Predictors for permanent pacemaker implantation after concomitant surgical ablation for atrial fibrillation

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Objectives: Concomitant surgical atrial fibrillation (AF) ablation is a safe and feasible procedure, recommended in guidelines. Pacemaker dependency is a known complication of AF ablation. We sought to determine independent predictors for pacemaker implantation after surgical AF ablation.

Methods: Between January 2003 and November 2012, 594 patients underwent concomitant surgical AF ablation. Various energy sources, including cryoablation (n = 139), unipolar radiofrequency (n = 278), and bipolar radiofrequency (n = 177), were used. Left atrial (n = 463, 77.9%) and biatrial (n = 131, 22.1%) ablation was performed. Univariate and multivariate logistic regression analysis was used to identify independent predictors for pacemaker implantation within 30 days after surgical AF ablation.

Results: The mean patient's age was 68.6 ± 9.4 years, and 66.8% were male. No major ablation-related complications occurred. A total of 41 (6.9%) of patients received pacemaker implantation during the 30-day follow-up period. Indications for pacemaker implantation were atrioventricular block in 25 (60.9%) of patients, sinus bradycardia or sinus arrest in 9 (22.0%) of patients, and bradyarrhythmia in 7 (17.1%) of patients. Demographic data, type of surgical procedure, and type of energy source did not have a significant impact on pacemaker implantation rate. However, biatrial ablation led to a significant pacemaker implantation rate compared with isolated left-sided ablation (6.3% vs 13.6%; $P = .028$).

Conclusions: Concomitant surgical AF ablation showed a pacemaker implantation rate of 6.9% after 30-day follow-up. Univariate and multivariate analysis showed biatrial lesion set as the only statistically significant predictor for pacemaker implantation after surgical AF ablation. (J Thorac Cardiovasc Surg 2014;147:984-8)

Atrial fibrillation (AF) is the most common sustaining arrhythmia in patients undergoing heart surgery. AF is associated with reduced atrial transport capacity and leads, by stasis of blood in the atrium, to more thromboembolic events, including stroke. It can, furthermore, cause heart failure and is associated with more hospitalizations. AF reduces quality of life and functional capacity.¹⁻³ Treatment of AF by antiarrhythmic drugs is limited because of significant adverse effects and poor success rates. Therefore, concomitant surgical AF ablation is recommended in guidelines for patients undergoing heart surgery.⁴ Cox first reported his technique for surgical AF ablation in 1987.⁵ The initial procedure has been modified and resulted in the so-called Cox Maze III procedure, which became the gold standard for surgical AF ablation over the years. However, because of the complexity of

this procedure, it did not reach broad application. Therefore, in recent years, the cut-and-sew technique has been replaced by creation of transmural atrial lesions using various thermal energy sources, which has been termed the Cox Maze IV procedure. Energy sources used include radiofrequency, laser, microwave, ultrasonography, and cryoablation. The aim is the creation of transmural lesions that block the arrhythmogenic circuits sustaining AF. Postoperative bradycardia requiring permanent pacemaker implantation is a known complication after surgical AF ablation. Postoperative pacemaker implantation has been high in first reported series of the initial Cox Maze procedure but was reduced by modifications of the initial lesion set, resulting in the so-called Cox Maze III procedure.⁵ With the Cox Maze III procedure, pacemaker implantation rates between 5% and 12% have been reported.^{6,7} Gillinov⁸ and Cheng⁹ and colleagues have reported similar pacemaker implantation rates for the Cox Maze IV procedure. However, there are only few data on the influence of different lesion sets, energy sources, and patient factors on permanent pacemaker implantation rate after surgical AF ablation available. Therefore, the aim of our study was to identify independent predictors for pacemaker implantation within 30 days after concomitant surgical AF ablation.

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Abbreviations and Acronyms

AF = atrial fibrillation

LA = left atrial

METHODS

From January 2003 to October 2012, 594 patients underwent concomitant surgical AF ablation due to paroxysmal ($n = 260$, 43.8%), persistent ($n = 45$, 7.6%), or long-standing ($n = 289$, 48.6%) persistent AF. The type of ablation is shown in Table 1. Complete left atrial (LA) ablation was performed in 323 (54.4%) of patients. Lesion set here included pulmonary vein isolation, box lesion, LA appendage, and isthmus isolation. Isolated bilateral pulmonary vein ablation was performed in 140 (23.6%) of patients. In patients with persistent and long-standing persistent AF, biatrial ablation was conducted in 131 (22.1%). In addition to the LA lesion set previously mentioned, right atrial ablation included intercaval lesion, isolation of the cavotricuspid isthmus, the right atrial appendage, and isolation of the terminal crest. Biatrial ablation was only conducted in patients with persistent or long-standing persistent AF. The decision of whether those patients received a biatrial or LA lesion set was up to the surgeon performing the procedure.

Applied energy sources included argon-based cryoablation (CryoICE Cryo-ablation probe [Atricure Inc, West Chester, Ohio] or Cryoblate CryoFlex Surgical Ablation Probe [Medtronic Inc, Minneapolis, Minn]) in 139 (23.4%) of patients, unipolar radiofrequency ablation (Cardioblate unipolar RF pen; Medtronic Inc) in 278 (46.8%) of patients and bipolar radiofrequency ablation (Cardioblate BP2 device and Cardioblate Surgical Ablation System Generator [Medtronic Inc] or Atricure Isolator Synergy EML 2 [Atricure Inc]) in 177 (29.8%) of patients.

Statistical Analysis

A retrospective single-center data analysis was accomplished. All statistical analyses were performed with SPSS statistical software, version 18.0 (SPSS Inc, Chicago, Ill). Continuous values are expressed as mean $\pm$ SD and were compared with a Student t test. Categorical variables are displayed as frequency and percentages and were compared using the χ^2 test or the Fisher exact test, as appropriate. $P < .05$ was considered statistically significant. The reported P values are 2 sided. Univariate and multivariate logistic regression analysis was used to identify independent predictors for permanent pacemaker requirement after 30 days. For univariate analysis, the following parameters were considered: age, sex, LA diameter, type and duration of AF, left ventricular ejection fraction, type of surgical procedure, lesion set, and energy source. For multivariate logistic regression analysis, significant covariates ($P < .10$) and covariates, which, from our experience, had been considered as clinically relevant, were included.

Follow-up

Documented preoperative data included age, sex, LA diameter, type and duration of AF, left ventricular ejection fraction, type of surgical procedure, lesion set, energy source, and comorbidities. At 30 days after surgery, data on postoperative outcome, including mortality, stroke, and requirement for permanent pacemaker implantation, were collected during clinical visit or by telephone interview.

RESULTS**Demographic Data**

Patient characteristics are shown in Table 2. Mean patient age was 68.6 ± 9.6 years, and 66.8% were male. A total of 54 (9.1%) of patients had a thromboembolic or ischemic

stroke before surgery. Preoperative pacemaker was present in 26 (4.4%) of patients.

Perioperative Data

No major ablation-related complication occurred in any of the patients. There was no intraoperative death. In 5 (0.9%) of patients, a perioperative stroke occurred. In-hospital mortality was 1.2%. The 30-day mortality was 2.0%, without differences between patients with and without permanent pacemaker implantation (2.2% vs 2.0%). Surgical procedures are displayed in Table 3.

Permanent Pacemaker Implantation

Permanent pacemaker implantation was required in 41 (6.9%) of 594 patients during the 30-day follow-up period. None of these patients had an indication for pacemaker implantation before the surgical procedure. Indications for pacemaker insertion were atrioventricular conduction block in 25 (4.2%), sinus bradycardia in 3 (0.5%), sinus arrest in 6 (1.0%), and bradyarrhythmia in 7 (1.2%) of patients. Generally, atrioventricular block was the most frequent indication for pacemaker implantation independent of applied lesion set. However, there is a difference in percentage of pacemaker implantation due to sinus node dysfunction. In patients with a biatrial lesion set, sinus node dysfunction was the indication for pacemaker placement in 40%, compared with 11.5%, in patients receiving only LA lesion set (Table 4).

Requirement for permanent pacemaker implantation in patients with LA ablation was 6.1%. In patients with biatrial lesion set, pacemaker implantation rate after 30-day follow-up was statistically significantly higher in univariate and multivariate analysis (6.1 vs 13.6; $P = .028$) (Figure 1 and Table 5).

Different types of energy sources used had no influence on pacemaker implantation rate after 30 days. The permanent pacemaker implantation rates were 6.5%, 7.4%, and 6.8% in patients with cryoablation, unipolar radiofrequency ablation, and bipolar radiofrequency ablation, respectively (Figure 2).

Type of surgical procedure did not affect permanent pacemaker implantation rate after AF ablation. Although the rate of postoperative pacemaker implantation was slightly higher in patients receiving valve surgery (aortic valve replacement, 8.2%; mitral valve replacement, 8.7%; tricuspid valve replacement, 7.8%) compared with isolated coronary artery bypass grafting (5.3%), there was no statistically significant difference. Furthermore, demographic data and preexisting diseases had no statistically significant influence on permanent pacemaker implantation rate after 30-day follow-up.

Subgroup Analysis of Patients With Persistent and Long-Standing Persistent AF

All patients receiving biatrial ablation had preoperative persistent or long-standing persistent AF. To analyze

TABLE 1. Type of ablation

Type	Patients (n = 594)	PPM (n = 41)	No PPM (n = 553)
Cryoablation	23.4 (139)	24.4 (10)	23.3 (129)
Radiofrequency	76.6 (455)	75.6 (31)	76.7 (424)
Unipolar	46.8 (278)	43.9 (18)	47.0 (260)
Bipolar	29.8 (177)	31.7 (13)	29.7 (164)
Left atrial	77.9 (463)	58.6 (24)	79.4 (439)
Biattrial	22.1 (131)	41.4 (17)	20.6 (114)

Values are given as percentage (number). PPM, Permanent pacemaker.

whether the higher pacemaker implantation rate was associated rather with the type of AF or with the type of ablation procedure, we performed a further subgroup analysis. Pacemaker implantation rates in 203 patients with persistent and long-standing persistent AF receiving LA ablation were compared with those receiving biatrial ablation. In patients with persistent or long-standing persistent AF receiving LA ablation, the rate of pacemaker implantation was 7.4% compared with 13.6% in patients with biatrial ablation. The difference between the 2 groups was statistically significant using univariate logistic regression analysis ($P = .045$) but not in the multivariate analysis ($P = .061$).

DISCUSSION

Surgical AF ablation is an established procedure recommended in guidelines for patients undergoing cardiac surgery.⁴ Because of the simplification of the Cox Maze III procedure by replacing the cut-and-sew principle by transmural thermal atrial lesions, the procedure has been used more frequently in recent years. The Cox Maze IV procedure can be performed safely, without additional risk for morbidity and mortality in patients undergoing cardiac surgery.⁹⁻¹² There is a low incidence of severe

TABLE 2. Patient characteristics

Characteristics	Patients (n = 594)	PPM (n = 41)	No PPM (n = 553)	P value
Age, y	68.6 ± 9.6	70.2 ± 8.7	68.3 ± 9.2	.20
Male sex	396 (66.8)	25 (60.9)	371 (67.1)	.49
AF duration, y	3.7 ± 3.0	3.2 ± 3.4	3.8 ± 3.1	.23
LA diameter, mm	49.2 ± 8.6	50.5 ± 7.8	49.1 ± 8.9	.32
Paroxysmal AF	260 (43.8)	16 (39.0)	244 (44.1)	.60
Persistent AF	45 (7.6)	4 (9.8)	41 (7.4)	.35
Long-standing per AF	289 (48.7)	19 (46.3)	270 (45.5)	.87
LVEF, %	52.5 ± 9.8	50.8 ± 8.4	52.8 ± 10.2	.22
Diabetes	102 (17.2)	6 (14.6)	96 (17.4)	.83
Renal insufficiency	59 (9.9)	5 (12.2)	54 (9.8)	.59
Prior stroke	50 (8.4)	4 (9.8)	46 (8.3)	.56
COPD	42 (7.1)	3 (7.3)	39 (7.1)	.98

Values are number (percentage) unless otherwise indicated. PPM, Permanent pacemaker; AF, atrial fibrillation; LA, left atrial; LVEF, left ventricular ejection fraction; COPD, chronic obstructive pulmonary disease.

TABLE 3. Surgical procedures

Procedures	Patients (n = 594)
CABG	122 (20.5)
AVR	67 (11.3)
MVR	145 (24.4)
MVR + CABG	50 (8.4)
AVR + CABG	65 (10.9)
MVR + TVR	45 (7.6)
AVR + MVR	39 (6.6)
Others	61 (10.3)

Values are number (percentage). CABG, Coronary artery bypass graft; AVR, aortic valve replacement; MVR, mitral valve replacement; TVR, tricuspid valve replacement.

complications, such as coronary artery or coronary sinus injuries or atrioesophageal fistula, reported in the literature.^{13,14} However, the permanent pacemaker implantation rate after surgical AF ablation remained relatively high, with rates up to 13% over the years.^{7,9} There are only few data available on the impact of different lesion sets, used energy sources, and patient factors. In our series, the additional right-sided lesion set was a statistically independent predictor for permanent pacemaker implantation after surgical AF ablation. One possible explanation for the higher rate of pacemaker implantation in biatrial group is that the additional right atrial lesions, such as the intercaval connection line or the lesion towards the tricuspid valve, might injure the sinus node and its blood supply. The trigonum lesion, with its vicinity to the Koch triangle, carries, if not conducted properly, a certain risk to injure the atrioventricular node, resulting in a complete heart block. Another possible explanation for the higher rate of pacemaker implantation in the biatrial group may be the reason that all patients had persistent or long-standing persistent AF, which might mask a preexisting disease of the sinus or atrioventricular node. The observation that isolated LA lesions necessitated less pacemaker implantation seems to support the hypothesis that postablation bradycardia is more likely lesion related, but remains to be proved because statistical relevance could only be calculated with univariate, but not with multivariate, analysis.

A further reason for pacemaker dependency in cardiac surgical patients may be the destruction of parasympathic fibers, due to separation of the aorta and pulmonary artery, leading to postoperative bradycardia in patients with ongoing atrial fibrillation.

TABLE 4. Indications for postoperative pacemaker implantation

Indication	Pacemaker all patients (n = 41)	Left atrial (n = 26)	Biattrial (n = 15)
AV block	25 (60.9)	18 (69.3)	7 (46.7)
Sinus arrest	6 (14.7)	2 (7.7)	4 (26.7)
Sinus bradycardia	3 (7.3)	1 (3.8)	2 (13.3)
Bradyarrhythmia	7 (17.1)	5 (19.2)	2 (13.3)

Values are given as number (percentage). AV, Atrioventricular.

TABLE 5. Predictors for permanent pacemaker implantation, multivariate analysis

Predictors	P value
Age	.121
Male sex	.212
Left atrial diameter	.192
Paroxysmal AF	.212
Duration of AF	.092
CABG	.982
AVR	.092
MVR	.212
TVR	.232
Unipolar radiofrequency	.321
Bipolar radiofrequency	.231
Cryoablation	.126
Biatrial lesion set	.028
Left atrial lesion set	.102

AF, Atrial fibrillation; CABG, coronary artery bypass graft; AVR, aortic valve replacement; MVR, mitral valve replacement; TVR, tricuspid valve replacement.

One further study by Worku et al¹⁵ investigated predictors for postoperative pacemaker implantation after surgical AF ablation. In their analysis of 701 patients, the overall pacemaker implantation rate was 7.6% within the 30-day follow-up.¹³ Multivariate analysis also identified additional right-sided lesions as an independent predictor for permanent pacemaker requirement after surgical AF ablation ($P = .039$) in this study. Gillinov et al analyzed, in their study of 575 patients, the impact of different lesion sets on ablation success. They also reported their permanent pacemaker implantation rate, which has been 8.7%. However, in this analysis, patients receiving LA ablation were grouped together with patients receiving biatrial ablation, rendering it impossible to analyze the impact

FIGURE 1. Postoperative pacemaker implantation rate, according to different lesion sets. **FIGURE 2.** Pacemaker implantation rate, according to different energy sources. RF, Radiofrequency.

of an additional right-sided lesion set on incidence of pacemaker implantation after AF surgery.

Despite a higher postoperative pacemaker implantation rate in patients with biatrial ablation, it seems worthwhile to be considered in patients with persistent and long-standing persistent AF, because superior results for sinus rhythm restoration have been described, when compared with isolated LA lesion set.^{8,9} However, surgeons should keep in mind that there is always a certain risk to injure the sinus or atrioventricular node, when performing right-sided lesions.

Regarding different energy sources, including unipolar or bipolar radiofrequency and cryoablation, we did not find any differences regarding permanent pacemaker implantation. Worku et al¹⁵ identified, in their analysis, use of microwave energy as an independent predictor for permanent pacemaker placement, although there is no clear explanation for this finding. They also did not see a difference in pacemaker requirement between patients receiving radiofrequency or cryoablation, which is consistent with our finding.

We did not find further predictors for permanent pacemaker implantation rate after surgical AF ablation. Neither type of surgical procedure nor demographic data or preexisting diseases had a statistically significant influence on pacemaker placement. This finding is similar to the findings in the study published by Worku et al.¹⁵

There are further studies reporting permanent pacemaker implantation rates between 5.0% and 13.0% after surgical AF ablation.^{7,9,16,17} However, in all of those series, investigators just reported their overall pacemaker implantation rate and did not look for factors associated with pacemaker implantation. Thus, these studies do not

contribute to identifying predictors for pacemaker dependency after AF ablation.

In our opinion, the most likely reason for the higher incidence of postoperative pacemaker implantation in patients with biatrial ablation is the additional right-sided lesions set with its risk to injure the sinoatrial or atrioventricular node. Furthermore, a preexisting sinoatrial or atrioventricular nodal dysfunction, which is masked by persistent AF and appears after successful ablation, may also play a certain role. In our study, further discrimination between these 2 reasons is not possible. Future investigations with a prospective, randomized study design will be needed to confirm these results.

The major limitation of the study is that we used a nonrandomized retrospective study design in which unknown confounders, and selection and detection bias, cannot be completely avoided. Furthermore, this study has been a single-center analysis.

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