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Niv Ad
West Virginia University

Sari D. Holmes
West Virginia University

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Early Stable Sinus Rhythm Associated With Greater Success 5 Years After Surgical Ablation

Niv Ad, MD and **Sari D. Holmes, PhD**

Department of Cardiovascular and Thoracic Surgery, West Virginia University, Morgantown, West Virginia; Cardiovascular Surgery, Washington Adventist Hospital, Takoma Park, Maryland; Inova Fairfax Hospital, Falls Church, Virginia; and Heart and Vascular Institute, West Virginia University Medicine, Morgantown, West Virginia

Abstract

Background—An important challenge in surgical ablation for atrial fibrillation (AF) is the scarcity of publications on credible predictors of long-term success in procedures performed with ablation tools that produce consistently reliable transmural lesions. We examined factors associated with 1-year success and no atrial arrhythmia (AA) recurrence during 1 to 5 years after surgical ablation for AF.

Methods—The study prospectively monitored 743 surgical ablation patients with complete rhythm follow-up at 12 months after the operation. No detected AA was defined as no known recurrence of AA, no cardioversions, and no catheter ablations at all available follow-up assessments.

Results—Patients were a mean age of 64.7 years, and 32% were women. Patients with no detected AA during the first year after surgical ablation were more likely to maintain sinus rhythm without recurrence during 1 to 5 years (74% vs 28%, $p < 0.001$) and to be in sinus rhythm off medication at 5 years (80% vs 53%, $p < 0.001$). Mixed-model logistic regression revealed that lower risk for AA recurrence during 1 to 5 years was associated with no detected AA during the first 12 months (odds ratio [OR], 0.11; $p < 0.001$) and surgeon experience with 50 or more cases (OR, 0.63; $p = 0.043$), whereas older age (OR, 1.03; $p < 0.001$) and longer preoperative AF duration (OR, 1.04; $p = 0.043$) were associated with greater risk for AA recurrence.

Conclusions—Most patients with no detected AA throughout the first 12 months after surgical ablation continued to be recurrence free for 5 years. Younger age, shorter preoperative AF duration, and greater surgeon experience may be associated with more persistent surgical correction of AF.

Surgical ablation procedures for atrial fibrillation (AF) have now been performed for 3 decades [1]. However, only a few large studies have reported follow-up of at least 5 years and used societal guidelines for outcomes and reporting. This unique phenomenon creates a

Address correspondence to Dr Ad, Department of Cardiovascular and Thoracic Surgery, West Virginia University, 1 Medical Center Dr, Morgantown, WV 26506; nivadmd14@gmail.com.

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challenge in identifying predictors of long-term success to develop credible procedural and postprocedural management strategies. The evidence is particularly lacking for procedures performed using ablation tools that produce consistently reliable transmural lesions and according to well-defined lesion sets.

In previous publications, we reported variables that were associated with success at 2 and 5 years after surgical ablation [2, 3], Investigators from Washington University in St. Louis reported a good success rate at 5 years after a Cox maze IV procedure with duration of preoperative AF as one of the predictors for failure [4]. Reported results on predictors for success after percutaneous catheter ablation clearly demonstrate that early termination of AF and success over the first few months is associated with higher long-term success with less requirement for repeated procedures [5].

The primary purpose of this study was to examine risk factors for recurrence of atrial arrhythmia during 5 years of follow-up. In particular, we evaluated the role of no detected atrial arrhythmia throughout the first 12 months after surgical ablation in maintaining sinus rhythm, freedom from reintervention, and AF-associated complications during 5 years after the procedure. The secondary purpose of this study was to evaluate whether risk factors for early atrial arrhythmia recurrence would also emerge as risk factors for late atrial arrhythmia recurrence.

Patients and Methods

Within the group of 953 patients who underwent surgical ablation for AF between January 2005 and June 2015, 743 patients reached the 12-month time point after the procedure (not due: n = 78; died <12 months: n = 46; withdrawn: n = 25; lost to follow-up: n = 61). The Inova Fairfax Hospital Institutional Review Board (IRB study #06.022 and #12.055) approved this study and granted a waiver of consent.

Data were collected prospectively before and after surgical ablation on rhythm, clinical events, and medication status at 3, 6, 9, 12, 18, and 24 months and yearly thereafter [6]. An institutional protocol guided recommendations for clinical decision making during follow-up [7, 8]. Data from the local Society of Thoracic Surgeons database were merged with the AF registry data [9]. The European System for Cardiac Operative Risk Evaluation 2011 revision (EuroSCORE II) was used to reflect operative risk because The Society of Thoracic Surgeons risk score is not calculated for surgical ablation cases.

Rhythm status was available for all patients at 12 months but was not available for all patients at each time point throughout the first 12 months after surgical ablation. No detected atrial arrhythmia was defined as no known recurrence of atrial arrhythmia, no follow-up cardioversions, and no follow-up ablations at all follow-up time points available for each patient. For the independent variable of no detected atrial arrhythmia by 12 months, this definition was applied for all time points beyond the blanking period up to and including 12 months after surgical ablation (6 to 12 months). For the primary outcome variable, no detected atrial arrhythmia more than 1 year after surgical ablation, this definition was applied for all time points past 1 year and up to and including 5 years after the procedure. By

5 years postoperatively, 287 patients with rhythm status were available in this sample (not due: n = 321; died 1 to 5 years: n = 40; withdrawn: n = 29; lost to follow-up: n = 66). Patients who withdrew or were lost to follow-up did not differ on any patient characteristics from the patients with rhythm status available at 5 years, except that the patients available were slightly older (64.2 vs 61.4 years, $p = 0.045$).

Success was defined according to the Heart Rhythm Society Expert Consensus Statement Guidelines [10] as sinus rhythm (freedom from atrial arrhythmia >30 seconds) without the use of class I/III antiarrhythmic drugs (AAD) and verified using 24-hour Holter or electrocardiogram, or both, at all time points. The proportion of rhythm verified with electrocardiogram alone ranged from 20% at 6 months to 5% at 60 months, with the values steadily decreasing throughout follow-up. All other rhythm verification included at least 24-hour Holter.

Surgical Procedure

The lesion set and energy source were based on surgeon discretion. All surgical ablation procedures were performed using cardiopulmonary bypass support, whether concomitant or stand alone, and no hybrid or epicardial beating heart ablations were included. The lesion set for the cryothermal-only procedures is the traditional Cox maze III procedure, and the lesion set for the cryothermal combined with bipolar radiofrequency energy procedures is the Cox maze IV as described by Damiano and colleagues [1, 11, 12]. For cryothermal energy only the CryoFlex (10 or 10S, Medtronic, Minneapolis, MN) or the Cryo 1 or Cryo 2 (AtriCure, Inc, Mason, OH) were used. Whether cryothermal energy only or in combination with bipolar radiofrequency was used, cryolesions were applied for 2 minutes for all lesions, including those crossing the atrioventricular groove both in the right atrium and left atrium and the epicardial coronary sinus lesion to complete the left atrial isthmus lesion on the left. The left atrial appendage was excised or excluded in all cases.

In this series, 11 surgeons performed surgical ablation procedures. Surgeon experience with surgical ablation was defined as the number of surgical ablation cases performed at our institution at the time of each procedure in a continuous and chronological format. Individual procedures were then categorized as having surgeon experience of less than 50 cases or 50 or more cases at the time of the procedure [13].

Statistical Analysis

All analyses were conducted with SPSS 17.0 software (SPSS Inc, Chicago, IL), and a two-tailed p value of less than 0.05 was considered statistically significant. Continuous data are presented as mean ± SD or median (interquartile range), and categorical data are presented as frequency (percentage). Group differences on continuous variables were examined using independent samples t tests or Mann-Whitney U tests, and group differences on categorical variables were examined using the χ^2 or Fisher exact tests, as appropriate.

Kaplan-Meier survival analysis with the log-rank test was used to compare groups on cumulative survival and freedom from embolic stroke and major bleeding during follow-up. The American Heart Association definition was used for embolic stroke, and major bleeding was defined as a bleeding event requiring hospitalization or blood units. Multivariable Cox regression was conducted to examine the role of stable rhythm up to 1 year on survival after adjustment for age, sex, EuroSCORE II, and stable rhythm between 1 and 5 years. Multivariable logistic regression was used to examine risk factors for stable rhythm up to 12 months, including age, sex, left atrial size (cm), duration of AF (years), type of AF defined by the Heart Rhythm Society (HRS) guidelines (paroxysmal atrial fibrillation [PAF] vs non-PAF), lesion set (full Cox maze vs all others), energy source (cryothermia alone vs all others), surgeon experience (≥50 cases vs <50 cases), and number of concomitant procedures.

A generalized linear mixed model using multivariable binomial logistic regression was conducted to examine the risk factors for recurrence at more than 1 year and up to 5 years after surgical ablation. Not all patients in this sample had reached 5 years after surgical ablation, but the mixed model methodology with random intercepts allowed inclusion of all available follow-up rhythm data for patients after 1 year and individual-specific random effects. The fixed effects factors included in this model were selected a priori based on clinical and theoretical justification and included age, sex, left atrium size (cm), duration of AF (years), type of AF (PAF vs non-PAF), lesion set (Cox maze vs all others), energy source (cryothermia alone vs all others), surgeon experience (≥50 cases vs <50 cases), number of concomitant procedures, and recurrence status up to 12 months [10].

Results

The patients in this sample were a mean age of 64.7 ± 11.2 years, and 32% were women. Operative and AF-specific details of the sample included 87% full Cox maze procedures, 20% stand-alone procedures, 37% of patients with persistent AF, and 49% of patients with longstanding persistent AF. Previous catheter ablations occurred in 16% of patients (41% of the stand-alone procedures). Surgical ablation was performed using cryothermia alone in 58% of procedures, bipolar radiofrequency alone in 10%, and a combination of the two energy sources in 32%.

In 68% (503 of 743) of patients, no detected atrial arrhythmia was reported during the first 12 months of follow-up. Compared with the group with detected atrial arrhythmias during the first 12 months, patients with no recurrences were younger ($p = 0.030$), had higher ejection fraction ($p = 0.043$), shorter duration of AF ($p = 0.007$), smaller left atrial size ($p = 0.016$), lower EuroSCORE II operative risk ($p = 0.003$), and greater median cases of surgeon experience with surgical ablation as a continuous variable ($p = 0.001$; Table 1). In addition, the group with no detected atrial arrhythmia during the first 12 months had a lower proportion of patients with concomitant tricuspid valve operations ($p = 0.027$).

When evaluated in a multivariable analysis, the factors significantly associated with having no detected atrial arrhythmia during the first 12 months were smaller left atrial size ($p = 0.006$), shorter duration of AF ($p = 0.009$), and surgeon experience with 50 or more surgical ablation cases ($p < 0.001$; Table 2). Each 1-cm increase in left atrial size and 1-year increase in AF duration was associated with 22% and 4% reduced odds for stable sinus rhythm during the first 12 months, respectively. Patients whose procedures were performed by surgeons with experience of 50 or more cases were close to 2.5-times more likely to have stable sinus rhythm during the first 12 months.

Late Rhythm Outcomes

The median follow-up period was 48 (35 to 79) months. Stable sinus rhythm at all points after surgical ablation up to 5 years occurred in 52% (388 of 743) of patients. There were 666 patients with follow-up longer than 12 months for late outcome analysis. Of these, 396 (60%) did not experience a documented or reported recurrence and remained off AAD during the entire 1 to 5 years of follow-up. Assessing success at an individual time point, 70% (202 of 287) of patients were in sinus rhythm off AAD at 5 years. The group with no recurrences during the first 12 months had significantly higher return to sinus rhythm off AAD at every follow-up assessment after 12 months (Fig 1), including 2 years (92% vs 48%, $p < 0.001$), 3 years (89% vs 51%, $p < 0.001$), 4 years (83% vs 48%, $p < 0.001$), and 5 years (80% vs 53%, $p < 0.001$) after surgical ablation. Within the group that experienced recurrences during the first 12 months, 65 patients never returned to sinus rhythm in 1 to 5 years, 61 remained in sinus rhythm throughout 1 to 5 years, 14 had a recurrence during 1 to 5 years but maintained sinus rhythm afterwards, and the remainder had inconsistent rhythm status during 1 to 5 years.

A significant difference between the groups was also found for any recurrence during the entire 1 to 5 years of follow-up. Specifically, patients with no detected atrial arrhythmia throughout the first 12 months after surgical ablation were more likely to continue to maintain sinus rhythm with no detected atrial arrhythmia recurrence throughout the entire follow-up period of 1 to 5 years (74% vs 28%, $p < 0.001$). When individual time points up to 1 year were examined, sinus rhythm off AAD at 6 months (90% vs 58%, $p < 0.001$), 9 months (95% vs 65%, $p < 0.001$), and 12 months (97% vs 65%, $p < 0.001$) was higher for patients who maintained stable sinus rhythm during late follow-up (1 to 5 years) compared with those who experienced recurrences beyond 1 year.

Mixed model logistic regression evaluating risk factors for arrhythmia recurrences during 1 to 5 years revealed that greater odds of atrial arrhythmia recurrence was associated with older age ($p < 0.001$) and longer preoperative years of AF duration ($p = 0.043$), whereas lower odds of atrial arrhythmia recurrence was associated with surgeon experience of 50 or more surgical ablation cases ($p = 0.043$) and no detected atrial arrhythmia during the first 12 months ($p < 0.001$; Table 3). For each year increase in age and duration of AF, there was a 3% and 4% greater risk for atrial arrhythmia recurrence during 1 to 5 years, respectively. In addition, patients with no detected atrial arrhythmia during the first 12 months after surgical ablation had 89% lower risk for an atrial arrhythmia recurrence during 1 to 5 years of follow-up postoperatively. Other factors in the model were not significantly associated with atrial recurrence during 1 to 5 years, including non-PAF and larger left atrial size.

Late Clinical Outcomes

Patients with no detected atrial arrhythmia during the first year were less likely to remain on anticoagulation at each late follow-up time point, including 2 years (23% vs 57%, $p < 0.001$), 3 years (21% vs 61%, $p < 0.001$), 4 years (20% vs 59%, $p < 0.001$), and 5 years

(27% vs 63%, $p < 0.001$). Freedom from major bleeding events during the first 5 years after surgical ablation was similar for patients with and without detected atrial arrhythmias during the first 12 months (89.6% vs 91.6%; log-rank = 0.76, $p = 0.382$). Similarly, freedom from embolic stroke during the first 5 years after surgical ablation was similar for patients with and without detected atrial arrhythmias during the first 12 months (98.8% vs 98.4%; log-rank = 0.13, $p = 0.714$). Although the incidence of embolic stroke was very low, preliminary analysis found that patients who underwent procedures that used cryothermia energy alone were less likely to experience an embolic stroke during the first 5 years of follow-up compared with those with bipolar radiofrequency energy included in the procedure (0.7% vs 2.6%, $p = 0.037$), regardless of rhythm stability. Mean time to embolic stroke did not differ between patients with cryothermia energy alone and those whose procedure included bipolar radiofrequency energy (11 vs 27 months, $p = 0.086$). Lastly, 5-year cumulative survival did not differ for patients with and without detected atrial arrhythmias during the first 12 months in Kaplan-Meier survival analysis (88.1% vs 92.8%; log-rank = 3.16, $p = 0.075$) or multivariable Cox regression analysis adjusting for important clinical variables (hazard ratio, 1.67; 95% confidence interval, 0.67 to 4.13; $p = 0.270$).

Comment

The results of this study demonstrated that surgical ablation for AF was associated with a relatively high freedom from atrial arrhythmia recurrence during the first 5 years after the procedure when the definitions of the HRS consensus guidelines for success were used [10]. Primary outcome analyses demonstrated that patients with no atrial arrhythmia during the first year after surgical ablation were more likely to maintain sinus rhythm during 5 years thereafter. In addition to the traditional factors of younger age and shorter AF duration, greater surgeon experience with surgical ablation was associated with stable sinus rhythm throughout the first 5 years after surgical ablation. Sinus rhythm and discontinuation of anticoagulation at each follow-up time point were also more likely for patients with no detected atrial arrhythmia throughout the first year postoperatively.

Data regarding long-term follow-up are extremely important to the field, and currently, there are no specific national tools to collect information besides The Society of Thoracic Surgeons database, which is limited to 30-day outcome. Such data are valuable to better understand the different variables associated with sustainable success and develop the best clinical management of patients after surgical ablation for AF. Recurrence of atrial arrhythmia early after surgical ablation has already been shown to be associated with inferior long-term success [3]. The same pattern of results is captured in the catheter ablation literature, where early recurrence, especially late in the blanking period, was strongly associated with late recurrences [14–16].

The mechanism of early and late recurrence may be completely different. Early recurrence is likely associated with acute myocardial injury, inflammation, and perhaps changes in myocardial autonomic innervation, whereas late recurrence is more likely to be related to reactivation of the arrhythmogenic substrate [17]. In the surgical literature it is evident that failure of surgical ablation for AF is associated with age, duration of AF, left atrium size, and AF type to some extent, especially with limited lesion sets [18–20].

Our findings suggest that some of the variables associated with long-term failure are also associated with short-term atrial arrhythmia recurrences during the first 12 months. This information is especially important in regards to surgical training and earlier intervention. Early recurrence of arrhythmia after surgical ablation was found to be an important risk factor for late failure at our center and at Washington University in St. Louis [3, 18].

Unlike studies of catheter ablation techniques, which are mainly based on stand-alone procedures and failures are readily studied for electrophysiological mechanisms, most patients are not electrophysiologically studied after surgical ablation and are usually patients who have undergone surgical ablation concomitant with another procedure rather than a stand-alone procedure. This fact may be very important, because many different techniques and technologies are applied in concomitant procedures that complicate our ability to study and understand failures. Identifying other potential modifiers of success associated with concomitant procedures is also essential. For instance, in structural heart disease (ie, mitral valve insufficiency repaired together with surgical ablation), there are no data on the potential effect of the mitral valve repair longevity on long-term success of surgical ablation.

Future research should examine specific methods of maintaining sinus rhythm during the first year, including surgical training, to increase the effect on atrial reverse remodeling and perhaps the longevity of surgical ablation. To that end, the clear HRS Consensus Statement Guidelines defining success as sinus rhythm off AAD may force clinicians to discontinue AAD early for patients in sinus rhythm who are older and have a long history of AF, even though they may benefit from longer duration of AAD and freedom from atrial arrhythmia recurrences.

Age, duration of AF, surgeon experience, and lack of early recurrences were associated with later recurrences independent of lesion set, which was not significantly associated with late recurrence in the mixed model analysis. This study was not designed to answer this important question under debate in the field, because patients were not randomized to different ablation and lesion set schemes. Also, patients who had left atrial-only lesion sets were different from those who had Cox maze procedures, reflecting our approach to patient selection for surgical ablation (Fig 2). These results emphasize the importance of selecting the appropriate patients for each lesion set based on preoperative characteristics, particularly for AF-specific factors. When decision making is applied appropriately, the lesion set may not affect the success of the procedure [21].

Surgical training in ablation is not mandated or structured, which results in a wide variation of surgical competency. This issue is sensitive but needs to be addressed on a societal level, and surgical ablation for AF should be approached like other surgical procedures with clear definitions for surgical training [13]. This is a key required step in standardizing surgical approaches to treat AF. It is reasonable to assume that better training and experience in surgical ablation will translate into better outcomes, as demonstrated for other surgical procedures and more recently with mitral valve repair [22]. We were able to show that in a large-volume center, differences in outcome throughout follow-up exist and are associated with surgical experience as captured by number of cases performed at the time of the indexed surgical ablation procedure. Today, there are no specific thresholds in surgeon education, training, or experience before performing surgical ablation, but should be formalized [13, 23].

Limitations

A limitation of this study is the format of rhythm status data collection. Although these data were collected in accordance with HRS Guidelines, rhythm status was not continuously monitored. It is possible that patients in sinus rhythm at all reported time points may still have experienced episodes of atrial arrhythmia recurrence that were not captured. However, an ideal monitoring strategy is not yet identified, because implantable devices that continuously monitor heart rhythm have shown high false positives, and recent studies have clearly demonstrated that there is no advantage over HRS recommended follow-up [24]. Even the Reveal LINQ (Medtronic, Minneapolis, Minnesota) is limited in patients with very low AF burden, which represents patients after the Cox maze procedure [25]. In addition, use of mixed model logistic regression analysis in this study allowed the inclusion of all available follow-up rhythm data during 1 to 5 years after surgical ablation and accounted for individual-specific effects that might affect this type of repeated outcome assessment.

In addition, the results from this study with highly experienced surgeons and this particular group of patients may not be generalizable to other centers. It is imperative that surgeons electing to perform surgical ablation are experienced. Further research into which patients benefit most from surgical ablation will improve the success of the procedure by informing decision making for patient selection because currently, there is no standardization in this process.

Conclusions

This study demonstrated that no detected atrial arrhythmia during the first 12 months after surgical ablation for AF has an important association with stable rhythm throughout follow-up and long-term success. The study does not necessarily suggest that failure to achieve freedom from early recurrence will result in failure during late follow-up, but clearly, some patients may experience significant recurrences. Those recurrences of atrial arrhythmia may be associated with higher rates of AADs, oral anticoagulation therapy, reduced quality of life, and increased risk for embolic strokes. Early and late outcomes were associated with duration of AF and surgical experience; therefore, earlier intervention and training may be valuable in improving the success of surgical ablation. Future studies should focus on gaining a deeper understanding of the surgical technique and energy source as well as a more tailored follow-up approach in patients with higher risk for recurrence, including number of office visits and antiarrhythmic strategies to maximize short-term and long-term success.

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References

1. Cox JL, Schuessler RB, D'Agostino HJ, et al. The surgical treatment of atrial fibrillation. III. Development of a definitive surgical procedure. J Thorac Cardiovasc Surg. 1991; 101:569–83. [PubMed: 2008095]
2. Ad N, Holmes SD, Stone LE, Pritchard G, Henry L. Rhythm course over 5 years following surgical ablation for atrial fibrillation. Eur J Cardiothorac Surg. 2015; 47:52–8. [PubMed: 24585551]
3. Ad N, Henry L, Holmes SD, Stone LE, Hunt S. The association between early atrial arrhythmia and long-term return to sinus rhythm for patients following the Cox maze procedure for atrial fibrillation. Eur J Cardiothorac Surg. 2013; 44:295–300. [PubMed: 23329227]
4. Henn MC, Lancaster TS, Miller JR, et al. Late outcomes after the Cox maze IV procedure for atrial fibrillation. J Thorac Cardiovasc Surg. 2015; 150:1168–76. [PubMed: 26432719]
5. Schreiber D, Rostock T, Frohlich M, et al. Five-year follow-up after catheter ablation of persistent atrial fibrillation using the stepwise approach and prognostic factors for success. Circ Arrhythm Electrophysiol. 2015; 8:308–17. [PubMed: 25744570]
6. Hunt S, Henry L, Ad N. Using multiple databases to produce comprehensive follow-up in an effort to enhance evaluation of outcome measurements: surgical ablation (maze) exemplar. J Healthc Qual. 2011; 33:50–63. [PubMed: 22251160]
7. Ad N, Henry L, Shuman DJ, Holmes SD. A more specific anticoagulation regimen is required for patients after the Cox maze procedure. Ann Thorac Surg. 2014; 98:1331–8. [PubMed: 25152383]
8. Ad N, Henry L, Hunt S, Stone L. The implementation of a comprehensive clinical protocol improves long-term success after surgical treatment of atrial fibrillation. J Thorac Cardiovasc Surg. 2010; 139:1146–52. [PubMed: 20412955]
9. [Accessed April 29, 2016] The STS Surgeon Composite Technical Appendix. Available at https://www.sts.org/sites/default/files/files/PDF/STS-SurgeonCompositeTechnicalAppendix-UpdatedFeb2015.pdf
10. Calkins H, Kuck KH, Cappato R, et al. 2012 HRS/EHRA/ECAS expert consensus statement on catheter and surgical ablation of atrial fibrillation: recommendations for patient selection, procedural techniques, patient management and follow-up, definitions, endpoints, and research trial design. J Interv Card Electrophysiol. 2012; 33:171–257. [PubMed: 22382715]
11. Cox JL. The surgical treatment of atrial fibrillation. IV. Surgical technique. J Thorac Cardiovasc Surg. 1991; 101:584–92. [PubMed: 2008096]
12. Damiano RJ Jr, Bailey M. The Cox maze IV procedure for lone atrial fibrillation. Multimed Man Cardiothorac Surg. 2007; 2007 mmcts.2007.002758.
13. Ad N, Damiano RJ Jr, Badhwar V, et al. Expert consensus guidelines: examining surgical ablation for atrial fibrillation. J Thorac Cardiovasc Surg. 2017; 153:1330–54. [PubMed: 28390766]
14. Andrade JG, Macle L, Khairy P, et al. Incidence and significance of early recurrences associated with different ablation strategies for AF: a STAR-AF substudy. J Cardiovasc Electrophysiol. 2012; 23:1295–301. [PubMed: 22897339]
15. Nalliah CJ, Lim TW, Kizana E, et al. Clinical significance of early atrial arrhythmia type and timing after single ring isolation of the pulmonary veins. Europace. 2015; 17:1038–44. [PubMed: 25935165]
16. Mugnai G, de Asmundis C, Hunuk B, et al. Second-generation cryoballoon ablation for paroxysmal atrial fibrillation: predictive role of atrial arrhythmias occurring in the blanking period on the incidence of late recurrences. Heart Rhythm. 2016; 13:845–51. [PubMed: 26724490]
17. Kumar P, Mounsey JP. Early recurrences are not always benign after catheter ablation of atrial fibrillation: do we need to reassess the need for a blanking period? J Cardiovasc Electrophysiol. 2012; 23:1302–3. [PubMed: 23131033]
18. Damiano RJ, Schwartz FH, Bailey MS, et al. The Cox maze IV procedure: predictors of late recurrence. J Thorac Cardiovasc Surg. 2011; 141:113–21. [PubMed: 21168019]
19. Gillinov AM, Bhavani S, Blackstone EH, et al. Surgery for permanent atrial fibrillation: impact of patient factors and lesion set. Ann Thorac Surg. 2006; 82:502–13. [PubMed: 16863753]

20. Ad N, Holmes SD. Prediction of sinus rhythm in patients undergoing concomitant Cox maze procedure through a median sternotomy. J Thorac Cardiovasc Surg. 2014; 148:881–6. [PubMed: 25043863]
21. Ad N, Holmes SD, Lamont D, Shuman DJ. Left-sided surgical ablation for patients with atrial fibrillation who are undergoing concomitant cardiac surgical procedures. Ann Thorac Surg. 2017; 103:58–65. [PubMed: 27544292]
22. Weiner MM, Hofer I, Lin HM, Castillo JG, Adams DH, Fischer GW. Relationship among surgical volume, repair quality, and perioperative outcomes for repair of mitral insufficiency in a mitral valve reference center. J Thorac Cardiovasc Surg. 2014; 148:2021–6. [PubMed: 24836989]
23. Badhwar V, Rankin JS, Damiano RJ Jr, et al. The Society of Thoracic Surgeons 2017 clinical practice guidelines for the surgical treatment of atrial fibrillation. Ann Thorac Surg. 2017; 103:329–41. [PubMed: 28007240]
24. Damiano RJ Jr, Lawrance CP, Saint LL, et al. Detection of atrial fibrillation after surgical ablation: conventional versus continuous monitoring. Ann Thorac Surg. 2016; 101:42–7. [PubMed: 26507426]
25. Mittal S, Rogers J, Sarkar S, et al. Real-world performance of an enhanced atrial fibrillation detection algorithm in an insertable cardiac monitor. Heart Rhythm. 2016; 13:1624–30. [PubMed: 27165694]

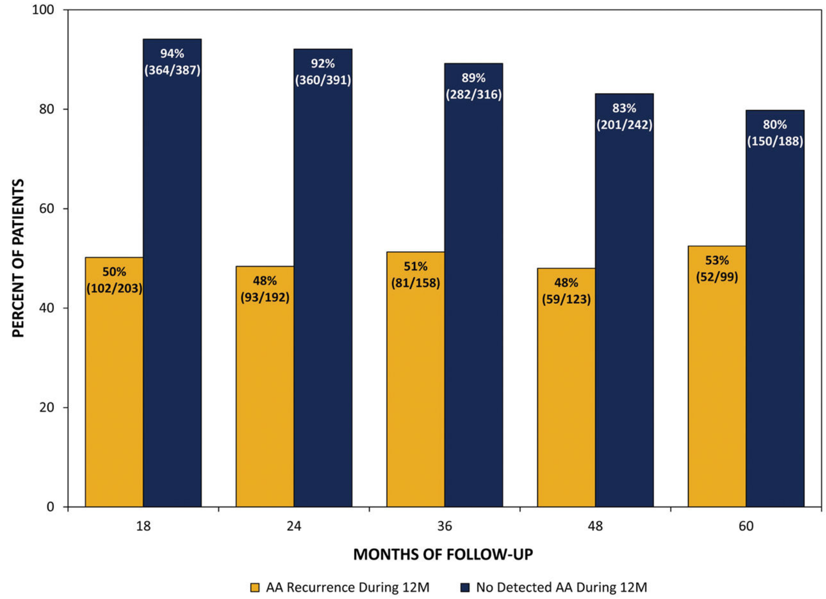

Fig. 1.

Comparison of patients with and without detected atrial arrhythmias (AA) up to 12 months (12M) on the proportion of patients in sinus rhythm off antiarrhythmic drugs at 1.5, 2, 3, 4, and 5 years after surgical ablation.

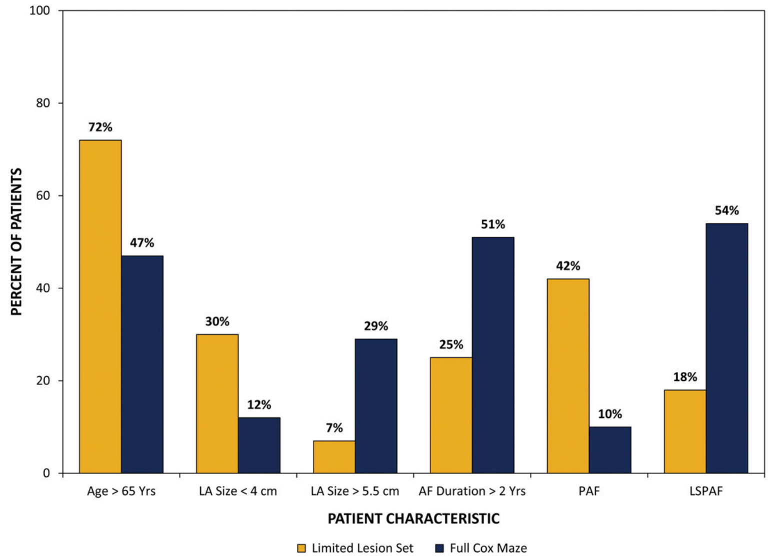

Fig. 2.

Comparison of full Cox maze and limited lesion sets on clinical characteristics of patients that appear to affect surgeon decision making for appropriate lesion set. All differences between lesion sets are statistically significant. (AF = atrial fibrillation; LA = left atrium; LSPAF = long-standing persistent atrial fibrillation; PAF = paroxysmal atrial fibrillation.)

Table 1

Patient Characteristics

	AA Recurrence During 12 Months		
Characteristic[a]	Yes (n = 240)	No (n = 503)	*p*
Age, y	66.0 ± 11.8	64.1 ± 10.8	0.030
Female	87 (36)	147 (29)	0.054
Body mass index, kg/m^2	28.6 ± 6.2	28.1 ± 5.5	0.303
Ejection fraction	0.538 ± 0.114	0.556 ± 0.106	0.043
Diabetes	42 (18)	75 (15)	0.365
Hypertension	156 (65)	324 (64)	0.876
Peripheral vascular disease	17 (7)	30 (6)	0.558
Previous cerebrovascular accident	16 (7)	36 (7)	0.806
Chronic pulmonary disease	49 (20)	80 (16)	0.129
Duration of AF, mo	27 (5–82)	19 (3–55)	0.007
Left atrium size, cm	5.1 ± 1.0	4.9 ± 1.0	0.016
Nonparoxysmal AF type	214 (89)	425 (85)	0.086
Previous catheter ablation	36 (15)	80 (16)	0.751
EuroSCORE II, %	4.5 ± 4.7	3.4 ± 4.3	0.003
Elective status	215 (90)	426 (85)	0.070
Cryothermia only energy source	129 (54)	302 (60)	0.104
Full Cox maze lesion set	210 (88)	433 (86)	0.597
Cases of surgeon experience,[b] No.	130.5 (26–369.5)	218 (64–415)	0.001
Concomitant surgical procedures[c]			
CABG	61 (25)	141 (28)	0.454
Mitral valve	122 (51)	233 (46)	0.250
Aortic valve	49 (20)	96 (19)	0.669
Tricuspid valve	47 (20)	67 (13)	0.027

[a]Continuous data are presented as mean ± SD or median (interquartile range) and categorical data as frequency (%).

[b]All cases of experience with surgical ablation for each surgeon at our institution.

[c]Categories are not mutually exclusive.

AA = atrial arrhythmia; AF = atrial fibrillation; CABG = coronary artery bypass grafting; EuroSCORE II = European System for Cardiac Operative Risk Evaluation 2011 revision.

Table 2

Logistic Regression Results Predicting Stable Sinus Rhythm During the First 12 Months After Surgical Ablation

Factor	OR	95% CI	*p*
Left atrium size, cm	0.78	0.65–0.93	0.006
Duration of AF, y	0.96	0.92–0.99	0.009
Surgeon experience ≥50 cases	2.42	1.57–3.73	<0.001
Age, y	0.99	0.97–1.002	0.078
Female	0.73	0.50–1.05	0.089
Nonparoxysmal AF	0.61	0.35–1.09	0.095
Cryothermia only energy source	0.99	0.68–1.46	0.971
Full Cox maze lesion set	0.95	0.53–1.69	0.861
Surgical procedures,[a] No.			
2	0.92	0.55–1.52	0.731
≥3	1.05	0.62–1.79	0.853

[a]Reference group = stand alone procedures.

AF = atrial fibrillation; CI = confidence interval; OR = odds ratio.

Table 3

Mixed Model Logistic Regression Results Predicting Atrial Arrhythmia Recurrence Between 1 and 5 Years

Factor	OR	95% CI	*p*
No detected AA up to 1 year	0.11	0.08–0.16	<0.001
Age, y	1.03	1.02–1.05	<0.001
Duration of AF, y	1.04	1.001–1.07	0.043
Surgeon experience ≥50 cases	0.63	0.41–0.99	0.043
Female	1.03	0.70–1.51	0.888
Nonparoxysmal AF	0.77	0.43–1.37	0.374
Left atrium size (cm)	1.20	0.998–1.45	0.052
Cryothermia only energy source	0.68	0.46–1.01	0.056
Full Cox maze lesion set	1.53	0.84–2.80	0.165
Surgical procedures,[a] No.			
2	0.78	0.46–1.32	0.357
≥3	1.07	0.62–1.85	0.811

[a]Reference group = stand alone procedures.

AA = atrial arrhythmia; AF = atrial fibrillation; CI = confidence interval; OR = odds ratio.