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Process Improvement Initiative for the Perioperative Management of Patients With a Cardiovascular Implantable Electronic Device

Margaret K. Menzel Ellis, MD,*† Miriam M. Treggiari, MD, PhD, MPH,* Jamie M. Robertson, PhD, MPH,*‡ Marc A. Rozner, PhD, MD,*§ Peter F. Graven, PhD,‖ Michael F. Aziz, MD,* Matthias J. Merkel, MD, PhD,*¶ Edward A. Kahl, MD,* Norman A. Cohen, MD,* Eric C. Stecker, MD, MPH,¶ and Peter M. Schulman, MD*

BACKGROUND: Economic, personnel, and procedural challenges often complicate and interfere with efficient and safe perioperative care of patients with cardiovascular implantable electronic devices (CIEDs). In the context of a process improvement initiative, we created and implemented a comprehensive anesthesiologist-run perioperative CIED service to respond to all routine requests for perioperative CIED consultations at a large academic medical center. This study was designed to determine whether this new care model was associated with improved operating room efficiency, reduced institutional cost, and adequate patient safety.

METHODS: We included patients with a CIED and a concurrent cohort of patients with the same eligibility criteria but without a CIED who underwent first-case-of-the-day surgery during the periods between February 1, 2008, and August 17, 2010 (preintervention) and between March 4, 2012, and August 1, 2014 (postintervention). The primary end point was delay in first-case-of-the day start time. We used multiple linear regression to compare delays in start times during the preintervention and postintervention periods and to adjust for potential confounders. A patient safety database was queried for CIED-related complications. Cost analysis was based on labor minutes saved and was calculated using nationally published administrative estimates.

RESULTS: A total of 18,148 first-case surgical procedures were performed in 15,100 patients (preintervention period—7293 patients and postintervention period—7807 patients). Of those, 151 (2.1%) patients had a CIED in the preintervention period, and 146 (1.9%) had a CIED in the postintervention period. After adjustment for imbalances in baseline characteristics (age, American Society of Anesthesiologists physical status, and surgical specialty), the difference in mean first-case start delay between the postintervention and preintervention periods in the cohort of patients with a CIED was −16.7 minutes (95% confidence interval [CI], −26.1 to −7.2). The difference in mean delay between the postintervention and preintervention periods in the cohort without a CIED was −4.7 minutes (95% CI, −5.4 to −3.9). There were 3 CIED-related adverse events during the preintervention period and none during the postintervention period. Based on reduction in first-case start delay, the intervention was associated with cost savings (estimated institutional savings $14,102 annually, or $94.06 per CIED patient), with a return on investment ratio of 2.18 over the course of the postintervention period.

CONCLUSIONS: Based on our experience, specially trained anesthesiologists can provide efficient and safe perioperative care for patients with CIEDs. Other centers may consider implementing a similar strategy as our specialty adopts the perioperative surgical home model. (Anesth Analg 2017;125:58–65)

From the *Department of Anesthesiology and Perioperative Medicine, Oregon Health & Science University, Portland, Oregon; †Operative Care Division, Veterans Affairs Portland Healthcare System, Portland, Oregon; ‡STRATUS Center for Medical Simulation, Brigham and Women's Hospital, Boston, Massachusetts; §Department of Cardiology, University of Texas MD Anderson Cancer Center, Houston, Texas; ‖Center for Health Systems Effectiveness, Department of Emergency Medicine, Oregon Health & Science University, Portland, Oregon; and ¶Knight Cardiovascular Institute, Oregon Health & Science University, Portland, Oregon.

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Address correspondence to Peter M. Schulman, MD, Department of Anesthesiology and Perioperative Medicine, Oregon Health & Science University, 3181 SW Sam Jackson Park Rd, Mail Code KPV-5A Portland, OR 97239. Address e-mail to schulman@ohsu.edu.

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In the United States, approximately 3 million people have an implantable pacemaker and more than 300,000 have an implantable cardioverter-defibrillator.[1] The number of patients with a cardiovascular implantable electronic device (CIED) presenting for surgery continues to increase. The perioperative management of patients with a CIED is complex and challenging, and it might be associated with increased morbidity and mortality.[2,3] In addition, these devices affect operative scheduling and potentially lead to delays in surgical start times.[4]

There are numerous economic, personnel, and procedural barriers to the safe and efficient perioperative care of patients with CIEDs. Preoperatively, the presence of a CIED should be identified before a scheduled procedure, because proper CIED function must be verified and an individualized perioperative CIED management plan must be created based on patient comorbidities, the planned surgical procedure, and the individual characteristics of the patient's CIED, as recommended by the Heart Rhythm Society (HRS)[5] and American Society of Anesthesiologists.[6] In addition, immediate preoperative reprogramming might be needed to mitigate the risks of electromagnetic interference arising from the use of radiofrequency instruments, primarily monopolar electrosurgery.

Clinicians such as cardiologists and specially trained advance practice providers with the appropriate skills, licensing, and privileging often are called on to interrogate and reprogram CIEDs before (and after) surgery but are sometimes not readily available. In this situation, the placement of a magnet over a CIED, presumably to change the pacing mode (pacemaker) or suspend antitachycardia therapies (implantable cardioverter defibrillator [ICD]), often is used. "Blind" magnet application (ie, substituting magnet application for individualized care), however, to a CIED during surgery can lead to adverse outcomes[7] and is only acceptable under extenuating circumstances. Although manufacturer representatives frequently are asked to independently deliver perioperative CIED care, this practice is well beyond their scope and should be avoided according to the HRS.[5]

At our institution, we found it was difficult to adhere to all of the American Society of Anesthesiologists practice advisory and HRS expert consensus statement recommendations without incurring surgical cancellations or delays. Thus, we implemented a quality improvement initiative to create an anesthesiology-run perioperative CIED service. The goals of this initiative were to adhere to published practice recommendations, improve operating room efficiency, and provide high-quality care. For the purpose of this study, we compared operating room start time delays for first-case-of-the day surgery during a time period when CIED care was rendered by the cardiac electrophysiology service with a period when CIED care was rendered by the anesthesiology-run perioperative CIED service. We hypothesized that when compared with our institution's historical perioperative CIED management provided by cardiologists and advanced practice providers, a new anesthesiologist-run perioperative CIED service would reduce operative delays without adversely affecting patient safety.

METHODS

In the context of a quality improvement process, we reviewed our experience with an anesthesiology-run perioperative CIED service at Oregon Health & Science University (OHSU), a 553-bed academic referral institution. This study was designed to evaluate the efficiency and safety before and after the implementation of the new perioperative CIED service. Implementation began on August 18, 2010, and the service was deployed fully on March 4, 2012.

All patients ≥18 years of age presenting with a CIED who underwent scheduled first-case-of-the day surgery during weekdays at OHSU between February 1, 2008, and August 17, 2010 (preintervention) and between March 4, 2012, and August 1, 2014 (postintervention), were considered for inclusion. The study was approved by our institutional review board with waiver of written informed consent and adheres to the applicable EQUATOR guidelines.

Design of the Anesthesiologist-Run CIED Service

The Department of Anesthesiology and Perioperative Medicine and the Electrophysiology Section of the Division of Cardiovascular Medicine jointly initiated a quality improvement project, starting on August 18, 2010, to address issues related to the perioperative care of surgical patients with a CIED. Before this quality improvement initiative, surgical patients with CIEDs were managed by the electrophysiology service (or occasionally by manufacturer representatives). The electrophysiology service consisted of attending electrophysiologists, electrophysiology and general cardiology fellows, and physician assistants. Anesthesia providers and/or surgeons would consult the electrophysiology service for perioperative CIED care when deemed necessary.

First, key stakeholders created a perioperative protocol (see Supplemental Digital Content, Appendix 1, http://links.lww.com/AA/B688) to standardize management of patients with CIEDs undergoing surgery. Initially based on recommendations from the American Society of Anesthesiologists practice advisory,[6] this protocol was later revised to reflect additional recommendations from the HRS expert consensus statement,[5] which was published after our initial protocol was developed.

This perioperative protocol mandates that (1) preoperatively, key information about a CIED is collected, scanned into our institution's electronic medical record during the patient's preoperative medicine clinic appointment, and an individualized perioperative CIED management plan is provided to the operative care team by a member of the CIED care team; (2) intraoperatively, the CIED plan is enacted (including, but not limited to suspending ICD antitachycardia therapy and/or reprogramming a pacemaker or ICD to an asynchronous pacing mode when appropriate); typically these interventions occur in the preoperative holding area immediately before surgery or in the operating room (see Supplemental Digital Content, Appendix 2, http://links.lww.com/AA/B688); and (3) postoperatively, the CIED is checked and appropriate settings are restored. Our protocol also specifically addresses the appropriate use of a magnet to alter the function of the CIED (see Supplemental Digital Content, Appendix 3, http://links.lww.com/AA/B688). This protocol was implemented by the Division of Cardiovascular Medicine and the Department of Anesthesiology before the development of the anesthesiology-run CIED service and was in place before any data collection.

Next, a pathway for training, demonstration of competency, and privileging of anesthesiologists in perioperative CIED management was created. Because no published recommendations for training anesthesiologists to manage CIEDs exist, we used the American College of Cardiology Foundation Core Cardiology Training Symposium 3[8] recommendations for cardiology fellows as a blueprint to create a perioperative training curriculum for anesthesiologists with a more limited scope but similar aims to the "level 1" training delineated in the Core Cardiology Training Symposium 3 document (see Supplemental Digital Content, Appendix 4, http://links.lww.com/AA/B688).[8]

A selected group of anesthesiologists, all of whom practice cardiac anesthesia or critical care medicine, then received formal interdisciplinary training via a proctoring process. The training predominantly occurred at our institution's electrophysiology clinic, where it was administered by attending electrophysiologists and advanced practice providers. Requisite technical skills gained by the anesthesiologists during this training process are outlined in Supplemental Digital Content, Appendix 5, http://links.lww.com/AA/B688. Training started with a full-day CIED programming workshop taught by electrophysiology clinic staff and allied professionals. Next, anesthesiologists received proctored training in the clinic and performed a minimum of 30 CIED interrogations (15 pacemakers and 15 ICDs with exposure to all of the CIED manufacturers). Trainees maintained a logbook of all interrogations. Finally, they had to demonstrate competency in conducting CIED interrogations, including identifying and reporting key CIED parameters, analyzing the CIED event log, determining battery status, determining pacing dependence, testing lead impedance, and determining pacing and sensing thresholds. They also had to demonstrate competency in basic CIED programming. After completion of the proctoring process, successful hospital privileging required a letter from an electrophysiology physician familiar with the anesthesiologist's performance, review by the anesthesiology department chair, and review by the institutional credentials committee.

On deployment of the anesthesiologist-run CIED service on March 4, 2012 (once a critical mass of 4 anesthesiologists had been privileged to staff the service >80% of the time during daytime hours), a designated "perioperative CIED team" member was assigned to manage the perioperative CIED service each day. This assignment was documented on the daily anesthesiology assignment schedule. An automated electronic roster of all surgical patients with CIEDs was compiled on the day before scheduled surgery based on *International Classification of Diseases, Ninth Revision* codes and information gathered during either a recent internal medicine or cardiology clinic visit or the patient's anesthesiology preoperative medicine clinic visit and distributed to all perioperative CIED team members. Thus, patients who were scheduled for surgery and required a preoperative de novo CIED interrogation and/or programming changes could be easily identified. Before surgery, the perioperative CIED team member then provided specific recommendations to the operative care team and performed CIED interrogation and programming when indicated.

Study Population

All patients who were scheduled to undergo first-case surgery in the main operating room block at OHSU between February 1, 2008, and August 17, 2010 (preintervention), and between March 4, 2010, and August 1, 2014 (postintervention), were identified from the electronic medical record. We restricted the eligibility criteria to first-case starts only so that an exact expected start time was available for all included cases. Elective first cases occurring on a weekday were selected based on the scheduled in-room time of the procedure (8:30 AM on Mondays and 7:30 AM Tuesdays to Fridays). Patients were excluded if they were <18 years of age at the time of surgery, underwent emergency surgery (American Society of Anesthesiologists [ASA] physical status designation of "E") or had an ASA physical status of 6 (indicating a brain dead patient/organ donor), or if their scheduled surgery was cancelled or did not occur on the same day as scheduled. Out-of-operating room procedures were also excluded because of the fact that the procedure start time for these cases is variable.

Study Procedures

The preintervention period began on February 1, 2008, when a new electronic medical record system allowed perioperative data to be archived for analysis and ended on August 17, 2010, when the first perioperative CIED team member was privileged. The postintervention period began on March 4, 2012, when the staffing of the anesthesiology-run CIED service became sufficient to manage >80% of the cases, and ended August 1, 2014. To avoid contamination during the program implementation, data from the period between August 18, 2010, and March 3, 2012, were not included, because management during this time was shared among members of the anesthesiology-run CIED team and faculty and trainees from the Division of Cardiovascular Medicine while additional anesthesiologists were trained.

There were rare (approximately 1–2 times a month) instances in the postintervention period when a member of the anesthesiologist-run CIED team was unavailable and the cardiology service provided care. Because these instances were negligible, these data were not accounted for during the anesthesiologist-run CIED (postintervention) period. Importantly, these instances were driven by physician availability and not case complexity or other patient-related factors.

The primary end point for the study was the magnitude of first-case start time delays in adult patients with CIEDs undergoing scheduled surgery during weekdays. First-case delay was defined as the difference between the actual in-room time, which is charted routinely for each surgery, and the scheduled in-room time. We compared the length of these delays between patients who underwent surgery before and after the service was fully implemented. Secondary end points were the evaluation of safety as indicated by occurrence of adverse events, and the evaluation of the institutional costs associated with the program.

Safety Evaluation

A departmental quality improvement and safety database was queried for all events reported during the preintervention and postintervention periods. This database is composed of all quality and safety incident reports generated by operating room staff and included all possible events for patients treated in the study period; deidentified data for each study period were provided to the investigators. Search terms included "CIED," "pacemaker," "ICD," or "defibrillator." Events meeting any of these criteria were reviewed by study investigators to determine whether they were related to perioperative CIED management.

Cost Evaluation

Using an estimate of direct labor cost savings attributable to reduced nonproductive operating room time, we calculated the potential economic value of our CIED service. OHSU provided direct cost data for nonphysician operating room staff (circulating registered nurse and scrub technician) of

$6.26/min for the sites where the CIED service was offered. Using Medical Group Management Association survey data for clinical anesthesiology faculty salary in the Western United States and OHSU data for clinical days worked by academic rank, an estimate of physician anesthesiologist cost of $2.47/min was calculated, resulting in total labor cost of $8.73/min. The costs from reduced first-case start time delays were estimated by multiplying the minute reduction in start times by the impact of reduced start times on labor time. This effect was then multiplied by the labor cost per minute to arrive at the savings per operating room per day. To reduce complexity of analysis, we did not include labor costs for care delivered by anesthesiology residents or certified registered nurse anesthetists.

The potential cost savings associated with reductions in first-case start times were calculated by use of the 11-step process described by Dexter and Epstein,[9] which specifies the approach developed in McIntosh et al.[10] The approach calculates the increased cost of labor associated with increased first-case start times. The key innovation over a simple application of reduced start times to labor cost savings is that it estimates empirically if reduced start times would actually affect labor, given the standard 8-hour shift schedules and existing surgery scheduling patterns that may include under or overused operating room time. In particular, because labor is fixed, for the first 8 hours, reduced first-case start times that simply reduce underutilized time would not result in cost savings since the staff is already scheduled to be paid for that time.

We also assessed the cost of implementing and maintaining the anesthesiologist-run CIED service. To determine the training costs, the number of "anesthesiologist-days" necessary for training was determined based on the number of full-time equivalents required and the interruption in regular work necessary for an anesthesiologist to complete CIED training. We then calculated the total cost of this training based on the median salary of an anesthesiologist in the Association of American Medical Colleges western region. Finally, we compared the expense of training to the cost of hiring a full-time advanced practice provider, such as a nurse practitioner or physician assistant, to provide this clinical service.

To calculate the opportunity cost of an electrophysiologist or cardiology physician assistant consultation, we used 2 approaches. The first was to estimate the revenue of an alternative procedure (insertion of a dual-lead CIED) foregone as a consequence of the time spent performing a CIED interrogation, less the revenue generated from CIED interrogation itself. The cost of the alternative procedure (Healthcare Common Procedure Coding System—33230) was calculated using the total relative value units (11.58) and conversion factor (34.023) using the National Payment amount from the Medicare Physician Fee Schedule. The cost of the interrogation was calculated as the average total relative value units (0.53) of Healthcare Common Procedure Coding System 93286 and 93287 (professional component). The time required to perform 2 CIED interrogations was assumed to be equal to the time required to implant 1 dual-lead CIED. The second approach was to estimate the cost of paying a cardiology physician assistant to perform the interrogations. The cost is based on the full time equivalent required for the annual volume of interrogations.

Statistical Analysis

Baseline characteristics of the patient population during the 2 time periods were compared with the χ^2 statistic for categorical variables and the 2-sample Student *t* test for continuous variables with assumption of unequal variance (Satterthwaite degrees of freedom).

Time delay was computed as the difference in minutes between scheduled start time and actual start time. Thus, for cases starting on time and for cases starting early, the delay time is 0; for delayed cases, the time delay takes a positive value. The mean length of delay among patients with a CIED was compared between the 2 time periods. To model the differences between the 2 time periods, we used linear regression techniques with robust variance estimation. Our predictor of interest was the time period (ie, preintervention or postintervention). To account for imbalances between the study periods and potential confounders, we used multivariable linear regression with robust variance estimation to account for possible violations in modeling assumptions. Because there was more than one procedure per patient in some instances, the analysis clustered on patient ID to account for repeated measures correlation in approximately 10% of the subjects.

To evaluate for temporal changes and whether the delay reduction was attributable to the implementation of the CIED service rather than to overall improvement in efficiency over time, we also compared the first-case delays between the 2 time periods among a concurrent cohort of first surgical case of the day patients with the same exclusion criteria but without a CIED and who underwent surgery during the study period.

To evaluate whether the difference in time delay between study periods depended on the presence of the CIED service among patients with and without a CIED, we fitted a model that included an interaction term of study period by an indicator variable of CIED. We used the Wald statistics to test for significance of the interaction term.

A 2-sided α level of 5% was required for statistical significance for all testing. All analyses were conducted using the statistical software Stata version 13 (Stata Corp, College Station, TX).

RESULTS

During the preimplementation and postimplementation study periods, we identified 15,100 eligible patients undergoing a total of 18,148 scheduled, first case of the day, adult surgeries; 7293 patients in the preintervention period and 7807 in the postintervention period. Of these, 151 patients had a CIED in the preintervention period, and 146 had a CIED in the postintervention period. A flowchart of the study cohort is shown in Figure 1. There were no differences in baseline characteristics among patients with a CIED, when we compared the preintervention and postintervention periods (Table 1).

Primary Study End Point: First Case of Day Delay

Mean delay times differed significantly between the preintervention and postintervention periods. Among patients

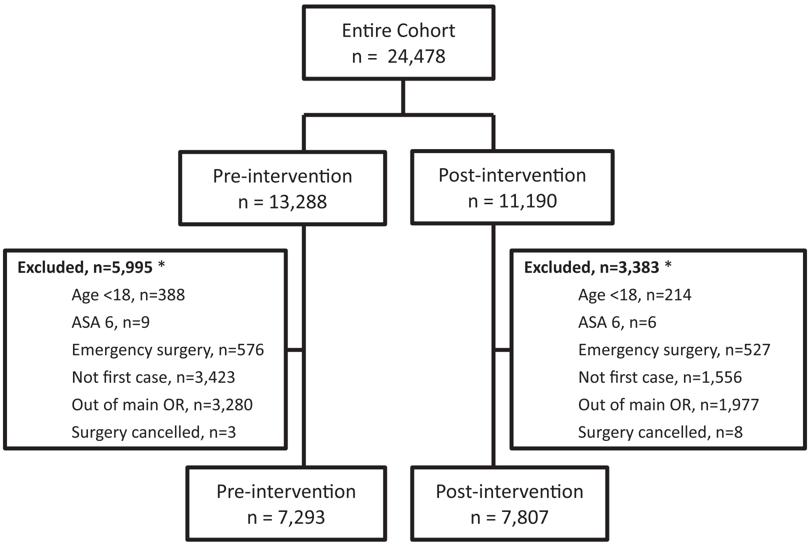

Figure 1. Study flowchart displaying the study cohort in the pre- and postintervention periods. *Numbers do not add up to 100% because patients may have more than one reason for exclusion.

Table 1. Characteristics of Study Cohorts (N = 15,100) Before and After the CIED Service Implementation

	Preintervention Cohort (N = 7293)		Postintervention Cohort (N = 7807)	
Baseline Characteristics	**CIED (n = 151)**	**No CIED (n = 7142)**	**CIED (n = 146)**	**No CIED (n = 7661)**
Surgical procedures (n)	171	8152	191	9634
Age (mean ± SD)	65.0 ± 15.8	54. 6 ± 15.9	62.8 ± 16.7	56.1 ± 15.7
ASA physical status, n (%)				
1	0 (0)	573 (8.0)	0 (0)	243 (7.2)
2	11 (7.3)	3082 (43.1)	6 (10.2)	1424 (42.2)
3	71 (47.0)	2900 (40.6)	72 (49.3)	1404 (41.6)
4	58 (38.4)	494 (6.9)	59 (40.4)	281 (8.3)
5	7 (4.6)	7 (0.1)	3 (2.1)	0 (0)
Missing	4 (2.7)	91 (1.3)	0 (0)	23 (0.7)
Surgical specialty, n (%)				
General surgery	17 (11.3)	1607 (22.5)	23 (15.8)	1910 (24.9)
Orthopedics	16 (10.6)	1635 (22.9)	23 (15.8)	1782 (23.3)
Neurosurgery	11 (7.3)	860 (12.0)	3 (2.1)	1078 (14.1)
Cardiothoracic/vascular	76 (50.3)	951 (13.3)	64 (43.8)	1106 (14.4)
Oral/maxillofacial/ENT	15 (9.9)	567 (7.9)	4 (2.7)	561 (7.3)
Plastics	3 (2.0)	249 (3.5)	1 (0.7)	207 (2.7)
Gynecology	2 (1.3)	590 (8.3)	3 (2.1)	469 (6.0)
Urology	9 (6.0)	546 (7.6)	3 (5.1)	526 (6.9)
Other	0 (0)	7 (0.1)	5 (3.4)	27 (0.4)
Missing	2 (1.3)	130 (1.8)	0 (0)	1 (0.0)

Abbreviations: CIED, cardiac implantable electronic device; ENT, otolaryngology.

with CIEDs, the mean delay was 21.6 ± 53.4 minutes in the preintervention period and 5.4 ± 20.2 minutes in the postintervention period. Among patients with no CIED, the mean delay was 9.2 ± 28.5 in the preintervention period and 4.1 ± 15.0 in the postintervention period. Figure 2 shows the mean delays in the CIED and no CIED cohorts in the 2 time periods segmented in 6-month intervals.

The results of the multivariable regression (identity link function and robust SE estimates) are shown in Table 2. In the model that adjusted for baseline patient factors including age, ASA physical status, and surgical specialty that differed between the preintervention and postintervention periods, the adjusted mean difference in delay between periods was 16.7 minutes (95% confidence interval [95% CI], 7.2–26.1). The adjusted mean difference in delay between study periods in the 2 overall cohorts of patients with no CIED was 4.7 minutes (95% CI, 3.9–5.4).

The final regression model, in addition to the main terms and the adjustment for confounders, also included an interaction term between study period and presence of a CIED. In this model, the interaction term was 9.93 minutes (95% CI, 1.6–18.3; P = .020). This estimate represents the delay difference between patients with and without CIED in the change from preintervention to postintervention and indicates that the larger reduction in delay between the 2 periods depended on the presence of the CIED service.

Safety Evaluation

There were 3 CIED-related adverse events reported during the preintervention period and none during the postintervention period. In one case, surgery was cancelled before the induction of general anesthesia when a pacemaker failed to capture after sedation was administered to facilitate placement of a thoracic epidural. In the second case, a pacemaker failed

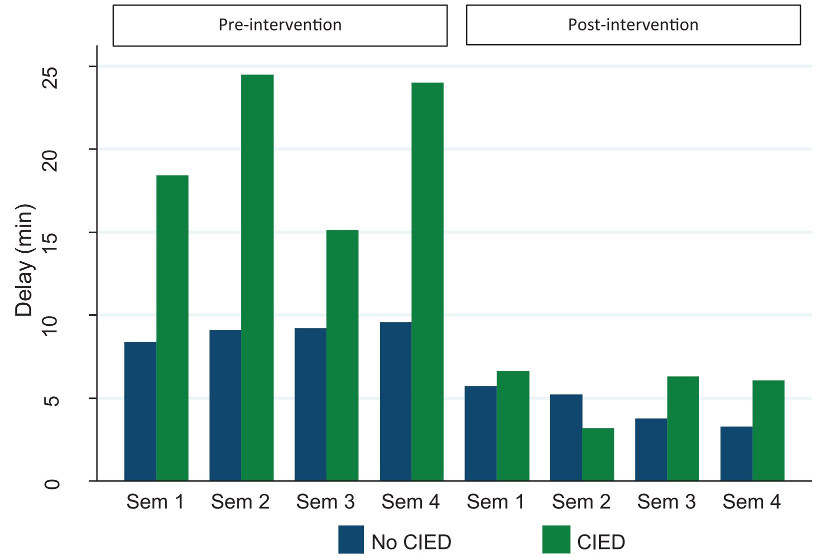

Figure 2. Temporal trend of mean delay over time. On the left, mean delays are shown for patients with and without CIEDs over the preintervention period and on the right, delays are shown for patients with and without CIEDs over the postintervention period. Each period has been divided into 4 equal semesters of 6-month intervals (Sem), except the last interval of each study period, which includes data to the end of that study period. CIED indicates cardiovascular implantable electronic device.

Table 2. Unadjusted (Univariable) and Adjusted (Multivariable) Estimates of Reduction in First-Case Start Delay for Patients With and Without a CIED Before and After the CEID Service Implementation

	Univariable Linear Regression		Multivariable Linear Regression	
	CIED	No CIED	CIED	No CIED
Mean reduction in delay (min)	13.7	4.6	16.7	4.7
95% CI	5.4–21.9	3.9–5.3	7.2–26.1	3.9–5.4

Multivariable linear regression model includes age, surgical specialty, and ASA physical status.

Abbreviations: ASA, American Society of Anesthesiologists; CI, confidence interval; CIED, cardiac implantable electronic device.

to capture intraoperatively, leading to bradycardia, hypotension, and an unplanned admission to the intensive care unit. In the third case, even though a magnet was placed over the ICD during surgery, postoperative interrogation revealed that the patient received 20 inappropriate shocks and 12 inappropriate antitachycardia pacing sequences from the ICD intraoperatively as a consequence of electromagnetic interference, resulting in premature battery depletion requiring ICD replacement. These events occurred because, unbeknownst to the operative care team, the device's magnet switch had been deactivated previously due to a manufacturer's product advisory. The patient also suffered a perioperative cerebrovascular accident. This case has been reported previously.[7]

Cost Evaluation

The 11-step process described in the Methods section arrived at an estimated mean ratio for the number of labor minutes saved per reduced first-case start time minute of 0.68 (95% CI, 0.64–0.71). As described in the Methods, the ratio of 0.68 was multiplied by the number of minutes saved (13.7 minutes) and was also multiplied by the per-minute cost of the operating room ($8.73/min). This yielded a savings of $1.61 per operating room per day. With a median of 24 operating rooms with over 8 hours of operating room time per day (in the last year) the cost savings amounts to $38 a day and thus more than $14,102 annually.

To evaluate the net costs, we deducted the cost of training and equipment as well as opportunity cost from the estimated savings. The median annual salary for an anesthesiologist in the Association of American Medical Colleges western region is $322,667; after accounting for weekends, holidays, and vacation time, each "anesthesiologist-day" costs $1355.74. Each anesthesiologist team member completed a total of 30 proctored CIED interrogations over an average time span of 4 nonclinical days; thus, training our entire cadre of 5 anesthesiologists took 20 anesthesiologist days, at a total cost of $27,114.87. Once the personnel had been trained, our anesthesiologist-run service incurs minimal or no additional costs to the institution, as anesthesiologists are assigned to regular clinical duties in our main operating room on the days of their CIED service assignments. Furthermore, no additional equipment was purchased, as the programming machines used by our CIED service were provided by the device manufacturers at no cost. The opportunity cost yielded a total cost of $26,128 using the displaced procedure approach and $24,146 using the cardiology physician assistant approach. The average value of the 2 opportunity cost scenarios, $25,137 divided by day was subtracted from costs. Therefore, the intervention cost (ie, $27,114) of training can be recovered in 403 working days. Over the 880 days of postintervention period, the return on investment ratio was 2.18 or 218%, indicating that the savings were more than twice as large as the costs.

DISCUSSION

In this observational study, we found that a perioperative CIED service consisting of specifically trained anesthesiologists contributed to a reduction in operating room start time delays for patients with a CIED. We also observed an overall reduction in first-case delay between preintervention and postintervention periods; however, the size of the change in delay was significantly larger for patients with a CIED. Therefore, this greater difference could be attributed to the presence of the new CIED service. In addition, there were no untoward reports related to patient safety after the implementation of the new CIED service. In our cost-containment evaluation, the program resulted in cost savings to the institution, after paying for itself in approximately slightly over 1 year (403 days).

During the study period, we observed a temporal trend for an overall reduction by 4.7 minutes in the delay of first-case starts. Although a number of other institutional factors contributed to the reduction in delay time, the substantial decrease in mean minutes delayed among those with CIEDs (13.7 minutes) was larger than would be expected if this had simply been the result of other institutional improvements.

This study has several limitations. Our data were collected in the context of a process improvement project and compare perioperative CIED management in 2 distinct, nonoverlapping periods spanning over 4 years, during which time temporal trends and changes within the institution could have occurred. The estimates of this study were only adjusted for a limited set of baseline characteristics. Although we used external comparisons with respective concurrent cohorts, this approach does not guarantee that the estimates are unaffected by the presence of residual confounding. Therefore, it is possible that unmeasured confounders that may not have been accounted for could bias the association between the implementation of the CIED service and the reduction in time delay, and that the true effect might be attenuated. However, there was very little change in the unadjusted and adjusted estimates, suggesting that it is unlikely that a substantial degree of confounding might distort these associations.

The sample was relatively small for evaluating secular trends using interrupted time series techniques. However, delays appeared to be stable for each study period when evaluated in 6-month intervals (Figure 2). We also tested for interaction of study period by the presence of CIED, which is a fairly robust mechanism to discriminate whether the reduction in first-case start delay was attributable to the CIED service implementation. This analysis suggested that the larger reduction in time delay among patients with a CIED above and beyond the overall study period cohorts depended on the presence of the CIED service. It is possible that, over time, anesthesia providers outside of the CIED service acquired more knowledge of perioperative CIED management because of their connection with members of the anesthesiologist-run perioperative CIED service.

There were rare instances during the postintervention period when interrogations were performed by the cardiovascular medicine service rather than the anesthesiologist-run CIED service. Although negligible, if anything, such contamination should bias our estimates toward the null, resulting in a conservative estimate of our service's true effect on start time delay reduction.

Although the setup of an anesthesiologist-run CIED service can be substantial in terms of nonclinical time for anesthesiologists undergoing training, our calculations showed that the costs of training could be recovered in just over 1 year at an institution with 24 operating rooms. In the absence of staff turnover, our anesthesiologist-run service incurs no ongoing maintenance costs, and the anesthesiology staff call schedule is not affected, because the CIED service is covered concurrently with regular clinical duties. Competencies are maintained via the management of at least 50 CIED patients during a 24-month period, which is accomplished easily in routine clinical practice. Another benefit of the anesthesiologist-run model is the ready availability of an anesthesiologist with expertise in CIED management to answer clinical questions in the operating room, preoperative holding area, and postanesthesia care unit, and to troubleshoot complex CIED-related anesthetic management issues.

Yet another benefit is enhanced education on this topic for trainees. Some authors have advocated for an increased focus on perioperative CIED management for anesthesiology residents[11] and for both formal and self-directed continuing medical education on this subject for anesthesiologists in practice.[12] As programs such as the Medicare value-based purchasing program prize patient satisfaction and the avoidance of preventable complications when calculating payment rates,[13] efficiency and safety gains from initiatives such as ours should contribute to value-based payments.

Our financial analysis showed an average daily cost savings of $38 based on the decrease in mean delay minutes and our calculations for cost savings per labor minute. The mean ratio for the number of labor minutes saved per reduced first-case start time minute in our study was 0.68, which is significantly lower than the 1.20 ratio described by McIntosh et al[10] and Dexter and Epstein.[9] There are many hospital factors between our study and the study that established this method that could explain this difference; however, the data are not available for comparison. Examination of the operating rooms at our hospital revealed that, with an 8-hour shift as the framework for determining operating room time allocation, 62% of scheduled cases finished within 1 hour of their scheduled end time. This falls within the typically published range (60%–66%) in which reduction in first-case start delay results in decreased expensive overused time rather than less expensive underused time during a regular 8-hour work block.[9] Based on the current operating room time use at our hospital, an improvement in on-time first-case starts is expected to result in cost savings.

The study estimated cost based on the reduction in delays attributable to first-case starts only. The number of potential patients who derive benefit from the service, however, is larger when accounting for all cases of the day, potentially reducing other delays during the day and averting the need for additional cardiology consultations. For the purpose of the present evaluation, we restricted to first cases only with the rationale that first cases are expected to reliably start at a precise time. Furthermore, we used a Medicare conversion factor (rather than a blended conversion factor) for this analysis, which provides the most conservative estimate of opportunity cost. Finally, other advantages have been realized that are harder to quantify, such as the benefit and convenience of having an anesthesiologist with CIED expertise and a programming machine readily available for CIED troubleshooting and reprogramming whenever required.

In summary, our data show that an anesthesiologist-run perioperative CIED service was associated with an average shorter delay in elective first-case start during weekdays, while maintaining patient safety. Currently, only a small number of such programs exist, and although a similar program has been described previously,[14] our program offers unique insight regarding cost, safety, and efficiency. This report also provides a framework for novel professional activity that contributes to the perioperative surgical home model. Although implementing an anesthesiologist-run CIED service is a time-intensive and labor-intensive process and requires interdisciplinary teamwork with cardiologists, it fosters collaboration and mentorship to assure requisite guidance, training, and cross coverage. As a result, this service has the potential to improve patient-centered care, perioperative efficiency, and likely offers an important vehicle in the transition to a perioperative surgical home model of care.[15]

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Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Name: Miriam M. Treggiari, MD, PhD, MPH.
Contribution: This author helped to analyze and interpret the data, and draft and critically revise the manuscript.
Name: Jamie M. Robertson, PhD, MPH.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Name: Marc A. Rozner, PhD, MD.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Name: Peter F. Graven, PhD.
Contribution: This author helped analyze the data and write the manuscript.
Name: Michael F. Aziz, MD.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Name: Matthias J. Merkel, MD, PhD.
Contribution: This author helped conduct the study, analyze the data, and write the manuscript.
Name: Edward A. Kahl, MD.
Contribution: This author helped conduct the study, analyze the data, and write the manuscript.
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Contribution: This author helped conduct the study, analyze the data, and write the manuscript.
Name: Eric C. Stecker, MD, MPH.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
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