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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.[1]

Methodology

Definition of Cardiac Implantable Electronic Devices

For this Advisory, a cardiac implantable electronic device (CIED) refers to any permanently implanted

* Updated by the Committee on Standards and Practice Parameters: Jeffrey L. Apfelbaum, M.D. (Committee Chair), Chicago, Illinois; Peter M. Schulman, M.D. (Task Force Co-Chair), Portland, Oregon, Aman Mahajan M.D. Ph.D. (Task Force Co-Chair), Pittsburg, Pennsylvania; Richard T. Connis, Ph.D. (Chief Methodologist), Woodinville, Washington; and Madhulika Agarkar, M.P.H. (Methodologist), Schaumburg, Illinois.

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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/XXXXXXXX. Address correspondence to the American Society of Anesthesiologists: 1061 American Lane, Schaumburg, Illinois 60173. 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.

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cardiac pacemaker or any implantable cardioverter-defibrillator (ICD). The term CIED also refers to any cardiac resynchronization therapy (CRT) device.†

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, postoperative 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, and inappropriate ICD therapies.‡

Adverse clinical outcomes include, but are not limited to, hypotension, tachyarrhythmia and bradyarrhythmia, 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, permanently implanted CIED for treatment of bradyarrhythmia, tachyarrhythmia or heart failure. This Advisory applies to all CIED 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 permanently implanted CIED, including those: (1) with a temporary CIED, (2) with a noncardiac implantable device (*e.g.,* neurological or spinal cord stimulator), (3) with an implantable mechanical cardiac assist device (*e.g.,* ventricular assist device), or (4) undergoing CIED implantation or revision. In addition, this updated Advisory does not address procedures where there are no known perioperative CIED concerns, such as plain radiography, fluoroscopy, mammograms, or ultrasound.

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. The update may also serve as a resource for other physicians and health care professionals who manage patients with CIEDs.

Task Force Members and Consultants

In 2018, the ASA Committee on Standards and Practice Parameters requested that this Advisory be updated. This Advisory update is a revision developed by an ASA-appointed task force. The update consists of an evaluation of literature that includes new studies obtained after publication of the previous

† Generic pacemaker and defibrillator codes are provided in Appendix 2. Note that every ICD includes both pacing and shock therapies for the management of bradyarrhythmias and tachyarrhythmias.

‡ 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.

updated Advisory. 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 updated Advisory by means of a five-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 CIEDs were evaluated and added to literature reported in the previous update. 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 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.

Availability and Strength of Evidence

Preparation of this updated advisory followed a rigorous methodological process. Evidence was obtained from two principal sources: scientific evidence and opinion-based evidence.

Scientific Evidence.

Scientific evidence used in the development of this advisory is based on cumulative findings from literature published in peer-reviewed journals. Literature citations are obtained from healthcare databases, direct internet searches, task force members, liaisons with other organizations, and manual searches of references located in reviewed articles.

Findings from the aggregated literature are reported in the text of this advisory by evidence category, level, and direction. 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 (RCTs), and category B evidence represents observational results obtained from nonrandomized study designs or RCTs 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. RCTs 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).[§]

[§] No Category A literature was found relevant to this Practice Advisory.

Level 1: The literature contains a sufficient number of RCTs to conduct meta-analysis, and meta-analytic findings from these aggregated studies are reported as evidence.

Level 2: The literature contains multiple RCTs, but the number of RCTs is not sufficient to conduct a viable meta-analysis for the purpose of these Guidelines. Findings from these RCTs are reported separately as evidence.

Level 3: The literature contains a single RCT, and findings from this study are reported as evidence.

Category B. Observational studies or RCTs 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.,* relative risk, 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 methodological 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 advisory.

Opinion-based Evidence.

All opinion-based evidence (*e.g.,* survey data, open forum testimony (from original advisory), internet-based comments, letters, and editorials) relevant to each topic was considered in the development of these guidelines. However, only the 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.

Expert and Participating Membership Opinion Surveys. Survey findings from task force–appointed expert consultants, and a random sample of the ASA membership are fully reported in this document. Survey responses were recorded using a 5-point scale and summarized based on median values as follows:

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)

Informal Opinion. Open forum testimony obtained during development of the Advisory, internet-based comments, letters, and editorials are all informally evaluated and discussed during the formulation of guideline recommendations. When warranted, the task force may add educational information or cautionary notes based on this information.

Advisory Evidence and Recommendations

Preoperative Evaluation

A focused preoperative evaluation of the patient with a CIED consists of the following topics: (1) determining whether a patient has a CIED, (2) determining the CIED type, manufacturer and primary indication for placement, (3) determining whether a patient is pacing dependent, and (4) determining the CIED's current settings and that it is functioning properly by interrogating the CIED 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 CIED patients, case reports indicate that adverse outcomes (*e.g.,* inappropriate shock, CIED 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 CIED *(Category B4-H evidence).*[2-5] The literature is insufficient to evaluate whether preoperatively determining the CIED 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 CIED damage when the CIED's current settings were not adequately assessed preoperatively. *(Category B4-H evidence)*.[6] The literature is insufficient to evaluate the benefit of any specific time interval to determine recency for review of a previous CIED interrogation.

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 CIED, determining the CIED type (i.e. PM, ICD, CRT), determining the primary indication for CIED 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 CIED manufacturer.

The consultants strongly agree and ASA members agree that a preoperative evaluation should include determining the CIED's current settings and confirming that the CIED is functioning properly (i.e. by interrogating the CIED or obtaining the most recent interrogation report). The consultants selected preferred time spans for determining proper ICD functioning prior to a procedure, as follows: immediately = 6% of consultants, at least 3 months prior = 48% of consultants, at least 6 months prior = 36% of

consultants, and at least 12 months prior = 6% of consultants. For a pacemaker the following time spans were selected by consultants: immediately = 3% of consultants, at least 3 months prior = 39% of consultants, at least 6 months prior = 30% of consultants, and at least 12 months prior = 27% of consultants. The ASA members selected the following time spans preferred to determine proper functioning of an ICD prior to the procedure: immediately = 10% of members, at least 3 months prior = 39% of members, at least 6 months prior = 44% of members, and at least 12 months prior = 7% of members. For a pacemaker the following time spans were selected by members - immediately = 9% of members, at least 3 months prior = 38%, at least 6 months prior = 36%, and at least 12 months prior = 18% of consultants.[**]

Advisory Recommendations for Preoperative Evaluation.

- Determine whether a patient has a CIED.
  - 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).
- Determine the CIED type, manufacturer and primary indication for placement.[††]
  - Obtain the manufacturer's ID card from the patient or other source.
  - Review the medical record.
  - Obtain and review the most recent CIED interrogation report.
  - Refer to supplemental resources (*e.g.,* manufacturer's databases, CIED clinic records).
  - Order a chest x-ray if no other data are available.[‡‡]
- Determine whether the patient is pacing dependent.
  - 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 CIED implantation.
    - Successful atrioventricular (A-V) nodal ablation resulting in CIED implantation.
    - A CIED interrogation showing no evidence of spontaneous ventricular activity when the CIED's pacing function is temporarily programmed to a non-tracking mode (*i.e.,* VVI) at the lowest programmable rate.
- Determine the CIED's current settings and that it is functioning properly (*i.e.,* by interrogating the CIED or obtaining the most recent interrogation report.[§§][***]

[**] To view a bar chart with the above findings, refer to Supplemental Digital Content 4, http://links.lww.com/ALN/XXXXXX.
[††] Table XXX contains a list of primary and secondary indications for CIED placement
[‡‡] Most CIEDs have an x-ray code inscribed on the generator that can be used to identify the CIED manufacturer.
[§§] A CIED specialist might need to be consulted to help determine key information about the CIED, whether the patient is pacing dependent, the CIED's current settings and that it is functioning properly.
[***] In many patients, determining proper CIED function can be accomplished by accessing the patient's most recent CIED interrogation report. Note that the majority of consultants and ASA members agree that a CIED should be interrogated within 3-6 months before a procedure.

Preoperative Preparation.

Preoperative preparation for patient safety and proper maintenance of the CIED during a planned procedure includes the following topics: (1) sources of electromagnetic interference (EMI), (2) preoperative reprogramming of the CIED's pacing function to an asynchronous pacing mode or disabling any special algorithms, including rate adaptive pacing functions, (3) suspending the anti-tachyarrhythmia functions for an ICD, and (4) availability of temporary pacing and defibrillation equipment.

Literature Findings. The literature was evaluated for the following potential sources of EMI from monopolar electrosurgery, bipolar electrosurgery, radiofrequency (RF) ablation, lithotripsy, external cardioversion or defibrillation, magnetic resonance imaging (MRI), radiation therapy, radiofrequency scanners, cardiac monitors, and electroconvulsive therapy (ECT).

Observational studies report that EMI may occur during monopolar electrosurgery[7-11] RF ablation[12-16] MRI[17-28] and radiation therapy[29-35] *(Category B3-H evidence).* Case reports also indicate the occurrence of EMI with monopolar electrosurgery[36-41] bipolar electrosurgery,[42] RF ablation,[43] MRI,[2-5,44-46] and radiation therapy.[47-45] *(Category B4-H evidence)*.

Case reports indicate that inappropriately high pacing rates may occur due to EMI effects between cardiac monitoring equipment and CIEDs with active minute ventilation sensors *(Category B4-H evidence).*[51-53] An observational study reports a significantly higher occurrence of EMI when electrosurgery above the umbilicus is performed compared with electrosurgery below the umbilicus *(Category B1-H evidence)*.[11] Although no controlled trials were found that evaluate the clinical impact of programming the pacing function of a CIED to an asynchronous pacing mode or suspending an ICD's anti-tachyarrhythmia function, observational studies indicate that despite these interventions, EMI may still occur with monopolar electrosurgery,[8-11] radiofrequency ablation,[54] MRI,[20,22-24,26,27,55-57] and radiation therapy[29,58] *(Category B3-H evidence)*. Case reports also indicate that despite these interventions EMI may still occur for monopolar electrosurgery,[59,60] RF ablation,[61] and MRI[46] *(Category B4-H evidence*). 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 EMI from monopolar electrosurgery or other sources is likely to occur, and strongly agree with the recommendation to alter the pacing function of a CIED 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 CIED 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 ICD's anti- tachycardia 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 ICD's anti- tachycardia

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 assure that the patient is in a monitored environment before suspending the anti-tachycardia function of an ICD. The consultants are equivocal and ASA members agree with the recommendation to avoid the routine use of a magnet over an ICD. The consultants and ASA members strongly agree that if needed, a specialist should be consulted to alter the pacing function of a CIED or to suspend the antitachycardia function of an ICD. 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 EMI potential. Finally, the consultants and ASA members agree with the recommendation that a CIED's active sensor for rate- responsive pacing should be suspended to prevent undesirable tachycardia.

Advisory Recommendations for Preoperative Preparation.

- Determine whether intraoperative electromagnetic interference (EMI) is likely to occur.
- 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 and suspend an ICD's anti-tachycardia function, if present.[†††‡‡‡§§§]
    - Before suspending the anti-tachycardia function, assure that the patient is in a monitored environment.
- Avoid the routine use of a magnet over an ICD.[****]
- If needed, consult a specialist to alter the pacing function of a CIED or to suspend the antitachycardia function of an ICD.
- Assure that temporary pacing and defibrillation equipment are immediately available before, during, and after all procedures with EMI potential.
- Suspend the CIED's active sensor for rate-responsive pacing to prevent undesirable tachycardia, if present.

Intraoperative Monitoring

Intraoperative monitoring topics include (1) continuous ECG monitoring, (2) continuous SpO_2

[†††] If EMI is unlikely it might be unnecessary to alter the pacing function of a CIED or suspend the antitachycardia function of an ICD

[‡‡‡] Note that the majority of consultants disagree and ASA members are equivocal regarding the recommendation to alter the pacing function of a CIED to an asynchronous pacing mode in the pacing dependent patient if monopolar electrosurgery ("bovie") use is planned *inferior* to the umbilicus,

[§§§] To view a bar chart with these findings, refer to Supplemental Digital Content 3, http://links.lww.com/ALN/XXXXXX.

[****] A magnet will not alter the pacing mode of an ICD. A magnet correctly applied to an ICD often results in suspension of antitachycardia therapy. For most ICDs, there is no reliable means to confirm the magnet response. Some ICDs may have no magnet response. In obese patients or those with a deep CIED implant (*i.e.,* subcutaneous ICD), magnet application might fail to elicit the magnet response. Some older ICDs can be permanently disabled by magnet application.

monitoring, and (3) peripheral pulse monitoring (e.g., pulse palpitation, pulse oximeter plethysmogram, and arterial line).

Literature Findings. Case reports indicate that continuous ECG monitoring may detect EMI related pacemaker function abnormalities,[40,46,62] and cardiac abnormalities during a procedure *(Category B4-B evidence).*[63,64] The literature is insufficient to examine the clinical impact of continuous perioperative monitoring of SpO_2, or peripheral pulse for CIED patients.

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

Advisory Recommendations for Intraoperative Monitoring.

- Continuously monitor and display a patient's ECG and SpO_2 as required by ASA standards[65,66] from the beginning of anesthesia until the patient is transferred out of the anesthetizing location.††††
- Perform continuous peripheral pulse monitoring for all CIED patients receiving anesthesia care.
- If unanticipated CIED interactions occur, discontinue the procedure until the source of interference can be identified and eliminated or managed.

Managing Potential Sources of EMI

Procedures using electrosurgery, radio frequency ablation, radiofrequency identification devices, lithotripsy, MRI, radiation therapy, nerve conduction studies, cardioversion, or ECT 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.

Electrosurgery

Management of potential sources of EMI associated with electrosurgery includes the following topics: (1) positioning the electrosurgical unit's (ESU) dispersive electrode so that the current pathway does not pass through or near the CIED generator and leads, (2) avoiding proximity of the ESU's electrical current to the generator or leads, (3) using intermittent and irregular bursts of monopolar electrosurgery at the lowest feasible energy levels, (4) using bipolar electrosurgery and (5) using ultrasonic (harmonic) scalpel.

†††† 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.

Literature Findings*.* The literature is insufficient to evaluate whether positioning the current pathway away from the CIED generator and leads reduces the occurrence of EMI. A case report indicates that EMI occurred when the ESU's electrical current was placed in proximity to the generator or leads *(Category B4-H* evidence).[67] An observational study reports that EMI may occur in spite of positioning the dispersive electrode to divert the return path away from the generator and leads *(Category B3-H evidence).*[11] Case reports also indicate that EMI may still occur when proximity is avoided *(Category B4-H evidence)*.[59,68] No controlled studies were found that examine the benefit of using short intermittent bursts of electrosurgery at the lowest feasible energy levels. One case report describes pacemaker failure when short bursts of current were used with a bipolar electrosurgery system *(Category B4-H evidence).*[42]

Case reports indicate that cardiac arrhythmias and asystole occurred when monopolar electrosurgery was initiated, and after changing to bipolar electrosurgery the procedures proceeded uneventfully *(Category B4-B evidence)*.[59,63,64] A case report indicated that arrhythmia and asystole occurred when monopolar electrosurgery was initiated, and after changing to a harmonic scalpel the procedure was completed successfully *(Category B4-B evidence)*.[37]

Survey Findings*.* The consultants and ASA members strongly agree with the recommendations to (1) 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, (2) avoid proximity of the electrosurgery 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 electrosurgery at the lowest feasible energy levels. The consultants agree and ASA members strongly agree with the recommendations to use bipolar electrosurgery or an ultrasonic (harmonic) scalpel, if possible.

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 generator and lead system 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 RF current path (electrode tip to current return pad) as far away from the generator and lead system 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 RF'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 EMI associated with lithotripsy consists of avoiding focus of the lithotripsy beam near the generator

Literature Findings. The literature 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 EMI associated with MRI include the topics of (1) moving 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 used, (2) interrogating the CIED before the MRI, (3) suspending the antitachycardia function of an ICD before the MRI, (4) altering the pacing function of the CIED to an asynchronous pacing mode in the pacing dependent patient before the MRI, (5) assuring that an individual capable of programming the CIED remains in attendance for the duration of the MRI, and (6) re-interrogating the CIED and restoring its permanent settings after the MRI is completed.‡‡‡‡

Literature Findings. Observational studies evaluating the effects of suspending the antitachycardia function of an ICD report that EMI may still occur *(Category B3-E evidence)*.[24,26,27,55] Observational studies of MRI conditional CIEDs report that EMI does not occur when a CIED is programmed to "MRI mode" and the antitachycardia function is suspended *(Category B3-E evidence)*.[17-19]

The literature is insufficient to examine the necessity of: (1) moving the patient outside of the MRI area when an external defibrillator/monitor, CIED programming system or any other MRI-unsafe equipment is used, (2) interrogating a CIED before an MRI is performed, (3) having an individual capable of programming the CIED remain in attendance for the duration of an MRI, (4) altering the pacing function of a CIED to an asynchronous pacing mode in a pacing dependent patient, and (5) re-interrogating the CIED and restoring its permanent settings after the MRI is completed.

Survey Findings. The consultants and ASA members strongly agree with the recommendations to 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 and monitor the patient's ECG and/or SpO_2 continuously throughout the MRI. The consultants agree and ASA members are equivocal regarding the recommendation to have an individual capable of programming the CIED remain in attendance for the duration of the MRI.

For MRI conditional CIEDs, the consultants strongly agree and ASA members agree with the recommendations to interrogate the CIED, program the CIED to "MRI Mode," suspend the antitachycardia function of an ICD, and alter the pacing function of the CIED to an asynchronous pacing mode in the pacing dependent patient before the MRI. The consultants and ASA members strongly agree with the recommendation that, following the MRI, to re-interrogate the CIED and restore its permanent settings after the MRI.

‡‡‡‡ Note that some CIEDs are labeled by the FDA as MRI conditional. Any CIED system not labeled as such by the FDA is considered MRI non-conditional.

For MRI non-conditional CIEDs, the consultants strongly agree and ASA members agree with the recommendations to interrogate the CIED before the MRI, alter the pacing function of the CIED to an asynchronous pacing mode in the pacing dependent patient, and suspend the antitachycardia function of an ICD if present. The consultants and ASA members strongly agree with the recommendation that, following the MRI, to re-interrogate the CIED and restore its permanent settings.

Radiation Therapy

Management of potential sources of EMI associated with radiation therapy include the topics of positioning the CIED outside the radiation field, shielding the CIED from direct radiation, relocating the generator to the patient's contralateral side, and determining whether the manufacturer recommends verification of CIED function both before and immediately after completion of the radiation therapy.

Literature Findings. No comparative studies were found that evaluated the effects of specific management activities related to CIED patients undergoing radiation therapy. Case reports indicate that CIED malfunction may still occur when the procedure is conducted inside the radiation field *(Category B4-H)*.[47,48] Observational studies report that EMI and device malfunction may still occur when a procedure is conducted outside the radiation field *(Category B3-E)*.[32,58] Case reports indicate that CIED malfunction still occurred when a procedure was conducted outside the radiation field *(Category B4-E)*.[49,50] One case indicated that shock impendence suggestive of shock coil failure occurred when the ICD was shielded from radiation *(Category B4-E)*.[47] The literature is insufficient to evaluate the benefits of relocating the generator to the patient's contralateral side during radiation therapy or to evaluate the benefit of verifying CIED function before and immediately after completion of radiation therapy.

Survey Findings. The consultants strongly agree and ASA members agree with the recommendations to avoid exposing the CIED to radiation whenever possible by positioning the CIED outside the radiation field, shielding the CIED from direct radiation, relocating the generator to the patient's contralateral side, and determining whether the manufacturer recommends verification of CIED function before and at the completion of radiation.

Radiofrequency Identification Devices

Management of potential sources of EMI associated with radiofrequency identification devices (RFIDs) addresses the topic of avoiding the use of these devices in close proximity to the CIED.

Literature Findings. The literature is insufficient to evaluate either the impact of RFIDs as a source of EMI or to evaluate whether EMI depends on the RF frequency or distance between the RF source and CIED in the perioperative setting.

Survey Findings. For RFIDs, the consultants strongly agree and ASA members agree with the recommendations to avoid using RFIDs in close proximity to the CIED whenever possible.

Electroconvulsive Therapy

Management of potential sources of EMI associated with electroconvulsive therapy includes the topics of altering the pacing function of a CIED to an asynchronous pacing mode in the pacing dependent

patient, suspending an ICD's antitachycardia functions, and monitoring and treating ventricular arrhythmias that may occur secondary to the hemodynamic effects of ECT.

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 CIED to an asynchronous pacing mode in the pacing dependent patient, and to suspend an ICD's anti-tachycardia 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 ECT.

Advisory Recommendations for Managing Potential Sources of EMI

Electrosurgery

- Minimize the risk of EMI from monopolar electrosurgery.
  - Position the electrosurgical instrument and dispersive electrode ("bovie pad") so the current pathway does not pass through or near the CIED system.[§§§§]
  - Avoid proximity of the electrosurgery electrical field to the generator and leads, including the avoidance of waving the activated electrode over the generator.[*****]
  - 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 (RF) Ablation

- Avoid direct contact between the ablation catheter and the generator and leads.
- Keep the RF'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 (MRI).

- Move the patient outside of the immediate MRI area when the use of an external defibrillator/monitor, 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 some cases, the electrosurgical dispersive electrode will need to be placed on a site different from the thigh. For example, in head and neck cases, the dispersive electrode 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 electrosurgery instrument is not touching the patient.

- 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.

- Assure that an individual capable of programming the CIED remains in attendance for the duration of the MRI.
- After the MRI is completed, re-interrogate the CIED and restore its permanent settings.

Radiation Therapy

- Avoid exposing the CIED to radiation whenever possible.
  - Position the CIED outside the radiation field.‡‡‡‡‡
  - Shield the CIED from direct radiation.
  - Relocate the generator to the patient's contralateral side.
- Determine whether the manufacturer recommends verification of CIED function before and immediately after completion of the radiation.

Radiofrequency Identification Devices (RFIDs)

- Avoid using RFIDs in close proximity to the CIED whenever possible.
- Monitor for signs of interference with the CIED and be prepared to stop using the RFID if interference occurs.

Electroconvulsive Therapy (ECT)

- Alter the pacing function of a CIED 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 External Defibrillation or Cardioversion

During the perioperative period, the CIED patient might require emergency external defibrillation or cardioversion. In this case, the primary 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 the patient with an ICD and magnet-disabled therapies, all

††††† Some CIEDs have received approval or conditional approval by the FDA for use with MRIs. Additional information may be found at fda.gov.
‡‡‡‡‡ Radiation shielding may not be feasible for some patients due to the size and weight of the shield. This may be compensated for by relocating the generator.

sources of EMI should be terminated and the magnet should be removed to re-enable the ICD's antitachycardia therapies, then the patient should be observed for the delivery of appropriate antitachycardia therapy from the ICD. The consultants agree and ASA members strongly agree with the recommendation to determine whether the antitachycardia therapy should be re-enabled when an ICD and antitachycardia therapy has been disabled by programming, The consultants and ASA members strongly agree that if the above activities fail to restore ICD antitachycardia function, emergency external defibrillation or cardioversion should be performed when needed using ACLS 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 CIED. 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 CIED, and to interrogate the CIED immediately after external cardioversion or defibrillation is performed.

Advisory Recommendations for Emergency Defibrillation or Cardioversion

- Before attempting to emergently externally defibrillate or cardiovert a patient with an ICD and magnet-disabled therapies, terminate all sources of EMI and remove the magnet to re-enable the ICD's antitachycardia therapies.
  - Observe the patient for appropriate antitachycardia therapy from the ICD.
  - Determine the need for re-enabling an ICD's antitachycardia therapy if it was disabled by programming
- If the above activities fail to restore ICD function, proceed with emergency external defibrillation or cardioversion when needed.
  - Follow ACLS guidelines for delivered energy level and pad placement.
  - Position the defibrillation or cardioversion pads so they are not directly over the CIED to minimize the current flowing through the generator and leads.
  - Use a clinically appropriate energy output regardless of the presence of the CIED.
  - Interrogate the CIED immediately after external cardioversion or defibrillation is performed.

Postoperative Management

Postoperative management of CIED patients primarily consists of interrogating and restoring CIED function.

Literature Findings. An observational study reports that a postoperative interrogation may reveal CIED malfunctions that occur during a procedure *(Category B3-B evidence).*[34] Case reports also indicate that postoperative interrogation can reveal intraoperative changes to CIED settings, and with the CIED subsequently reprogrammed to its original settings or replaced *(Category B4-B evidence)*.[6,61] The literature is insufficient to evaluate the benefits of; (1) continuing to monitor and display a patient's ECG,

(2)monitoring cardiac rate and rhythm throughout the immediate postoperative period, (3) assuring that back-up pacing and cardioversion-defibrillation equipment are immediately available, and (4) restoring the CIED to its permanent setting before the patient is discharged from a monitored environment when the CIED 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 CIED that was reprogrammed pre-or-intraoperatively, assure that back-up pacing and cardioversion-defibrillation equipment are immediately available until its permanent settings are restored (3) 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 (4) if interrogation determines that the CIED settings are inappropriate, then reprogram the CIED to newly appropriate settings (5) perform a postoperative CIED interrogation if emergency surgery occurred without appropriate preoperative CIED evaluation (5) perform a postoperative CIED interrogation if there is suspicion that antitachycardia therapy might have been disabled rather than temporarily suspended with magnet placement (6) perform a postoperative CIED interrogation if significant EMI occurred in close proximity to the CIED, and (7) perform a postoperative CIED interrogation if the delivery of antitachycardia therapy was observed, or there is concern for CIED malfunction. The consultants strongly agree and ASA members agree that if the CIED is not interrogated during the immediate postoperative period, interrogate within 30 days following the procedure.

Advisory Recommendations for Postoperative Management:

- Continue to monitor and display a patient's ECG 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:
  - Assure that back-up pacing and cardioversion-defibrillation equipment are immediately available until its permanent settings are restored.[XX]
  - 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 EMI occurred in close proximity to the CIED.

[XX] 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 case).

[******] In some instances new settings may be needed.

526 - The delivery of antitachycardia therapy was observed
527 - There is concern for CIED malfunction.
528 • If interrogation determines that the CIED settings are inappropriate, reprogram to newly
529 appropriate settings.
530 • If the CIED is not interrogated during the immediate postoperative period, have it interrogated
531 within 30 days after the procedure.

Appendix 1: Summary of Advisory Recommendations

Preoperative Evaluation

- Determine whether a patient has a CIED.
  - 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).
- Determine the CIED type, manufacturer and primary indication for placement.††††††
  - Obtain the manufacturer's ID card from the patient or other source.
  - Review the medical record.
  - Obtain and review the most recent CIED interrogation report.
  - Refer to supplemental resources (*e.g.,* manufacturer's databases, CIED clinic records).
  - Order a chest x-ray if no other data are available.‡‡‡‡‡‡
- Determine whether the patient is pacing dependent.
  - 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 CIED implantation.
    - Successful atrioventricular (A-V) nodal ablation resulting in CIED implantation.
    - A CIED interrogation showing no evidence of spontaneous ventricular activity when the CIED's pacing function is temporarily programmed to a non-tracking mode (*i.e.,* VVI) at the lowest programmable rate.
- Determine the CIED's current settings and that it is functioning properly (*i.e.,* by interrogating the CIED or obtaining the most recent interrogation report.§§§§§§*******

Preoperative Preparation

- Determine whether intraoperative electromagnetic interference (EMI) is likely to occur.
- 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 and suspend an ICD's anti-tachycardia function, if present.†††††††‡‡‡‡‡‡‡§§§§§§§
  - Before suspending the anti-tachycardia function, assure that the patient is in a monitored environment.

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†††††† Table XXX contains a list of primary and secondary indications for CIED placement
‡‡‡‡‡‡ Most CIEDs have an x-ray code inscribed on the generator that can be used to identify the CIED manufacturer.
§§§§§§ A CIED specialist might need to be consulted to help determine key information about the CIED, whether the patient is pacing dependent, the CIED's current settings and that it is functioning properly.
******* In many patients, determining proper CIED function can be accomplished by accessing the patient's most recent CIED interrogation report. Note that the majority of consultants and ASA members agree that a CIED should be interrogated within 3-6 months before a procedure.
††††††† If EMI is unlikely it might be unnecessary to alter the pacing function of a CIED or suspend the antitachycardia function of an ICD
‡‡‡‡‡‡‡ Note that the majority of consultants disagree and ASA members are equivocal regarding the recommendation to alter the pacing function of a CIED to an asynchronous pacing mode in the pacing dependent patient if monopolar electrosurgery ("bovie") use is planned *inferior* to the umbilicus,
§§§§§§§ To view a bar chart with these findings, refer to Supplemental Digital Content 3, http://links.lww.com/ALN/XXXXXX.

- Avoid the routine use of a magnet over an ICD.[********]
- If needed, consult a specialist to alter the pacing function of a CIED or to suspend the antitachycardia function of an ICD.
- Assure that temporary pacing and defibrillation equipment are immediately available before, during, and after all procedures with EMI potential.
- Suspend the CIED's active sensor for rate-responsive pacing to prevent undesirable tachycardia, if present.

Intraoperative Monitoring

- Continuously monitor and display a patient's ECG and SpO_2 as required by ASA standards[64,65] from the beginning of anesthesia until the patient is transferred out of the anesthetizing location.[††††††††]
- Perform continuous peripheral pulse monitoring for all CIED patients receiving anesthesia care.
- If unanticipated CIED interactions occur, discontinue the procedure until the source of interference can be identified and eliminated or managed.

Managing Potential Sources of EMI

Electrosurgery

- Minimize the risk of EMI from monopolar electrosurgery.
  - Position the electrosurgical instrument and dispersive electrode ("bovie pad") so the current pathway does not pass through or near the CIED system.[‡‡‡‡‡‡‡‡]
  - Avoid proximity of the electrosurgery electrical field to the generator and leads, including the avoidance of waving the activated electrode over the generator.[§§§§§§§§]
  - 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 (RF) Ablation

- Avoid direct contact between the ablation catheter and the generator and leads.
- Keep the RF'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 (MRI)

- Move the patient outside of the immediate MRI area when the use of an external defibrillator/monitor, CIED programmer or any other MRI-unsafe equipment is required.
- Before the MRI, perform the following:

[********] A magnet will not alter the pacing mode of an ICD. A magnet correctly applied to an ICD often results in suspension of antitachycardia therapy. For most ICDs, there is no reliable means to confirm the magnet response. Some ICDs may have no magnet response. In obese patients or those with a deep CIED implant (*i.e.,* subcutaneous ICD), magnet application might fail to elicit the magnet response. Some older ICDs can be permanently disabled by magnet application.

[††††††††] 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.

[‡‡‡‡‡‡‡‡] For some cases, the electrosurgical dispersive electrode will need to be placed on a site different from the thigh. For example, in head and neck cases, the dispersive electrode 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 electrosurgery instrument is not touching the patient.

  - 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.
- Assure that an individual capable of programming the CIED remains in attendance for the duration of the MRI.
- After the MRI is completed, re-interrogate the CIED and restore its permanent settings.

Radiation Therapy

- Avoid exposing the CIED to radiation whenever possible.
  - Position the CIED outside the radiation field.†††††††††
  - Shield the CIED from direct radiation.
  - Relocate the generator to the patient's contralateral side.
- Determine whether the manufacturer recommends verification of CIED function before and immediately after completion of the radiation.

Radiofrequency Identification Devices (RFIDs)

- Avoid using RFIDs in close proximity to the CIED whenever possible.
- Monitor for signs of interference with the CIED and be prepared to stop using the RFID if interference occurs.

***Electroconvulsive Therapy* (ECT)**

- Alter the pacing function of a CIED 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 or Cardioversion

- Before attempting to emergently externally defibrillate or cardiovert a patient with an ICD and magnet-disabled therapies, terminate all sources of EMI and remove the magnet to re-enable the ICD's antitachycardia therapies.
  - Observe the patient for appropriate antitachycardia therapy from the ICD.
  - Determine the need for re-enabling an ICD's antitachycardia therapy if it was disabled by programming
- If the above activities fail to restore ICD function, proceed with emergency external defibrillation or cardioversion when needed.
  - Follow ACLS guidelines for delivered energy level and pad placement.
  - Position the defibrillation or cardioversion pads so they are not directly over the CIED to minimize the current flowing through the generator and leads.
  - Use a clinically appropriate energy output regardless of the presence of the CIED.
  - Interrogate the CIED immediately after external cardioversion or defibrillation is performed.

********* Some CIEDs have received approval or conditional approval by the FDA for use with MRIs. Additional information may be found at fda.gov.

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

Postoperative Management:

- Continue to monitor and display a patient's ECG 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:
  - Assure that back-up pacing and cardioversion-defibrillation equipment are immediately available until its permanent settings are restored.[xxxv]
  - 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 EMI 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.
- If the CIED is not interrogated during the immediate postoperative period, have it interrogated within 30 days after the procedure.

[xxxv] 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 case).

[§§§§§§§§§] In some instances new settings may be needed.

Appendix 2: Generic Pacemaker and Defibrillator Codes

The generic pacemaker and defibrillator codes were developed as joint projects 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 CIED *(Tables 1 and 2)*.

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

Position 1	Position II	Position III	Position IV	Position V
Pacing Chamber(s)	Sensing Chamber(s)	Response(s) to Sensing	Programmability	Multisite Pacing
O None A Atrium V Ventricle D Dual (AV)	O None A Atrium V Ventricle D Dual (AV)	O None I Inhibited T Triggered D Dual (TI)	O None R Rate Modulation	O None A Atrium V Ventricle D Dual (AV)

Examples:

AAI = Atrial-only antibradycardia pacing. In the AAI mode, 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 this mode, 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 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 VVI mode, 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.

********** Now the Heart Rhythm Society (HRS)

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

Position 1	Position II	Position III	Position IV
Shock Chamber(s)	Antitachycardia Pacing Chamber(s)	Tachycardia Detection	Antibradycardia Pacing
O None A Atrium V Ventricle D Dual (AV)	O None A Atrium V Ventricle D Dual (AV)	E Electrocardiogram H Hemodynamic	O None A Atrium V Ventricle D Dual (AV)

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).

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

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 if 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 if pacing pulses are present and generate appropriate paced beats
Preoperative preparation	EMI unlikely during procedure	If EMI unlikely, then special precautions are not needed
	EMI likely; CIED is pacemaker	Reprogram to asynchronous mode when indicated Suspend rate adaptive pacing functions**********
	EMI likely: CIED is ICD	Suspend antitachycardia therapy 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 per ASA standard	Electrocardiographic monitoring Peripheral pulse monitoring

†††††††††† 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.

	Electrosurgery 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 PB
	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 re-enable therapies Observe for appropriate therapies
	ICD: programming disabled	Programming to re-enable 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
Postoperative management	Immediate postop 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?††††††††††

†††††††††† If necessary, reprogram appropriate settings.

Is CIED an ICD?‡‡‡‡‡‡‡‡‡‡‡

Use cardiology/pacemaker-ICD service if needed

CIED cardiac implantable electronic 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.

‡‡‡‡‡‡‡‡‡ Restore all antitachycardia therapies.

Appendix 3: 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 was 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 EMI outcomes associated with CIEDs. The evidence linkage interventions are listed 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 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 preexisting, permanently implanted CIED (cardiac implantable electronic device) for treatment of bradyarrhythmia, tachyarrhythmia, or heart failure
        - Cardiac pacemakers
        - Cardioverter-defibrillators (ICD)
        - Cardiac resynchronization devices
- Exclusion criteria:
    - Patients undergoing CIED implantation or revision
    - Patients without a permanently implanted pacemaker or ICD
    - Patients with a temporary CIED
    - Patients with a non-cardiac implantable device
        - Neurologic or spinal cord stimulators
    - Patients with an implantable mechanical cardiac-assist device
        - Ventricular-assist devices

Procedures

- Inclusion criteria:
    - Inpatient procedures
    - Outpatient procedures
- Exclusion criteria:
    - Procedures where there are no known perioperative CIED concerns
        - Plain radiography
        - Fluoroscopy
        - Mammograms
        - Ultrasound

Practice Settings

- Inclusion criteria:
    - Any perioperative setting where an anesthesia provider will be delivering anesthesia care
        - Preoperative settings
        - Intraoperative settings
        - Postoperative settings
        - Recovery settings
- Exclusion criteria:
    - Non-perioperative 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 rhythm management device
            - Conduct a focused history
            - Obtain manufacturer's ID 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 device dependency
        - Determine device function
            - Interrogate device
            - Determine if device will capture when it paces
            - Contact the manufacturer
    - Preoperative preparation
        - Determine if EMI to pacemaker or ICD occurs with procedure
            - Electrosurgery
            - RF ablation
            - Lithotripsy
            - External defibrillation
            - MRI
            - Radiation therapy
            - Direct-current ablation
            - Electroconvulsive therapy (ECT)
        - Determine whether reprogramming the CIED to asynchronous pacing mode is needed
            - Electrosurgery
            - RF ablation
            - Lithotripsy
            - Magnetic resonance imaging (MRI)
        - Program anti-tachyarrhythmia functions off
        - Temporary pacing and defibrillation equipment immediately available
        - Advise operator to consider use of a bipolar electrosurgery system or ultrasonic scalpel
    - Intraoperative management
        - Monitor operation of the cardiovascular device
            - ECG Monitoring (per ASA standard)

- Monitor pulse wave form (e.g., pulse oximeter plethysmogram, arterial line)

- Manage potential device dysfunction due to EMI
  - Electrosurgery
    - Position the receiving plate so that the current pathway does not pass through or near the pacemaker system
    - Avoid direct contact with the pacemaker or leads
    - Use short, intermittent and irregular bursts at the lowest feasible energy levels
    - Use a bipolar electrosurgery system (a bipolar electrosurgery system can be safely used without affecting a pacemaker or ICD)
    - Use an ultrasonic (harmonic) scalpel (an ultrasonic scalpel can be safely used without affecting a pacemaker or ICD)
  - Radiofrequency (RF) ablation
    - Keep the current path (electrode tip to ground plate) as far away from the pulse generator and lead system 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 MRI area when the use of an external defibrillator/monitor, CIED programming system, or any other MRI-unsafe equipment is required.
    - Monitor the patient's ECG and/or SpO_2 continuously throughout the MRI.
    - An individual capable of programming the CIED should remain in attendance for the duration of the MRI.

    MRI Conditional CIEDs
    - Prior to the MRI, interrogate the CIED and program to "MRI Mode" to suspend the antitachycardia function for an ICD.
    - Alter the pacing function of the CIED to an asynchronous pacing mode in the pacing dependent patient.
    - After the MRI is completed, re-interrogate the CIED and restore its permanent settings.

    MRI Non-Conditional CIEDs
    - Interrogate the CIED prior to and after the MRI is completed.
    - Alter the pacing function of the CIED to an asynchronous pacing mode in the pacing dependent patient
    - Suspend the antitachycardia function of an ICD, if present.
    - After the MRI is completed, re-interrogate the CIED and restore its permanent settings.
  - Radiation therapy
    - Avoid exposing the CIED to radiation whenever possible.
      - Position the CIED outside the radiation field.
      - Shield the CIED from direct radiation.
      - Relocate the generator to the patient's contralateral side.
    - Determine whether the manufacturer recommends verification of CIED function before and at the completion of radiation.
  - Radiofrequency identification devices
    - Avoid using this equipment in close proximity to the CIED whenever possible.
    - Monitor for signs of interference with the CIED and be prepared to stop using the RFID if interference occurs.
  - Electroconvulsive therapy

- Alter the pacing function of a CIED to an asynchronous pacing mode in the pacing dependent patient,
- Suspend an ICD's anti-tachyarrhythmia functions, if present.
- Monitor for and treat ventricular arrhythmias that may occur secondary to the hemodynamic effects of ECT.

- Emergency defibrillation or cardioversion
  - Patients with an ICD and magnet-disabled therapies:
    - Remove the magnet to re-enable antitachycardia therapies
    - Terminate all sources of EMI while magnet is removed
    - Observe the patient for appropriate CIED therapy
  - Patients with an ICD and antiarrhythmic therapies that have been disabled by programming
    - Re-enable therapies through programming
  - Minimize the current flowing through the pulse generator and lead system
    - Position defibrillation/cardioversion pads or paddles as far as possible from the pulse generator
    - Use apex – (anterior-) posterior position
    - Position current flow between the pads/paddles perpendicular to the major lead axis of the CIED
    - Use a clinically appropriate energy output regardless of the device
- Postoperative management
  - Confirm or restore device function (i.e., in PACU or ICU).
    - Interrogate device
    - Reprogram device to appropriate settings
    - Restore all anti-arrhythmic therapies
    - Patients with ICD antitachycardia functions disabled
      - Continuously monitor cardiac function
      - Keep defibrillation equipment immediately available until antitachycardia function has been restored anesthesia

Outcomes

- Expected benefits:
  - Successful procedure
  - Reduced frequency/severity of adverse outcomes:
    - Adverse outcomes associated with a CIED device
      - Damage to device
      - Inability of device to deliver pacing or shocks
      - Lead-tissue interface damage
      - Changes in pacing behavior
      - Electrical reset to the backup pacing mode
      - Inappropriate ICD therapies
    - 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 greater than 5 years old
  - Unpublished studies
  - Studies in non-peer reviewed 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 re-reviewed, 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[§§§§§§§§§§] flow diagram is available as Supplemental Digital Content 4, http://links.lww.com/ALN/XXXXXXXX.

In total, 1143 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 5, http://links.lww.com/ALN/XXXXXXXX.

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 6, http://links.lww.com/ALN/XXXXXX.

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, κ = 0.72 to 0.90; (2) type of analysis, k = 0.80 to 0.90; (3) evidence linkage assignment, κ = 0.84 to 1.00; and (4) literature inclusion for database, κ = 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

§§§§§§§§§§ Preferred reporting items of systematic reviews and meta-analyses

= 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 these Guidelines and subsequent recommendations proposed was obtained by consensus 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, (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, (4) internet commentary, and (5) Task Force opinion and interpretation. The survey rate of return was 34% (N = 32/94) for Consultants, and 5% (N=245/5000) for the ASA membership.

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 was instituted. The rate of return was __% (N = __/__). The percent of responding Consultants expecting *no change* associated with each linkage were as follows: preoperative evaluation - __%; preoperative patient preparation- __%; intraoperative monitoring of CIEDs - __%; emergency defibrillation or cardioversion - __%; postoperative monitoring of CIEDs - __%; postoperative interrogation and restoration of CIED function - __%; intraoperative management of EMI during: electrosurgery - __%; radio-frequency ablation - __%, lithotripsy - __%, MRI - __%, radiation therapy - __%, and electroconvulsive therapy - 73%. ___ percent of the respondents indicated that the Advisory would have *no effect* on the amount of time spent on a typical case. ___ respondents (__%) 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 __-__ minutes.

Research Support

Support was provided solely by the American Society of Anesthesiologists.

Competing Interests

The authors declare no competing interests.

Correspondence

Address correspondence to the American Society of Anesthesiologists: 1061 American Lane, Schaumburg, Illinois 60173. These updated Practice Advisories, and all ASA Practice Parameters, may be obtained at no cost through the Journal Web site, www.anesthesiology.org.

********** Consultants were drawn from the following specialties where perioperative management of CIEDs are a concern: anesthesiology (85% of respondents), and cardiac electrophysiology (15% of respondents).

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.e. 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.e. by interrogating the CIED or obtaining the most recent interrogation report.)	32	72*	22	6	0	0
8. Determine whether intraoperative electromagnetic interference (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 patient is pacing dependent.	32	34	6	25	34*	28
11. If monopolar electrosurgery ("bovie") use is planned superior to the umbilicus, suspend an ICD's anti-tachycardia 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 anti-tachycardia function, if present.	31	23	29*	13	23	13
13. Before suspending the anti-tachycardia function of an ICD, assure 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
17. Assure 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 ECG as required by ASA standards, from the beginning of anesthesia until the patient is transferred out of the anesthetizing location, with additional ECG 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

††††††††††† N = number of members who responded to each item. An asterisk beside a percentage score indicates the median.

Recommendations	N	Strongly Agree (%)	Agree (%)	Equivocal (%)	Disagree (%)	Strongly Disagree (%)
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 ECG and/or SpO2 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. Prior to 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. Following the MRI, re-interrogate 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 prior to and following 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. Following the MRI, re-interrogate the CIED and restore its permanent settings.	28	82*	14	4	0	0

Recommendations	N	Strongly Agree (%)	Agree (%)	Equivocal (%)	Disagree (%)	Strongly Disagree (%)
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: Radiofrequency Identification Devices (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: Electroconvulsive Therapy (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 anti-tachyarrhythmia 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
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 re-enable 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 re-enabled.	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

	N	Strongly Agree (%)	Agree (%)	Equivocal (%)	Disagree (%)	Strongly Disagree (%)
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, assure 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 EMI 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 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 following the procedure.	28	50*	29	11	11	0

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.e. 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
7. Confirm that the CIED is functioning properly (i.e. by interrogating the CIED or obtaining the most recent interrogation report.)	243	49	28*	19	3	1
8. Determine whether intraoperative electromagnetic interference (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 patient is pacing dependent.	210	10	17	24*	40	9
11. If monopolar electrosurgery ("bovie") use is planned superior to the umbilicus, suspend an ICD's anti-tachycardia 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 anti-tachycardia function, if present.	209	19	22	24*	31	4
13. Before suspending the anti-tachycardia function of an ICD, assure 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. Assure 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 ECG as required by ASA standards, from the beginning of anesthesia until the patient is transferred out of the anesthetizing location, with additional ECG monitoring in the postoperative	200	89*	10	1	0	1

‡‡‡‡‡‡‡‡‡‡‡ N = number of members who responded to each item. An asterisk beside a percentage score indicates the median.

Recommendations	N	Strongly Agree (%)	Agree (%)	Equivocal (%)	Disagree (%)	Strongly Disagree (%)
period as indicated by the patient's medical condition.						
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 ECG and/or SpO2 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. Prior to 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. Following the MRI, re-interrogate the CIED and restore its permanent settings.	179	60*	30	8	1	1

Recommendations	N	Strongly Agree (%)	Agree (%)	Equivocal (%)	Disagree (%)	Strongly Disagree (%)
Intraoperative Management of EMI Sources: Non-MRI conditional CIEDs						
35. Interrogate the CIED prior to and following the MRI	172	44	31*	22	2	1
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. Following the MRI, re-interrogate 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: Radiofrequency Identification Devices (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: Electroconvulsive Therapy (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 anti-tachyarrhythmia 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 re-enable 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 re-enabled.	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

Recommendations	N	Strongly Agree (%)	Agree (%)	Equivocal (%)	Disagree (%)	Strongly Disagree (%)
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, assure 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 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 following the procedure.	145	42	33*	17	6	1

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