of a tracing of intra-arterial pressure, ultrasound peripheral pulse monitoring, or pulse plethysmography or oximetry).[48] Although no controlled trials were found that examine the clinical impact of electrocardiography or peripheral pulse monitoring for CIED patients, case reports note the importance of intraoperative electrocardiography monitoring in the detection of pacemaker or cardiac dysfunction for these patients (*Category B3 evidence*).[2,49–53]

The majority of consultants, ASA members, and HRS members agree that (1) continuous electrocardiographic monitoring should be done for all CIED patients and (2) continuous peripheral pulse monitoring should be conducted.

Advisory for Intraoperative Monitoring. ECG and peripheral pulse monitoring are important components of perioperative management of the patient with a CIED. A patient's electrocardiogram should be continuously displayed, as required by ASA standards, from the beginning of anesthesia until the patient is transferred out of the anesthetizing location, with additional electrocardiographic monitoring in the postoperative period as indicated by the patient's medical condition.[48,54] These standards should apply to all CIED patients receiving general or regional anesthesia, sedation, or monitored anesthesia care. Continuous peripheral pulse monitoring should be performed for all CIED patients receiving general or regional anesthesia, sedation, or monitored anesthesia care. If unanticipated device interactions are found, consider discontinuation of the procedure until the source of interference can be eliminated or managed.

Managing Potential Sources of EMI. Procedures using electrocautery, radiofrequency ablation, lithotripsy, MRI, or radiation therapy may damage CIEDs or interfere with CIED function, potentially resulting in severe adverse outcomes. Sources of EMI are often unique to specific procedures, and the management of each of these potential EMI sources is reported separately below.

Electrocautery. Management of potential sources of EMI associated with electrocautery includes (1) assuring that the cautery tool and current return pad*** are positioned so the current pathway does not pass through or near the CIED pulse generator and leads; (2) avoiding proximity of the cautery's electrical field to the pulse generator or leads; (3) using short, intermittent, and irregular bursts at the lowest feasible energy levels; and (4) using a bipolar electrocautery system or an ultrasonic (harmonic) scalpel if possible. Fn13

There is insufficient literature to evaluate whether positioning the current pathway away from the CIED pulse generator and leads reduces the occurrence of EMI.

Two case reports[52,55] and one observational study[56] suggest that EMI may occur in spite of positioning the current return pad as far as possible away from the generator and leads (*Category B2–B3 evidence*). One case report suggested that application of unipolar electrocautery on the sternum resulted in complete pacemaker inhibition (*Category B3 evidence*).[1]

Although no recent studies were found examining the benefit of using short, intermittent bursts at the lowest feasible energy levels, previous literature††† suggests that short, intermittent bursts may be useful in completing procedures without notable EMI interference (*Category B2–B3 evidence*).[57–60] One case report describes pacemaker failure when short bursts of electrocautery current were used (*Category B3 evidence*).[60] Fn14

Finally, case reports suggest that surgery for pacemaker patients may proceed uneventfully when bipolar electrocautery systems[45,46,49] or harmonic scalpels[61,62] are used (*Category B3 evidence*). However, a case report describes pacemaker failure occurring when bipolar electrocautery was used (*Category B3 evidence* .[63]

The majority of consultants, ASA members, and HRS members agree that the current return pad should be positioned so the electrosurgical current pathway does not pass through or near the CIED pulse generator or leads. The majority of consultants, ASA members, and HRS members agree that direct contact between the electrocautery system and the CIED pulse generator or its leads should be avoided. The majority of consultants, ASA members, and HRS members agree that short, intermittent bursts should be performed. The majority of consultants and ASA members agree that harmonic scalpels should be used when possible, and HRS members are equivocal. The majority of consultants, ASA members, and HRS members agree that bipolar electrocautery systems should be used when possible.

Advisory for Managing EMI from Electrocautery. The Task Force believes that EMI could be minimized during certain procedures using a variety of intraoperative management techniques. The risk of intraoperative interference from electrocautery systems may be minimized by (1) positioning the cautery tool and current return pad, so the current pathway does not pass through or near the CIED

*** Although commonly referred to as the grounding pad, most operating room power supplies in the United States are ungrounded.

††† See appendix 3 for an explanation of the term *previous literature.*

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Fn15 system‡‡‡; (2) avoiding proximity of the cautery's electrical field to the pulse generator and leads, including avoidance of Fn16 waving the activated electrode over the generator§§§; (3) using short, intermittent, and irregular bursts at the lowest feasible energy levels; and (4) using bipolar electrocautery systems or ultrasonic (harmonic) scalpels if possible. Advising or reminding the individual performing the procedure to implement these management techniques should be considered.

Radiofrequency (RF) Ablation. Management of potential sources of EMI associated with RF ablation primarily involves keeping the RF current path (electrode tip to current return pad) as far away from the pulse generator and lead system as possible. One observational study reports 3 of 12 cases that resulted in a significant drop in resistance on the pacemaker leads when RF ablation was used in proximity to the leads (*Category B2 evidence*).[64] One case report suggests that positioning of the RF ablation cluster electrode no closer than 5 cm from the pacer leads allowed the procedure to continue uneventfully (*Category B3 evidence*).[65]

The majority of consultants, ASA members, and HRS members agree that the individual performing the procedure should avoid direct contact between the ablation catheter and the CIED and leads and should keep the RF ablation current path as far away from the pulse generator and lead system as possible.

Advisory for Managing EMI from RF Ablation. The risk of interference from RF ablation may be reduced by avoiding direct contact between the ablation catheter and the pulse generator and leads and keeping the RF's current path (electrode tip to current return pad) as far away from the pulse generator and leads as possible. During all RF ablative procedures, consider discussing with the individual performing the procedure any concerns regarding the proximity of the ablation catheter to the CIED leads.

Lithotripsy. Management of potential sources of EMI associated with lithotripsy includes (1) avoiding focus of the lithotripsy beam near the pulse generator and (2) disabling atrial pacing if the lithotripsy system triggers on the R-wave. The literature is silent regarding the benefits of focusing the lithotripsy beam away from the pulse generator as well as the benefits of disabling atrial pacing during lithotripsy (*Category D evidence*).

The majority of consultants, ASA members, and HRS members agree that focusing the lithotripsy beam near the pulse generator should be avoided, and all three groups are equivocal regarding whether atrial pacing should be disabled before a procedure if the lithotripsy system triggers on the R-wave.

Advisory for Managing EMI from Lithotripsy. During lithotripsy, the lithotripsy beam should not be focused near the pulse generator. If the lithotripsy system triggers on the R-wave, atrial pacing might need to be disabled before the procedure.

Magnetic Resonance Imaging. There is insufficient rigorous literature to examine the effects of specific management activities related to CIED patients receiving MRI (*Category D evidence*). Observational studies and case reports suggest that the MRI may be completed without notable EMI under specific circumstances and with appropriate patient qualification and monitoring (*Category B2–B3 evidence*).[17,66–69] However, other literature generally suggests that MRI is contraindicated (*Category B2–B3 evidence*).[21–25,28,30]

The majority of consultants, ASA members, and HRS members generally agree that an MRI is contraindicated for all CIED patients.

Advisory for Managing EMI from Magnetic Resonance Imaging. An MRI is generally contraindicated for CIED patients. If an MRI must be performed, consult with the ordering physician, the patient's pacemaker specialist or cardiologist, the diagnostic radiologist, and the CIED manufacturer.

Radiation Therapy. The literature does not provide sufficient guidance regarding specific management activities related to CIED patients undergoing radiation therapy (*Category D evidence*).

None of the consultants or HRS members and only 10% of the ASA members agree that radiation therapy is contraindicated for all CIED patients. Fifty-seven percent of the consultants, 59% of the HRS members, and 37% of the ASA members agree that radiation therapy is contraindicated for some but not all CIED patients, whereas 43% of the consultants, 41% of the HRS members, and 53% of the ASA members agree that radiation therapy is not contraindicated for any CIED patient.

Advisory for Managing EMI from Radiation Therapy. The Task Force believes that radiation therapy can be safely performed for CIED patients.‖‖‖ The device must Fn17 be outside the field of radiation. Therefore, some pulse generators will require surgical relocation before commencing radiation. Most manufacturers recommend verification of pulse generator function during and at the completion of radiation. Problems may include pacemaker failure and runaway pacemaker.### Fn18

Electroconvulsive Therapy. No clinical studies were found that report EMI effects or permanent CIED malfunctions associated with electroconvulsive therapy (ECT) (*Category D evidence*). One study reports two cases where patients' ICDs were turned off before ECT but does not report the effect of the therapy on ICD function (*Category*

‡‡‡ For some cases, the electrosurgical receiving plate will need to be placed on a site different from the thigh. For example, in head and neck cases, the receiving plate can be placed on the posterior-superior aspect of the shoulder contralateral to the generator position.

§§§ An inhibitory effect could occur even when the active electrode of the electrocautery is not touching the patient.

‖‖‖ Radiation shielding may not be feasible for some patients because of the size and weight of the shield. This may be compensated for by relocating the generator.

Runaway pacemaker is a potentially catastrophic pulse generator malfunction characterized by the sudden onset of rapid, erratic pacing. Runaway pacemaker is the result of multiple internal component failure, and it is relatively uncommon in modern devices. Circuitry in modern pacemakers (and ICDs) limits the runaway pacing rate to less than 210 beats per minute.

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B3 evidence).[70] However, the author indicates that treatment with ECT might be associated with significant cardiac risks. Transient electrocardiographic changes (*e.g.*, increased P-wave amplitude, altered QRS shape, and T-wave and ST-T abnormalities) may result from ECT, and additional cardiac complications (*e.g.*, arrhythmia or ischemia) may occur in patients with preexisting cardiac disease. Finally, physiologic stresses after ECT, such as a period of bradycardia and reduced blood pressure followed by tachycardia and a rise in blood pressure, may account for cardiac failure in the extended postoperative period (*i.e.*, several hours or days after ECT) among patients with marginal cardiac function.

Advisory for Managing EMI from Electroconvulsive Therapy. Although transient or long-term myocardial and nervous system effects may be associated with ECT, the Task Force believes that such therapies may be administered to CIED patients without significant damage to a disabled CIED. If ECT must be performed, consult with the ordering physician and the patient's cardiologist to plan for the first and subsequent ECT's. All CIEDs should undergo a comprehensive interrogation before the procedure(s). ICD functions should be disabled for shock therapy during ECT; however, be prepared to treat ventricula arrhythmias that occur secondary to the hemodynamic effects of ECT. CIED-dependent patients may require a temporary pacing system to preserve cardiac rate and rhythm during shock therapy. Also, the CIED may require programming to asynchronous activity to avoid myopotential inhibition of the device in pacemaker-dependent patients.

Emergency Defibrillation or Cardioversion. During the perioperative period, emergency defibrillation or cardioversion may become necessary for the CIED patient. In this case, the primary concern is to minimize the current flowing through the pulse generator and lead system. Case reports suggest that optimal positioning of the defibrillation or cardioversion pads or paddles may be an important factor in the prevention of adverse CIED-related outcomes.[71–75]

The majority of consultants, ASA members, and HRS members agree that positioning the defibrillation or cardioversion pads as far as possible from the pulse generator should be done. The majority of consultants, ASA members, and HRS members also agree that the anterior-posterior position should be used and that a clinically appropriate energy output should be used regardless of the type of CIED.

Advisory for Emergency Defibrillation or Cardioversion. Before attempting emergency defibrillation or cardioversion of the patient with an ICD and magnet-disabled therapies, all sources of EMI should be terminated and the magnet removed to reenable antitachycardia therapies. The patient should then be observed for appropriate CIED therapy. For the patient with an ICD and antiarrhythmic therapies that have been disabled by programming, consider reenabling therapies through programming. If the above activities fail to restore ICD function, proceed with emergency external defibrillation or cardioversion.

Overriding the above discussion is the need to follow existing ACLS and emergency guidelines[76] to provide rapid cardioversion or defibrillation, and attention should be turned to providing this therapy as quickly as possible.

If a life-threatening arrhythmia occurs, follow ACLS guidelines for energy level and for paddle placement. If possible, attempt to minimize the current flowing through the pulse generator and lead system by (1) positioning the defibrillation or cardioversion pads or paddles as far as possible from the pulse generator and (2) positioning defibrillation or cardioversion pads or paddles perpendicular to the major axis of the CIED pulse generator and leads to the extent possible by placing them in an anterior-posterior location. A clinically-appropriate energy output should always be used regardless of the presence of a CIED, and the paddles should be positioned as best as can be done in an emergency.

IV. Postoperative Management

Postoperative management of CIED patients primarily consists of interrogating and restoring CIED function. One observational study and a case report indicate that postoperative pacemaker checks revealed the need to alter pacing mode or other parameters, which included increasing ventricular pacing output because of pacing threshold increase (*Category B2-B3 evidence*).[77,78] The case report also indicates that a postoperative check of a pacemaker identified a safety mode reset, which they attributed to EMI from monopolar electrosurgery. A second observational study indicates that a postoperative ICD check identified the appearance of the elective replacement indicator, probably from EMI during surgery (*Category B2 evidence*).[79] In addition, this report identifies EMI detections on the atrial lead in both pacemakers and defibrillators and on the ventricular lead in patients with pacemakers, without significant consequence to the patients.

The majority of consultants, ASA members, and HRS members agree that postoperative patient management should include interrogating and restoring CIED function in the postanesthesia care unit or the intensive care unit.

Advisory for Postoperative Management. Cardiac rate and rhythm should be monitored continuously throughout the immediate postoperative period. Back-up pacing capability and cardioversion-defibrillation equipment should be immediately available at all times.

Postoperative interrogation and restoration of CIED function are basic elements of postoperative management. The CIED first should be interrogated to assess postoperative device functions.**** If interrogation determines that CIED settings are inappropriate, then the device should be reprogrammed to appropriate settings. For an ICD, all antitachyarrhythmic therapies should be restored. Consultation with a cardiologist or pacemaker-ICD service may be necessary. Fn19

**** Postoperative checks of CIEDs may not be needed in low-risk situations (*e.g.*, appropriate preoperative CIED check, no EMI-generating devices used during case, no blood transfused, no perioperative reprogramming took place, and no problems identified during the case).

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Appendix 1: Generic Pacemaker and Defibrillator Codes

The generic pacemaker and defibrillator codes were developed as joint projects by the North American Society of Pacing and Electrophysiology (NASPE)†††† and the British Pacing and Electrophysiology Group (BPEG).[80,81] The five positions refer to the order of the programmed settings on the CIED (tables 1 and 2). Fn20 TA1-TA2

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

Position I Pacing Chamber(s)	Position II Sensing Chamber(s)	Position III Response(s) to Sensing	Position IV Programmability	Position V Multisite Pacing
O = None	O = None	O = None	O = None	O = None
A = Atrium	A = Atrium	I = Inhibited	R = Rate Modulation	A = Atrium
V = Ventricle	V = Ventricle	T = Triggered		V = Ventricle
D = Dual (A+V)	D = Dual (A+V)	D = Dual (T+I)		D = Dual (A+V)

Examples: AAI = atrial-only antibradycardia pacing in which any failure of the atrium to produce an intrinsic event, within the appropriate time window (determined by the lower rate limit), will result in an atrial pacing pulse emission. There is no ventricular sensing; thus a premature ventricular event will not likely reset the pacing timer. AOO = asynchronous atrial-only pacing in which the pacing device emits a pacing pulse, regardless of the underlying cardiac rhythm. DDD = dual-chamber antibradycardia pacing function in which every atrial event, within programmed limits, will be followed by a ventricular event. The DDD mode implies dual chamber pacing with atrial tracking. In the absence of intrinsic activity in the atrium, it will be paced, and, after any sensed or paced atrial event, an intrinsic ventricular event must appear before the expiration of the atrioventricular (A-V) timer or the ventricle will be paced. DDI = dual-chamber behavior in which the atrial activity is tracked into the ventricle only when the atrial event is created by the antibradycardia pacing function of the generator. In the DDI mode, the ventricle is paced only when no intrinsic ventricular activity is present. DOO = asynchronous A-V sequential pacing without regard to underlying cardiac rhythm. VOO = asynchronous ventricular-only pacing without regard to the underlying cardiac rhythm. VVI = ventricular-only antibradycardia pacing in which any failure of the ventricle to produce an intrinsic event, within the appropriate time window (determined by the lower rate limit), will result in a ventricular pacing pulse emission. There is no atrial sensing; thus, there can be no A-V synchrony in a patient with a VVI pacemaker and any intrinsic atrial activity.

* NBG: N refers to NASPE, B refers to BPEG, and G refers to generic.

Table 2. Generic Defibrillator Code (NBD): NASPE/BPEG

Position I Shock Chambers(s)	Position II Antitachycardia Pacing Chamber(s)	Position III Tachycardia Detection	Position IV * Antibradycardia Pacing Chamber(s)
O = None	O = None	E = Electrogram	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)

* For robust identification, Position IV is expanded into its complete NBG code. For example, a biventricular pacing defibrillator with ventricular shock and antitachycardia pacing functionality would be identified as VVE-DDDRV, assuming that the pacing section was programmed DDDRV. Currently, no hemodynamic sensors have been approved for tachycardia detection (Position III).

Appendix 2: Summary of Advisory Statements‡‡‡‡ Fn21

I. Preoperative Evaluation
   A. Establish whether a patient has a cardiac rhythm management device (CIED).
      1. Conduct a focused history (patient interview, medical records review, and review of available chest x-rays, electrocardiograms, or any available monitor or rhythm strip information).
      2. Conduct a focused physical examination (check for scars and palpate for device).
      3. Define the type of CIED.
         a. Obtain manufacturer's identification card from patient or other source.
         b. Order chest x-ray if no other data are available.
         c. Refer to supplemental resources (*e.g.*, manufacturer's databases).
   B. Determine the dependence on pacing function of the CIED.
      1. Patient has history of symptomatic bradyarrhythmia resulting in CIED implantation.
      2. Patient has history of successful atrioventricular nodal ablation.
      3. Patient has inadequate escape rhythm at lowest programmable pacing rate.
   C. Determine CIED function.
      1. Interrogate device (consultation with a cardiologist or pacemaker-ICD service may be necessary).
      2. Determine whether the device will capture when it paces (*i.e.*, produce a mechanical systole with a pacemaker impulse).
      3. Consider contacting the manufacturer for perioperative recommendations.

†††† Now called the Heart Rhythm Society (HRS).

‡‡‡‡ Refer to table 3 for an example of a stepwise approach to the perioperative management of the patient with a CIED.

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II. Preoperative Preparation
- A. Determine whether EMI is likely to occur during the planned procedure.
  1. Determine whether reprogramming pacing function to asynchronous mode or disabling rate responsive function is advantageous.
  2. Suspend antitachyarrhythmia functions if present.
  3. Advise the individual performing the procedure to consider use of a bipolar electrocautery system or ultrasonic (harmonic) scalpel.
  4. Temporary pacing and defibrillation equipment should be immediately available.
- B. Evaluate the possible effects of anesthetic techniques and of the procedure on CIED function and patient-CIED interactions.

III. Intraoperative Management
- A. Monitor operation of the CIED.
  1. Conduct electorcardiographic monitoring per ASA standard.
  2. Monitor peripheral pulse (*e.g.*, manual pulse palpation, pulse oximeter plethysmogram, and arterial line).
  3. Manage potential CIED dysfunction as a result of EMI.
- B. Electrocautery.
  1. Assure that the electrosurgical receiving plate is positioned so the current pathway does not pass through or near the CIED system. For some cases, the receiving plate might need to be placed on a site different from the thigh (*e.g.*, the superior posterior aspect of the shoulder contralateral to the generator position for a head and neck case).
  2. Advise the individual performing the procedure to avoid proximity of the cautery's electrical field to the pulse generator or leads.
  3. Advise the individual performing the procedure to use short, intermittent and irregular bursts at the lowest feasible energy levels.
  4. Advise the individual performing the procedure to reconsider the use of a bipolar electrocautery system or ultrasonic (harmonic) scalpel in place of a monopolar electrocautery system if possible.
- C. Radiofrequency (RF) ablation.
  1. Advise the individual performing the procedure to avoid direct contact between the ablation catheter and the pulse generator and leads.
  2. Advise the individual performing the procedure to keep the RF's current path as far away from the pulse generator and lead system as possible.
- D. Lithotripsy.
  1. Advise the individual performing the procedure to avoid focusing the lithotripsy beam near the pulse generator.
  2. If the lithotripsy system triggers on the R-wave, consider preoperative disabling of atrial pacing.
- E. Magnetic resonance imaging.
  1. MRI is generally contraindicated in patients with CIEDs.
  2. If an MRI must be performed, consult with the ordering physician, the patient's cardiologist, the diagnostic radiologist, and the CIED manufacturer.
- F. Radiation therapy.
  1. Radiation therapy can be safely performed in patients who have CIEDs.
  2. Surgically relocate the CIED if the device will be in the field of radiation.
- G. Electroconvulsive therapy.
  1. Consult with the ordering physician, the patient's cardiologist, a CIED service, or the CIED manufacturer.
- H. Emergency defibrillation or cardioversion.
  1. For the patient with an ICD and magnet-disabled therapies:
     - a. Advise the individual performing the procedure to terminate all sources of EMI while the magnet is removed.
     - b. Remove the magnet to reenable antitachycardia therapies.
     - c. Observe the patient and the monitors for appropriate CIED therapy.
     - d. If the above activities fail to restore ICD function, proceed with emergency external defibrillation or cardioversion.
  2. For the patient with an ICD and programming-disabled therapies:
     - a. Advise the individual performing the procedure to terminate all sources of EMI while the magnet is removed.
     - b. Re-enable therapies through programming if the programmer is immediately available and ready to be used.
     - c. Observe the patient and the monitors for appropriate CIED therapy.
     - d. If the above activities fail to restore ICD function, proceed with emergency external defibrillation or cardioversion.
  3. For external defibrillation:
     - a. Position defibrillation/cardioversion pads or paddles as far as possible from the pulse generator.
     - b. Position defibrillation/cardioversion pads or paddles perpendicular to the major axis of the CIED to the extent possible by placing them in an anterior-posterior location.
     - c. If it is technically impossible to place the pads or paddles in locations that help to protect the CIED, then defibrillate/cardiovert the patient in the quickest possible way and be prepared to provide pacing through other routes.
     - d. Use a clinically appropriate energy output.

IV. Postoperative Management
- A. Continuously monitor cardiac rate and rhythm and have back-up pacing and defibrillation equipment immediately available throughout the immediate postoperative period.
- B. Interrogate and restore CIED function in the immediate postoperative period.
  1. Interrogate CIED; consultation with a cardiologist or pacemaker-ICD service may be necessary.
  2. Restore all antitachyarrhythmic therapies in ICDs.
  3. Assure that all other settings of the CIED are appropriate.

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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 examination
	Determine CIED type (PM, ICD, CRT)	Manufacturer's CIED identification card Chest x-ray (no data available) Supplemental resources*
	Determine if patient is CIED-dependent for pacing function	Verbal history Bradyarrhythmia symptoms Atrioventricular node ablation No spontaneous ventricular activity†
	Determine CIED function	Comprehensive CIED evaluation‡ Determine if pacing pulses are present and create paced beats
Preoperative preparation	EMI unlikely during procedure	If EMI unlikely, then special precautions are not needed
	EMI likely; CIED is PM	Reprogram to asynchronous mode when indicated Suspend rate adaptive functions§
	EMI likely: CIED is ICD	Suspend antitachyarrhythmia functions If patient is dependent on pacing function, then alter pacing functions as above
	EMI likely: All CIED	Use bipolar cautery; ultrasonic scalpel Temporary pacing and cardioversion-defibrillation available
	Intraoperative physiologic changes likely (e.g. bradycardia, ischemia)	Plan for possible adverse CIED-patient interaction
Intraoperative management	Monitoring	Electrocardiographic monitoring per ASA standard Peripheral pulse monitoring
	Electrocautery interference	CT/CRP no current through PG/leads Avoid proximity of CT to PG/leads Short bursts at lowest possible energy Use bipolar cautery; ultrasonic scalpel
	RF catheter ablation	Avoid contact RF catheter with PG/leads RF current path far away from PG/leads Discuss these concerns with operator
	Lithotripsy	Do not focus lithotripsy beam near PG R-wave triggers lithotripsy? Disable atrial pacing‖
	MRI	Generally contraindicated If required, consult ordering physician, cardiologist, radiologist, and manufacturer
	Radiation therapy	PG/leads must be outside of RT field Possible surgical relocation of PG Verify PG function during/after RT course
	ECT	Consult with ordering physician, patient's cardiologist, a CIED service, or CIED manufacturer
Emergency defibrillation-cardioversion	ICD: magnet-disabled	Terminate all EMI sources Remove magnet to reenable therapies Observe for appropriate therapies
	ICD: programming disabled	Programming to reenable therapies or proceed directly with external cardioversion/defibrillation
	ICD: either of above	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	Immediate postoperative period	Monitor cardiac R&R continuously Back-up pacing and cardioversion/defibrillation capability
	Postoperative interrogation and restoration of CIED function	Interrogation to assess function Settings Appropriate?# Is CIED an ICD?** Use cardiology/pacemaker-ICD service if needed

* Manufacturer's databases, pacemaker clinic records, and cardiology consultation. † With CIED programmed VVI at lowest programmable rate. ‡ Ideally CIED function assessed by interrogation, with function altered by reprogramming if required. § Most times this will be necessary; when in doubt, assume so. ‖Atrial pacing spikes may be interpreted by device as R waves, possible inciting the lithotripter to deliver a shock during a vulnerable period in the heart. # If necessary, reprogram appropriate settings. ** Restore all antitachycardia therapies.

CIED = cardiac rhythm management device; CRP = current return pad; CRT = cardiac resynchronization therapy; CT = cautery tool; ECT = electroconvulsive therapy; EMI = electromagnetic interference; ICD = internal cardioverter-defibrillator; MRI = magnetic resonance imaging; PG = pulse generator; PP = cardioversion-defibrillation pads or paddles; R&R = rhythm and rate; RT = radiation therapy.

Appendix 3: Methods and Analyses

State of the Literature

For this updated Advisory, a review of the studies used in the development of the original Advisory and published after 1990 were combined with studies published subsequent to approval of the original Advisory. The updated literature review was based on evidence linkages, consisting of directional statements about relationships between specific perioperative management activities and CIED function or clinical outcomes.

For the literature review, potentially relevant studies were identified *via* electronic and manual searches of the literature. The updated electronic search covered a 7-yr period from 2004 to 2010. The manual search covered a 21-yr period of time from 1990 to 2010. Because CIEDs represent a rapidly changing technology, previous literature (*i.e.*, literature published before 1990) was rarely included in the evaluation of evidence for this Practice Advisory. More than 300 citations that addressed topics related to the evidence linkages were initially identified. These articles were reviewed and combined with pre-2004 articles used in the original Advisory, resulting in a total of 134 articles that contained direct linkage-related evidence. There was no sufficient literature with well-defined experimental designs and statistical information to conduct an analysis of aggregated studies (*i.e.*, meta-analysis) contained in the evidence linkage. A complete bibliography used to develop this updated Advisory, organized by section, is available as Supplemental Digital Content 1, http://links.lww.com/ALN/A656.

For the original Advisory, an interobserver agreement among Task Force members and two methodologists was established by interrater reliability testing. Agreement levels using a kappa (κ) statistic for two-rater agreement pairs were 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 chance-corrected 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

For the original Advisory, consensus was obtained from multiple sources, including (1) survey opinions from consultants who were selected based on their knowledge or expertise in perioperative management of CIEDs, (2) survey opinions from randomly selected samples of active members of the American Society of Anesthesiologists and active members of the Heart Rhythm Society, (3) testimony from attendees of two publicly-held open forums at a national anesthesia meeting and at a major cardiology meeting, (4) Internet commentary, and (5) Task Force opinion and interpretation. The survey rate of return was 56% (n = 23/41) for Consultants, 15% (n = 89/600) for the ASA membership, and 15% (n = 44/300) for the HRS membership (tables 3 and 4). TA3-TA4,AQ

For the original Advisory, an additional survey was sent to the consultants asking them to indicate which, if any, of the evidence linkages would change their clinical practices if the Advisory was instituted. The rate of return was 39% (n = 16/41). The percent of responding Consultants expecting *no change* associated with each linkage were as follows: preoperative evaluation, 67%; preoperative patient preparation, 67%; intraoperative monitoring of CIEDs, 67%; emergency defibrillation or cardioversion, 87%; postoperative monitoring of CIEDs, 73%; postoperative interrogation and restoration of CIED function, 60%; and intraoperative management of EMI during: electrocautery, 73%; radiofrequency ablation, 73%; lithotripsy, 80%; MRI, 80%; radiation therapy, 80%; and electroconvulsive therapy, 73%. Forty percent of the respondents indicated that the Advisory would have *no effect* on the amount of time spent on a typical case. Nine respondents (60%) indicated that there would be an increase in the amount of time they would spend on a typical case with the implementation of this Advisory. The amount of increased time anticipated by these respondents ranged from 5–30 minutes.

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Table 4. Consultant and Membership Survey Responses: Percent Agreement/Disagreement*

Survey Item	Consultants N	Consultants Percent Agree/Disagree	ASA Members† N	ASA Members† Percent Agree/Disagree	HRS Members‡ N	HRS Members‡ Percent Agree/Disagree
1. To perform a preoperative evaluation:						
Establish whether a patient has a CIED	23	100/0	89	100/0	44	100/0
Define the type of device	23	100/0	87	95/0	44	100/0
Determine whether a patient is CIED-dependent for pacemaking function	23	96/0	89	96/0	44	96/4
Determine CIED function	23	96/0	89	88/3	44	71/11
2. To prepare a CIED patient for a procedure:	—	—	—	—	—	—
Determine if EMI is likely to occur	23	96/4	89	91/2	44	96/2
Turn pacemaking rate-adaptive therapy off	23	52/35	89	35/35	44	34/34
Program pacemaking function to asynchronous mode:	—	—	—	—	—	—
All CIED patients	22	0/82	88	21/48	43	9/84
Pacemaker-dependent patients only	22	73/23	83	47/27	43	54/28
Suspend antitachyarrhythmia functions	21	86/5	87	54/21	43	63/21
Consider using a bipolar electrocautery system (when applicable)	22	91/0	86	90/2	44	77/14
Consider using an ultrasonic (harmonic) scalpel (when applicable)	22	68/18	88	63/3	44	34/9
Assure the availability of temporary pacing and defibrillation equipment	22	100/0	87	95/1	44	89/7
Consider the possible effects of anesthetic agents or techniques on CIED function	22	64/18	86	779	44	66/21
3. Intraoperative monitoring should include:	—	—	—	—	—	—
Continuous ECG	23	100/0	88	100/0	44	100/0
Continuous peripheral pulse	23	96/0	88	86/11	44	61/18
4. For procedures using electrocautery:	—	—	—	—	—	—
Position the electrosurgical receiving plate, so current pathway does not pass through or near the generator or leads	23	100/0	88	97/0	44	96/0
Avoid proximity of the cautery's electrical field to the pulse generator or leads	23	100/0	87	100/0	44	96/2
Use short, intermittent, and irregular bursts at the lowest feasible energy levels	23	96/0	87	83/2	44	91/7
Use a bipolar electrocautery system (when applicable)	23	91/0	88	94/1	44	84/2
Use an ultrasonic (harmonic) scalpel (when applicable)	23	57/13	88	65/1	44	41/9
5. For Radiofrequency ablation:	—	—	—	—	—	—
Avoid direct contact between the ablation catheter and the CIED and leads	23	83/0	87	76/0	44	91/2
Keep the current path (electrode tip to return plate) as far away from the pulse generator and lead system as possible	23	87/0	87	78/0	44	89/5
6. For lithotripsy:	—	—	—	—	—	—
Avoid focusing the lithotripsy beam near the pulse generator	23	91/0	86	78/1	44	86/0
If the lithotripsy system triggers on the R-wave, disable atrial pacing prior to procedure	23	39/26	86	38/13	44	39/9
7. For MRI (percent agreement only):§	—	—	—	—	—	—
MRI contraindicated for all CIED patients	21	81	79	80	44	55
MRI contraindicated for some but not all CIED patients	21	19	79	18	44	39
MRI not contraindicated for any CIED patient	21	0	79	2	44	6
8. For RT (percent agreement only):§	—	—	—	—	—	—
RT contraindicated for all CIED patients	21	0	73	10	44	0
RT contraindicated for some but not all CIED patients	21	57	73	37	44	59
RT not contraindicated for any CIED patient	21	43	73	53	44	41
9. For emergency defibrillation or cardioversion:	—	—	—	—	—	—
Position the defibrillation or cardioversion pads as far as possible from the pulse generator	23	83/0	87	69/13	44	91/7
Use an anterior-posterior position	23	74/9	84	61/6	44	68/25
Use a clinically appropriate energy output regardless of the device	23	100/0	87	87/0	44	100/0

(*continued*)

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Table 4. Continued

Survey Item	Consultants N	Consultants Percent Agree/Disagree	ASA Members† N	ASA Members† Percent Agree/Disagree	HRS Members‡ N	HRS Members‡ Percent Agree/Disagree
10. To manage CIED patients postoperatively:	—	—	—	—	—	—
Interrogate and restore CIED function in the PACU or ICU	23	96/4	88	98/1	44	77/21

* The percentage of respondents who agreed/disagreed with each item is presented. The percentage of respondents who were uncertain are not presented. † American Society of Anesthesiologists. ‡ Heart Rhythm Society. § Respondents were asked to select one of the three choices; therefore, the numbers represent percentage agreement only.

CIED = cardiac rhythm management device; ECG = electrocardiogram; EMI = electromagnetic interference; ICU = intensive care unit; MRI = magnetic resonance imaging; PACU = postanesthesia care unit; RT = radiation therapy.

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§§§§ A complete bibliography used to develop this Advisory, arranged alphabetically by author, is available as Supplemental Digital Content 2, http://links.lww.com/ALN/A657.

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