Midterm survival in patients treated for atrial fibrillation: A propensity-matched comparison to patients without a history of atrial fibrillation

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Objective: Patients undergoing cardiac surgery with a history of untreated atrial fibrillation have reduced survival compared with similar patients without atrial fibrillation. We sought to compare the midterm survival of patients who received concomitant surgical ablation treatment for atrial fibrillation (atrial fibrillation ablated) with that of matched patients without a history of atrial fibrillation (no atrial fibrillation).

Methods: We evaluated 3262 consecutive patients (813 [25%] with atrial fibrillation and 2449 [75%] without preoperative atrial fibrillation) undergoing cardiac surgery at a single institution from April 2004 to April 2009. Of patients with atrial fibrillation, 565 (70%) were treated with a concomitant surgical ablation procedure. Propensity scores were calculated on the basis of 37 known preoperative risk factors and yielded 744 patients. Midterm survival was compared between patients with atrial fibrillation ablation ($n = 372$) and patients without atrial fibrillation ($n = 372$). Survival was also compared between patients with successful vs unsuccessful ablation, and a matched analysis was performed at 1 year between the 2 groups.

Results: Mean follow-up was 2.7 ± 1.6 years. Patients without atrial fibrillation and patients with treated atrial fibrillation had similar early 30-day mortality (1.2% vs 0.3%, $P = .37$) and overall mortality rates (11.6% vs 9.4%, $P = .344$), respectively. Survival analysis showed no differences at 1, 3, and 5 years between the 2 groups (log-rank $P = .22$). At last follow-up, 78% of treated patients were free of atrial fibrillation. At 1 year, 68% of patients were free of atrial fibrillation and antiarrhythmic medication. Freedom from atrial fibrillation and antiarrhythmic medication at 1 year predicted improved midterm survival ($P = .03$) compared with patients in atrial fibrillation or taking antiarrhythmic medication. Propensity-matched analysis after 1 year demonstrated improved survival for patients who were successfully treated ($P = .016$).

Conclusions: Patients undergoing surgical treatment of atrial fibrillation had survival similar to that of patients without a history of atrial fibrillation. Those with successful sinus restoration had improved survival compared with those who were treated but remained in atrial fibrillation. (*J Thorac Cardiovasc Surg* 2012;143:1341-51)

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Patients with atrial fibrillation (AF) have a reduced survival when compared with patients in sinus rhythm.¹ Patients with AF have increased rates of stroke, heart failure, and

all-cause mortality.² Pharmacologic attempts at sinus restoration have been unable to establish a survival advantage over rate control alone.³ However, on subsequent multivariate analysis, patients with successful restoration of sinus rhythm demonstrated a survival advantage over those in AF, suggesting that a therapy that successfully treats AF may affect survival.⁴

Patients with preoperative AF undergoing cardiac surgery also have an increased risk of mortality.⁵⁻⁹ For example, patients with AF undergoing coronary artery bypass grafting (CABG) have a 24% survival disadvantage at 10 years compared with matched patients undergoing CABG without preoperative AF.^{5,6} In matched patients undergoing aortic valve replacement, patients with AF have worse survival and an increased incidence of strokes and heart failure.^{7,8}

Surgical ablation of AF in patients undergoing cardiac surgery has improved and is more widely applied, but it is still performed in the minority of cases.¹⁰ Ablation usually adds little to the operation (9 minutes to crossclamp time and 9 minutes to cardiopulmonary bypass time in patients

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Abbreviations and Acronyms

AA	= antiarrhythmic
AF	= atrial fibrillation
CABG	= coronary artery bypass grafting
CI	= confidence interval
HR	= hazard ratio

undergoing mitral valve surgery).¹⁰ Surgery for AF has been shown to be safe and effective and does not add to perioperative morbidity and mortality when combined with other cardiac procedures; however, a benefit to midterm survival has not been established.¹¹⁻¹⁵

The purpose of this study was to compare the midterm survival of patients with AF who received surgical ablation for AF (AF ablated) at the time of cardiac surgery with that of similar patients without preoperative AF (no AF). Our hypotheses were that (1) the AF ablated group would have a similar survival as the no AF group after adjusting for preoperative risk factors, and that (2) the successful restoration of sinus rhythm would improve survival compared with patients who return to AF.

MATERIALS AND METHODS

We queried the Bluhm Cardiovascular Institute's Clinical Trials Cardiac Surgery Outcomes Registry for all patients who underwent cardiac surgery since the inception of the database from April 2004 to April 2009. This Registry is approved by the institutional review board at Northwestern University (project STU00012288). Data were collected from patients enrolled in the Registry and from medical record review. All patients in this study consented for the use of their follow-up data. Data were deidentified before analysis.

Study Population

We evaluated 3262 consecutive patients (813 [25%] with AF and 2449 [75%] without preoperative AF). Of the 813 patients with AF, 565 (70%) were treated with a surgical AF ablation procedure (classic cut-and-sew Maze in 78, biatrial Maze in 140, left atrial Maze in 213, pulmonary vein isolation [island] in 108, pulmonary vein isolation [box] in 23, and procedures that not fit into any other category in 3). The AF untreated (n = 248) group had similar age but several adverse preoperative risk factors, including diabetes, hypertension, congestive heart failure, New York Heart Association class, renal failure, chronic obstructive pulmonary disease, peripheral vascular disease, myocardial infarction, stroke, and transient ischemic attack compared with the AF ablated group (Table 1). Patients were treated for AF when the risks of adding the procedure were considered to be low, there was a reasonable chance for success, and the surgery was performed by an experienced surgeon in accordance with the Heart Rhythm Society/European Heart Rhythm Association/European Cardiac Arrhythmia Society Expert Consensus Statement.¹⁶ Preoperative demographic and clinical data were collected on all patients, as were perioperative outcomes. The standard Society of Thoracic Surgeons' database definitions were used for all variables. The Society of Thoracic Surgeons' risk score could not be implemented in those with AF; therefore, Ambler risk scores were calculated and compared. Midterm survival was identified by the Social Security Death Index and measured as time (days) to death or last follow-up from date of surgery. Follow-up was 100% complete.

Statistical Analysis

Before final statistical analysis, preliminary data were analyzed using univariate and graphic methods wherever applicable to facilitate inspection and interpretation of the data. Outliers and influential observations were identified and checked for accuracy. Data error due to data entry oversight was appropriately corrected. Data were summarized using descriptive statistics (eg, means and standard deviation for continuous variables; count and frequency for categorical variables). Group differences in patient demographics and clinical and surgical characteristics were compared using a *t* test (parametric) or Wilcoxon Mann-Whitney test (nonparametric) for continuous variables and chi-square test or Fisher exact test for categorical data.

Unadjusted survival estimates were analyzed using the Kaplan-Meier method, and adjusted hazard ratio (HR) of long-term mortality was estimated using the Cox proportional hazard models. Risk factors by which these survival estimates were adjusted for are shown in Table 2. Propensity scores were further calculated on the basis of the probability of undergoing a surgical AF ablation procedure and no preoperative AF condition. The propensity score was developed by fitting a logistic regression model with AF treatment as the outcome variable and all risk factors in Table 1 as the predictor variables. Missing data of predictor variables were imputed using multiple imputations of SAS PROC MI (SAS Institute Inc, Cary, NC) procedure. All *P* values after propensity score adjustment were not statistically significant (Table 2), indicating a good balance after adjustment.

The AF ablated group (n = 372) was propensity matched (1:1) with the no AF history (n = 372) group using the caliper-matching method.¹⁷ Specifically, we imposed a 0.02 propensity score tolerance on the maximum propensity score distance (caliper) in our matching algorithm so that bad matches could be avoided. Balance of covariates before and after propensity adjustment was checked using both density distribution of the propensity score and Wald chi-square statistics to assess the quality of the match. The 744 matched patients were analyzed for differences in midterm survival using Kaplan-Meier and log-rank methodology. Additional matches were performed for patients undergoing isolated aortic valve replacement (n = 44), mitral valve repair or replacement (n = 130), and concomitant coronary artery bypass and valve intervention (CABG + valve) (n = 186).

For the AF ablated group, the standard protocol for postoperative monitoring and medication management of AF at Bluhm Cardiovascular Institute, developed in collaboration with cardiac electrophysiologists, was reviewed with patients and shared with referring cardiologists. The protocol recommends continuous electrocardiographic monitoring for a minimum of 24 hours at 3 and 6 months to guide medication changes and every 6 months for 2 years after intervention to monitor rhythm status. Pacemaker interrogation was used whenever possible. If any monitor showed AF and no further attempts were made to restore sinus rhythm, the patient was deemed a "failure" and continuous monitoring was no longer required. Patients were also contacted by phone at 3, 6, and 12 months to track medications and provide support.

Survival was compared in the AF ablation group between patients with successful sinus restoration and patients with "failed" treatment. Success was defined at 1 year as freedom from any episode of AF without antiarrhythmic (AA) medications. Throughout the report, statistical significance was established at an alpha level of .05. All statistical analyses were performed using SAS 9.2 statistical software (SAS Institute Inc). In an effort to assess whether the return to AF was a marker or cause of mortality, after 1 year, 77 patients successfully treated were propensity matched (1:1) with 77 patients with unsuccessful treatment using the caliper matching method.^{17,18} We again imposed a 0.02 propensity score tolerance on the maximum propensity score distance (caliper) in our matching algorithm so that bad matches could be avoided. Covariate balance before and after propensity adjustment was checked using both density distribution of the propensity score and Wald chi-square statistics to assess the quality of the match. The 154 matched patients were analyzed for differences in midterm survival using Kaplan-Meier and log-rank methodology.

TABLE 1. Comparison of characteristics in the AF population: AF ablated versus AF untreated

Variables	AF ablated (N = 565)		AF untreated (N = 248)		P value
	n	%	n	%	
Demographics					
Age (mean $\pm$ SD)		65.9 $\pm$ 12.2		66.5 $\pm$ 15.1	.5628
Male	329	58.2	173	69.8	.0018
Race					.0376
White	435	77.0	194	78.2	
AA	26	4.6	20	8.1	
Hispanic	10	1.8	7	2.8	
Asian	11	2.0	5	2.0	
Other	83	14.7	22	8.9	
Health characteristics					
CHADS ₂ (mean $\pm$ SD)		1.6 $\pm$ 1.2		2.3 $\pm$ 1.3	<.0001
BMI (mean $\pm$ SD)		27.5 $\pm$ 5.9		27.7 $\pm$ 6.5	.7728
Smoker	149	26.4	68	27.4	.7559
Diabetes	77	13.6	66	26.6	<.0001
Hypertension	321	56.8	164	66.1	.0127
CHF	206	36.5	149	60.1	<.0001
NYHA					<.0001
Class 1	121	21.4	19	7.7	
Class 2	246	43.5	65	26.2	
Class 3	173	30.6	91	36.7	
Class 4	25	4.4	73	29.4	
Renal failure	24	4.2	30	12.1	<.0001
Previous dialysis	5	0.9	11	4.4	.0008
COPD	71	12.6	58	23.4	.0001
PVD	26	4.6	29	11.7	.0002
Moderate pulmonary HTN	188	33.3	79	31.9	.6915
Severe pulmonary HTN	130	23.0	67	27.0	.2195
MI	58	10.3	69	27.8	<.0001
Angina	70	12.4	43	17.3	.0603
Stroke/TIA	57	10.1	46	18.5	.0008
Family history CAD	105	18.6	38	15.3	.2607
Surgical characteristics					
No. of diseased vessels (mean $\pm$ SD)		0.8 $\pm$ 1.2		1.3 $\pm$ 1.3	<.0001
Left main disease	30	5.4	32	13.2	.0001
Preoperative creatinine (mean $\pm$ SD)		1.17 $\pm$ 0.8		1.46 $\pm$ 1.1	.0002
Surgical incidence					<.0001
1st	465	82.3	137	55.2	
2nd	90	15.9	93	37.5	
3+	10	1.8	18	7.3	
Indication of surgery					<.0001
Elective	511	90.4	138	55.7	
Emergency	1	0.2	10	4.0	
Urgent	53	9.4	100	40.3	
Type of surgery					
CABG	172	30.4	83	33.5	.3920
Aortic valve	167	29.6	107	43.1	.0002
Mitral valve	341	60.4	51	20.6	<.0001
Tricuspid valve	162	28.7	42	16.9	.0004
Valve + CABG	141	25.0	50	20.2	.1376
Previous medications					
ACE	201	35.7	87	35.2	.8957
ADP	9	1.6	12	4.9	.0071
Aspirin	121	21.4	96	38.9	<.0001
Beta-blockers	362	64.1	138	55.6	.0230

(Continued)

TABLE 1. Continued

Variables	AF ablated (N = 565)		AF untreated (N = 248)		P value
	n	%	n	%	
Warfarin	88	15.6	69	28.0	<.0001
Nonstatin	28	5.0	17	6.9	.2756
Statin	240	42.5	120	48.4	.1183
Discharge medications					
ACE	129	23.7	50	23.0	.8535
ADP	17	3.1	18	8.0	.0026
Aspirin	500	90.1	206	91.6	.5269
Beta-blockers	381	70.0	151	67.1	.4241
Warfarin	472	85.2	121	53.5	<.0001
Nonstatin	23	4.1	13	5.2	.4548
Statin	406	71.9	160	64.5	.03613
Ambler score (mean $\pm$ SD)	8.4 $\pm$ 8.2		12.5 $\pm$ 9.8		<.0001

AF, Atrial fibrillation; SD, standard deviation; AA, antiarrhythmic; CHADS₂, Congestive heart failure, Hypertension, Age $\geq$ 75 years, Diabetes, previous Stroke; BMI, body mass index; CHF, congestive heart failure; NYHA, New York Heart Association; COPD, chronic obstructive pulmonary disease; PVD, peripheral vascular disease; HTN, hypertension; MI, myocardial infarction; TIA, transient ischemic attack; CAD, coronary artery disease; CABG, coronary artery bypass grafting; ACE, angiotensin-converting enzyme; ADP, adenosine diphosphate.

RESULTS

There was no difference in 30-day mortality (0.3% vs 1.2%, $P = .4$) (Ambler score predicted mortality 6.9% and 6.3%, $P = .22$), postoperative stroke (2.4% vs 4.1%, $P = .15$), length of stay (8 vs 9 days, $P = .3$), intensive care unit stay (77 vs 80 hours, $P = .8$), or length of follow-up (2.8 vs 2.7 years, $P = .12$) between the propensity-matched AF ablated and no AF groups, respectively.

In the unadjusted model, patients undergoing surgery with a history of AF had reduced survival compared with patients with no AF (Figure 1, $P < .0001$). The unadjusted HR was 1.65 (95% confidence interval [CI], 1.33–2.04). The AF ablated group had better survival than the AF untreated group (HR, 0.39; 95% CI, 0.27–0.55) and similar survival to the no AF group (HR, 1.15; 95% CI, 0.88–1.51) (Figure 2).

There was no difference in mortality between the matched AF ablated and no AF groups ($P = .22$, Figure 3). Both groups illustrated similar patient survival at 1, 3, and 5 years (95% vs 94%, 90% vs 87%, and 87% vs 82% for AF ablated vs no AF, respectively). Additional comparisons were performed between matched patients undergoing isolated aortic valve replacement, mitral valve replacement, and CABG+valve. There was no difference in survival between patients in the AF ablated group and patients in the no AF group undergoing any of these procedures.

Follow-up at 1 year was available for 336 patients in the AF ablated group. A total of 225 of these patients (67%) had no episode of AF lasting more than 30 seconds within the first year and were free of AA medications and classified as having “successful treatment.” Freedom from AF and AA medications at 1 year independently predicted long-term survival compared with patients in whom ablation failed

(unadjusted $P = .0003$ and adjusted $P = .03$) (Figure 4). At last follow-up, 78% of patients were free of AF. There was a trend for improved survival in this group ($P = .06$) compared with treated patients who remained in AF.

After 1 year, survivors who were successfully treated were similar in many ways to those patients whose treatment failed (Table 3). However, they were younger, had lower serum creatinine, and were more likely to have no prior cardiac operation. Seventy-seven patients who were successfully treated after 1 year were matched with 77 patients who had failed treatment (in AF or taking AA medication). Survival was different between these groups (Figure 5) and favored those patients who were successfully treated.

DISCUSSION

The published literature suggests that patients with AF undergoing cardiac surgery have reduced survival compared with patients in sinus rhythm.⁵⁻⁹ Our article demonstrates that when select patients are treated for AF at the time of cardiac surgery, their midterm survival is the same as those without a history of AF. Further, successful restoration of sinus rhythm improves survival compared with treated patients who remain in AF, a finding analogous to the Atrial Fibrillation Follow-Up Investigation of Rhythm Management trial.⁴ This finding persists even with the passage of time and the change of the patient population.¹⁸

Patients undergoing cardiac surgery represent a unique population. Adding a concomitant AF procedure does not add much to the operation but results in sinus restoration approximately 80% of the time^{13,19-23} (in our study 78%, including 67% free of AA medications and AF). At least 6 randomized trials in patients undergoing mitral valve surgery have shown that treating AF is more likely to restore sinus rhythm than nontreatment.^{14,24-29} However,

TABLE 2. Comparison of characteristics of AF ablated versus no AF populations: Total sample and propensity-matched groups

Variables	Total sample (N = 3014)					Propensity-matched sample (N = 744)				
	AF ablated (N = 565)		No AF (N = 2449)		P value	AF ablated (N = 372)		No AF (N = 372)		P value
	n	%	n	%		n	%	n	%	
Demographics										
Age (mean ± SD)	65.9 ± 12.2		61.7 ± 13.8		<.0001	64.8 ± 12.5		64.7 ± 13.1		.9088
Male	329	58.2	1644	67.1	<.0001	224	60.2	231	62.1	.5985
Race					<.0001					.8932
White	435	77.0	1718	70.2		279	75.0	282	75.8	
AA	26	4.6	235	9.6		23	6.2	28	7.5	
Hispanic	10	1.8	104	4.3		7	1.9	6	1.6	
Asian	11	2.0	63	2.6		8	2.2	6	1.6	
Other	83	14.7	329	13.4		55	14.8	50	13.4	
Health characteristics										
CHADS ₂ (mean ± SD)	1.6 ± 1.2		1.4 ± 1.2		.0357	1.5 ± 1.2		1.5 ± 1.2		.8519
BMI (mean ± SD)	27.5 ± 5.9		28.0 ± 5.8		.0751	27.5 ± 6.0		27.8 ± 6.0		.4750
Smoker	149	26.4	764	31.2	.0245	95	25.5	114	30.7	.1212
Diabetes	77	13.6	515	21.0	<.0001	56	15.1	61	16.4	.6146
Hypertension	321	56.8	1554	63.5	.0033	223	60.0	223	60.0	1.0000
CHF	206	36.5	580	23.7	<.0001	120	32.3	129	34.7	.4844
NYHA					<.0001					.8771
Class 1	121	21.4	675	27.6		89	23.9	84	22.6	
Class 2	246	43.5	928	37.9		163	43.8	159	42.7	
Class 3	173	30.6	640	26.1		105	28.2	115	30.9	
Class 4	25	4.4	205	8.4		15	4.0	14	3.8	
Renal failure	24	4.2	119	4.9	.5366	11	3.0	14	3.8	.5416
Previous dialysis	5	0.9	61	2.5	.0187	3	0.8	3	0.8	1.0000
COPD	71	12.6	255	10.4	.1373	44	11.8	49	13.2	.5794
PVD	26	4.6	213	8.7	.0017	17	4.6	23	6.2	.3294
Moderate pulmonary HTN	188	33.3	491	20.0	<.0001	112	30.1	115	30.9	.8112
Severe pulmonary HTN	130	23.0	251	10.2	<.0001	74	19.9	75	20.2	.9270
MI	58	10.3	496	20.3	<.0001	39	10.5	50	13.4	.2140
Angina	70	12.4	824	33.6	<.0001	55	14.8	58	15.6	.7593
Stroke/TIA	57	10.1	206	8.4	.2030	32	8.6	29	7.8	.6885
Family history CAD	105	18.6	513	20.9	.2098	70	18.8	74	19.9	.7105
Surgical characteristics										
No. of diseased vessels (mean ± SD)	0.8 ± 1.2		1.5 ± 1.3		<.0001	0.9 ± 1.2		1.0 ± 1.2		.1065
Left main disease	30	5.4	380	15.7	<.0001	23	6.2	31	8.3	.2583
Preoperative creatinine (mean ± SD)	1.17 ± 0.8		1.19 ± 0.9		.5784	1.13 ± 0.7		1.13 ± 0.5		.9887
Surgical incidence					.0010					.8314
1st	465	82.3	2148	87.7		309	83.1	303	81.5	
2nd	90	15.9	255	10.4		55	14.8	61	16.4	
3+	10	1.8	46	1.9		8	2.2	8	2.2	
Indication of surgery					<.0001					.9014
Elective	511	90.4	1889	77.1		335	90.1	337	90.6	
Emergency	1	0.2	55	2.3		0	0	0	0	
Urgent	53	9.4	505	20.6		37	9.9	36	9.4	
Type of surgery										
CABG	172	30.4	1305	53.3	<.0001	122	32.8	140	37.6	.1671
Aortic valve	167	29.6	891	36.4	.0022	128	34.4	121	32.5	.5865
Mitral valve	341	60.4	590	24.1	<.0001	201	54.0	208	55.9	.6060
Tricuspid valve	162	28.7	139	5.7	<.0001	66	17.7	63	16.9	.7714
Valve+CABG	141	25.0	423	17.3	<.0001	93	25.0	107	28.8	.2470
Previous medications										
ACE	201	35.7	930	38.1	.2992	131	35.2	133	35.8	.8782
ADP	9	1.6	104	4.3	.0027	8	2.2	11	3.0	.4857

(Continued)

TABLE 2. Continued

Variables	Total sample (N = 3014)					Propensity-matched sample (N = 744)				
	AF ablated (N = 565)		No AF (N = 2449)		P value	AF ablated (N = 372)		No AF (N = 372)		P value
	n	%	n	%		n	%	n	%	
Aspirin	121	21.4	977	40.0	<.0001	89	23.9	100	26.9	.3542
Beta-blockers	362	64.1	1358	55.6	.0002	220	59.1	227	61.0	.6003
Warfarin	88	15.6	315	12.9	.0877	42	11.3	39	10.5	.7240
Nonstatin	28	5.0	120	4.9	.9559	15	4.0	23	6.2	.1828
Statin	240	42.5	1299	53.0	<.0001	162	43.6	175	47.0	.3383
Discharge medications										
ACE	129	23.7	608	25.9	.2899	93	25.0	97	26.1	.7367
ADP	17	3.1	509	21.3	<.0001	16	4.3	22	5.9	.3177
Aspirin	500	90.1	2187	91.8	.2009	332	89.3	341	91.7	.2615
Beta-blockers	381	70.0	2063	87.0	<.0001	284	76.3	277	74.5	.5512
Warfarin	472	85.2	687	28.8	<.0001	293	78.8	300	80.7	.5234
Nonstatin	23	4.1	99	4.0	.9754	15	4.0	23	6.2	.1828
Statin	406	71.9	1854	75.7	.0571	271	72.9	282	75.8	.3559
Ambler score (mean $\pm$ SD)	8.4 $\pm$ 8.2		4.8 $\pm$ 6.5		<.0001	6.3 $\pm$ 6.1		6.9 $\pm$ 8.0		.2218

AF, Atrial fibrillation; SD, standard deviation; AA, antiarrhythmic; CHADS₂, Congestive heart failure, Hypertension, Age $\geq$ 75 years, Diabetes, previous Stroke; BMI, body mass index; CHF, congestive heart failure; NYHA, New York Heart Association; COPD, chronic obstructive pulmonary disease; PVD, peripheral vascular disease; HTN, hypertension; MI, myocardial infarction; TIA, transient ischemic attack; CAD, coronary artery disease; CABG, coronary artery bypass grafting; ACE, angiotensin-converting enzyme; ADP, adenosine diphosphate.

none of these trials were powered or followed to look at whether sinus restoration improved survival or reduced other morbidity.

Few studies have attempted to establish an improved survival after the surgical treatment of AF. In a series of 103 patients with persistent AF, Louagie and colleagues³⁰ demonstrated an improved survival at 5 years in 37 patients who underwent a Maze procedure compared with controls. They postulated that sinus restoration (90% in Maze group vs 33% in control) explained the difference.³⁰ However, in the non-ablated control group, exclusion of the left atrial appendage was associated with lower mortality, suggesting that a reduction in late stroke may play a role in both populations. In a large series of 521 combined mitral and maze cases, Itoh and colleagues³¹ demonstrated that successful

sinus restoration improved survival and freedom from stroke. However, these studies preceded current follow-up guidelines and definitions of success. In addition, the use of AA therapy was not considered a failure.

Our propensity-matched analysis demonstrates that in the matched treated population, survival was the same as for patients without a history of AF. Although this could be due to selection bias, it is important to note that those with successful sinus restoration did have improved survival compared with those who failed treatment. The elimination of the left atrial appendage also may be a factor. The role of both these factors on late stroke and survival merits future investigation.

In North America, only 38% of patients with a history of AF receive an AF correction procedure.^{10,32} For some time,

FIGURE 1. Patient survival: history of AF vs no AF. Kaplan-Meier analyses of survival in AF (N = 813) and no AF (N = 2449) groups. AF, Atrial fibrillation.

FIGURE 2. Patient survival: no AF vs AF ablated vs AF untreated. Kaplan-Meier analyses of survival for AF ablated (N = 565), AF untreated (N = 248), and no AF (N = 2449) groups. AF, Atrial fibrillation.

FIGURE 3. Propensity-matched patient survival: AF ablated vs no AF. Kaplan–Meier analyses of survival for propensity-matched AF ablated (N = 372) and no AF (N = 372) groups. *AF*, Atrial fibrillation.

we have thought that if AF can be eliminated at the time of cardiac surgery, survival should improve to that of patients without a history of AF.⁵ Our study is the first propensity-matched analysis to demonstrate that survival in a population in whom AF was surgically treated in accordance with the Heart Rhythm Society guidelines is comparable to that of patients without AF. Because successful sinus restoration seems to have an impact, an effort should be made to optimize success at the time of surgery. This may have future implications on lesion set selection.

Limitations

There are several limitations to our study that restrict our ability to definitively state that AF treatment improved survival. The patient sample may not be adequate. Further, although the patients were matched with accepted statistical methodology, there may still be inherent differences in the population that cannot be equated. Despite our best efforts, we may have “selected out” the healthy patients who were destined to have comparable survival. In addition, because of the relatively small sample, we do not know the effect

FIGURE 4. Survival in AF ablated group: “success” (freedom from AF and AA therapy at 1 year) vs “failure.” Kaplan–Meier analyses of survival for patients in AF ablated group who had no episode of AF lasting more than 30 seconds within the first year, were free of AA medications (success, N = 225), and had AF within 1 year or were taking AA medications (failure, N = 111). *HR*, Hazard ratio.

TABLE 3. Comparison of characteristics of successful versus unsuccessful AF treatment patients: Total sample and propensity-matched sample 1 year after treatment

Variables	Total sample					Propensity-matched sample				
	Success (N = 203)		Failure (N = 104)		P value	Success (N = 77)		Failure (N = 77)		P value
	n	%	n	%		n	%	n	%	
Demographics										
Age (mean ± SD)	64.4 ± 11.8		68.9 ± 11.8		.0017	67.9 ± 10.9		67.6 ± 12.0		.8498
Male	118	58.1	53	51.0	.2315	42	54.5	44	57.1	.7455
Race					.6895					1.0000
White	157	77.3	87	83.7		62	80.5	62	80.5	
AA	10	4.9	4	3.8		3	3.9	3	3.9	
Hispanic	3	1.5	2	1.9		2	1.3	2	1.3	
Asian	2	1.0	1	1.0		1	2.2	1	2.2	
Other	31	15.3	10	9.6		9	11.7	9	11.7	
Health characteristics										
CHADS ₂ (mean ± SD)	1.4 ± 1.2		1.7 ± 1.2		.0115	1.5 ± 1.2		1.5 ± 1.1		.8869
BMI (mean ± SD)	27.7 ± 6.3		27.2 ± 5.7		.4909	27.9 ± 4.0		27.4 ± 5.6		.5627
Smoker	61	30.0	30	28.8	.8271	27	35.1	24	31.2	.6075
Diabetes	24	11.8	17	16.3	.2701	9	11.7	10	13.0	.8064
Hypertension	114	56.2	56	53.8	.6998	43	55.8	40	51.9	.6277
CHF	60	29.6	42	40.4	.0566	24	31.2	27	35.1	.6075
NYHA					.3968					.9619
Class 1	39	19.2	18	17.3		12	15.6	14	18.2	
Class 2	105	43.5	48	37.9		41	53.3	38	49.3	
Class 3	55	30.6	33	26.1		22	28.6	23	29.9	
Class 4	4	4.4	5	8.4		2	2.6	2	2.6	
Renal failure	3	1.5	5	4.8	.0830	2	2.6	2	2.6	1.0000
Previous dialysis	0	0.0	1	1.0	.1617	0	0.0	0	0.0	1.0000
COPD	21	10.3	12	11.5	.7493	8	10.4	8	10.4	1.0000
PVD	10	4.9	4	3.8	.6677	2	2.6	2	2.6	1.0000
Moderate pulmonary HTN	71	35.0	37	35.6	.9168	28	36.4	26	33.8	.7356
Severe pulmonary HTN	46	22.7	27	26.0	.5202	18	23.4	17	22.1	.8475
MI	12	5.9	11	10.6	.1417	4	5.2	6	7.8	.5131
Angina	19	9.4	11	10.6	.7339	7	9.1	9	11.7	.5974
Stroke/TIA	16	7.9	11	10.6	.4300	9	11.7	7	9.1	.5974
Family history CAD	38	18.7	20	19.2	.9137	13	16.9	14	18.2	.8322
Surgical characteristics										
No. of diseased vessels (mean ± SD)	0.6 ± 1.0		0.8 ± 1.1		.2829	0.7 ± 1.1		0.7 ± 1.1		.9018
Left main disease	8	4.0	3	2.9	.6426	1	1.3	3	3.9	.3109
Preoperative creatinine (mean ± SD)	1.1 ± 0.3		1.3 ± 1.1		.0244	1.17 ± 0.4		1.16 ± 0.6		.9887
Surgical incidence					.0054					.5594
1st	175	86.2	77	74.0		64	83.1	63	81.8	
2nd	27	13.3	22	21.2		12	15.6	14	18.2	
3+	1	0.5	5	4.8		1	1.3	0	0.0	
Indication of surgery					.2816					.9999
Elective	189	93.1	100	96.2		75	97.0	74	96.1	
Emergency	0	0.0	0	0.0		0	0.0	0	0.0	
Urgent	14	6.9	4	3.8		2	2.6	3	3.9	
Type of surgery										
CABG	53	26.1	32	30.8	.3877	29	37.7	23	29.9	.3066
Aortic valve	52	25.6	26	25.0	.9066	21	27.3	18	23.4	.5783
Mitral valve	123	60.6	76	73.1	.0301	53	68.8	53	68.8	1.0000
Tricuspid valve	54	26.6	41	39.4	.0214	27	35.1	26	33.8	.8653
Valve+CABG	44	21.7	27	26.0	.3992	26	33.8	19	24.7	.2149
Previous medications										
ACE	71	35.1	42	40.8	.3358	34	44.2	33	42.9	.8709
ADP	1	0.5	2	1.9	.2241	1	1.3	0	0.0	.3157

(Continued)

TABLE 3. Continued

Variables	Total sample					Propensity-matched sample				
	Success (N = 203)		Failure (N = 104)		P value	Success (N = 77)		Failure (N = 77)		P value
	n	%	n	%		n	%	n	%	
Aspirin	39	19.2	17	16.3	.5383	13	16.9	11	14.3	.6568
Beta-blockers	130	64.0	59	56.7	.2128	42	54.5	43	55.8	.8713
Warfarin	24	11.8	12	11.5	.9416	7	9.1	8	10.4	.7858
Nonstatin	12	5.9	6	5.8	.9600	4	5.2	4	5.2	1.0000
Statin	78	38.4	45	43.3	.4122	31	40.3	33	42.9	.7437
Discharge medications										
ACE	49	24.4	26	25.2	.8685	24	31.2	19	24.7	.3691
ADP	5	2.5	0	0.0	.1074	0	0.0	0	0.0	1.0000
Aspirin	185	91.1	99	95.2	.2010	66	85.7	72	93.5	.5131
Beta-blockers	133	66.8	70	69.3	.6652	51	66.2	52	67.5	.8641
Warfarin	176	87.1	91	87.5	.9265	67	87.0	69	89.6	.6159
Nonstatin	12	5.9	3	2.9	.2443	1	1.3	2	2.6	.5599
Statin	147	72.4	76	73.1	.9018	51	66.2	56	72.7	.3816
Ambler score (mean ± SD)	7.0 ± 7.3		10.3 ± 8.3		.0004	7.8 ± 8.7		7.9 ± 6.3		.8819

SD, Standard deviation; AA, antiarrhythmic; CHADS₂, Congestive heart failure, Hypertension, Age ≥ 75 years, Diabetes, previous Stroke; BMI, body mass index; CHF, congestive heart failure; NYHA, New York Heart Association; COPD, chronic obstructive pulmonary disease; PVD, peripheral vascular disease; HTN, hypertension; MI, myocardial infarction; TIA, transient ischemic attack; CAD, coronary artery disease; CABG, coronary artery bypass grafting; ACE, angiotensin-converting enzyme; ADP, adenosine diphosphate.

of nontreatment in this group; however, we do know that patients had a worse survival when treatment failed. AF ablation was not performed on these patients when the surgeon judged the procedure too complex or the patients were too ill and the risk outweighed the potential benefit; generally, these patients were likely to have worse survival. Thus, little information can be gained from the untreated population in this study. Because the untreated patients were different from the treated patients, we did not find an adequate sample for matching this group. Other limitations include a lack of knowledge of late causes of death that may be unrelated

to AF. Late adverse events were not investigated; only mid-term survival was investigated. Longer follow-up will provide a more definitive answer.

CONCLUSIONS

In matched patients with a history of AF who underwent ablation during concomitant surgery, there was no difference in early or midterm survival compared with patients without a preoperative history of AF. The 67% of patients who were free of AA therapy and AF at 1 year had better long-term survival, and 78% of patients in sinus rhythm

FIGURE 5. Survival after 1 year in propensity-matched patients: “success” (freedom from AF and AA therapy at 1 year) vs failure. Kaplan–Meier analysis of survival after 1 year in propensity-matched patients; a comparison of AF treatment success (N = 77) and failure (N = 77) groups.

at last follow-up showed a trend ($P = .06$) toward improved survival compared with patients in AF. In matched patients, successful treatment predicted survival, even after 1 year. Because several prior studies have indicated reduced survival in patients with a history of AF, these results are encouraging and merit further investigation. This may have implications for a broader application of AF surgery in low-risk patients.

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Discussion

Dr John Doty (Murray, Utah). This study emphasizes the importance of concomitant treatment of AF, particularly your last graphs. Your follow-up is relatively short, but we may see that those patients have improved survival by treatment of AF. There is ongoing debate about the wide range of operations that are used for the treatment of AF. Would you describe the particular procedures your group uses for treatment of AF and how you decide which patient gets what procedure in this complex group?

Dr Lee. I have another article that I am putting together that looks at AF by lesion set, and in general our results are approximately 75% to 90% depending on the type of procedure that we use in the patient population. Our rule of thumb is essentially this. The American College of Cardiology/American Heart Association recommends treating everybody with AF if it does not add anything more to the procedure. So if you are performing mitral valve surgery, you are fairly obligated to do a full left-sided Maze and strongly consider a right side, especially as more data emerge that doing both by atrial lesion sets may improve AF outcomes. On the flip side, if you have an elderly person undergoing CABG, especially off-pump, and you are not going to open the heart, well, it may be reasonable to do pulmonary vein isolation

alone. We segment it by procedure and by how AF affects the patient. If AF is a real problem, we make every effort to treat it with the biatrial lesion set. If it is paroxysmal, especially if we are not going to open the heart anyway, we would do a more limited lesion set like a PVI alone. And for those patients in between those extremes, we perhaps do a left-sided only Maze.

Dr Doty. Maybe you could clarify a bit more. When you say lesion sets, what energy modality are you using? You did mention in your article sometimes you have cut and sew as an option.

Dr Lee. In the article you wrote 2 years ago, you showed that cut and sew is probably better than everything else, and even though some of the other reports conflict with that, we have a similar experience. Now if you have a patient with AF and that is the number 1 problem, you are going to do a cut-and-sew Maze. If you have a patient who has paroxysmal or perhaps long-standing persistent and not permanent AF, you will perform bipolar RF. The majority of our patients are older, more frail, and so approximately 75% of our patients receive bipolar radiofrequency with supplementation at the annulus with cryothermia.

Dr Doty. We all recognize that some surgeons may not be willing to add an additional procedure for AF to what they are doing, particularly if it is complex. Can you estimate for us how much additional time it takes your group to do some type of ablative or incisional Maze procedure?

Dr Lee. That is important, but even the experience of our group is not as important as the experience of the whole population. Gammie and colleagues wrote an article using the Society of Thoracic Surgeons' database. In that added meta-analysis, they showed that it added 9 minutes to crossclamp time and 9 additional minutes to bypass time in general. With the bypass time, you are clamping the beating heart anyway. I think it is even less than that in many instances, so if we are using bipolar radiofrequency we go on pump. We do the pulmonary vein isolations on pump. We stop the heart. We do the connecting lesions, and that really does not take more than 1 minute of clamp time. Then we unclamp and do the right-sided lesions if we are going to do it, and again even if you do multiple lesions it is 40 seconds per burn times 3. It is just a couple minutes per lesion, so in all it adds approximately 18 minutes at the most, but in general, more like 10 minutes for us.

Dr Doty. Your group is similar to ours. We have a strong bias to treat everyone who presents with AF with some type of procedure during their concomitant operation. I am particularly interested in the subset of patients who had existing AF but did not receive a concomitant procedure. You noted these patients were more ill and had more comorbidities. If that is the case, shouldn't these patients be the very ones who receive a concomitant operation, and, if not, can you explain which patients in whom you would not perform an AF operation?

Dr Lee. I did not analyze those data, but you know we have shifted. Now we look at how many patients we have with AF, and now we are at 90% of patients treated for AF, so we have had a paradigm shift. We have a group we assembled right around the beginning of that time period, and as we have gone on we have increased the application, but we also use alternate energy sources, so if you have a redo, for example, say a redo mitral that is pretty stuck, you don't want to dissect out the whole heart. I don't want to do a cut-and-sew Maze in that patient. I don't even want to do bipolar radiofrequency in that patient because I don't want to get around the left-sided veins. But what we will do is use a CryoCath (Medtronic Corporation, Minneapolis, Minn) around the entire surface or Frigitronics cryo (Atricure Corporation, Cincinnati, Ohio), 1 of those 2, and I would say we are down to not operating on approximately 10% of the patients. In general, if we are not going to open the heart, say it is an 85-year-old patient with a redo aortic valve, we are probably just going to do the redo aortic valve. If it is a CABG, especially a redo, we probably would let that go if it is an older or frail patient. That being said, now we are down to approximately 10% or less of patients with a history of AF who are in that category.

Dr Doty. Let me clarify. Are there specific patients in whom you would not perform a concomitant operation? You mentioned redos, if they are older. Are there other criteria you generally use?

Dr Lee. If the patient is older, we are not going to open the heart. Even if the patient is old and a redo and we are going to perform mitral valve surgery, that is still easy to do a left sided, but the guidelines state that it adds to the operation significantly, so I would not open the heart in a 90-year-old patient with redo aortic valves and patent grafts. That is clearly a patient I would not operate on. I cannot give you an individual patient because it is a case-by-case decision, but that is clearly to the extreme where I say no.

Dr William Northrup (Atlanta, Ga). I wonder if the phrase "expected survival" is a little misleading. For instance, when we say that mitral valve repair has the potential to restore expected survival, we are comparing it with a normal matched population. In this case, you are comparing 2 surgical subgroups. When I first read the article, I thought this is pretty exciting. Nevertheless, the article presents exciting data.

Dr Lee. Thank you for your comment, and we will take that into consideration for the final article. We did not compare with the general population because we do not know what that survival should be compared with regular cardiac surgery, but we do know what survival should be for similar patients undergoing aortic valve surgery, mitral valve surgery, and CABG, so by the word "expected," that is what we meant, and we did restore it to that population.