

Initial Experience of an Anesthesiology-based Service for Perioperative Management of Pacemakers and Implantable Cardioverter Defibrillators

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ABSTRACT

Background: Management of cardiovascular implantable electronic devices (CIEDs), including pacemakers and implantable cardioverter defibrillators, for surgical procedures is challenging due to the increasing number of patients with CIEDs and limited availability of trained providers. At the authors' institution, a small group of anesthesiologists were trained to interrogate CIEDs, devise a management plan, and perform preoperative and postoperative programming and device testing whenever necessary.

Methods: Patients undergoing surgery between October 1, 2009 and June 30, 2013 at the University of Washington Medical Center were included in a retrospective chart review to determine the number of devices actively managed by the Electrophysiology/Cardiology Service (EPCS) *versus* the Anesthesiology Device Service (ADS), changes in workload over time, surgical case delays due to device management, and errors and problems encountered in device programming.

Results: The EPCS managed 254 CIEDs, the ADS managed 548, and 227 by neither service. Over time, the ADS providers managed an increasing percentage of devices with decreasing supervision from the EPCS. Only two CIEDs managed by the ADS required immediate assistance from the EPCS. Patients who were unstable postoperatively were referred to the EPCS. Although numerous issues in programming were encountered, primarily when restoring demand pacing after programming asynchronous pacing for surgery, no patient harm resulted from ADS or EPCS management of CIEDs.

Conclusions: An ADS can provide safe CIED management for surgery, but it requires specialized provider training and strong support from the EPCS. Due to the complexity of CIED management, an ADS will likely only be feasible in high-volume settings. (*ANESTHESIOLOGY* 2015; 123:1024-32)

SURGERIES that involve the use of equipment that emits electromagnetic radiation such as monopolar electrosurgery present a management challenge in patients who have a cardiovascular implantable electronic device (CIED) such as a pacemaker or an implantable cardioverter defibrillator (ICD). The most common pacing problem encountered with either type of device is suppression of demand pacing. This can result in no rhythm changes to mild bradycardia to asystole, depending on the underlying rhythm of the heart.¹ ICDs may additionally interpret electromagnetic interference (EMI) as ventricular tachycardia or fibrillation and deliver inappropriate antitachyarrhythmia therapy.^{1,2}

The risk of CIED malfunction depends on the intensity of EMI, the lead sensing polarity, and the battery status.^{1,3,4} High-intensity EMI coupled with a weak battery may cause a "power on reset" in which the EMI transiently decreases

What We Already Know about This Topic

- The management of patients with cardiovascular implantable electronic devices, including pacemakers and implantable cardiac defibrillators, in the perioperative period is an important concern
- The limited availability of trained providers in the management of cardiovascular implantable electronic devices in the perioperative period often is a challenge

What This Article Tells Us That Is New

- The authors describe successful training of a group of anesthesiologists at their institution to perform perioperative cardiovascular implantable electronic device management
- Their experience suggests that an anesthesiology-based service can meet the challenge of providing efficient and high-level care for surgical patients with cardiovascular implantable electronic devices

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the battery voltage, causing the CIED to “reboot” and operate with the manufacturer’s default values that may not be appropriate for the patient, including unwanted restoration of tachyarrhythmia therapy.¹ Unipolar sensing increases the risk of detecting EMI because of greater separation of the electrodes.³

Placement of a magnet to prevent CIED malfunction in the presence of EMI is not a panacea.^{1–3,5} Not all pacemakers convert to asynchronous pacing with magnet placement. When they do, the resulting pacing rate can be anywhere from 85 to 100 beats/min depending on the manufacturer (assuming normal battery status) and may not be appropriate for certain patients. A magnet will usually disable the ability of an ICD to detect tachyarrhythmias. However, in some ICDs, this “magnet response” may be programmed off, and therefore the patient remains at risk of inappropriate antitachyarrhythmia therapy despite application of the magnet.² Furthermore, placing a magnet on an ICD does not alter the pacing programming of the ICD (except for ICDs manufactured by Sorin, Italy), and the patient may still be at risk for undesired suppression of demand pacing.

The Heart Rhythm Society/American Society of Anesthesiologists (HRS/ASA) Consensus Statement recommends that a qualified individual familiar with the patient and their CIED programming should provide recommendations to individuals providing clinical care on the day of surgery.¹ At the University of Washington Medical Center, day of surgery perioperative CIED management was previously provided by general cardiology or electrophysiology fellows. This sometimes resulted in case delays when cardiology support was not immediately available. As a solution to perceived case delays, the Anesthesiology and Electrophysiology departments developed an anesthesiologist-based service for perioperative CIED management. This article describes the program, problems encountered in program development, problems experienced with programming CIEDs, and perioperative rhythm disturbances. Wherever possible, CIED management by the Electrophysiology/Cardiology Service (EPCS) and the Anesthesiology Device Service (ADS) was compared.

Materials and Methods

This retrospective review was approved with a waiver of informed consent by the University of Washington, Human Subjects Division, Seattle, Washington.

The ADS

Five volunteer anesthesiologists initially received ten 2-h evening training sessions that provided basic information on CIED function and manufacturer-specific programming details. Training sessions were taught by members of the EPCS section (J.E.P. and L.W.L.) and representatives of the companies whose CIEDs were managed by the program (Medtronic, St. Jude Medical, Boston Scientific, and Biotronik USA, USA). A basic introductory text was required

reading.⁶ One year after program initiation, representatives from each of the four companies provided separate 2-h refresher sessions. The lead anesthesiologist (G.A.R.) for the ADS passed the International Board of Heart Rhythm Examiners Certification Examination for Competency in Cardiac Rhythm Device Therapy for the Physician in 2009, which is the only examination available to physicians at the time. Approximately 30 h of preparation for the examination was spent over and above the standard training for other ADS providers. The lead anesthesiologist was responsible for creating the electronic note templates used for clinical documentation, assigning the monthly CIED coverage schedule, organizing team member education, providing initial backup for CIED management issues, and reviewing CIED service performance.

Daily ADS coverage was posted in the preoperative holding areas and postanesthesia care unit. On the day of surgery, the preoperative holding area nurse or the operating room (OR) anesthesia team contacted the assigned ADS physician. Failure to reach the assigned or the backup ADS physician led to a call to the cardiology fellow assigned to the EPCS consult rotation. CIEDs were occasionally interrogated during the preanesthesia clinic visit, most often when the CIED did not appear to have an appropriately recent evaluation.

A computer program was created in 2011 that identified patients on the surgical schedule by scanning the preanesthesia note for mention of a CIED. This allowed the ADS provider to plan their work for the day because that physician was typically also providing other clinical care (*e.g.*, in the OR or preanesthesia clinic).

All interrogations by the ADS were initially supervised by an electrophysiologist or CIED-trained healthcare provider (J.E.P. or L.W.L.). Within 6 months, the lead anesthesiologist (G.A.R.) began supervising the other team members and reviewing their performance, with backup from the EPCS.

Cardiovascular implantable electronic device evaluation began by obtaining two printouts of the baseline parameters—a copy for the ADS physician and one for the patient chart—before any programming changes. Baseline parameters were also stored in the programmer itself whenever possible. The OR anesthesia team was involved with programming decisions and informed of expected CIED performance during surgery.

Cardiovascular implantable electronic devices were reinterrogated postoperatively to restore preoperative settings and in cases where no preoperative programming had been needed but where there was concern that perioperative events or proximity of the monopolar electrosurgery to the CIED could have altered function (*e.g.*, chest and shoulder surgeries). Preoperative and postoperative printouts were compared to ensure accurate restoration of device parameters. On occasion, patients sent to the intensive care unit benefitted from a higher basal pacing rate than their presurgery settings. Such minor programming changes were made by the ADS, but CIED management was thereafter assumed

in-hospital by the EPCS. Device management was documented in the electronic medical record.

The EPCS

Electrophysiology/Cardiology Service management was sometimes performed by an electrophysiology fellow, but most commonly by a general cardiology fellow whose training included 4 to 6 h of dedicated sessions by electrophysiology faculty and industry representatives, introducing them to interrogation and programming of CIEDs. This was followed by direct attending supervision for the first 10 to 15 interrogations. Thereafter, the fellow worked independently although the electrophysiology attending would later review the notes.

Data Acquisition

The computer search program previously described was used to search preanesthesia notes for as far back as the database permitted (October 1, 2009) through June 30, 2013. Because patients who had undergone ventricular assist device placement or heart transplant frequently did not have a preanesthesia note, a separate search of anesthetic records was carried out to identify these patients.

All cases were classified as having been managed by the EPCS if that service interrogated the CIED on the day of or the day before surgery and as managed by the ADS if the CIED had been interrogated by that service on the day of surgery or in the preanesthesia clinic. In all other cases, the CIED was classified as not actively managed. Cases excluded from review were cardioversions, procedures performed on the CIED or leads, arrhythmia ablation, or percutaneous heart valve placements.

All cases were classified either as having occurred during regular work hours (surgery scheduled start time between 7:30 AM and 5:00 PM) or after-hours (all other cases).

Surgery Delay Time

Only patients with CIEDs that were interrogated in the preoperative holding area were included in analyzing case delays. Cases were further classified as a "first case" or a "to-follow case." A "first case" was defined as any case scheduled to begin at 7:30 AM on a regular workday. First case delay time was considered zero if the anesthesia start time was at or before 7:30 AM. A "to-follow case" was defined as any subsequent case occurring in the same OR, preceded by a case with the same surgeon, and that surgeon could only be staffing one room. Cases that were "urgent/emergent" were excluded, but all scheduled cases were included even if started after 5:00 PM. The delay time for a "to-follow case" was defined as the time from when the patient in the case preceding the "to-follow" case left the OR to the anesthesia start time for the "to-follow" case.

Statistical Analysis

Descriptive statistics of numerical data are expressed as mean \pm SD. Comparisons between the two groups were made using the Fisher exact test. Differences were considered

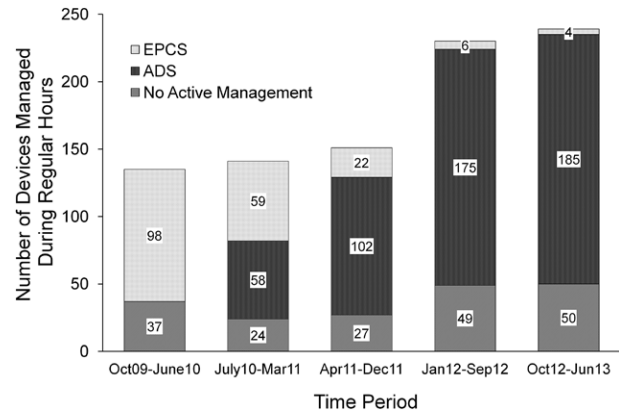


Fig. 1. Distribution of caseload by service during regular workday hours. By the last time block, the Anesthesia Device Service managed 77% of the workload during regular operating room hours. ADS = Anesthesiology Device Service; EPCS = Electrophysiology/Cardiology Service.

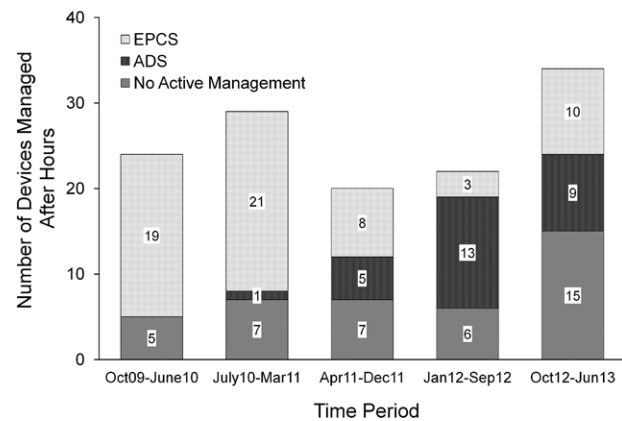


Fig. 2. Distribution of caseload by service for surgeries performed after regular working hours. ADS = Anesthesiology Device Service; EPCS = Electrophysiology/Cardiology Service.

significant at the P value less than 0.05 level. Statistical calculations were performed using OpenEpi.⁷

Results

Six hundred sixty-two patients underwent a total of 1,025 procedures. The average number of cases requiring CIED interrogation and/or programming was 22.8 per month, representing 2.3% of 44,707 anesthetics administered during the study period. The first interrogation by the ADS occurred on September 24, 2010. Thereafter, the ADS managed an increasing percentage of the patients during working hours (fig. 1) and a significant percentage of the after-hours procedures (fig. 2).

In consultation with the EPCS, completion of 30 separate CIED programmings was defined as a benchmark of experience to achieve a comfortable level of basic expertise in CIED programming. The five ADS team members achieved this benchmark at 6, 13, 17, 17, and 23 months, respectively.

Table 1. Cases Managed by the EPCS (250) and by the ADS (548)

Programming Performed	EPCS		ADS	
	75 Pacemakers	175 ICDs	257 Pacemakers	291 ICDs
Tachyarrhythmia therapy disabled		All (25 below umbilicus)		261 (40 below umbilicus)
Why tachyarrhythmia therapy was not disabled		Not applicable		21 with bipolar or no cautery 7 below umbilicus, magnet used 1 below umbilicus, no magnet 1 accidental failure
Pacing mode to asynchronous	67	78	130	89
Base pacing rate increased in	96 of 145 devices programmed to asynchronous; 8 of 105 devices left in demand mode		152 of 219 devices programmed to asynchronous; 57 of 329 devices left in demand mode	
Rate responsive feature disabled in	92 of 95 devices programmed to asynchronous; 3 of 18 devices left in demand mode		All 155 devices programmed to asynchronous; 61 of 68 devices left in demand mode	

ADS = Anesthesiology Device Service; EPCS = Electrophysiology/Cardiology Service; ICD = implantable cardioverter defibrillator.

Table 2. Management Issues with EPCS and the ADS

Issues	Comments	EPCS	ADS First 274	ADS Second 274
Failure to inactivate tachyarrhythmia sensing	Error recognized after the device-delivered therapy during an episode of ventricular tachycardia during reoperation for bleeding after cardiac surgery		0	1
Tachyarrhythmia sensing disabled in patients with no use of monopolar cautery	Patient now dependent on external defibrillation	1	0	0
Failure to restore original device settings	See below for details*		2	2
Missing note in the medical record	Poor record keeping	15	4	0
Unintentional entering of values for atrial tachycardia therapy	This error did not activate those therapies so no potential adverse consequence to patient		2	0
Asynchronous pacing when not pacing dependent†	Could create a tachycardia due to competing rhythms or pose a risk of R-on-T and ventricular fibrillation	13	0	0
Minute ventilation sensor turned “off”‡	Using “off” instead of “passive” mandated a 4-min baseline ventilation acquisition		3	1
Could not figure out how to program asynchronous pacing§	If pacing dependent, patient would be vulnerable to low heart rates with inhibition of demand pacing	3	0	0
Failure to turn off rate–response feature	Potential for undesired pacemaker-induced tachycardia	18	5	2
Total		50	16	6

Entries were left blank if it was not possible to determine occurrence. For the ADS, the incidence of each event is divided between that service's first and second half of their 548 cases. For the ADS, the difference in the rate of management issues between the first 274 and the second 274 cases was significant ($P < 0.05$).

* Failure to reinitiate autothreshold testing (twice), failure to recognize that dynamic atrioventricular delay had turned on with restoration of demand pacing and failure to turn on the Monitor zone when restoring tachyarrhythmia detections. † As determined by baseline programming of ventricular demand pacing at a base rate of 40 per minute (virtually always indicates that the patient is not pacing dependent) and/or comments in the record that clearly identify the patient as having an adequate underlying rhythm before surgery. Three additional cases were likely not pacing dependent. ‡ Applied only to Boston Scientific pacemakers. § In devices that could be converted to asynchronous pacing.

ADS = Anesthesiology Device Service; EPCS = Electrophysiology/Cardiology Service.

Actively Managed Cases

Table 1 shows basic programming changes made to 250 CIEDs managed by the EPCS and 548 CIEDs managed by the ADS. Management by the two services was similar but not identical. For surgical procedures below the umbilicus, the ADS would occasionally advise magnet use instead of disabling tachyarrhythmia sensing, whereas the EPCS

almost always disabled tachyarrhythmia detection. The ADS disabled the rate–response feature more frequently than EPCS (216 of 223 *vs.* 95 of 113, $P < 0.0001$).

CIED Management Issues

Table 2 shows problems or errors observed with CIED management, organized by service. The most serious error

found was failure to complete the steps necessary to suspend tachyarrhythmia detection. The accuracy of postoperative restoration of the original CIED settings could not be determined for the cases managed by the EPCS because it was not their usual practice to obtain and preserve printouts of these sessions. Four errors were noted in postoperative restoration by the ADS. These were recognized in all cases within 2 days and either corrected immediately or *via* arrangements made with the primary cardiologist. No patient harm occurred as a result of these errors. The overall error rate by the ADS appeared to decrease with experience.

Other than suboptimal record keeping, the most common management error with EPCS was the frequency with which asynchronous pacing was used when there were indications that the patient was not pacing dependent. Part of the problem may lie with existence of an “electrocautery mode” option in Boston Scientific ICDs. Despite its name, this mode is not always appropriate for surgery because it not only turns off tachyarrhythmia detection but also converts the ICD to asynchronous pacing. This conversion poses theoretical risks of tachycardia due to competition between an intrinsic rhythm and the paced rhythm. Such tachycardia did occur in seven patients who had Boston Scientific ICDs and were not pacer dependent, and in one of these patients, the anesthesia care team had the ADS restore demand pacing in the OR.

Cases Not Actively Managed

No formal interrogation of the CIED was performed for 227 procedures. Magnet use for these procedures is shown in table 3. For cases involving monopolar electrosurgery, ICD tachyarrhythmia detection was not disabled on 19 occasions for surgical procedures carried out above the umbilicus and on seven occasions for procedures below the umbilicus. After one case (to control bleeding after cardiac surgery) in which

no magnet was applied to the ICD, postoperative interrogation revealed multiple episodes of intraoperative EMI interpreted as ventricular tachycardia. Fortunately, no therapy was delivered by the device.

Of the 227 procedures without active management, many occurred either in patients who were returning for additional procedures and whose previous evaluation by the ADS had indicated that no programming was necessary or the upcoming procedure did not involve monopolar cautery. On some occasions, the OR anesthesia team failed to contact the ADS. Nevertheless, there were times when the ADS was aware of the procedure but did not interrogate the CIED or determine whether a recent evaluation had been performed.

Preoperative Problems with CIEDs

On the preoperative interrogation, a number of CIED or lead problems were recognized (table 4). Of 19 such instances involving the ADS, 2 were serious enough to require immediate help from the EPCS. Approximately 1% of the CIEDs (7 of 798) presented with a significantly low battery status. Overall, 2.1% of the cases presented with issues that required at least some level of follow-up.

Intraoperative Rhythm Disturbances

During surgery, the anesthesia OR team noted rhythm disturbances that were in some way related to the CIED on a number of occasions. The most serious problem was abrupt loss of ventricular capture that occurred in three patients managed by the ADS undergoing placement of a left ventricular assist device. Capture was restored by the ADS by increasing either the ventricular output voltage or pulse duration or by having the surgeon place temporary pacing wires.

Four patients demonstrated competing intrinsic and asynchronously paced rhythms despite appearing to be pacing dependent preoperatively. Hemodynamic compromise was not observed although the OR anesthesia team was concerned enough to call the ADS for evaluation in one instance. In this case, restoration of demand pacing failed to eliminate unnecessary pacing due to undersensing of the QRS complexes. This was resolved by increasing the lead sensitivity (fig. 3).

Modest decreases in heart rate were commonly observed in patients who remained in demand pacing. On two occasions, the anesthesia team requested conversion to asynchronous pacing although no hemodynamic compromise was observed. The one case where significant bradycardia and hypotension were observed occurred in a patient with an ICD (Biotronik Lumax, Oswego, OR) that could not be programmed to asynchronous pacing. For all three cases, electrosurgery return pads were located appropriately.

The anesthesia OR team often reported seeing paced ventricular complexes at rates higher than the programmed lower rate. Several types of these pseudomalfuctions were noted. Most commonly, the pacing system depolarized the ventricles after a sensed atrial event at the atrial rate, which was greater than the programmed lower rate. In patients with cardiac

Table 3. Use of a Magnet in Cases (227) Where There Was No Cardiovascular Implantable Electronic Device Interrogation on the Day of Surgery by Either the EPCS or the ADS

	Magnet Use with Pacemakers	Magnet Use with Implantable Cardioverter Defibrillators
Cases with monopolar cautery above the umbilicus	2 of 20*	6 of 25
Cases with monopolar cautery below the umbilicus	0 of 34	3 of 10
Cases with bipolar or no cautery	0 of 49	0 of 86

In addition to the cases listed above, there were three procedures where tachyarrhythmia detection had been previously disabled on a permanent basis.

* Of the two cases where a magnet was placed on a pacemaker, one was likely inappropriate as the patient had a documented sinus tachycardia before magnet placement. Low pulse rates during cautery were noted in the anesthetic record in 2 of the 18 cases where a magnet was not placed. ADS = Anesthesia device service; EPCS = Electrophysiology/Cardiology Service.

Table 4. Device or Lead Problems Discovered on Initial Interrogation in the 250 Cases Managed by EPCS and the 548 Cases Managed by the ADS

Problem	EPCS	ADS	Management
Previously known single lead failure	3	5	None needed
Atrial and right ventricular lead failure		1	EPCS consulted, temporary pacer placed for surgery
Battery at elective replacement	3	4	Referred to regular cardiologist if not already aware
Lead output voltages higher than needed		5	All referred to regular cardiologist, but in one instance, the output voltage was lowered by the ADS
Lead capture threshold dangerously high		1	Referred to EPCS
Device going in and out of mode switching (farfield sensing of ventricular-paced beats by the atrial lead was interpreted as a high atrial rate)		1	Referred to regular cardiologist
Right ventricular lead sensing failure, causing unneeded paced beats		1	EPCS consulted, right ventricular lead sensitivity was decreased
Episodes of ventricular tachycardia present between interrogations		1	Referred to EPCS, patient had an ICD implanted

The number of times each service experienced the problem is shown. Excluding the patients with known lead failures, 17 of the cases (2.1%) presented with some issue that could have adversely affect patient care.

ADS = Anesthesiology Device Service; EPCS = Electrophysiology/Cardiology Service; ICD = implantable cardioverter defibrillator.

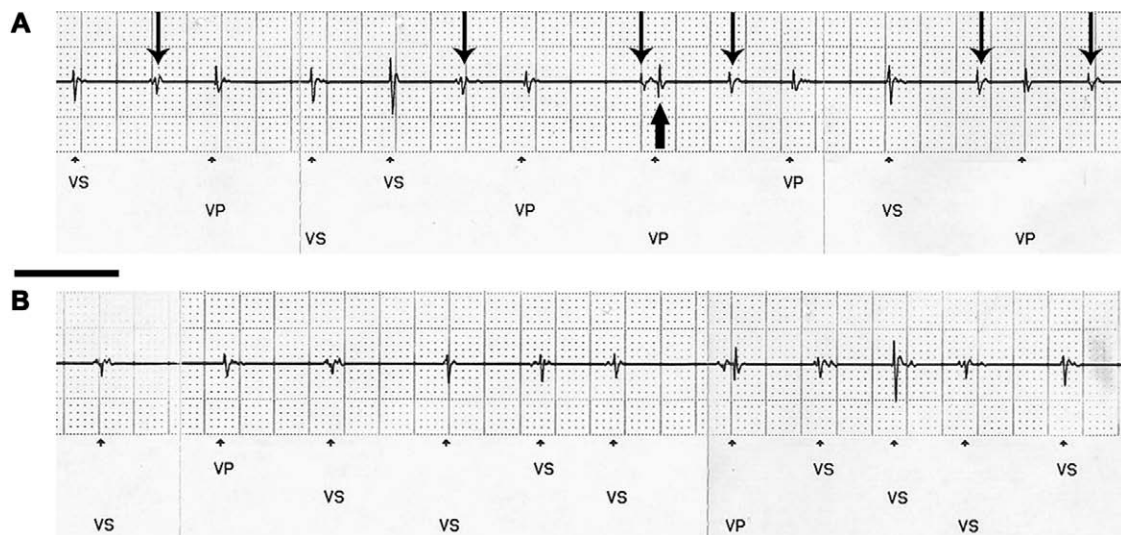


Fig. 3. Example of undersensing that caused excess pacing in the operating room. (A) The right ventricular electrogram and the channel markers are shown while the lead sensitivity was set to 2.5 mV. Shown on the electrogram are six ventricular depolarizations that are not sensed by the device (down-pointing arrows). In addition, ventricular-paced beats are observed, often shortly after unsensed ventricular depolarizations including one R-on-T paced beat (large, up-pointing arrow). (B) The right ventricular electrogram is shown after the lead was programmed to be more sensitive (threshold set to 1.5 mV). All ventricular depolarizations are now detected, and no unnecessary ventricular pacing is present. VP = ventricular pacing; VS = ventricular sensing.

resynchronization therapy, a feature called “BiV trigger” forces left ventricular depolarization in response to a sensed event from the right ventricle because these devices have been designed to perform biventricular pacing greater than 90% of the time. Thus, any signal on the right ventricular lead (either native or EMI) will trigger left ventricular pacing. Another example of unexpected pacing occurred when a St. Jude Accent DR 2210 pacemaker initiated a brief self-test, which results in a very short AV delay (to force ventricular pacing) and several QRS events with two or three pacing artifacts each.*

* St. Jude Medical Technical Insight bulletin on “Loss of Capture Recovery,” August, 1999; obtained by contacting St. Jude support at 1-800-933-9956.

Problems with CIED Parameter Restoration

The most unexpected finding was frequent unanticipated changes to programmed settings after the initial attempt to restore the preoperative settings (table 1, Supplemental Digital Content 1, <http://links.lww.com/ALN/B195>). The great majority (> 80%) of these problems occurred on restoration of demand pacing when asynchronous pacing had been used for surgery. Many device settings disappear when CIEDs are programmed to asynchronous pacing at a fixed rate. Upon reactivation of demand pacing, nominal values for those settings are automatically entered, but these default values may not be the same as the patient’s baseline settings. Of particular note, altered settings did occur at times even when the

baseline settings could be stored in the programming box and reloaded postoperatively into the CIED.

A known interaction between ventricular assist devices and some St. Jude CIEDs prevented some aspects of postoperative testing and programming.⁸ Postoperative evaluation was deferred to the EPCS who often used an “iron skillet” whereby an iron-based frying pan is placed over the programming wand to shield it from the EMI generated by the ventricular assist device.⁸

Delay Times and Case Load

First case delay times for the ADS averaged 10.3 ± 12.9 min (SD) ($n = 81$) and for the EPCS 26.1 ± 30.4 min (SD) ($n = 20$). To-follow case delay times for the ADS averaged 41.3 ± 15.7 min (SD) ($n = 180$) and for the EPCS 48.1 ± 26.0 min (SD) ($n = 72$).

During the first 15 months of the study when the EPCS performed most of the programming, the 5 busiest single days involved active management of three CIEDs. During the last 15 months of the study, the ADS managed three CIEDs in 1 day on 17 occasions and four CIEDs in 1 day on three occasions.

Discussion

A major obstacle to perioperative management of CIEDs is that no specialty group has claimed ownership of the task. Cardiology fellows, who had many other clinical responsibilities, did not prioritize this service, and OR personnel felt that slow response times frequently delayed case starts. The use of industry-employed allied professionals (company representatives) is not a viable solution, in part due to limits of scheduling and last-minute availability, and because they do not have the clinical privileges to determine the appropriate programming for surgery.¹

The ASA, the HRS, and the American Heart Association all agree that a systematic approach is necessary for safe management.^{1,9,10} A knowledgeable individual should base a prescription on current information about the CIED, performance of that device in the patient, the surgical site, and the expected extent of monopolar electrosurgery use. Because of their expertise in these issues and the physiology of the anesthetized patient, our belief was that it would be appropriate to have anesthesiologists perform these tasks.

There are potential benefits from having anesthesiologists perform perioperative CIED management. Anesthesiologists are familiar with the degree of expected EMI and determine the optimal basal heart rate necessary for hemodynamic stability in a given surgical procedure. The anesthesia OR team may be more comfortable interacting with colleagues regarding device management than with unfamiliar cardiology fellows. They may therefore be more likely to participate in the CIED management plan, ask questions about expected CIED function during surgery, and call for help in the OR when faced with confusing paced rhythms or possible CIED

malfunction. Several recent publications contain examples where an educated anesthesia team would have been useful to intraoperative CIED management.^{2,5,11,12}

Caseload for the ADS increased considerably during the study period, especially the number of days when multiple CIEDs needed evaluation. Had the increased workload been shouldered exclusively by the cardiology fellows, OR delays might have worsened. Several factors account for the increasing workload by the ADS. Initially, all ADS interrogations required in-person EPC supervision, which limited the number of cases the ADS could perform. ADS-managed cases increased when the Anesthesiology team lead (G.A.R.) began supervising other team members. Eventually each team member gained enough experience to proceed independently on straightforward cases. Another major increment in anesthesia workload occurred when the ADS assumed management of in-house cardiac surgery patients on the day of surgery as the cardiac surgeons became more comfortable with the ADS managing their patients. These patients, typically with severe heart failure and implanted ICDs, had previously been managed by the EPCS the night before surgery. Finally, the total number of patients with CIEDs requiring management increased over time.

Workload on the day of surgery might have been considerably reduced if a more manageable system had been in place to determine the operative plan in advance of the surgery date. The data in table 5 suggest that only 47% of pacemakers and 35% of ICDs involving monopolar electrosurgery would have required programming on the day of surgery.

Given that less than half of the devices actually required programming on the day of surgery, and the fact that a substantial percentage (2.1%) of the devices presented with some abnormality, including batteries near their end-of-life (table 4), it can be argued that a better approach would be to evaluate the CIEDs well in advance of surgery. Patients who were seen in our preanesthesia clinic received device evaluation if appropriately recent evaluation was lacking, but the preanesthesia clinic sees only a fraction of the patients with devices. Our issues with workload and device problems discovered on the day of surgery present a strong argument that CIED management could and should be a component of the perioperative surgical home.

Cardiovascular implantable electronic device management was not perfect by the ADS although errors were not common and appeared to become less frequent with experience (table 3). Errors in preoperative programming by general cardiology fellows were observed as well, but it was impossible to assess how accurately they restored CIED settings postoperatively. The EPCS faculty report that the general cardiology fellows rarely made preoperative and postoperative parameter printouts for comparison and therefore may have missed many of the programming changes that the ADS observed. Even EPCS attendings were surprised by some of the observed alterations in parameters.

Table 5. Theoretical Minimal CIED Management Necessary for the Cases in the Present Study

CIED Type and Location of Monopolar Electrocautery, Except as Noted	Programming Needed	Magnet Sufficient	No Active Management
ICD, above umbilicus	153		
ICD, above umbilicus, not pacer dependent		235	
ICD, below umbilicus surgery		44	
Pacemaker, above umbilicus surgery, pacer dependent	183		
Pacemaker, above umbilicus surgery, not pacer dependent		124	
Pacemaker, below umbilicus surgery		85	
No cautery or bipolar cautery only			201
Total	336	488	201

Beginning with the assumption that every device had been appropriately evaluated before surgery, this table examines what the minimal management could have been on the day of surgery. For purposes of this table, programming was considered necessary for any procedure with monopolar electrocautery performed above the umbilicus on a patient who had an ICD or was pacer dependent. Placement of a magnet over an ICD was considered sufficient management for procedures where monopolar electrocautery was applied below the umbilicus. Having a magnet available for placement over a pacemaker during monopolar electrocautery use was considered sufficient if the patient was not pacer dependent or if the surgical site was below the umbilicus. Cases with no cautery or bipolar cautery would not generally require any programming although having a magnet available may be a reasonable precaution. Overall, perhaps only one-third of the cases in the study would have required programming immediately prior to surgery if device evaluation and plan formulation had been performed in advance of surgery.

CIED = cardiovascular implantable electronic device; ICD = implantable cardioverter defibrillator.

The importance of item by item corroboration between the preoperative and postoperative printouts became an obsession with the ADS team to the point that we decided it was necessary for two people to confirm the comparison.

Management of CIEDs is not a trivial undertaking. Considerable personal time was spent learning about CIED management. Learning has been a continuous process. When it became apparent, for example, that lead capture threshold testing was not always being performed correctly, a separate training session about threshold testing was given to team members. It is also clear that the ADS did not interpret the HRS guidelines correctly with regard to ensuring that an appropriately recent CIED evaluation had been performed, even if electrosurgery was not going to be used.¹ It is possible that some of the CIEDs that were not actively managed had problems at the time of surgery, given the frequency of CIED problems found in managed cases preoperatively. The ADS now attempts to ensure that all devices have at least been recently evaluated. A recent case report provides an example in which pacemaker malfunction was unmasked by magnet placement before surgery and the malfunction resulted in hemodynamic compromise.²

Cardiovascular implantable electronic device management was typically performed during the ADS attendings' regular clinical workdays (*i.e.*, OR or preanesthesia clinic), making what are already busy days even busier. It is not uncommon for team members to work later than usual to complete interrogation notes. During the study, only the team lead received academic support, but it did not cover all the time spent supervising and teaching other team members. Monetary compensation was only awarded for CIED management when it was performed by an ADS team member who was not otherwise engaged in clinical activity that day. Compensation by the federal government and private insurance for this service is low, approximately \$20 and \$30 per interrogation, respectively. We have had an occasional

denial of payment because "only cardiology is qualified to perform this service." We are appealing these because there is no Centers for Medicare and Medicaid Services rule to support denials on that basis.

The process for hospital credentialing to provide this service has not been entirely determined. The team lead, in part by virtue of passing the International Board of Heart Rhythm Examiners examination, has formal hospital privileges to manage CIEDs in the perioperative period but the other team members as yet do not, in large part over difficulty in determining what would constitute adequate credentials.

Having anesthesiologists manage CIEDs will not be feasible in all care settings. Remaining facile with all the idiosyncrasies of programming requires a high volume of cases, a trait not shared by all healthcare systems. The patient workloads at the other five hospitals in the University of Washington system do not currently support an ADS. It is also important to recognize the vital contribution of the EPCS. Without their support, our anesthesiologist run service would not have been possible. EPCS involvement is still necessary although currently it is primarily for follow-up management of complex issues that are beyond our skill and comfort level.

In summary, this report documents our experience with an anesthesia-based service for the perioperative management of CIEDs. Significant findings included the presence of preexisting CIED dysfunction, errors in management by both the ADS and EPCS, the utility of intraoperative interrogation, and the difficulty in restoring the original CIED settings. Although there are advantages to having anesthesiologists manage CIEDs in the perioperative period, the complexity of that management suggests that our current approach will likely be useful only in high-volume settings.

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Competing Interests

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