

Updated Worldwide Survey on the Methods, Efficacy, and Safety of Catheter Ablation for Human Atrial Fibrillation

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Background—The purpose of this study was to provide an updated worldwide report on the methods, efficacy, and safety of catheter ablation of atrial fibrillation (AF).

Methods and Results—A questionnaire with 46 questions was sent to 521 centers from 24 countries in 4 continents. Complete interviews were collected from 182 centers, of which 85 reported to have performed 20 825 catheter ablation procedures on 16 309 patients with AF between 2003 and 2006. The median number of procedures per center was 245 (range, 2 to 2715). All centers included paroxysmal AF, 85.9% also included persistent and 47.1% also included long-lasting AF. Carto-guided left atrial circumferential ablation (48.2% of patients) and Lasso-guided ostial electric disconnection (27.4%) were the most commonly used techniques. Efficacy data were analyzed with centers representing the unit of analysis. Of 16 309 patients with full disclosure of outcome data, 10 488 (median, 70.0%; interquartile range, 57.7% to 75.4%) became asymptomatic without antiarrhythmic drugs and another 2047 (10.0%; 0.5% to 17.1%) became asymptomatic in the presence of previously ineffective antiarrhythmic drugs over 18 (range, 3 to 24) months of follow-up. Success rates free of antiarrhythmic drugs and overall success rates were significantly larger in 9590 patients with paroxysmal AF (74.9% and 83.2%) than in 2800 patients with persistent AF (64.8% and 75.0%) and 1108 patients with long-lasting AF (63.1% and 72.3%) ($P < 0.0001$). Major complications were reported in 741 patients (4.5%).

Conclusions—When analyzed in a large number of electrophysiology laboratories worldwide, catheter ablation of AF shows to be effective in $\approx 80\%$ of patients after 1.3 procedures per patient, with $\approx 70\%$ of them not requiring further antiarrhythmic drugs during intermediate follow-up. (*Circ Arrhythm Electrophysiol.* 2010;3:32-38.)

Key Words: atrial fibrillation ■ catheter ablation ■ antiarrhythmic drugs ■ follow-up studies

Catheter ablation (CA) has been proven to effectively cure atrial fibrillation (AF) in variable proportions of patients with this arrhythmia,¹⁻⁶ and its popularity continues to escalate.^{7,8} A few years ago, a large international survey was conducted with the aim of providing data on CA of AF over a wide spectrum of patients, techniques, and electrophysiology (EP) laboratories with variable experience.⁷ The study results reflected the evolution in the predominant techniques during the years after the introduction of this therapy, its increasing penetration in clinical practice, and the efficacy and safety observed in 8745 patients from ≈ 100 EP laboratories between 1995 and 2002. Data from this survey sug-

gested that this therapy was less effective and safe than reported in literature.^{1-3,9-11} CA of AF has evolved, leading to newer techniques applied to broadened indications in sicker patient categories.¹² The impact of recent developments and increasing investigators experience in everyday practice has not been assessed.

Clinical Perspective on p 38

The purpose of the present study was to provide an updated survey on the most recent methods, efficacy, and safety of CA of AF obtained in a large retrospective case series over a broad spectrum of EP laboratories.

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The present article reports on a clinical trial that has not been registered because it is a retrospective survey.

The online-only Data Supplement is available at <http://circep.ahajournals.org/cgi/content/full/CIRCEP.109.859116/DC1>.

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Methods

Study Design

Data relevant to the study purpose were drawn from a questionnaire developed by an independent steering committee (represented in the authors' list) with the aim of investigating the methods and efficacy of CA of AF as observed in a large number of EP laboratories worldwide between 2003 and 2006 (see supplemental material). The survey was approved by the institutional review board at Policlinico San Donato.

The questionnaire was sent to 791 e-mail and/or facsimile doctor addresses corresponding to 521 eligible EP centers worldwide. Contacts were selected from the following sources: the Heart Rhythm Society member list, the European Society of Cardiology member list, and official lists of national working groups on arrhythmias in the different countries of Europe, Asia, North Central and South America, Africa, and Asia/Australia/New Zealand. Between March and November 2006, selected addresses were contacted using facsimile reinforced by e-mail in all cases. For those not responding after the first contact, a second contact was attempted 1 month later using the same modalities. Each nonresponder was telephoned to confirm the contact information. All questionnaires were submitted under the assumption that the identity of physicians and institutions would remain anonymous. Completed questionnaires were sent to an independent statistical center (Bioepidemiology Center of Policlinico, San Donato, Italy) for analysis. All data were entered into a database using Excel, and the statistical analysis was performed using the SPSS software.

The questionnaire comprised 46 questions (see supplemental material) addressing the following issues: year of start of a CA program; number of catheter procedures performed each year; whether a CA program attempting curative treatment of AF had been started and year of start; the different techniques used; patient entry criteria and characteristics; anticoagulation techniques used before, during, and after the ablation procedure; success rate with and without adjuvant antiarrhythmic drugs (AADs); number of procedures per patient to obtain the reported success rates; and the incidence of each of a preselected list of complications.

An interview was considered "complete" if more than 80% of applicable questions inclusive of crucial questions were answered.¹³ An interview was considered "partial" if less than 80% of applicable questions were answered. For the purpose of the present study, crucial questions were those addressing outcome measures (questions 23 and 24) and safety measures (questions 26 through 46). Only complete interviews were used to generate the database of this study. All centers with a complete interview had a 100% response rate to the requested questions.

Of the 521 identified centers, 12 were ineligible to participate in the survey because they declared inability to retrieve the requested information and 21 were ineligible because they did not perform interventional electrophysiology. This yielded a raw eligibility rate of 94%. Eligible centers were representative of 24 nations on 4 continents. Of the 488 eligible centers, 327 responded to the questionnaire, for an overall response rate of 67%. Of these, 85 were complete interviews and 242 were incomplete interviews, including 97 interviews from centers declaring no active program for catheter ablation of atrial fibrillation. One hundred sixty-one interviews were not returned.

To investigate the contribution on clinical outcome of most recent experience and developments^{4,5,8,14-17} in comparison to our previous survey,⁷ responders were required to report outcome measures collected during the 2 most recent years of activity. Subgroup analyses of outcome measures were predetermined according to the geographical location of ablation center (ie, North America, Europe, and Asia/Australia), number of AF ablation procedures performed (ie, from 1 to 30, from 31 to 60, from 61 to 90, from 91 to 120, from 121 to 150, from 151 to 180, from 181 to 230, from 231 to 300, and above 300), type of AF (ie, paroxysmal, persistent, and long-lasting as categorized according to recent guidelines),¹² type of mapping/ablation strategy (ie, Lasso-guided versus Carto-guided), and type of ablation catheter (ie, 4-mm tip and irrigation/cooled tip). These ablation techniques and ablation catheters were selected post hoc as they were those most frequently used by centers participating in the

Table 1. Entry Criteria, Outcome, and Complications in the 2 Surveys

	Previous Survey	Current Survey
Period Investigated	1995–2002	2003–2006
No. of centers enrolled	90	85
No. of patients	8745	16 309
No. of patients per center	97	192
No. procedures	12 830	20 825
No. procedures per patient	1.5	1.3
Male, %	63.8	60.8
Lower and upper age limit for entry	18–82	15–90
Proportion of centers (%) performing ablation of		
Paroxysmal AF	100	100
Persistent AF	53.4	85.9
Long-lasting AF	20	47.1
Success rate, %, median		
Free of AADs	52.0	70.0
With AADs	23.5	10.0
Overall	75.5	80.0
Proportion of centers (%) using as exclusion		
Left atrial size upper limit	46.3	31.8
Prior heart surgery	65.1	23.5
Lower cut-off limit of LVEF	64.3	22.4
Overall complication rate, %	4.0	4.5
Iatrogenic flutter	3.9	8.6

surveys. Subgroups were formed based on patients treated in centers with exclusive experience in the analyzed strategies.

Statistical Analysis

The analysis of success and failure was made using a mixed-effect logistic regression. Because the unit of observation (patient) was different from the unit of analysis (center), a within-center correlation of outcomes was taken into account by means of a random-effect analysis with grouping by center. The models were fit separately for each outcome (success without AADs and success with AADs) and for type of AF, type of ablation catheter, and ablation strategy. Models were adjusted for year of start of CA program and number of procedures performed by center considered as continuous variables. The effects of factors of interest (whether categorical or continuous) were evaluated by odds ratios (OR), along with confidence intervals (CI) as well as model-based Wald tests. Nonlinear effects on continuous covariates were investigated by means of restricted cubic splines with three knots. The regression models including type of ablation catheter and catheter type were adjusted only by the number of procedures performed. Comparisons of success rates and incidence of postablation iatrogenic flutter between the previous and the present survey were made using exact testing procedures. Analyses were performed by SPSS-PC+ (SPSS-PC+, Inc, Chicago, Ill) and R software (www.R-project.org). A probability value <0.05 was considered to indicate statistical significance.

Results

Table 1 summarizes the entry criteria, outcome parameters, and complication rates of the present survey in comparison with those of our previous survey conducted between 1995 and 2002.⁷ In the 85 centers with complete interviews, 16 309

Table 2. Distribution of Centers and Patients According to Performed Ablation Technique

Technique	No. of Centers	No. of Patients	%*
RAC	8	75	0.5
CA-TF	10	222	1.6
OED	34	3889	27.4
Carto			
w/o PV isolation	15	1460	10.3
w/ PV isolation	37	5394	37.9
3D noncontact	11	663	4.7
Basket	10	150	1.1
CFAEs	16	349	2.4
Other	5	968	6.8
Combination	19	1048	7.4
Total	165	14 218	100.0

RAC indicates right atrial compartmentalization; CA-TF, catheter ablation of the triggering focus; OED, Lasso-guided ostial electrical disconnection of pulmonary veins; PV, pulmonary vein; CFAE, catheter ablation of fragmented atrial electrograms.

*Proportion of patients undergoing CA of AF with the use of the indicated technique.

patients underwent 20 825 procedures over 18 (range, 3 to 24) months of follow-up. This yielded a median of 245 procedures per center (range, 2 to 2715) and 1.3 procedures per patient. Single, dual, and triple transseptal punctures were used in 37.1%, 59.8%, and 4.1% of centers, respectively. Males represented 60.8% of patients. The lower and upper age limits for entry were 15 years and 90 years, respectively. Ninety-five percent of centers reported drug refractoriness as a prerequisite for entry in their catheter ablation program; 52% of centers reported to include patients with all clinical forms of AF, 38.8% to include patients with paroxysmal or persistent AF, and 14.1% to include patients with paroxysmal AF only. A list of the exclusion criteria and relative proportion of centers adopting them for patient selection are reported in Table 1.

Ablation Strategy

Data relative to the technique used for ablation were made available for 14 218 patients. In these patients, the use of 8 different strategies was reported (Table 2). Carto-guided ablation or ostial electric disconnection were used in 10 743 patients (75.6%), with the former strategy being used in 6854 patients (48.2%) and the latter strategy in 3889 patients (27.4%). In 68.7% of patients in the Carto-guided group, catheter ablation was performed with the aim of producing pulmonary vein (PV) isolation, whereas in the remaining patients PV isolation was not

a required procedure end point. 3D noncontact mapping was used in 4.7% of patients, ablation guided by catheter ablation of fragmented atrial electrograms (CFAE) in 2.4% of patients, and a combination of 2 or more strategies in 7.4% of patients. Data relative to the modality used for energy delivery were made available for 17 729 patients, of whom 12 068 (68.1%) received radiofrequency (RF) current delivered through an irrigated (46.4%), cooled (20.4%), or 8-mm tip electrode (1.3%), 5449 received RF current delivered through conventional 4-mm tip electrode, 207 (1.2%) underwent cryo-ablation, and 5 (0.002%) ultrasound ablation.

Clinical Outcome

Of 16 309 patients, 10 488 (median, 70.0%; interquartile range, 57.7% to 75.4%) became asymptomatic in the absence of any AAD, whereas another 2047 (10.0%; 0.5% to 17.1%) became asymptomatic with the continued use of formerly ineffective AADs during 10±8 months of follow-up. A minimum follow-up of 4 months was reported by all centers. Similar to what was observed in the previous survey,⁷ all centers reported freedom from documented AF as the definition of success. Therefore, 12 535 patients (80.0%; 74.0% to 83.8%) obtained resolution of symptoms after completion of any of the ablation protocols used. The success rate free of AADs was 69.9% in 11 centers performing catheter ablation of paroxysmal AF only, 61.3% in 33 centers performing catheter ablation of paroxysmal and persistent AF, and 62.0% in 41 centers performing catheter ablation of paroxysmal, persistent, and long-lasting AF.

Outcome data in relationship with the type of AF were made available for 16 155 patients (Table 3). Success rates free of AADs were significantly lower in patients with persistent AF (OR, 0.61; CI, 0.54 to 0.69) and long-lasting AF (OR, 0.41; CI, 0.34 to 0.49) than in patients with paroxysmal AF (Table 4). No significant nonlinear effects for the number of procedures performed and for the year of start of CA program were evidenced by means of the Wald test. The odds of success free of AADs increased with the number of procedures performed per center ($P=0.007$) (Table 4). Overall success rates (free of AADs and with AADs) were significantly lower in patients with persistent AF (OR, 0.57; CI, 0.49 to 0.66) and long-lasting AF (OR, 0.40; CI, 0.33 to 0.49) than in patients with paroxysmal AF. The odds of overall success did not correlate with the number of procedures performed per center ($P=0.08$) (Table 4).

Success rates did not differ in Europe versus North America versus South America versus Asia/Australia/New Zealand (AAD free: $\chi^2_3=1.2$; $P=0.76$; overall: $\chi^2_3=2.2$; $P=0.54$) (Table 4). These outcomes were achieved with a similar median

Table 3. Success Rates in Relationship With the Type of AF

Type of AF	Success Without AADs				Success With AADs		Overall Success	
	No. of Centers	No. of Patients	No. of Patients	Rate, Median (Interquartile Range)*	No. of Patients	Rate Median (Interquartile Range)*	No. of Patients	Rate Median (Interquartile Range)*
Paroxysmal	85	9590	6580	74.9 (64.9–82.6)	1290	9.1 (0.2–14.7)	7870	84.0 (79.7–88.6)
Persistent	73	4712	2800	64.8 (52.4–72.0)	595	10.0 (0.8–15.2)	3395	74.8 (66.1–80.0)
Long-lasting	40	1853	1108	63.1 (53.3–71.4)	162	7.9 (0.9–15.9)	1270	71.0 (67.4–76.3)

*Median and interquartile range are calculated using center as unit of analysis.

Table 4. Multivariable Models

	Free of AADs			Overall		
	<i>P</i>	OR	(95% CI)	<i>P</i>	OR	(95% CI)
AF type						
Persistent vs paroxysmal	<0.001	0.61	0.54–0.69	<0.001	0.57	0.49–0.66
Long-lasting vs paroxysmal	<0.001	0.41	0.34–0.49	<0.001	0.40	0.33–0.49
Year of start	0.38	1.02	0.98–1.05	0.17	1.02	0.99–1.06
Procedures	0.007	1.04	1.01–1.06	0.08	1.021	0.99–1.04
Increase of 30 procedures						
Area						
North America vs Europe		1.07	0.67–1.70		0.98	0.64–1.48
South America vs Europe	0.76	0.77	0.22–2.65	0.54	1.28	0.44–3.74
Asia/Oceania vs Europe		1.33	0.72–2.47		1.45	0.83–2.54
AF type						
Persistent vs paroxysmal	<0.001	0.65	0.57–0.75	<0.001	0.58	0.48–0.69
Long-lasting vs paroxysmal	<0.001	0.34	0.27–0.43	<0.001	0.29	0.21–0.39
Catheter						
Irrigated vs 4-mm	0.88	0.96	0.55–1.68	0.01	0.49	0.29–0.83
Procedures	0.06	1.04	0.99–1.07	0.76	1.01	0.97–1.03
Increase of 30 procedures						
AF type						
Persistent vs Paroxysmal	<0.001	0.63	0.53–0.76	<0.001	0.56	0.44–0.70
Long-lasting vs paroxysmal	<0.001	0.37	0.26–0.52	<0.001	0.30	0.20–0.45
Ablation strategy						
Lasso vs Carto	0.14	1.62	0.88–2.99	0.37	1.42	0.67–3.00
Procedures	0.71	1.00	0.96–1.04	0.77	0.99	0.94–1.04
Increase of 30 procedures						

The *P* value, OR, and corresponding 95% CIs are reported for success rates free of AADs and overall success rates according to the different parameters investigated (AF type, year of start, geographic area, type of catheter, and ablation strategy). The OR for procedures estimates the role of center experience as calculated in steps of 30 procedural units.

number of procedures per patient (Europe, 1.4; North America, 1.3; South America, 1.3; Asia/Australia/New Zealand, 1.4).

Outcome data in relationship with the type of ablation catheter and CA strategy used were made available for 9566 patients (Table 5) and 10 781 patients (Table 6), respectively. The proportion of success rates free of AADs did not differ between 6674 patients undergoing CA with the use of an irrigated/cooled tip catheter versus 2892 patients undergoing CA with the use of a 4-mm tip catheter (*P*=0.88; OR, 0.96; CI, 0.55 to 1.68) (Table 4). When considering overall success, the odds of success was at 0.49 (CI, 0.29 to 0.83; *P*=0.01), significantly larger with the use of irrigated/cooled tip catheter than with the 4-mm tip catheter.

Similarly, the proportion of success rates free of AADs did not differ between 3722 patients undergoing CA using a Lasso-guided strategy versus 7059 patients undergoing CA using a Carto-guided strategy (*P*=0.14) (OR, 1.62; CI, 0.88 to 2.99). When considering success free of AADs and with AADs, the odds of success with the use of Lasso-guided versus Carto-guide strategy were at 1.42 (CI, 0.67 to 3.00), still not significant (*P*=0.37) (Table 4).

Anticoagulation Strategies

Before ablation, subcutaneous (4.1%), low-molecular-weight (27.5%), or intravenous heparin (7.2%) was used, regardless

Table 5. Success Rates in Relationship With Type of Ablation Catheter

Type of Catheter	No. of Centers	No. of Patients	Success Without AADs		Success With AADs		Overall Success	
			No. of Patients	Rate, Median (Interquartile Range)*	No. of Patients	Rate, Median (Interquartile Range)*	No. of Patients	Rate, Median (Interquartile Range)*
4-mm	23	2892	1803	68.3 (48.4–80.8)	609	11.5 (8.6–26.7)	2412	79.8 (65.0–82.2)
Irrigated/cooled	39	6674	3891	67.9 (44.7–73.6)	721	9.0 (0.0–14.8)	4612	76.9 (66.4–82.5)
Total	62	9566	5694	68.1 (46.2–73.6)	1330	10.0 (0.0–20.0)	7024	78.1 (66.8–86.7)

*Median and interquartile range are calculated using center as unit of analysis.

Table 6. Success Rates in Relationship With Type of Ablation Strategy

Type of Strategy	No. of Centers	No. of Patients	Success Without AADs		Success With AADs		Overall Success	
			No. of Patients	Rate, Median (Interquartile Range)*	No. of Patients	Rate, Median (Interquartile Range)*	No. of Patients	Rate, Median (Interquartile Range)*
Lasso	21	3722	2616	78.0 (67.9–78.8)	499	6.7 (0.0–13.3)	3115	84.7 (78.8–89.5)
Carto	33	7059	4369	69.8 (56.8–73.4)	795	10.4 (5.1–13.0)	5164	80.2 (76.8–83.8)
Total	54	10 781	6985	71.1 (58.3–78.0)	1294	10.0 (0.0–13.0)	8279	81.1 (73.3–86.0)

*Median and interquartile range are calculated using center as unit of analysis.

of whether or not patients were taking long-term oral anticoagulants. A transesophageal echocardiogram was required before the ablation procedure in 73.2% of centers. During the ablation procedure, 94.9% of centers reported using intravenously administered heparin, of which 79.4% were guided by activated clotting time (minimum activated clotting time range, 200 to 350 seconds), whereas 15.5% were not. After ablation, 84.5% of centers used oral anticoagulants, whereas aspirin was administered in 13.4% of centers and clopidogrel in 2.1% of centers.

Complications

A major complication occurred in 741 patients (4.5%). A detailed list of the different complications reported with their relative incidence is outlined in Table 7. There were 25 procedure-related deaths, 37 strokes, 115 transient ischemic attacks, and 213 episodes of tamponade. Altogether, 216 PVs sustained significant (>50%) stenosis (assessed by means of preablation and postablation PV angiography in 71.3% and magnetic resonance in 28.7% of centers), which resulted in the need for a corrective intervention in 48 patients. Atypical atrial flutter of new onset (iatrogenic) was reported in 1404 patients (8.6%) and was significantly ($P<0.001$) more frequently observed in centers using exclusively 3D Carto-guided ablation (14.3%) than in centers performing exclusively Lasso-guided ablation (1.8%).

Comparison With the Previous Survey

Compared with the previous survey (Table 1), a significantly larger proportion of centers in the current survey recruited

patients with persistent and long-lasting AF or did not contemplate exclusion criteria for catheter ablation such as left atrial size upper limits, lower cutoff limits for left ventricular ejection fraction, or prior heart surgery ($P<0.0001$). The proportion of successes free of AADs was significantly larger in the current survey (70.0%) than in the previous survey (52.0%) ($P<0.0001$); this difference was counterbalanced by a significantly larger proportion of successes with AADs in the previous survey (23.9%) than in the current survey (10.0%) ($P<0.0001$), leading to similar overall proportion of successes (79.8% in the previous survey and 80.0% in the current survey). The overall complication rate was similar in the 2 surveys ($P=0.691$), but iatrogenic flutter was significantly more frequent in the present survey ($P<0.0001$).

Discussion

There are 8 main observations collected from the present survey: (1) CA is increasingly being offered to patients with AF; (2) it is increasingly being offered to sicker AF patients; (3) 2 mapping/ablation techniques have become established as the most frequently used; (4) PV isolation is used as an acute procedural end point in the majority of centers, regardless of the mapping technique used; (5) RF remains the dominant energy form used for CA of AF; (6) proportions of success free of AADs appear to increase with experience; (7) the proportion of overall successes does not appear to have improved, as better results with CA only appear to be counterbalanced by poorer efficacy of previously ineffective AADs; and (8) complication rates and incidence of iatrogenic atrial flutter do not appear to be decreased with experience.

The increase in CA procedures performed during the investigated years was corroborated by an almost 2-fold increase in number of patients treated between 2003 and 2006 as compared with between 1995 and 2002.⁷ Also, compared with the previous survey, $\approx 15\%$ more centers included patients with persistent and long-lasting AF, and $\approx 30\%$ more centers included patients with larger atria, presence of left ventricular dysfunction, and prior heart surgery. The dominant role of Carto and Lasso strategies was outlined by the large proportion of patients ($\approx 50\%$ and 25% , respectively) receiving these techniques. In the remaining patients, techniques such as 3D noncontact, basket, CFAE, and search for the triggering focus of AF were used alone or in variable combination. PV isolation was reported as an acute EP end point in 75% of patients undergoing Carto-guided ablation; when added to the totality of patients receiving Lasso-guided ablation, this figure outlines the development of a dominant perception that PV isolation is an important requisite for CA

Table 7. Major Complications in the Overall Population

Type of Complication	No. of Patients	Rate, %
Death	25	0.15
Tamponade	213	1.31
Pneumothorax	15	0.09
Hemothorax	4	0.02
Sepsis, abscesses, or endocarditis	2	0.01
Permanent diaphragmatic paralysis	28	0.17
Total femoral pseudoaneurysm	152	0.93
Total artero-venous fistulae	88	0.54
Valve damage/requiring surgery	11/7	0.07
Atrium-esophageal fistulae	6	0.04
Stroke	37	0.23
Transient ischemic attack	115	0.71
PV stenoses requiring intervention	48	0.29
Total	741	4.54

of AF.¹⁸ RF current was used in more than 98% of patients; ≈70% of patients received RF current delivered through an irrigated-tip (two thirds of cases) or cooled-tip (one third of cases) electrode, whereas the remaining 30% received RF current delivered through the conventional 4-mm tip electrode. Cryoablation was used in fewer than 2% of all patients.

The proportion of successes free of AADs was 64.3% with an additional 12.5% gained with the continued use of previously ineffective AADs. Success rates free of AADs of 70.0% (range, 57.7% to 75.5%) and overall success rates of 80.0% (range, 74.4% to 83.8%) represent a most probable outcome figure in centers with a mean experience, as they were obtained after removal of the contribution from centers with the least and the most experience, respectively. Factors such as a reduced prevalence of ineffective techniques (ie, right atrial compartmentalization or ablation of the PV trigger) and completion of learning curve may have contributed to improved efficacy in this survey as compared with the previous survey.⁷

The overall incidence of major complications was 4.5%. Tamponade was the most frequent complication, but its rate was comparable to values commonly observed during CA of other arrhythmogenic substrates.^{19,20} Death and stroke did not differ in the 2 surveys, whereas transient ischemic attacks and PV stenoses were reduced by at least 2-fold and 3-fold, respectively. Atrio-esophageal fistulae were not reported in the previous survey and presented with a 0.04% rate in the present survey, with 71% of events leading to death. Atypical atrial flutter of new onset almost doubled in this survey.

Subgroup Analyses

Success rates did not differ among the 4 continents, suggestive of similar efficacy standards obtained around the world after ≈10 years of experience in CA of AF. Success rates were higher in patients with paroxysmal AF than in patients with persistent AF or long-lasting AF. AADs conferred a 20% to 25% increase in success rate regardless of the type of AF.

Consistent with the previous survey,⁷ the success rate free of AADs was higher in centers with larger as compared with centers with smaller volumes of activity, but it was counterbalanced by previously ineffective AADs. As a consequence, overall success rates did not differ significantly between centers with the lowest experience and centers with the highest experience; however, it should be noted that persistent AF and long-lasting AF contributed more prevalently to the overall success figure as the center experience increased.

The success rate free of AADs did not differ between patients undergoing CA using an irrigation/cooled tip electrode and patients undergoing CA using conventional 4-mm tip electrode. This finding is not in agreement with previous studies showing that irrigated tip electrodes produce deeper lesions in the experimental setting²¹ and are more effective than conventional 4-mm tip electrode when ablating the cavo-tricuspid isthmus.²² One possible explanation for our finding may be that the full potential of irrigation/cooled tip electrode is not entirely driven to the target because of a number of conditions, including the complexity of the substrate, the lack of feed-back of tip temperature, the number of lesions required, and others, ultimately leading to a reduction of the catheter-tissue contact that disperses the delivered

power away from its target more than with the conventional technique. Irrigation/cooled electrode catheters showed a larger overall success rate, possibly reflecting larger degrees of substrate modification as compared to 4-mm tip electrodes and ultimately enabling an improved AAD efficacy. Finally, success rate free of AADs and overall success rate were similar in patients receiving Lasso-guided and Carto-guided CA.

Study Limitations

Our study has several limitations. First, these results reflect the experience of centers that elected to respond to our call and do not correspond to the experience of all contacted centers. Although 67% of the centers responded to the survey, 45% of the responses were incomplete and were not used in the analysis, so only 27% of centers were represented in any of the analyses and only 85 centers (less than 20% of those originally surveyed) contributed to the substantive analyses. However, the distribution of responding centers provides a representative sample of the general population of centers with regard to geographical distribution, variability of patient volume, and distribution of mapping and ablation techniques used. In a previous survey using the same data collection model, similar distributions of response were observed. A special value of this study relies on the possibility to comparatively assess outcome and efficacy data with those from the previous survey conducted with similar methods. The 10% increase of success rate free of AADs and the 0.8% reduction in major complication appear to reflect a trend toward improved skill by the EP community. Second, definition of success may vary when referring to catheter ablation of AF; therefore, it is possible that success rates reported in this survey indicate different clinical conditions. However, the previous survey showed that freedom from symptoms associated with AF was the only recognized definition corresponding to success among 6 alternatives by investigators from all centers.⁷ This same definition was confirmed in centers responding to both surveys and probably is representative of the majority of responders. Third, the follow-up available to test efficacy is relatively short and does not assess long-term efficacy of CA in these patients. Fourth, postablation asymptomatic AF was not investigated in this survey. The variability in monitoring methods and their accuracy together with the intensity of monitoring²³ inherently limit interpretation of data coming from a large survey. Based on this observation, it is possible that freedom of all AF episodes in the investigated population was 10% to 20% lower than that reported in this analysis. Finally, CA of AF is a rapidly evolving technique, and data collected between 2003 and 2006 may be out of date by 2009. This appears substantiated by recent reports showing very promising outcome data in patients with significant comorbidity.^{6,12}

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CLINICAL PERSPECTIVE

The use of catheter ablation to treat atrial fibrillation has been expanding worldwide, but much of the information regarding risks and outcomes is from a limited number of specialized centers. Using a center-based questionnaire, data on methods, efficacy, and safety of this technique were retrieved from 85 centers reporting more than 20 825 procedures on more than 16 000 patients. Most patients had paroxysmal rather than persistent atrial fibrillation. Clinical benefit was reported for ≈80% of patients. Major complications were reported in 4.5% of cases. Data from this self-reported registry provide an indication of the risks and benefits of atrial fibrillation in a broad population.

SUPPLEMENT MATERIAL

AFib Survey II

Questionnaire

1. Which country is your center from?
2. In which year was a catheter ablation program introduced in your center?
3. How many catheter ablation procedures have been performed at your center during the past twelve months?
4. Are you currently performing a catheter ablation program for atrial fibrillation (A Fib)?
 - A Fib ablation for the purpose of this survey includes one or more of the following
 - right atrial compartmentalization (RAC) with two or more lines
 - left atrial compartmentalization (LAC) with two or more lines from outside the atrium-to-PV ostium, and no final EP control for PV isolation
 - ablation of the PVs, including ablation of the triggering focus (TF) or isolation at the atrium-to-PV junction (PVI)
 - other techniques
 - A Fib ablation for the purpose of this survey does not include AV nodal modification or ablation
 - If your program does not meet the entry criteria for the survey, please stop your questionnaire here and return it by FAX to the data collection center (for address, see the presentation letter)
5. In which year was a catheter ablation program for A Fib introduced in your center?
6. How many patients with A Fib have undergone one or more ablation procedures at your center altogether?
7. Which of the following criteria have been used as entry or exclusion criteria in the A Fib ablation program at your center? (please, select one or more)

	Entry	Exclusion
- failed medical therapy	<input type="checkbox"/>	<input type="checkbox"/>
- left atrium size upper limit	<input type="checkbox"/>	<input type="checkbox"/>
- no prior heart surgery	<input type="checkbox"/>	<input type="checkbox"/>
- no LV dysfunction	<input type="checkbox"/>	<input type="checkbox"/>
- age limit (\leq or \geq in years)	<input type="checkbox"/>	<input type="checkbox"/>
- paroxysmal A Fib	<input type="checkbox"/>	<input type="checkbox"/>
- persistent A Fib	<input type="checkbox"/>	<input type="checkbox"/>
- permanent A Fib	<input type="checkbox"/>	<input type="checkbox"/>
- others (please, specify) _____		

8. How many patients with A Fib have undergone A Fib ablation at your center and according to which technique? (please specify one or more where appropriate)

Note: Centers that have already contributed to the former survey (see Appendix 1 of Circulation Manuscript in the Online version, ref.) should provide data only for the years 2003, 2004 and 2005.

	RAC	TF	LACA		OSD	Fragm	other
			w/ lasso	w/o lasso			
- in 1995							
- in 1996							
- in 1997							
- in 1998							
- in 1999							
- in 2000							
. in 2001							
- in 2002							
- in 2003							
- in 2004							
- in 2005							

Table legend. Fragm, Ablation of left atrial segments with fragmented activity; RAC, right atrial compartmentalization (assisted by 3-D computer reconstruction of target substrate); LACA, left atrial circumferential ablation (assisted by 3-D computer reconstruction of target substrate); OSD, PV ostial segmental disconnection; TF, PV-triggering focus ablation; PV-PVI, PV electrical isolation from atrium; other, includes triggering focus ablation, ablation of Marshall vein, ablation of coronary sinus, isolation of superior vena cava,

Note: centers reporting data on only one technique should qualify for comparative assessment of efficacy among different techniques

9. Age, from _____ to _____ years (range)

10. Sex

- male (number) _____
- female (number) _____

11. For centers aiming at PV isolation, how many PVs are targeted:

	per procedure	per patient
- 1	<input type="checkbox"/>	<input type="checkbox"/>
- 2	<input type="checkbox"/>	<input type="checkbox"/>
- 3	<input type="checkbox"/>	<input type="checkbox"/>
- 4	<input type="checkbox"/>	<input type="checkbox"/>

12. Do you routinely perform one or more of the following tests prior to and after ablation?

	Prior	During procedure	Late (months)
0 PV angiography	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1 magnetic resonance imaging (MRI)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2 computerized tomography (CT)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3 intracardiac echocardiography	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4 transesophageal echo	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5 PV scan	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Do you routinely perform TEE prior to ablation

- yes
- yes except for ...
- never

13. Do you currently routinely perform MRI or CT-scan following abl to screen for PV stenosis?

- yes
- no

14. Are you also aiming for ablation of veins other than the pulmonary veins?

If yes, which veins?

- | | |
|----------------------|----------------------|
| - superior vena cava | - number of patients |
| - Marshall vein | - number of patients |
| - coronary sinus | - number of patients |

15. Which technique are you currently (w/in last ? mos) using (indicate one or more)

- for mapping

	number of patients
0. RAC	<input type="checkbox"/>
1. TG Focus	<input type="checkbox"/>
a. Segmental, including LASSO, fluoro-guided	<input type="checkbox"/>
b. 3-D mapping CARTO	
- endpoint: not PV isolation	<input type="checkbox"/>
- endpoint: PV isolation	<input type="checkbox"/>
c. 3-D mapping noncontact	<input type="checkbox"/>
d. Basket catheter	<input type="checkbox"/>
e. high fract activity	<input type="checkbox"/>
g. a combination	<input type="checkbox"/>
g. others (please specify) _____	<input type="checkbox"/>

- for ablation

	number of patients
a. ICE-guided	<input type="checkbox"/>
b. RF standard	<input type="checkbox"/>
c. RF irrigated or cooled tip	<input type="checkbox"/>
d. ultrasound	<input type="checkbox"/>
e. cryoablation	<input type="checkbox"/>
f. laser	<input type="checkbox"/>
g. other (please specify) _____	

catheter T cut off, 8 mm (T and Power cut off), 4 mm, irr, chilli, cryo, ICE

- for TS only _____
- for TS plus targeting lesions _____

16. Are you currently employing vagal ablation (same for fract act ablation)

- as primary proc
- as adjunctive strategy

17. Do you routinely perform SVC isol

- yes n all
- only selected
- never

18. Number of procedures per patient

- how many patients required a second procedure?
- how many patients required a third procedure?

19. Number of catheters per procedure

20. Number of transseptal catheters per procedure 1 2 3

21. Mean follow-up (months) _____ and range, from _____ to _____ months

22. Which of the following is the best definition of success of catheter ablation

- a. freedom from atrial fibrillation without drugs
 - 1. yes
 - 2. no (please specify your definition)

23. Number and percent of patients in whom “success” was observed without drugs

- during the last 24 mos
 - paroysmal
 - persistent
 - permanent

24. Number and percent of patients in whom “success” was observed with drugs
 - during the last 24 mos
 - paroxysmal
 - persistent
 - permanent

25. Anticoagulation (1 or more in combination)

	pre-procedure	during procedure	post-procedure
ASA	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Clopidogrel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Oral ATCG, eg warfarin	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sq heparin	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
IV heparin			
1. ACT-guided	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. no ACT guided	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Low-molecular weight heparin	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (please specify)			

Complications,

26. Number of PV stenoses (>50%)

- acute
- chronic

27. Number of PV closures

- acute
- chronic

28. Number of patients with symptoms associated with PV stenosis or closure

- acute
- chronic

29. Number of patients requiring interventional therapy because of PV stenosis/closure

30. Number of patients requiring surgery because of PV stenosis/closure

31. Number of systemic embolic events

- prior events?	Yes _____	No _____
- transient	Yes _____	No _____
- cerebral		<input type="checkbox"/>
- cardiac		<input type="checkbox"/>
- arms		<input type="checkbox"/>
- legs		<input type="checkbox"/>
- kidney		<input type="checkbox"/>
- bowels		<input type="checkbox"/>

-other (please specify) _____

- prior events? (*)	Yes _____	No _____
- permanent	Yes _____	No _____
- cerebral		<input type="checkbox"/>
- cardiac		<input type="checkbox"/>
- arms		<input type="checkbox"/>
- legs		<input type="checkbox"/>
- kidney		<input type="checkbox"/>
- bowels		<input type="checkbox"/>

-other (please specify) _____

(*) embolic events prior to first catheter ablation: _____

32. Number of permanent neurologic events)

33. Number of iatrogenic flutters

34. Number of tamponade

35. Number of pericardial effusions

36. Number with sepsis, abscesses or endocarditis

- requiring surgery

37. Number of pneumothorax

- requiring intervention

38. Number of hemothorax

- requiring intervention

39. Number of diaphragmatic paralyses

- permanent

40. Number of femoral pseudoaneurysms

- requiring intervention

41. Number of artero-venous fistulae

- requiring intervention

42. Number of valve damage

- requiring intervention

43. Number of aortic dissections

- requiring intervention

44. Number of atrium-esophageal fistulae

- requiring surgery

- causing death

45. Number of peri-procedural early (within 30 days) deaths

intra-operative

post-operative

- cause _____

46. Number of late deaths (more than 30 days) clearly associated with procedural complications

- cause _____

Updated Worldwide Survey on the Methods, Efficacy, and Safety of Catheter Ablation for Human Atrial Fibrillation

Riccardo Cappato, Hugh Calkins, Shih-Ann Chen, Wyn Davies, Yoshito Iesaka, Jonathan Kalman, You-Ho Kim, George Klein, Andrea Natale, Douglas Packer, Allan Skanes, Federico Ambrogi and Elia Biganzoli

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