Original Research

Proarrhythmic Effects of Atrial Fibrillation Ablation Techniques

Eleftherios Giazitzoglou, Socrates Korovesis, Evangelia Karvouni, George Paxinos, Georgia Kourlaba, Demosthenes Katritsis

Department of Cardiology, Athens Euroclinic, Athens, Greece

Key words:
Atrial fibrillation, ablation, flutter, tachycardia.

Background: The incidence of proarrhythmia induced by ablation for atrial fibrillation (AF) is not entirely known. We describe the incidence and management of atrial arrhythmias occurring after various techniques for the ablative therapy of AF.

Methods: Ninety-four patients with paroxysmal AF underwent ostial pulmonary vein (PV) ablation (n=54) or circumferential ablation around the PV ostia (n=40).

Results: Atrial tachycardia or flutter was detected during the first 6 months after AF ablation in 10 patients. Atrial arrhythmia was more common among patients who underwent circumferential ablation or circumferential with lines (18.2% and 22.2%, respectively) than in those who were treated with other techniques (p=0.037). The incidence of atrial tachycardia or flutter among patients who underwent ostial ablation or ostial with lines was 2.4% and 8.3%, respectively. No difference was observed in the risk of atrial arrhythmia between patients who underwent ablation with or without additional lines, either ostial (p=0.398) or circumferential (p=0.999). Re-ablation was performed in 7 patients with sustained atrial arrhythmia. At 6 months, no recurrence of atrial tachycardia or flutter was seen in 6 of these patients, nor in 3 patients with non-sustained atrial tachycardia or flutter.

Conclusions: The incidence of atrial tachycardia or flutter following AF ablation is lower for ostial than for circumferential ablation. The addition of lines along the mitral isthmus and between the superior PVs does not significantly affect the risk of ablation-induced arrhythmia. Non-sustained atrial tachycardia or flutter during or early after AF ablation procedures does not require additional ablation.

Manuscript received:
April 18, 2006;
Accepted:
June 8, 2006.

Address:
D. Katritsis

Department of Cardiology
Athens Euroclinic
9 Athanassiadou St.
115 21 Athens, Greece
e-mail:
dkatritsis@euroclinic.gr

Atrial arrhythmias represent a serious complication of current ablation techniques for atrial fibrillation (AF) and several questions still remain regarding their incidence, particularly in relation to different ablation techniques, clinical significance, and optimum treatment. The reported incidence of left atrial tachycardia after ostial pulmonary vein (PV) ablation or circumferential ablation around the PV ostia ranges between 1% and 25%.[1-5] Usually, macro-reentrant left or right atrial arrhythmias are seen following circumferential ablation,[4,6-9] whereas focal reentrant or non-reentrant atrial tachycardias may be seen following ostial PV ablation.[2,10] However, left atrial flutter has been described following ostial PV ablation[2,7] and focal atrial tachycardia may complicate circumferential[5,11] or linear[12] ablation. Atrial tachycardia induction within the electrophysiology laboratory may not identify patients who are prone to clinical recurrences,[3] while a considerable proportion of these arrhythmias have a good prognosis without intervention.[3,13]

In this report we describe our experience with atrial arrhythmias occurring after various techniques for ablative therapy of AF.

Methods

Patients

Patients with symptomatic, paroxysmal AF who underwent catheter ablation were prospectively assessed for atrial arrhythmias other than AF. All cases of atrial arrhythmias that were induced in the electrophysiology laboratory during AF ablation or documented at follow-up, and which had not been documented prior to AF ablation, were considered for further electrophysiological evaluation and ablation. All patients gave their written, informed consent to the procedures.

Ablation techniques for AF

Left atrial ablation was performed by either segmental ostial PV isolation, with or without linear lesions between the left and right superior PVs and along the mitral isthmus, or circumferential ablation around the ostia of the PVs, with or without additional linear lesions.

Segmental ostial ablation of all PVs was accomplished with a 20 mm Lasso circular electrode (Cordis-Webster) as previously described.[14] The PV isolation end-points were the elimination of PV muscle conduction distal to the ablation site, based on abolition or dissociation of distal PV potentials, and demonstration of entrance and exit block. Circumferential ablation was performed with the aid of electroanatomical mapping (Carto, Biosence-Webster) at a distance of approximately 1-2 cm from the ostia of the left and right PVs, aimed at a voltage reduction by >80% or a peak to peak bipolar electrogram <0.1 mV (Figure 1). If these end-points were not achieved after 30 s of radiofrequency current application, the catheter was moved to the next site until completion of the circumferential lesions around the PV ostia was achieved. Linear ablation was performed following ostial or circumferential ablation along the mitral isthmus (i.e. from the left inferior PV to the mitral annulus) and the posterior wall or the roof of the left atrium (connecting the left and right superior PVs). End-points were bipolar peak to peak potentials <0.1 mV or double potentials in the lesion line (conduction delay >30 ms between contiguous points lying in the same axial plane along the line) or energy delivery at each point for 1 min.

Ablation procedures were performed using a conventional catheter with a 4 mm tip and 2.5 mm interelectrode spacing (Cordis-Webster), at a preset electrical power of 40 W, aiming at a target temperature of 52° C, or an irrigated-tip ablation catheter (infusion rate of 17 ml/min) with a 4 mm tip and 2.5 mm interelectrode spacing (Cordis-Webster), electrical power of 30 W and aiming at a target temperature of 50° C.

Electrophysiology study of atrial arrhythmias

Atrial tachycardias other than AF were documented either during the initial procedure for AF ablation or during follow-up. All patients underwent electrophysiological assessment of their arrhythmia. A detailed left atrial electroanatomical map was acquired and entrainment mapping was performed from multiple left and right atrial sites during tachycardia. Atrial tachycardias were defined as either: 1) *focal*, i.e. radial spread of activation, with sequential activation covering less than 50% of the tachycardia cycle length; 2) *macro-reentrant*, having a continuous propagation sequence with earliest and latest activation adjacent to each other (with a minimum diameter of >3 cm) and a range of activation times encompassing most of the tachycardia cycle length; or 3) *small re-entrant*, defined as circuits with a diameter <3 cm along with activation covering the en-

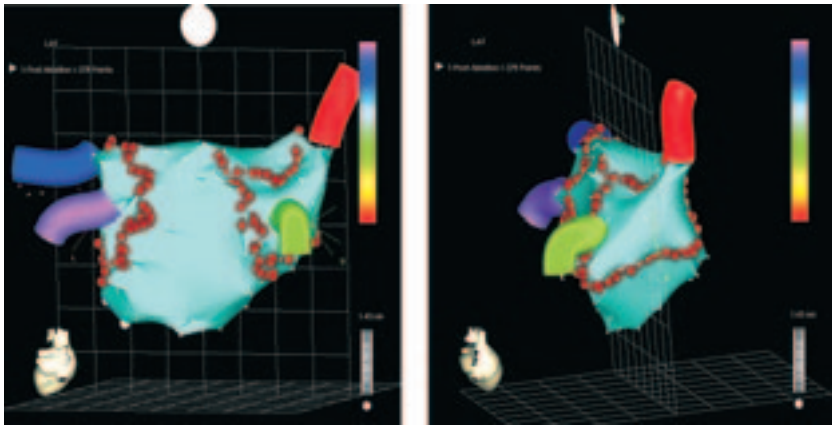

Figure 1. Anatomical map (CARTO) depicting the creation of circumferential lesions around the pulmonary veins. Left panel postero-anterior and right panel right-lateral view. Blue – left superior pulmonary vein; Purple – left inferior pulmonary vein; Red – right superior pulmonary vein; Green – right inferior pulmonary vein.

tire cycle length and centrifugal activation of the remaining left atrium. Right and left atrial flutters were defined according to conventional criteria.[15] The entrainment criterion for the identification of reentry was the feasibility of atrial capture at more than one point, with demonstration of post-pacing intervals less than 40 ms but longer than the tachycardia cycle length. The Pentarray mapping catheter was available in some patients and was also used for focal atrial tachycardia mapping.[10]

Ablation of atrial arrhythmias

Ablation of macro-reentrant circuits was attempted across the critical isthmus, aimed at a reduction of the local electrogram amplitude by >80% or demonstration of double potentials. If the tachycardia was not interrupted ablation was directed to close identifiable gaps involved in the tachycardia circuit. Ablation of focal tachycardias was directed at the site of earliest activation. Non-inducibility of the arrhythmia was the endpoint for these procedures. Inducibility of the arrhythmia was assessed before and after the ablation procedure with high-rate left and right atrial pacing following intravenous administration of isoprenaline at a rate of 10 μg/min.

Follow up

Patients were put on the previously ineffective antiarrhythmic therapy as well as warfarin for one month. Patients underwent monthly clinical assessment and ambulatory electrocardiographic monitoring at 3 and 6 months after AF ablation. A successful outcome over the follow-up period was defined as the absence of electrocardiographically recorded atrial arrhythmia along with symptomatic improvement. No blanking period was considered for this study.

Statistical analysis

The association between the occurrence of atrial arrhythmia (taking into account the type of induced arrhythmia or not) and the technique used for AF ablation was evaluated using Fisher's exact test, since some cells had less than 5 observations. Fisher's exact test was also used for comparisons between the rates of AF or atrial tachycardia/flutter recurrence in those who had been treated with reablation and those who had not, and in patients with atrial flutter versus those with focal atrial tachycardia. All reported p-values were based on two-sided tests and were compared to a 5% level of significance.

Results

AF ablation techniques

Among 94 patients with AF recruited in our study, 42 (44.6%), 12 (12.7%), 22 (23.4%), and 18 (19.1%) patients underwent ostial ablation, ostial with lines, circumferential ablation and circumferential with lines, respectively. At 6 months, the numbers of patients with recurrence of AF were 13 (30.9%), 3 (25%), 5 (22.7%), and 4 (22.2%) in the four groups, respectively. Thus, considering AF alone, the success rate after 6 months ranged from 69 to 77.8% in our population treated with various techniques. These percentages, however, were compromised by the considerable rate of ablation-induced atrial arrhythmia.

Atrial arrhythmia following AF ablation

Atrial arrhythmia other than AF (atrial flutter or focal atrial tachycardia) occurred in 10 patients (10.6%) during 6 months' follow up after the AF ablation. The characteristics of patients with arrhythmia are presented in Table 1. Atrial arrhythmia during the first 6 months after AF ablation was more common among patients subjected to circumferential or circumferential and linear ablation (18.2% and 22.2%, respectively) compared to the other patients (p=0.037) (Table 2). The risk of atrial arrhythmia among patients who underwent ostial ablation or ostial with lines was 2.4%, and 8.3% respectively. No difference was observed in the risk of atrial arrhythmia between patients who underwent ostial ablation or ostial with lines (p=0.398). Likewise, no difference was observed between those who underwent circumferential ablation or circumferential with lines (p=0.999). Regarding the type of induced arrhythmia, both atrial flutter and atrial tachycardia were significantly more likely to occur among patients who underwent circumferential ablation, with or without lines, (12.5% for atrial flutter and 7.5% for atrial tachycardia) compared to patients who underwent ostial ablation (p=0.012). Reentrant arrhythmias (macro- or micro-reentrant) were seen in 5 patients with circumferential ablation (3 patients with additional lines).

Atrial tachycardia/flutter was observed in 3 patients during AF ablation, while in the remainder the mean time of occurrence of atrial arrhythmia was almost 1.3 months after AF ablation. Re-ablation for

Table 1. Patients with AF ablation-induced arrhythmia.

Pt	Age	Sex	Background	AF ablation	Atrial Arrhythmia	Time of AT (months post-AF ablation)	AT/AFl Ablation	Outcome (6-month follow up)
1	56	M	IHD, HTN	Circumferential and linear	Non-sustained left AFl (peri-LPVs)	During AF ablation	No	No AF, No AT
2	48	M	HTN	Ostial	Non-sustained focal AT (LSPV)	1	No	No AF, No AT
3	49	M	HTN	Ostial and linear	Focal AT LSPV	1	Re-isolation of LSPV	No AT but AF recurrence
4	47	M	COPD	Circumferential and ostial and linear	AF recurrence and right AFl	2	Ostial PV and cavotricuspid isthmus ablation	No AF, No AT
5	72	F	HTN	Circumferential	AF recurrence and focal AT (RIPV)	2	Mapping-guided ablation and closing of gaps	No AF, No AT
6	65	M	HTN	Circumferential	Non-sustained left AFl (peri-LPVs)	During AF ablation	No	No AF, No AT
7	49	M	HTN	Circumferential	Perimitral left AFl	During AF ablation	Mitral isthmus	No AT but AF recurrence
8	40	M	Lone AF	Circumferential and linear	Focal, micro-reentrant AT (LSPV)	1	Mapping-guided ablation	No AF, No AT
9	58	M	HTN	Circumferential and linear	Left AFl (peri-LPVs)	1	Closing of gaps	No AF, No AT
10	68	M	IHD	Circumferential	Focal AT (LSPV)	1	Mapping-guided ablation and closing of gaps	AT recurrence, No AF

AF – atrial fibrillation; AFl – atrial flutter; AT – atrial tachycardia; COPD – chronic obstructive pulmonary disease; HTN – hypertension; IHD – ischemic heart disease; LPV – left pulmonary vein; LSPV – left superior pulmonary vein; RIPV – right inferior pulmonary vein.

Table 2. Atrial fibrillation ablation technique and incidence of ablation-induced arrhythmia.

Type of AF Ablation	No. of Patients	Atrial Tachycardia	Atrial Flutter
Ostial	42	1 (2.3%)	0
Ostial and linear	12	1 (8.3%)	0
Circumferential	22	2 (9.1%)	2 (9.1%)
Circumferential and linear	18	1 (5.5%)*	3 (16.6%)

*one case micro-reentrant atrial tachycardia.

atrial tachycardia/flutter was performed in only 7 patients with sustained arrhythmia (Figures 2, 3). During a 6-month follow up after the diagnosis of atrial tachycardia/flutter, 7 of 10 patients (70%) were free of AF or atrial tachycardia/flutter recurrence. No patient with non-sustained arrhythmia had AF or atrial tachycardia/flutter recurrence, although no re-ablation was performed (p=0.475). Moreover, no statistically significant difference was observed in the recurrence of AF or atrial arrhythmia between patients who presented with atrial flutter and those who presented with atrial tachycardia after AF ablation (p=0.999), or between patients who underwent various techniques of AF ablation (p=0.999).

Discussion

Our results are in line with previous reports on ablation-induced atrial arrhythmias following procedures for the elimination of AF.[2-6] Circumferential ablation has an 18% incidence of left atrial flutter or focal atrial tachycardia, whereas ostial ablation is associated with an approximately 1-3% incidence of focal tachycardias. According to our results, focal, usually non-reentrant, rhythms are most common after ostial ablation with the Lasso technique, whereas circumferential ablation may result in both macro-reentrant and focal tachycardias.

However, our data suggest that the addition of linear lesions, at least as performed in our patients, does not appear to offer any benefit in terms of reducing ablation-induced atrial flutter, as has been suggested by Pappone et al.[1] Whether this discrepancy is due to the fact that we did not verify the achievement of complete block along left atrial ablation lines cannot be deduced from our data. Complete transmural lesions are difficult to accomplish with percutaneous ablation techniques,[6,17] and the achievement and verification of complete lines of block may be onerous. In a recent report, complete block along the mistral isthmus line was achieved in only 30% of the patients subjected to ablation.[8] There is also further evidence that linear lesions may not completely eliminate post-ablation macro-reentrant arrhythmias[4,18] and may actually be proarrhythmic, predisposing to left atrial flutter.[18-20] Extensive left atrial ablation has also been associated with life-threatening complications.[21-23] Although higher success rates in terms of eradicating AF were seen in groups with linear lesions, this should be considered in the context of the increased incidence of ablation-induced atrial arrhythmias. Our experience does not support the creation of such lesions on a routine basis when attempting ablation of AF with either technique, ostial or circumferential.

The mechanism of post-ablation left atrial flutter is not known. Although gaps in the ablation line have been traditionally held responsible,[1,4] other mechanisms, such as neural remodelling induced by extensive ablation, may also play a role.[16] Perhaps such mechanisms could explain the fact that focal as well as macro-reentrant arrhythmias may be seen following linear ablation around or connecting the PVs.[6,11,12] Another interesting observation is the demonstration of isthmus-dependent right atrial flutter following left atrial ablation techniques.[4,9] We do not know whether such cases represent ablation-induced proarrhythmia or merely the unmasking of underlying rhythms that result in or arise from AF. We have previously published a report on a group of patients in whom cavotricuspid isthmus ablation eliminated episodes of AF.[24] In these patients the paroxysms of AF may be preceded by episodes of atrial flutter on Holter monitoring and during an electrophysiological study there may be documentation of simultaneous flutter in the right atrium and fibrillation in the left atrium.[24]

In 3 of our patients in whom only non-sustained atrial arrhythmias were seen, either immediately after the procedure or during follow-up, the tachycardia resolved spontaneously without further ablation. Clinical

Figure 2. The use of the PentaRay catheter for the mapping of an atrial tachycardia originating near the ostium of the right inferior pulmonary vein. A, B, C, D, and E are the five spines of the PentaRay. Note the similarity (but not identity) of the activation sequence during tachycardia and sinus beats (last two beats).

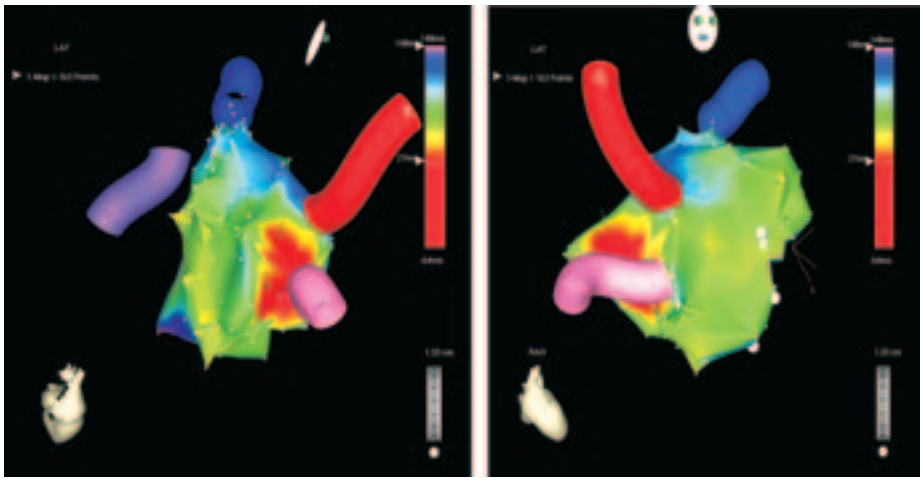

Figure 3. CARTO activation map of the same tachycardia as in figure 2. The focus is located at the ostium of the right inferior pulmonary vein (pink). Left and right panels show left and right anterior oblique views, respectively.

tachycardia is expected to occur in 50% of patients with inducible arrhythmia at the end of the AF ablation procedure, and at least 30% of these tachycardias do not require ablative therapy and resolve spontaneously within the next 5 months.[3] Hocini et al have also reported a 22% incidence of left atrial flutter following a line of verified complete block at the left atrial roof, but only 30% of these patients presented with clinical arrhythmia requiring ablation during follow-up.[19] Additional ablation, therefore, may be deferred for cases of arrhythmia that occur early after the first procedure, particularly when these arrhythmias are not sustained in the electrophysiology laboratory.

In conclusion, our results indicate that: 1) ostial ablation of the PVs may result in focal atrial tachycardias in 1% of treated patients; 2) circumferential ablation is

associated with a 18% incidence of left atrial arrhythmias, macro-reentrant or focal; 3) the addition of linear lesions along the mitral isthmus and between the superior PVs does not affect the risk of ablation-induced arrhythmia; and 4) non-sustained atrial tachycardia or flutter following AF ablation procedures does not require additional ablation.

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