A single center's experience with pacemaker implantation after the Cox maze procedure for atrial fibrillation

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ABSTRACT

Objective: The Cox maze procedure (CM) is safe and effective for all atrial fibrillation (AF) types. A recent randomized trial found alarming rates of pacemaker implantation (PMI) during hospitalization after CM. The purpose of this study was to assess the rate of PMI and its impact on outcomes after CM.

Methods: Incidence of PMI was captured for all CM patients (2005-2015; N = 739). Data were collected prospectively. Multivariable logistic regression was conducted to determine risk factors for PMI. Propensity score matching was conducted between concomitant CM patients and patients without surgical ablation since 2011.

Results: Fifty-two patients (7.0%) had in-hospital PMI after CM. Most common primary indication for PMI was sick sinus syndrome (67%), followed by complete heart block (23%) and sinus bradycardia (10%). The only risk factor for in-hospital PMI was type of procedure ($P = .020$). Patients with multiple valve procedures were at greatest risk ($P = .004$ -.035). STS-defined perioperative outcomes were similar for patients with and without in-hospital PMI. Sinus rhythm off antiarrhythmic drugs were similar by PMI. After propensity score matching ($n = 180$ per group), in-hospital PMI was similar in CM patients and those without surgical ablation (5% vs 4%, $P = .609$).

Conclusions: This study demonstrated lower incidence of PMI after CM procedures than recently reported. When indicated, PMI was not associated with increased short- or long-term morbidity or inferior freedom from atrial arrhythmia. Efforts to increase surgeon training with the CM procedure and postoperative management awareness are warranted to improve rhythm outcome and minimize adverse events and PMI. (J Thorac Cardiovasc Surg 2017;154:139-46)

Patients with and without in-hospital PMI in sinus rhythm off AAD during follow-up.

Central Message

In Cox maze patients, in-hospital PMI was low and not associated with increased morbidity, inferior rhythm outcome, or long-term survival.

Perspective

Evidence from this study indicated a lower rate of PMI following Cox maze procedures than recently reported. PMI was not associated with increased morbidity or recurrence of atrial arrhythmia. Surgeon training with the Cox maze procedure and postoperative management is warranted, particularly during complicated concomitant procedures, to improve rhythm outcome and minimize adverse events and PMI.

See Editorial Commentary page 147.

The Cox maze (CM) procedure has been performed for more than 25 years and its success when conducted in experienced hands, using either cut and sew technique or ablation devices with proven delivery of transmural, is well-documented.¹⁻⁵ The CM procedure, performed appropriately, is also demonstrated to be very safe for all

atrial fibrillation (AF) types and across operative risk groups.⁶⁻¹⁰ One of the challenges when assessing the efficacy and safety of the procedure is the lack of standardization in the way the procedure is being performed in terms of ablation tools as well as the lesion set. This point is especially important when it comes to lesions applied to the right atrium, with lesion patterns and tissue handling that can lead to relatively high rates of pacemaker implantation (PMI) following the procedure.¹¹ There are other potential explanations for

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Abbreviations and Acronyms

AAD	= antiarrhythmic drugs
AF	= atrial fibrillation
AV	= atrioventricular
CABG	= coronary artery bypass grafting
CM	= Cox maze procedure
CTSN	= Cardiothoracic Surgical Trials Network
IQR	= interquartile range
LA	= left atrium
LOS	= length of stay
PMI	= pacemaker implantation
STS	= Society of Thoracic Surgeons

PMI that cannot be explained by technical variability, such as the fact that sinus node dysfunction is recognized to be highly associated with AF and the potential for remodeling of the sinus node tissue and function secondary to AF and antiarrhythmic therapy.¹²⁻¹⁴ The diagnosis of sinus node dysfunction, whether temporary or not, is therefore not unusual after a successful CM procedure simply because a successful procedure would challenge the sinus node to activate the atria that can no longer fibrillate. Sinus node damage secondary to ablative damage during surgical ablation should be extremely rare in a well-performed procedure. However, conduction disturbances, such as atrioventricular block, can be the result of mismanagement of the lateral wall of the right atria or a lesion set that is not consistent with the CM procedure, together with the indexed concomitant procedure performed.¹¹ A recent Cardiothoracic Surgical Trials Network (CTSN) randomized trial found alarming rates of PMI during hospitalization after surgical ablation (23 of 133), especially in patients following what was defined by the authors as a CM procedure.¹⁵ We were surprised by the unusual rate of PMI in that study and the potential implication on the decision-making associated with surgical ablation of AF. Therefore, we decided to assess our own outcomes, particularly to understand if there are factors, whether preoperative or operative, that may predispose some patients to PMI. In our center, the CM procedure III/IV is performed in a uniform way with regard to lesion set and energy source.^{2,16,17} The purpose of this study was to assess the rate of in-hospital PMI for CM III/IV patients in an experienced center, examine factors that may be associated with PMI in those patients, and compare PMI incidence with patients with AF who did not undergo surgical ablation. We also sought to investigate the potential impact of PMI on early patient outcomes and long-term success rate and survival.

METHODS

All patients who had a CM III/IV procedure^{2,16,17} from 2005 to 2015 (N = 739) with or without other cardiac procedures were included in this

study sample. Patients were excluded if they had previous PMI before surgery (n = 92). Data were collected prospectively before and after surgery in our comprehensive AF registry and with the Society of Thoracic Surgeons (STS) institutional database.¹⁸ Data on rhythm status (24-hour Holter monitoring and electrocardiography), medications, interventions, and clinical events were collected at 3, 6, 9, 12, 18, and 24 months and then yearly after surgery. Rhythm status was defined according to Heart Rhythm Society guidelines as freedom from atrial arrhythmia >30 seconds without use of class I/III antiarrhythmic drugs (AAD).¹⁹ Data on new PMI after surgery in the same surgical hospitalization was collected on all CM patients. This study was approved by our institutional review board (institutional review board no. 06.022 and 12.055), and patient consent was waived.

Surgical CM Procedure

All CM III/IV procedures were performed either using cryothermal energy alone (ATS CryoMaze, Medtronic, Minneapolis, Minn; or Frigitronics, CooperSurgical, Inc, Trumbull, Conn; and Cryo1, AtriCure, West Chester, Ohio) or a combination of bipolar radiofrequency (Isolator Synergy Bipolar Ablation System, AtriCure) and cryothermal energy. The lesion pattern in all cases adhered to the CM III/IV lesion set.^{2,16,17}

Statistical Analysis

All data analyses were performed with SPSS Version 17.0 (SPSS Inc., Chicago, Ill) and R version 3.1.3 (The R Foundation for Statistical Computing, Vienna, Austria). Continuous variables are presented as mean $\pm$ standard deviation or median [interquartile range (IQR)], whereas categorical variables are presented as frequency (percentage). Group differences were evaluated with Student *t* tests or Mann-Whitney *U* tests for continuous variables and with χ^2 tests or Fisher exact test for categorical variables, as appropriate. Risk factors for length of stay (LOS) were examined with multivariable linear regression with the following covariates: age, EuroSCORE II, ejection fraction, gender, body mass index, duration of AF, left atrium (LA) size, AF type, year of surgery, elective versus nonelective status, and type of procedure (stand-alone CM [reference group], multiple concomitant valves, concomitant single valve, concomitant coronary artery bypass grafting [CABG], concomitant CABG with valve surgery, and other concomitant procedures). Multivariable logistic regression was conducted to determine the risk factors for PMI, including age, AF duration, LA size, type of procedure (multiple concomitant valves [reference group], stand-alone CM, concomitant single valve, concomitant CABG, concomitant CABG with valve surgery, and other concomitant procedures), and year of surgery. Kaplan-Meier analysis with the log-rank test was conducted to compare cumulative survival curves between patients with and without in-hospital PMI.

In the group of patients with a history of atrial arrhythmia since 2011 who had a concomitant CM procedure (n = 251) and patients without surgical ablation (n = 415), propensity score matching was conducted to simulate randomization and improve balance on preoperative characteristics.^{20,21} This time frame was chosen because the STS database began collecting data on in-hospital PMI for all patients in 2011. The control group included all cardiac surgery patients since 2011 with a history of atrial arrhythmia who did not undergo any surgical ablation procedure. Propensity scores were estimated via a logistic model with the R MatchIt package and were matched between groups within a caliper of 0.25 propensity score standard deviations. The variables used to create the propensity score model were selected a priori based on clinical and theoretical relevance and included age, gender, body mass index, diabetes, hypertension, cerebrovascular disease, chronic pulmonary disease, peripheral vascular disease, ejection fraction, preoperative creatinine level, EuroSCORE II, elective status, concomitant valve surgery, and concomitant CABG surgery. Most CM patients were matched to patients in the control group, those without surgical ablation, and balance was improved between the groups (Figure E1). The 180 patients in each group remaining after propensity score matching were used for all outcome analyses comparing

patients who had CM and those without surgical ablation, particularly to examine in-hospital incidence of PMI.

RESULTS

The study sample consisted of 739 patients who underwent the full CM procedure. The mean age was 63.4 ± 11.1 years and 238 patients were women (32%). The CM procedure was performed concomitant with other surgical procedures in 79% of patients and as a stand-alone procedure in 21% of patients.

Fifty-two patients (7.0%) had newly implanted pacemakers during the hospital stay after the CM procedure. The type of in-hospital PMI was dual-chamber in all of these patients and mean time between surgery and PMI was 9.3 ± 5.5 days (median [IQR] = 8 [6-11] days). The most common primary indication for PMI was sick sinus syndrome (67%), followed by complete heart block (23%) and sinus bradycardia (10%). Patients with in-hospital PMI had lower body mass index ($P = .006$), lower median duration of AF ($P = .047$), were more likely to be women ($P = .011$), and were less likely to have hypertension ($P = .017$) than patients without in-hospital PMI (Table 1). Otherwise, the patients with in-hospital PMI had similar preoperative characteristics as patients without in-hospital PMI. Patients who had 2 or more concomitant valve procedures had the highest total incidence of PMI (PMI = 14%). In addition, the group of patients with in-hospital PMI were significantly less likely to have a

stand-alone CM procedure compared with patients without in-hospital PMI (10% vs 22%, $P = .032$).

In multivariable analyses (Table 2), the only significant independent association with in-hospital PMI was type of surgical procedure (Wald = 13.44, $P = .020$), such that patients who had multiple concomitant valve procedures were at greater risk than other surgery categories. Compared with patients with multiple concomitant valve procedures, those with stand-alone CM procedures had 80% lower odds for in-hospital PMI, those with concomitant single-valve procedures had 57% lower odds, those with concomitant CABG surgery procedures had 89% lower odds, and those with concomitant CABG with valve surgery procedures had 73% lower odds.

Clinical Outcome

Patients with in-hospital PMI had similar incidence of STS-defined perioperative complications compared with patients without in-hospital PMI, including deep sternal wound infection (0% vs 0.1%, $P > .999$), stroke/transient ischemic attack (0% vs 0.9%, $P > .999$), prolonged ventilation >24 hours (12% vs 8%, $P = .428$), pneumonia (2% vs 4%, $P > .999$), renal failure (2% vs 4%, $P > .999$), reoperation for bleeding (0% vs 3%, $P = .397$), readmissions <30 days (8% vs 13%, $P = .386$), and operative mortality <30 days (0% vs 2%, $P = .615$). However, patients with in-hospital PMI had a longer median hospital LOS than patients without in-hospital PMI (12 [9-15]

TABLE 1. Patient characteristics by in-hospital PMI

Characteristic*	No PMI (n = 687)	PMI (n = 52)	P
Age (y)	63.3 $\pm$ 11.1	64.2 $\pm$ 12.0	.581
Female	213 (31)	25 (48)	.011
Body mass index (kg/m ²)	28.4 $\pm$ 5.8	26.1 $\pm$ 5.6	.006
Ejection fraction (%)	55.4 $\pm$ 10.7	55.8 $\pm$ 10.6	.751
Diabetes	91 (13)	8 (15)	.662
Hypertension	432 (63)	24 (46)	.017
Peripheral vascular disease	38 (6)	3 (6)	>.999
Previous cerebrovascular accident	41 (6)	6 (12)	.132
Chronic pulmonary disease	131 (19)	7 (14)	.317
Duration of AF (mo)	24 [4-64]	10 [3-34]	.047
Left atrium size (cm)	5.1 $\pm$ 1.0	4.9 $\pm$ 0.8	.196
Long-standing persistent AF type	349 (51)	23 (44)	.361
EuroSCORE II (%)	3.6 $\pm$ 4.6	4.2 $\pm$ 4.5	.359
Elective status	598 (87)	44 (85)	.617
Cryothermia only energy source	418 (61)	35 (67)	.376
Concomitant procedures			
CABG surgery	61 (9)	3 (6)	.441
Single mitral valve surgery	171 (25)	13 (25)	.984
Single aortic valve surgery	47 (7)	2 (4)	.401
Single tricuspid valve surgery	8 (1)	2 (4)	.107
CABG/valve surgery	87 (13)	5 (10)	.522
Multiple valve surgery	107 (16)	18 (35)	<.001
Other procedures	53 (8)	4 (8)	.992

PMI, Pacemaker implantation; AF, atrial fibrillation; CABG, coronary artery bypass grafting. *Data presented as mean $\pm$ standard deviation, median [interquartile range], or frequency (percent).

TABLE 2. Results of multivariable analysis predicting in-hospital PMI

Predictor	OR	95% CI	P
Age (y)	1.002	0.98-1.03	.871
Duration of AF (y)	0.95	0.87-1.03	.220
Left atrium size (cm)	0.73	0.52-1.03	.074
Year of surgery	0.92	0.82-1.03	.132
Type of procedure*			
Stand-alone	0.20	0.07-0.60	.004
Single valve	0.43	0.20-0.93	.032
CABG	0.11	0.01-0.86	.035
CABG/valve surgery	0.27	0.08-0.87	.028
Other procedures	0.35	0.10-1.30	.118

PMI, Pacemaker implantation; OR, odds ratio; CI, confidence interval; AF, atrial fibrillation; CABG, coronary artery bypass grafting. *Reference group = multiple concomitant valve procedures.

days vs 6 [4-8] days, $P < .001$), partly related to the timing of PMI, which was a median of 8 days following the procedure. In addition, longer LOS was significantly associated with higher EuroSCORE II ($t = 3.78$, $P < .001$), nonelective status ($t = 1.96$, $P = .050$), and all concomitant procedure types compared with stand-alone procedures ($P = .048$ - $P < .001$) in a multivariable analysis.

During follow-up, patients with an in-hospital PMI did not differ from patients without an in-hospital PMI on return to sinus rhythm off AAD at 6 months (73% vs 78%, $P = .515$), 12 months (80% vs 85%, $P = .409$), and 24 months (71% vs 80%, $P = .265$; Figure 1). There was also no difference between patients receiving in-hospital PMI and those without in-hospital PMI on the proportion of patients who required cardioversions (23% vs 20%, $P = .569$) or ablations (8% vs 6%, $P = .564$) during a mean follow-up of 53 ± 36 months.

During follow-up, none of the patients with in-hospital PMI had an embolic stroke and only 12 patients without

PMI had embolic strokes (0% vs 1.7%, $P > .999$). There was no significant difference in percentage of patients who remained on anticoagulation at 6 months (68% vs 52%, $P = .061$), but more patients with in-hospital PMI were on anticoagulation at 12 months (50% vs 34%, $P = .042$) and 24 months (50% vs 32%, $P = .041$) after surgery compared with those without in-hospital PMI. However, most patients in both groups (with and without in-hospital PMI) who remained on anticoagulation had clinically appropriate indications (eg, mechanical valve, history of deep vein thrombosis, atrial arrhythmia recurrence) at 6 months (78% vs 77%, $P = .943$), 12 months (65% vs 63%, $P = .871$), and 24 months (87% vs 79%, $P = .736$). Patients with in-hospital PMI also did not differ from patients without in-hospital PMI on survival up to 5 years after surgery (81.9% vs 88.9%, log-rank = 2.8, $P = .093$; Figure 2).

Pacemaker interrogation reports reviewed during follow-up indicated that for those with in-hospital PMI, 12 patients had return of intact conduction (ie, no longer pacemaker-dependent), 28 patients had not returned to intact conduction, and 12 patients were unknown either because no interrogation reports were available or there was no description of conduction by the electrophysiologist.

Propensity Score-Matched Analyses

Before propensity score matching, the group of patients with concomitant CM surgery ($n = 251$) differed from the patients with AF without surgical ablation ($n = 415$) on many preoperative characteristics, including age (65 vs 69 years, $P < .001$), ejection fraction (55% vs 47%, $P < .001$), EuroSCORE II (3.9% vs 8.7%, $P < .001$), diabetes (16% vs 31%, $P < .001$), elective status (87% vs 57%, $P < .001$), valve procedures (84% vs 51%, $P < .001$), and CABG surgery (24% vs 37%, $P = .001$). After propensity score matching to simulate randomization and balance covariates, 180 patients in the CM group were matched to 180 patients with AF without surgical ablation (Figure E1). There were no significant differences between the groups after matching on any of the preoperative characteristics and the standardized differences were appropriate (Table 3). After matching, the incidence of in-hospital PMI was similar in patients with AF who had concomitant CM and those who did not have surgical ablation (5% vs 4%, $P = .609$). In a double robust analysis, addition of the CM procedure also was not associated with greater incidence of in-hospital PMI after controlling for the covariates included in the propensity score model (odds ratio 1.32, 95% confidence interval 0.45-3.85, $P = .612$).

DISCUSSION

The results of this study indicate that in patients who undergo a CM III/IV procedure, the incidence of in-hospital

FIGURE 1. Percent of Cox maze patients with and without in-hospital pacemaker implantation (PMI) who returned to sinus rhythm off antiarrhythmic drugs during follow-up.

FIGURE 2. Comparison of 5-year survival between patients with and without in-hospital pacemaker implantation (PMI) (log-rank = 2.8, $P = .093$). *CI*, Confidence interval.

PMI was low and was not associated with increased morbidity, inferior rhythm outcome, or differences in long-term survival. Evidence from our study shows that the incidence of in-hospital PMI after a CM procedure is considerably lower than recently reported.¹⁵ When the CM procedure is performed, even concomitantly with more complicated multiple valve procedures, a very low

incidence of atrioventricular (AV) block was documented, which is probably the result of surgical valve procedures and not with any of the lesions associated with the CM procedure. In addition, propensity score-matched analyses suggest that adding the CM procedure was not associated with excess in-hospital PMI risk. This result was found in patients with comparable preoperative characteristics.

TABLE 3. Patient characteristics for patients with atrial fibrillation with the Cox maze procedure and those without surgical ablation after propensity score matching

Characteristic	No ablation (n = 180)	Cox maze (n = 180)	P	St Diffs
Age (y)	68.2 ± 12.7	67.1 ± 10.2	.365	−0.096
Female	61 (34)	59 (33)	.823	−0.021
Body mass index (kg/m ²)	28.2 ± 6.0	28.1 ± 6.1	.907	−0.013
Ejection fraction (%)	53.5 ± 14.2	54.8 ± 11.0	.309	0.102
Diabetes	43 (24)	38 (21)	.528	−0.071
Hypertension	129 (72)	125 (69)	.644	−0.059
Preoperative creatinine level	1.0 [0.8–1.1]	1.0 [0.8–1.1]	.477	−0.060
Peripheral vascular disease	14 (8)	14 (8)	>.999	0
Cerebrovascular disease	32 (18)	29 (16)	.673	−0.053
Chronic pulmonary disease	55 (31)	50 (28)	.562	−0.065
EuroSCORE II (%)	4.9 ± 3.8	4.4 ± 4.5	.282	−0.114
Elective status	149 (83)	149 (83)	>.999	0
Concomitant CABG surgery	60 (33)	55 (31)	.572	−0.043
Concomitant valve procedures	135 (75)	140 (78)	.535	0.067

Data presented as mean ± standard deviation, median [interquartile range], or frequency (percent). *St Diffs*, Standardized differences; *CABG*, coronary artery bypass grafting.

In recent years, there has been a growing interest in the rate of PMI following surgical ablation of AF, especially when a biatrial lesion set is performed.^{11,15} Two different reports based on the STS database recognized PMI following surgical ablation and reported slightly higher incidence following surgical ablation combined with mitral valve surgery, but no difference in the rate of postsurgical PMI was identified in stand-alone procedures when comparing surgical ablation performed on and off cardiopulmonary bypass, which probably indicates the same rates of PMI when a biatrial lesion set is performed.^{22,23} The International Society for Minimally Invasive Cardiothoracic Surgery consensus statement clearly showed no increase in the risk for PMI associated with concomitant surgical ablation.²⁴

PMI following any cardiac surgical procedures, especially in patients who underwent complex valve surgery, transcatheter aortic valve implantation, or in patients who are elderly, is not uncommon and is a well-accepted outcome among the medical community.²⁵⁻²⁷ However, when it comes to surgical ablation procedures for AF, it is clearly emphasized by some as an especially negative outcome and is readily overstated. The questions to ask in future research are whether the incidence can be managed by implementing training and appropriate techniques and if PMI following surgical ablation is associated with inferior clinical outcome and rhythm control. In the present study, we found that at an experienced center, incidence of in-hospital PMI could be maintained at a low level, which was comparable to patients without surgical ablation for AF. In addition, for patients who underwent the CM III/IV procedure using standardized techniques, in-hospital PMI was not associated with inferior clinical or rhythm outcomes during follow-up.

The incidence of PMI following any surgical ablation is variable and is dependent on patient characteristics with regard to preoperative sinus node dysfunction and surgical technique and manipulation. However, it is also important to standardize the clinical indications for PMI. In our center, patients with postprocedural bradycardia are being paced and atrial electrocardiogram is being captured daily. Therefore, the decision is based on clinical data demonstrating no recovery of sinus node activity, clinically significant conduction blocks or delays, and sinus bradycardia. The impact of PMI should be examined carefully, and in the context of surgical ablation it should always be evaluated beyond the immediate increase in perioperative cost. Although LOS was longer for patients with in-hospital PMI, part of this increase was due to other important factors that would increase LOS anyway, such as gender, EuroSCORE II, elective status, and more complex types of procedures. This issue is important to examine more closely in future research, but ultimately if longer LOS is generally the only perioperative complication associated with in-hospital PMI after surgical ablation, then

the impact may not be that critical. In our center, patients who are at risk for PMI are followed daily before the decision and this together with the delayed anticoagulation treatment is well reflected in LOS for these patients. The slight delay in the decision to proceed with PMI may be perceived by some as one of the main reasons for our lower rates of PMI. It is difficult to explain the PMI rate only by extended wait time in patients with bradycardia before the decision for implantation. In the CTSN study, the mean LOS was 13.2 ± 8.8 days for the ablation group and 12.4 ± 10.3 days for the control group, similar to the reported LOS for patients with PMI in our study.¹⁵ We believe that if indeed our postoperative management has such an impact, it would be very important to conduct a controlled study to compare different schemes of postoperative care and decision-making. However, it is important to notice that if a longer wait before PMI had a true impact on the incidence of PMI it would be reflected in the rate of pacemaker dependency during follow-up. In the ABLATE trial, it was reported that approximately 40% of the patients were still in various degrees of pacemaker dependency after 18 months.²⁸ These rates somewhat resemble the data from our study.

In this study, we investigated the incidence of PMI following a full CM procedure in a relatively large number of patients. We found that the incidence of in-hospital PMI was relatively low, especially when compared with a recent CTSN study.¹⁵ In our series, the vast majority of patients had PMI due to sinus node dysfunction and severe sinus bradycardia, whereas the CTSN study demonstrated relatively high incidence of AV block or delay as the primary indication. This observation is particularly noteworthy because when it comes to the right atrial lesion set and technique, it is especially important not to place additional lesions and avoid any unnecessary manipulations to the right atrial free wall. The concern when reviewing the CTSN study is that the study protocol allows an additional cavo isthmus line (flutter line) that is not part of the CM procedure and results in significant compartmentalization of the right atrium and conduction delays.^{11,15} It is also especially important to recognize that in our series, despite high rates of sinus rhythm in the early postoperative time frame, the incidence of PMI remained fairly low.

Sinus node dysfunction is associated with AF.^{12-14,29} The role of antiarrhythmic therapy before surgery is also worth investigation, as it may lead to a temporary sinus node dysfunction or severe bradycardia. The CM procedure should not result in primary sinus node dysfunction if careful application of the lesions is followed. In our study, the major indications for PMI were sick sinus syndrome, heart block, and sinus bradycardia, and more complex valve procedures were associated with greater likelihood of in-hospital PMI. A significant number of our patients were no longer pacemaker-dependent during follow-up (30%) and maintained sinus rhythm off AAD (71% at

2 years). This finding is not the first observation of such outcome, although our study was not specifically designed to follow the recovery of the sinus node and the autonomic nervous system.^{30,31} These studies also may suggest that procedures that are associated with higher success in ablating AF may reveal higher rates of sinus node dysfunction, as the heart is no longer allowed to fibrillate and generate heart rate. The concept of success in surgical ablation resulting in sinus node challenge should be investigated further.

CONCLUSIONS

One of the most important aspects of PMI following the CM procedure that was addressed in our study is the potential impact on patient outcome during both early and late follow-up. In our study, no such effect was discovered, including morbidity, mortality, rhythm status, and embolic events. PMI following the CM III/IV procedure was definitely associated with increased resource utilization; however, this should be reviewed carefully in the long-term as higher rates of sinus rhythm together with improved quality of life, reduced risk of stroke, and anticoagulation treatment and overall health-related cost. A careful examination into surgeon training and experience with the CM procedure, particularly during complicated concomitant procedures, may well help to improve rhythm outcomes and minimize adverse events, including in-hospital PMI.

Conflict of Interest Statement

Dr Ad is a consultant for Medtronic, a member of the speaker's bureau for AtriCure, proctor and member of the speaker's bureau for LivaNova, on the advisory board for Nido Surgical, and co-owner for Left Atrial Appendage Occlusion, LLC. All other authors have nothing to disclose with regard to commercial support.

Data were collected and maintained at Inova Fairfax Hospital in Falls Church, Va.

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Key Words: atrial fibrillation, arrhythmia therapy, arrhythmia, pacemaker

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FIGURE E1. Distribution of propensity scores for Cox maze patients (treated units) and patients without surgical ablation (control units) after propensity score matching.