Predicting atrial fibrillation ablation outcome: The CAAP-AF score

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BACKGROUND Patients with a variety of clinical presentations undergo atrial fibrillation (AF) ablation. Long-term ablation success rates can vary considerably.

OBJECTIVE The purpose of this study was to develop a clinical scoring system to predict long-term freedom from AF after ablation.

METHODS We retrospectively derived the scoring system on a development cohort (DC) of 1125 patients undergoing AF ablation and tested it prospectively in a test cohort (TC) of 937 patients undergoing AF ablation.

RESULTS The demographics of the DC patients were as follows: age 62.3 ± 10.3 years, male sex 801 (71.2%), left atrial size 4.30 ± 0.69 cm, paroxysmal AF 348 (30.9%), number of drugs failed 1.3 ± 1.1, hypertension 525 (46.7%), diabetes 100 (8.9%), prior stroke/transient ischemic attack 78 (6.9%), prior cardioversion 528 (46.9%), and CHADS2 score 0.87 ± 0.97. Multivariate analysis showed 6 independent variables predicting freedom from AF after final ablation: coronary artery disease ($P = .021$), atrial diameter ($P = .0003$), age ($P = .004$), persistent or long-standing AF ($P < .0001$), number of antiarrhythmic drugs failed ($P < .0001$), and female sex ($P = .0001$). We created a scoring system (CAAP-AF) using these 6 variables, with scores ranging from 0 to 13 points. The 2-year AF-free rates by CAAP-AF scores were as follows: 0 = 100%, 1 = 95.7%, 2 = 96.3%, 3 = 83.1%, 4 = 85.5%, 5 = 79.9%, 6 = 76.1%, 7 = 63.4%, 8 = 51.1%, 9 = 53.6%, and ≥10 = 29.1%. Ablation success decreased as CAAP-AF scores increased ($P < .0001$). The CAAP-AF score also predicted freedom from AF in the TC. The 2-year Kaplan-Meier AF-free rates by CAAP-AF scores were as follows: 0 = 100%, 1 = 87.0%, 2 = 89.0%, 3 = 91.6%, 4 = 90.5%, 5 = 84.4%, 6 = 70.1%, 7 = 71.0%, 8 = 60.7%, 9 = 68.9%, and ≥10 = 51.3%. As CAAP-AF scores increased, 2-year freedom from AF in the TC decreased ($P < .0001$).

CONCLUSION An easily determined clinical scoring system was derived retrospectively and applied prospectively. The CAAP-AF score predicted freedom from AF after ablation in both a DC and a TC of patients undergoing AF ablation. The CAAP-AF score provides a realistic AF ablation outcome expectation for individual patients.

KEYWORDS Atrial fibrillation; Atrial fibrillation ablation; Ablation outcomes; Catheter ablation; Radiofrequency ablation

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Introduction

Catheter ablation of atrial fibrillation (AF) can be effective for restoring sinus rhythm in many patients.[1–4] However, not all patients have sinus rhythm restored by ablation and there can be both early and late relapses to AF in many patients.[2] The percentage of patients maintaining sinus rhythm after ablation can vary widely, from as high as 90% to as low as 29%.[3–5] Retrospective analyses of outcome data have identified a number of independent clinical variables related to ablation success or failure. Ablation failure after single or multiple ablation procedures has been correlated with larger left atrial (LA) size,[3,4,6] persistent vs paroxysmal AF,[3,4,7] AF duration,[6] older age of patients at the time of ablation,[7,8] female sex,[9] number of antiarrhythmic drugs failed before ablation,[10,11] higher $CHADS_2$ and CHA_2DS_2-VASc scores,[12–14]), and the presence of hypertension,[3,15] untreated obstructive sleep apnea,[16] coronary artery disease (CAD),[4] and metabolic syndrome.[17] Because AF ablation is an expensive procedure and is associated with a small but definite risk of serious complications, it would be desirable to estimate outcomes before embarking on an AF ablation strategy. In this study, we retrospectively develop a simple and inexpensive scoring system to predict ablation outcomes on the basis of clinical variables in a population of patients undergoing ablation therapy. We then prospectively evaluate the score's ability to predict the outcome in a separate and subsequent population of patients undergoing AF ablation.

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Methods

Patient population

The participants were consecutive symptomatic patients undergoing AF ablation at Sequoia Hospital, Redwood City, CA, from October 10, 2003, to December 31, 2012. All signed written informed consent. Patients were divided into 2 groups: a development cohort (DC) of 1125 consecutive patients undergoing initial ablation from 2003 to 2010 and a test cohort (TC) of 937 patients undergoing initial AF ablation from 2010 to 2012.

Data were collected prospectively, and analysis was performed retrospectively and approved by the Western Institutional Review Board. AF type was categorized as paroxysmal: lasting <1 week; persistent: lasting >1 week and <1 year or requiring pharmacological or electrical cardioversion in <1 week; and long-standing persistent: lasting >1 year.

Ablation protocol

Our ablation protocol has been previously described.[4] Antiarrhythmic drugs were discontinued at least 5 half-lives and amiodarone at least 3 months before ablation. The NavX system (St. Jude Medical, Inc., Saint Paul, MN) or CARTO systems (Biosense Webster Inc., Diamond Bar, CA) were used for 3-dimensional mapping in all cases. Before January 2006, we used a closed-tip catheter; and after January 2006, an open-irrigated tip catheter. After July 2006, all irrigated-tip catheter ablation procedures were performed using 50 W for short durations (generally <10 seconds) at each site,[18,19] including the posterior wall. All patients underwent circumferential pulmonary vein isolation and linear ablation of the LA roof. Patients with right or LA isthmus flutter underwent linear ablation of the cavotricuspid and/or mitral isthmus. Patients with persistent AF had low posterior LA lines and LA complex fractionated electrograms ablated. Some patients with long-standing persistent AF underwent additional ablation within the coronary sinus (at 30–35 W), ablation of complex right atrial fractionated electrograms, and/or superior vena cava isolation. Isoproterenol was given, and nonpulmonary vein triggers were mapped and ablated. Repeat ablation procedures were not performed until at least 3 months after initial ablation.

Data collection and analysis

For each patient we recorded preablation age, sex, duration of AF (defined as time from the first clinical episode of AF to the time of first ablation), AF type, prior antiarrhythmic drug therapy, $CHADS_2$ and CHA_2DS_2-VASc scores, cardioversions, body mass index, LA size measured on a preablation transthoracic echocardiogram in the parasternal long-axis view, prior cerebral vascular accidents/transient ischemic attacks, and the presence of hypertension, diabetes, CAD, cardiomyopathy, and obstructive sleep apnea.

Follow-up

Some patients were treated with antiarrhythmic drugs and/or cardioverted during the first 3 months after ablation. Patients sent daily transtelephonic electrocardiographic (ECG) strips for 1–3 months after ablation and were seen at 3 and 12 months at which time continuous monitoring consisted of 24- to 48-hour ECG recording before 2006 and of 7- to 14-day ECG recording thereafter. Patients were seen or contacted frequently from 3 to 12 months. Thereafter, patients were seen directly or contacted by phone at least annually and arrhythmia records obtained from hospitals and referring physicians. ECG recorders were reissued for any arrhythmia symptoms. Pacemaker AF data were used when available. Patients were taught to check their pulse daily and to use pulse oximeters, fitness monitors, or smartphone apps when unable to feel their pulse. A successful ablation was defined as no AF, flutter, or tachycardia lasting more than 30 seconds off antiarrhythmic drugs after a 3-month blanking period. Initial failures were encouraged to undergo repeat ablation after the 3-month blanking period.

Statistical analysis

Statistical analysis was performed using XLSTAT 2014 (XLSTAT Paris, France). Continuous data are presented as mean ± SD and categorical data as counts and percentages. The Student t test and χ^2 test were used to compare clinical characteristics and variables between the DC and the TC. Multivariate Cox regression analysis was employed for the DC using 14 clinical variables to identify independent predictors of ablation freedom from AF after final ablation. For each of the independent predictors of freedom from AF after final ablation Kaplan-Meier curves were generated for AF-free survival on the basis of the presence or absence of the variable for discrete variables (AF type, sex, presence of CAD, and number of antiarrhythmic drugs failed) or by ranges for the continuous variables (age and LA size). Based on the degree of separation of the Kaplan-Meier curves over time, an empirically derived point–based weighting scheme was developed. The variables with the largest separation on the Kaplan-Meier curves over time were given the highest number of points in the scoring system. The CAAP-AF acronym stands for the presenceor absence of **C**AD, the left **A**trial diameter, **A**ge, the presence of **P**ersistent or long-standing AF, the number of **A**ntiarrhythmic drugs failed, and **F**emale sex. The CAAP-AF score (range 0–13 points) is the sum of the points assigned to the 6 weighted independent variables predicting postablation freedom from AF. This score was then applied prospectively to the TC to see how it performed in a new cohort of patients undergoing AF ablation. The C statistic was calculated for both the DC and the TC. Cochran-Armitage trend analysis was performed on the 2-year AF ablation success rates as a function of CAAP-AF score for both the DC and the TC. All tests were 2-sided, and $P < .05$ was considered statistically significant.

Results

Patient population

The patient population consisted of 2 cohorts of patients undergoing AF ablation. The DC consisted of 1125 patients undergoing AF ablation from 2003 to 2010. The DC was used for retrospective evaluation and development of the CAAP-AF scoring system to predict the patient's freedom from AF after

Table 1 Comparison of clinical characteristics between the development and test cohorts

Characteristic	Development cohort	Test cohort	*P*
No. of patients	1125	937	NA
Age (y)	62.3 ± 10.3	64.9 ± 9.3	<.0005*
Sex: female	324 (28.8%)	299 (31.9%)	.135
Duration of AF (y)	6.4 ± 7.0	6.3 ± 7.6	.599
No. of drugs failed	1.30 ± 1.05	1.25 ± 1.05	.283
Left atrial size (cm)	4.30 ± 0.69	4.27 ± 0.68	.322
$CHADS_2$ score	0.88 ± 0.97	1.49 ± 1.14	<.0005*
CHA_2DS_2-VASc score	1.60 ± 1.34	2.00 ± 1.44	<.001*
Hypertension	525 (46.7%)	572 (61.0%)	<.0005*
Diabetes	100 (8.9%)	135 (14.4%)	<.0005*
Body mass index (kg/m^2)	29.5 ± 5.4	29.1 ± 5.7	.087
Paroxysmal AF	348 (30.9%)	296 (31.6%)	.738
Persistent AF	594 (52.8%)	552 (58.8%)	.007*
Long-standing AF	183 (16.3%)	89 (9.4%)	<.0005*
Prior cardioversion	528 (46.9%)	442 (47.2%)	.914
Coronary artery disease	150 (13.3%)	150 (16.0%)	.103
Dilated cardiomyopathy	91 (8.1%)	109 (11.6%)	.007*
Obstructive sleep apnea	118 (10.5%)	193 (20.6%)	<.0005*
Prior stroke/TIA	78 (6.9%)	75 (8.0%)	.399

Values are presented as mean ± SD or as n (%)
AF = atrial fibrillation; TIA = transient ischemic attack.
* = statistically significant.

their last AF ablation. The second cohort was the TC, which consisted of 937 patients undergoing AF ablation from 2010 to 2012. The CAAP-AF scoring system developed on the DC was applied to the TC to evaluate its ability to predict freedom from AF in a separate group of patients undergoing AF ablation. Table 1 shows the clinical characteristics of the DC compared with those of the TC. There were moderate differences between the 2 cohorts. The TC was older (64.9 ± 9.3 years vs 62.3 ± 10.3 years; $P < .005$), had higher $CHADS_2$ scores (1.49 ± 1.14 vs 0.88 ± 0.97; $P < .0005$) and CHA_2DS_2-VASc scores (2.00 ± 1.44 vs 1.60 ± 1.34; $P < .0001$), had more persistent AF (58.8% vs 52.8%; $P = .007$), had less long-standing persistent AF (9.4% vs 16.3%; $P < .0005$), and had more hypertension (61% vs 46.7%; $P < .0005$), diabetes (14.4% vs 8.9%; $P < .005$), dilated cardiomyopathies (11.6% vs 8.1%; $P = .007$), and obstructive sleep apnea (20.6% vs 10.5%; $P < .0005$). These clinical differences most likely represent broader patient selection for AF ablation, as older patients with more comorbidities have been ablated in later years compared with earlier years.

Evaluation of the TC

The 14 clinical variables evaluated as possible predictors of freedom from AF after the final ablation in the DC are listed in Table 2. The average duration of follow-up at the time the CAAP-AF score was developed for these 1125 patients was 2.5 ± 1.7 years. Multivariate analysis showed that 6 of these 14 variables were independent predictors of long-term freedom from AF. These included age, LA size, sex, paroxysmal vs persistent/long-standing AF, the number of previous antiarrhythmic drugs failed, and the presence or absence of coronary heart disease. Repeat multivariate analysis using these 6 variables alone indicated that all remained statistically significant independent predictors of long-term freedom from AF after final AF ablation.

Development of the CAAP-AF score

Kaplan-Meier curves for each independent predictor of long-term freedom from AF were evaluated. Figure 1 shows an example of the separation of the Kaplan-Meier curves over time for 3 of the clinical predictors. The presence of CAD (Figure 1A) reduced long-term freedom from AF after final ablation by 13% from 69% to 56%. The presence of CAD was assigned 1 point in the CAAP-AF scoring system. The presence of persistent or long-standing persistent AF compared with paroxysmal AF (Figure 1B) reduced long-term freedom from AF after final ablation by 23% from 83% to 60%. The presence of persistent or long-standing AF was assigned 2 points in the CAAP-AF score. The presence of a progressively larger left atrium (Figure 1C) reduced long-term freedom from AF after final ablation by 30% from 77% to 47%. LA size was assigned up to 4 points in the CAAP-AF score. Similarly, points were assigned to the other 3 variables as 1 point for female sex, up to 2 points for more antiarrhythmic drugs failed, and up to 3 points for older age. This final CAAP-AF score is shown in Figure 2. The CAAP-AF acronym stands for the presence or absence of CAD, the left **A**trial diameter, **A**ge, the presence of **P**ersistent or long-standing AF, the number of **A**ntiarrhythmic drugs failed, and **F**emale sex. The CAAP-AF score can range from 0 to 13 points.

Freedom from AF based on the CAAP-AF score in the DC

Table 3 shows freedom from AF after final AF ablation at the time of follow-up by each CAAP-AF score in the DC. There was a decrease in the percentage of patients free from AF as the CAAP-AF score increased, which was found to be statistically significant by using the Cochran-Armitage trend test ($P < .0001$).

Because of the small number of patients in the low and high CAAP-AF score groups, Kaplan-Meier curves were created for ranges of CAAP-AF scores and are shown in Figure 3A. This shows a 4-year freedom from AF of ~85% for those patients with the lowest CAAP-AF scores and a <50% freedom from AF for those with the highest CAAP-AF scores. The C statistic for the CAAP-AF score was 0.691 (Figure 4A).

Prospective evaluation in the TC

The average duration of follow-up for these 937 patients was 1.8 ± 0.9 years. Table 3 shows freedom from AF after final AF ablation at the time of follow-up by each CAAP-AF score in the TC. An increase in CAAP-AF scores was associated with a decrease in the percentage of patients free from AF, which was found to be statistically significant by using the Cochran-Armitage trend test ($P < .0001$). Because of the small number of patients in the low and high CAAP-AF score groups, Kaplan-Meier curves were created for ranges of CAAP-AF scores and are shown in Figure 3B. This

Table 2 Multivariate Cox regression analysis of factors affecting AF recurrence in the development cohort after ≥1 AF ablation procedures (ie, final outcome)

Variable	Hazard ratio	Hazard ratio 95% Boundary	*P*
Age	1.024	1.011–1.038	.0044*
Left atrial size	1.421	1.175–1.718	.00029*
Sex: male vs female	0.492	0.381–0.635	<.0001*
Paroxysmal vs persistent/long-standing AF	0.389	0.255–0.594	<.0001*
No. of antiarrhythmic drugs failed	1.223	1.105–1.354	<.0001*
Coronary disease (present vs absent)	1.443	1.057–1.970	.021*
AF duration	1.007	0.992–1.023	.374
Obstructive sleep apnea	1.272	0.877–1.844	.205
Dilated cardiomyopathy	1.468	0.953–2.261	.082
NYHA functional class	0.917	0.766–1.097	.342
Prior cardioversion	1.139	0.725–1.277	.790
Body mass index	0.991	0.968–1.015	.479
Hypertension (present vs absent)	0.920	0.721–1.172	.498
Diabetes (present vs absent)	1.204	0.824–1.579	.338

AF = atrial fibrillation; NYHA = New York Heart Association.
*Statistically significant.

shows a 3-year freedom from AF of 90% for those patients with the lowest CAAP-AF scores to just over 60% for those with the highest CAAP-AF scores. The C statistic for the CAAP-AF score was 0.650 (Figure 4B).

Comparison of the DC and the TC

Because of the different time of follow-up in the 2 cohorts, we compared the AF-free rate at 2 years between the DC and the TC (Figure 5). Both cohorts show a decline in freedom from AF with an increase in CAAP-AF scores. The TC has a slightly higher rate of freedom from AF than does the DC, probably because of technological improvements and operator experience over time.

Repeat ablation

Although there was a modest increase in the average number of ablation procedures performed per patient with higher CAAP-AF scores in both the DC (ranging from 1.23 ± 0.44 ablation procedures for scores 0–3 and 1.37 ± 0.55 ablation procedures for scores ≥8) and the TC (ranging from 1.17 ± 0.41 ablation procedures for scores 0–3 and 1.27 ± 0.4 ablation procedures for scores ≥8), this did not reach statistical significance in either the DC or the TC.

Discussion

The main finding of this study is that based on simple and easily obtained clinical variables that are available before any ablation is performed, it is possible to develop a clinical scoring system that predicts long-term freedom from AF after ablation. When applied prospectively to a new population of patients undergoing AF ablation, this score was also able to predict long-term freedom from AF after ablation.

All the individual clinical variables that proved to be independent predictors of ablation success have been previously reported to influence AF ablation outcome. LA size is the most commonly cited predictor of ablation outcome. Numerous studies[3,4,6] have shown that larger LA size is associated with poorer long-term outcome of AF ablation. Persistent AF has also been shown in almost all studies to be associated with a poorer long-term outcome after ablation when compared with paroxysmal AF.[3,4,6] Older age,[7,8] female sex,[9] and the presence of CAD[4] have also all been shown to

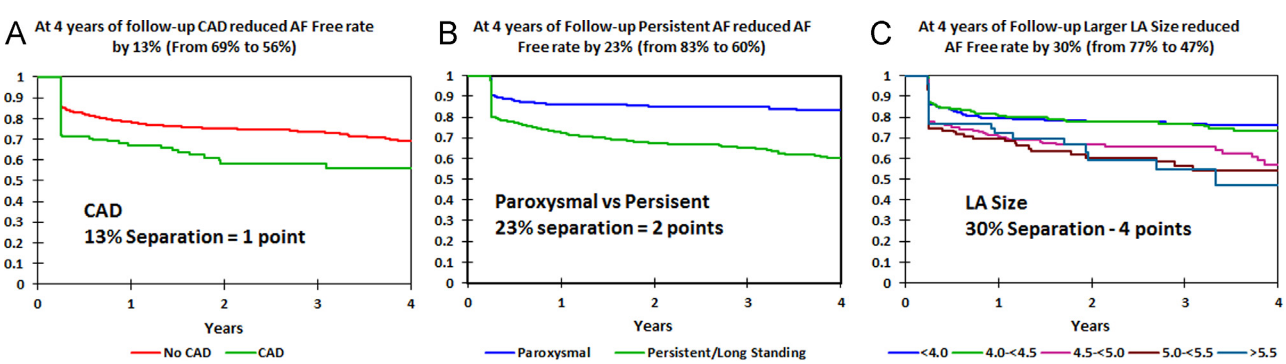

Figure 1 Kaplan-Meier curves for freedom from AF after final AF ablation by presence or absence of CAD (**A**), by type of AF (**B**), and by ranges of LA size (**C**). Parameters associated with larger separation of the Kaplan-Meier curves were given more weight in the CAAP-AF score. AF = atrial fibrillation; CAAP-AF = presence or absence of *c*oronary artery disease, left *a*trial diameter, *a*ge, presence of *p*ersistent or long-standing atrial fibrillation, number of *a*ntiarrhythmic drugs failed, and *f*emale sex; CAD = coronary artery disease; LA = left atrial.

	Clinical Descriptor	Score
C	Coronary Artery Disease	1
A	Atrial diameter (left, cm)	
	<4.0	0
	4.0--<4.5	1
	4.5-<5.0	2
	5.0-<5.5	3
	≥5.5	4
A	Age	
	<50	0
	50-<60	1
	60-<70	2
	≥70	3
P	Persistent or longstanding AF	2
A	Antiarrhythmics failed	
	None	0
	1 or 2	1
	>2	2
F	Female gender	1
	Maximum score	13

Figure 2 CAAP-AF score. CAAP-AF = presence or absence of *c*oronary artery disease, left *a*trial diameter, *a*ge, presence of *p*ersistent or long-standing atrial fibrillation, number of *a*ntiarrhythmic drugs failed, and *f*emale sex.

influence AF ablation outcome. Other studies have shown that obstructive sleep apnea[16] is associated with a poor ablation outcome. We did not find sleep apnea to be an independent predictor of outcome. This may have been due to underdiagnosis in our patient population. We did not formally screen patients for obstructive sleep apnea, but instead relied on their clinical history as to whether they had been given this diagnosis previously. We also did not try to account for those patients who had their sleep apnea treated by surgery or by positive pressure breathing machines. Several studies[12–14] have shown that both the $CHADS_2$ and CHA_2DS_2-VASc scores are correlated with AF ablation outcome. We did not include these derived scores in our analysis as they do not provide independent clinical information. They are each derived from parameters such as age, sex, left ventricular dysfunction, hypertension, CAD, and diabetes, all of which were included individually in our multivariate analysis.

The extent of LA scar, as assessed by delayed enhancement cardiac magnetic resonance imaging (MRI), has also been shown to predict AF ablation outcome—the greater the amount of scar, the worse the outcome.[20] Those patients with the lowest amount of LA scar on MRI had a 475-day AF recurrence rate of 15.3%, and there was a stepwise worsening outcome as LA scar burden increased. The patients with the largest amount of LA scar had a 475-day ablation failure rate of 69.4%. These failure rates are similar to those seen in our patient cohorts with the lowest, progressing to the highest CAAP-AF scores. One of the reasons that the CAAP-AF score compares favorably to the predictive value of a cardiac MRI is that there is probably a strong correlation between LA scar and LA atrial size. A study by Verma et al[21] showed that in patients undergoing AF ablation, more extensive LA scar as measured by voltage mapping at the time of ablation was associated with a much poorer ablation outcome. In that study, the average LA dimension of patients without LA scar was 4.0 ± 0.8 cm vs a dimension of 4.9 ± 0.7 cm in patients with extensive LA scar. It seems appropriate that the CAAP-AF score assigns the most points of any variable to LA size. The simple clinical variables used in the CAAP-AF score may be more appealing to most ablationists and medical insurers rather than obtaining an expensive cardiac MRI, which may be available and reproducibly measured only at specialized centers. The parameters in the CAAP-AF score are readily available preablation and do not depend on findings obtained only during ablation, such as extent of LA scar by voltage map, slowing of AF cycle length, or AF termination by ablation.

The importance of LA scar as a predictor of long-term outcome is emphasized by a recent publication by Kosiuk et al.[22] The study derived a clinical scoring system to predict LA scar at the time of ablation. Although the score was designed to predict the extent of LA scar, it had an excellent predictive value for long-term outcome of AF ablation, not only in the population where it was derived but also in a prospective validation cohort. Several of the predictors of both LA scar and outcome, namely, larger LA diameter, older age, and female sex, were the same predictors we found for the CAAP-AF score.

As the CAAP-AF scores increased, there was a slightly better freedom from AF in the TC than in the DC. Since the TC underwent ablation in later years, this modestly improved outcome is

Table 3 Freedom from AF after final ablation by CAAP-AF score in the development cohort and the test cohort

	Number of AF-free patients/total number of patients (percentage of AF-free patients)	
CAAP-AF score	Development cohort	Test cohort
0	4/4 (100%)	4/4 (100%)
1	22/23 (95.7%)	20/23 (86.9%)
2	51/54 (94.4%)	34/38 (89.5%)
3	98/119 (82.4%)	59/64 (92.2%)
4	130/152 (85.5%)	105/116 (90.5%)
5	152/189 (80.4%)	138/161 (85.7%)
6	140/186 (75.3%)	132/175 (75.4%)
7	116/182 (67.4%)	110/148 (74.3%)
8	57/109 (52.3%)	74/109 (67.9%)
9	36/59 (52.2%)	41/60 (68.3%)
10	16/38 (42.1%)	20/29 (69.0%)
11	1/9 (11.1%)	4/10 (40.0%)
12	0/1 (0.00%)	None
13	None	None
Total	823/1125 (73.2%)	741/937 (79.1%)

AF = atrial fibrillation; CAAP-AF = presence or absence of *c*oronary artery disease, left *a*trial diameter, *a*ge, presence of *p*ersistent or long-standing atrial fibrillation, number of *a*ntiarrhythmic drugs failed, and *f*emale sex.

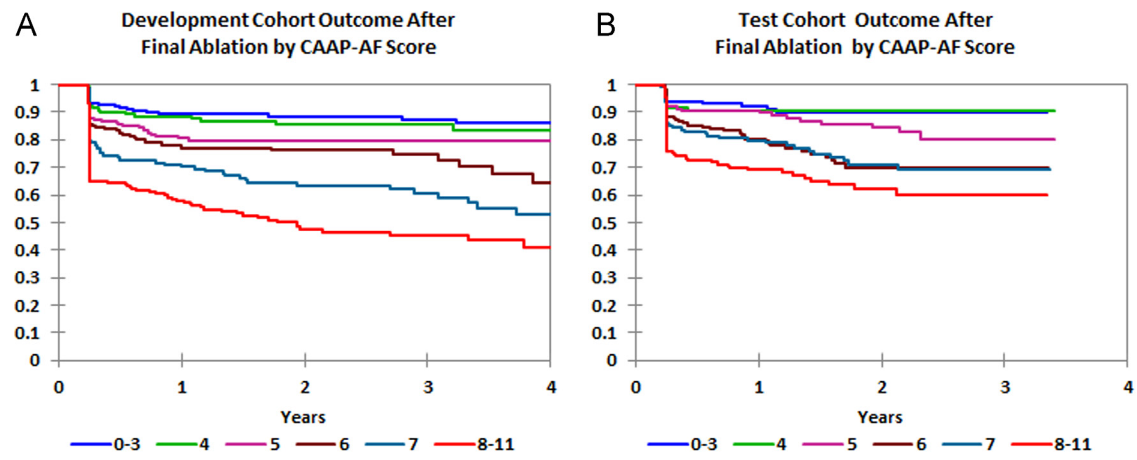

Figure 3 Kaplan-Meier curves for freedom from AF after final AF ablation by CAAP-AF score in the development cohort (**A**) and in the test cohort (**B**). AF = atrial fibrillation; CAAP-AF = presence or absence of *c*oronary artery disease, left *a*trial diameter, *a*ge, presence of *p*ersistent or long-standing atrial fibrillation, number of *a*ntiarrhythmic drugs failed, and *f*emale sex. The vertical axis represents the proportion of patients free of AF at each time interval.

likely related to improvements in mapping, ablation catheters, and operator experience. We have previously shown that ablation outcomes improved year by year for both paroxysmal and persistent AF but not for long-standing persistent AF.[23]

We do not believe that any single clinical variable or combination of variables should be the sole determinant of which patients should undergo AF ablation. Certainly, for those patients with a low CAAP-AF score, the excellent anticipated freedom from AF should encourage physicians to recommend that these patients undergo ablation therapy earlier rather than later. For patients with high CAAP-AF scores, who are extremely symptomatic or developing left ventricular dysfunction, ablation therapy may still be appropriate despite a lower likelihood of success. Although the CAAP-AF score predicted outcome in the TC quite well, the TC had an overall better outcome than did the DC despite the TC being a somewhat sicker group with such factors as older age and more hypertension, diabetes, and obstructive sleep apnea. This improved outcome likely represents the impact of better ablation technology and ablation experience in more recent years. The use of this type of scoring system should help both physicians and patients in deciding whether to pursue catheter ablation for AF.

Study limitations

This was a single-center study. It remains for other centers with slightly different ablation techniques or experience to verify or improve upon the CAAP-AF score in their populations. Patients did not have implantable loop recorders after ablation, so we undoubtedly missed some episodes of asymptomatic AF. We have previously examined the recurrence rate of silent AF in patients we have classified as free of AF[24] after ablation. At an average of 3.1 years of follow-up, 7-day continuous ECG monitoring showed that only 4.3% of patients had more than a 30-second episode of atrial arrhythmia and only 1.6% of patients had an AF burden exceeding 1%. Therefore, our rate

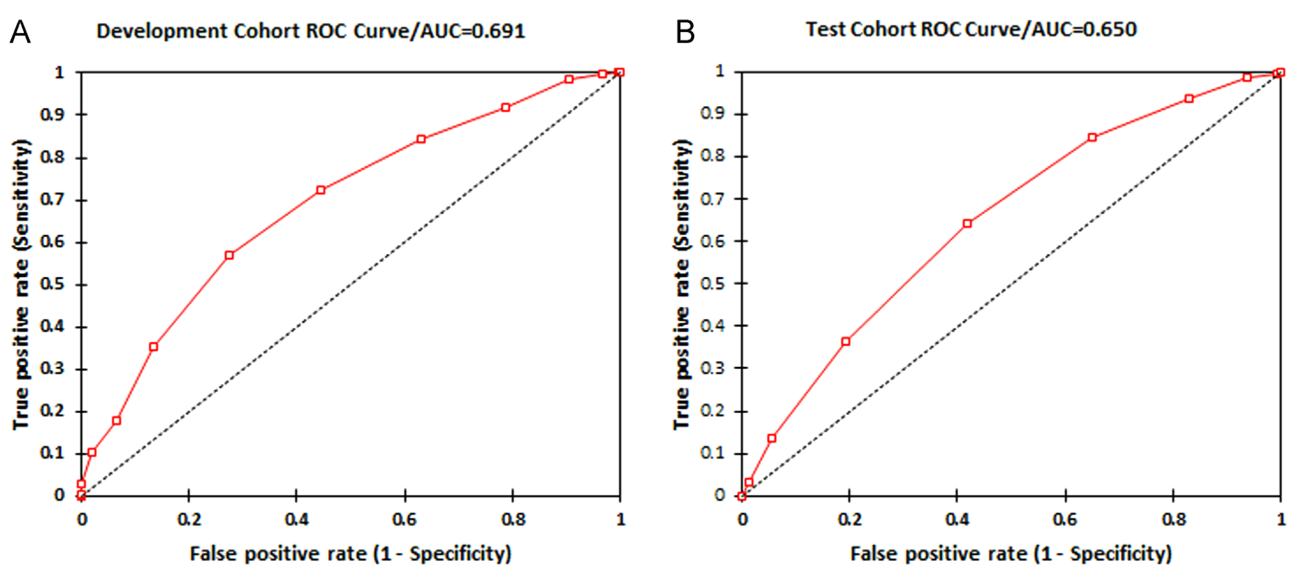

Figure 4 Receiver operating characteristic curves for the CAAP-AF score in the development cohort (**A**) and in the test cohort (**B**). AUC = area under the curve; CAAP-AF = presence or absence of *c*oronary artery disease, left *a*trial diameter, *a*ge, presence of *p*ersistent or long-standing atrial fibrillation, number of *a*ntiarrhythmic drugs failed, and *f*emale sex; ROC = receiver operating characteristic.

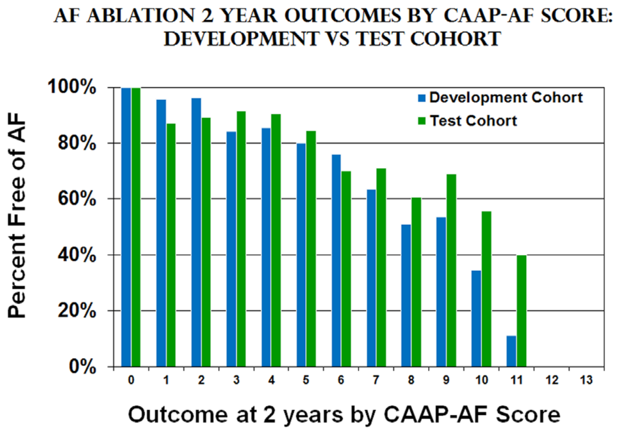

Figure 5 Comparison of 2-year freedom from AF after final AF ablation by CAAP-AF score between the development cohort and the test cohort. AF = atrial fibrillation; CAAP-AF = presence or absence of *c*oronary artery disease, left *a*trial diameter, *a*ge, presence of *p*ersistent or long-standing atrial fibrillation, number of *a*ntiarrhythmic drugs failed, and *f*emale sex.

of misclassified outcomes would appear to be fairly low. Furthermore, any missed AF should have been distributed across all CAAP-AF scores and should not influence the overall conclusions of our study. The C statistic indicates that there are probably other unknown variables that contribute to ablation success in addition to the ones included in the CAAP-AF score. Nonetheless, the C statistic for the CAAP-AF score is similar to or better than the C statistic for other commonly used predictive scoring systems based on clinical variables such as $CHADS_2$ and CHA_2DS_2-VASc scores.[25] Finally, although our CAAP-AF score was derived using simple statistical tools compared with some other predictive scores, virtually all of the other scores were derived only retrospectively and were not applied prospectively to a new cohort of similar patients for validation as we did in the present study. Regardless of how it is derived, this is the ultimate test of how a score performs.

Conclusion

An easily determined clinical scoring system was derived retrospectively and applied prospectively. The CAAP-AF score predicted the final freedom from AF after final AF ablation in both a DC and a TC of patients undergoing AF ablation. The CAAP-AF score provides a realistic expectation for freedom from AF following ablation for individual patients.

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