

# Benefit of Left Atrial Roof Linear Ablation in Paroxysmal Atrial Fibrillation: A Prospective, Randomized Study

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**Background**—Isolation of the pulmonary veins (PVs) for the treatment of atrial fibrillation (AF) is often supplemented with linear lesions within the left atrium (LA). However, there are conflicting data on the effects of creating a roof line (RL) joining the superior PVs in paroxysmal atrial fibrillation (PAF).

**Methods and Results**—A cohort of 120 patients with drug-refractory PAF referred for ablation were prospectively randomized into 2 strategies: (1) PV isolation in combination with RL ablation (LA roof ablation [LARA]-1: 59 patients) or (2) PV isolation (LARA-2: 61 patients). Follow-up was performed at 1, 3, and 6 months after the procedure and every 6 months thereafter. After a 3-month blanking period, recurrence was defined as the occurrence of any atrial tachyarrhythmia lasting  $\geq 30$  seconds. PV isolation was achieved in 89% and complete RL block in 81%. RF duration, fluoroscopy, and procedural times were slightly, but not significantly, longer in the LARA-1 group. After  $15 \pm 10$  months, there was no difference in the arrhythmia-free survival after a single AF ablation procedure (LARA-1: 59% vs. LARA-2: 56% at 12 months; log rank  $P=0.77$ ). The achievement of complete RL block did not influence the results. The incidence of LA macroreentrant tachycardias was 5.1% in the LARA-1 group ( $n=3$ ) versus 8.2% in the LARA-2 ( $n=5$ ) ( $P=ns$ ). Univariate analysis only identified AF duration as a covariate associated with arrhythmia recurrence (hazard ratio, 1.01 [95% confidence interval, 1.002 to 1.012];  $P<0.01$ ).

**Conclusion**—The linear block at the LA roof is not associated with an improved clinical outcome compared with PV isolation alone.

**Clinical Trial Registration**—URL: ClinicalTrials.gov. Unique identifier: NCT01203241. (*J Am Heart Assoc.* 2014;3:e000877 doi: 10.1161/JAHA.114.000877)

**Key Words:** atrial fibrillation • catheter ablation • roof line

Electrical isolation of the pulmonary veins (PVs) is currently the most commonly employed ablation strategy for the treatment of paroxysmal atrial fibrillation (PAF).<sup>1–4</sup> However, in some patients, PV isolation may not be sufficient as a result of greater extension of atrial fibrosis.<sup>5</sup> For this reason, the creation of additional linear lesions in the left atrium (LA) has been proposed. These lines include the LA “roof,” the posterior line, and the mitral isthmus.<sup>6–12</sup>

Still, the role of additional lines remains controversial. The systematic isolation of the posterior wall does not seem to

achieve better results.<sup>13</sup> In contrast, one single-centre prospective randomized study suggests a better outcome with the addition of the roof line (RL) in PAF.<sup>9</sup>

The aim of the present study is to assess whether the LA roof ablation (LARA) adds any benefit to the arrhythmia-free probability after PAF ablation.

## Methods

Between September 2009 and October 2011, 120 consecutive patients admitted for a first catheter ablation for symptomatic, drug-refractory, paroxysmal PAF were prospectively included in the study. Patients with any treatable cause of atrial fibrillation (AF), contraindication for anticoagulation or LA thrombus, LA anteroposterior diameter  $>50$  mm, moderate or severe mitral valve disease, prosthetic mitral valve, and/or left ventricular (LV) ejection fraction (LVEF)  $<30\%$  were excluded (Figure 1).

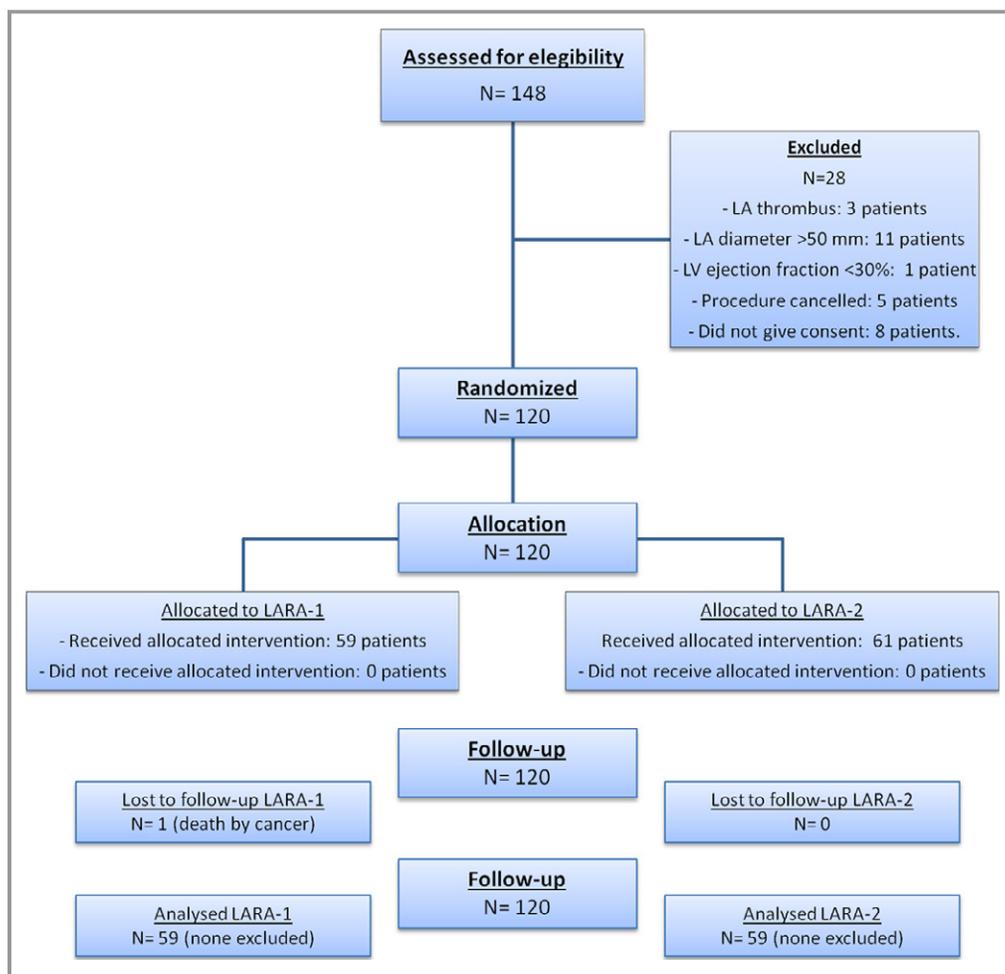
The study protocol was approved by our hospital’s ethics committee, and written informed consent was obtained from all patients according to the Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects.

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**Figure 1.** Consort flow chart of the study population. LA indicates left atrium; LAVA, left atrial roof linear ablation; LV, left ventricle.

### Baseline Assessment

After written informed consent was obtained, a complete clinical evaluation was performed (including physical examination, 12-lead electrocardiogram (ECG), and laboratory exams). All patients underwent a transthoracic echocardiogram (TTE) 1 to 30 days before the procedure and a multislice computed tomography (CT) or magnetic resonance (MR) to image the LA and PV anatomy. Transesophageal echocardiography was performed 24 to 48 hours before the procedure in patients with indication for chronic oral anticoagulation resulting from a high cardioembolic risk.<sup>14</sup> In patients treated with chronic oral anticoagulation, bridging with low-molecular-weight heparin (LMWH) was used, which was interrupted 12 hours before the procedure.

### Ablation Procedure

The procedure was performed under deep sedation. After dual transseptal access, a bolus of intravenous heparin (50 UI/kg)

was administered, with additional boluses to maintain an activated clotting time of >250 seconds and a 20-pole circular mapping catheter (Lasso<sup>®</sup>; Biosense Webster, Diamond Bar, CA or Inquiry Optima<sup>®</sup>; St. Jude Medical, St. Paul, MN) was placed at the PV ostium. Ablation was assisted by a three-dimensional (3D) nonfluoroscopic mapping system (CARTO XP<sup>®</sup> or CARTO 3<sup>®</sup>; Biosense Webster or EnSite NavX<sup>®</sup>; St. Jude Medical). For accurate visualization of the PVs and other left atrial landmarks, we used image integration of the electroanatomical map with the anatomical information provided by CT or MR imaging (obtained before the procedure) in all patients. Radiofrequency (RF) was delivered by a 3.5-mm open-irrigation catheter at a target temperature of 45°C and a maximum output of 40 W (NaviStar<sup>®</sup> or Celsius<sup>®</sup>; Biosense Webster). In order to reduce the risk of esophageal complications, power was reduced to 35 W in the posterior wall and RF application was limited to 10 to 20 seconds per point. For all other areas in the LA (including the roof), a 40-W power limit was used.

Isolation of PVs was achieved by continuous circular lesions around the venoatrial junction of ipsilateral PVs,

checking for bidirectional conduction block. An additional line was performed at the carina between ipsilateral veins in case of separate ostia.

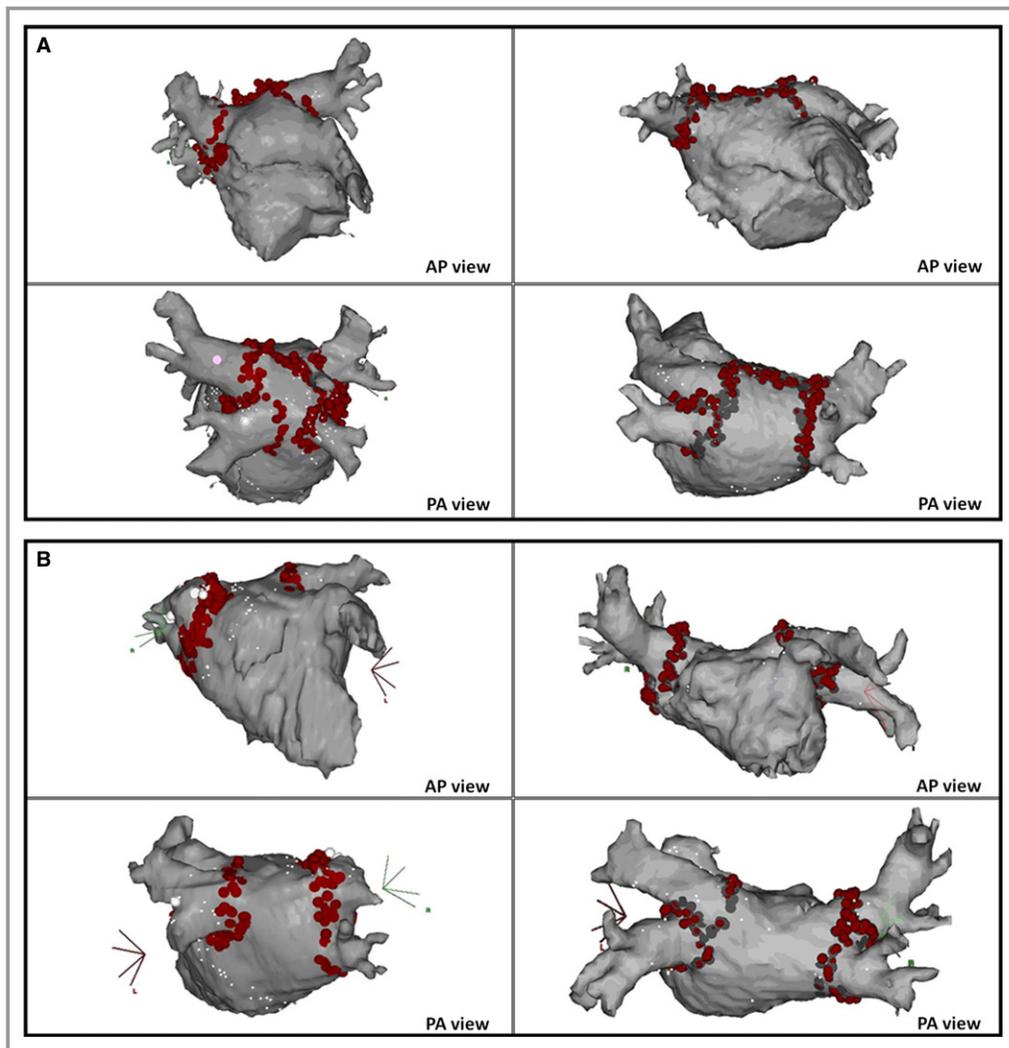
After PV electrical isolation, patients were randomly assigned to the 2 ablation strategies (Figure 2): (1) linear ablation at the LA roof (LARA-1) or (2) no further ablation (LARA-2). The RL ablation was performed at the most cranial part of the LA, connecting the upper aspect of the right and left PV encircling lesions. RF energy was delivered for 30 to 90 seconds at each point until local potential elimination or double potentials were observed. Completeness of conduction block was confirmed during LA appendage pacing by the online mapping of continuous double potential and an activation detour propagating around the PVs to activate caudocranially the posterior wall of the LA (Figure 3).<sup>9,15</sup>

When residual conduction was demonstrated, detailed mapping was performed to identify and ablate gaps in the linear lesion.

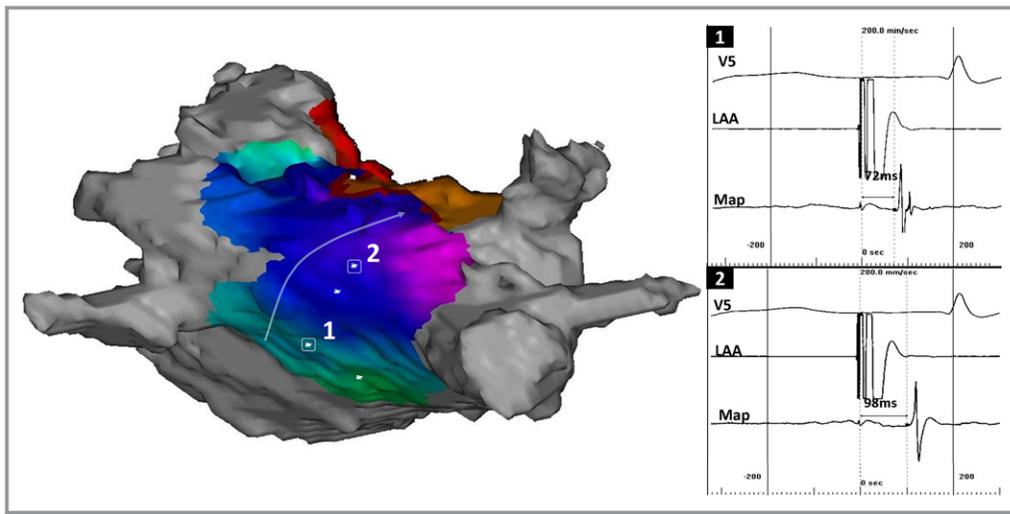
All procedural endpoints were evaluated in sinus rhythm. Electrical cardioversion was performed when necessary.

### Postprocedural Management

After the procedure, a TTE was performed to rule out pericardial effusion. Anticoagulation was started by LMWH and acenocumarol afterward until an international normalized ratio >2 was achieved, then maintained for 3 months in all patients and according to the individual cardioembolic risk score thereafter. Antiarrhythmic treatment was given to all patients during the first 3 months after the procedure:



**Figure 2.** Ablation strategy. A, PV isolation with roof linear ablation (LARA-1). B, PV isolation without roof linear ablation (LARA-2). AP indicates anteroposterior; LAVA, left atrial roof linear ablation; PA, posteroanterior; PV, pulmonary veins.



**Figure 3.** Evaluation of conduction block across the roof during pacing from the LA appendage (LAA). A, Color-coded 3D activation map showing a caudocranial activation of the posterior wall. B, Electrical activation showing shorter activation times at the lower (1: 72 ms) than at the upper posterior wall (2: 98 ms). LA indicates left atrium.

flecainide (100 mg BID) in the absence of structural heart disease and amiodarone (200 mg QD) or sotalol (80 to 160 mg BID), if present. Afterward, antiarrhythmic drugs were interrupted and only reintroduced if any arrhythmic event was documented.

### Follow-up

Follow-up was performed at the outpatient clinic at 1, 3, and 6 months after the procedure and every 6 months thereafter. Evaluation included assessment of arrhythmia-related symptoms, adverse events, and treatment adherence and any additional therapy since the previous follow-up visit. Routine 48-hour Holter monitoring was performed before each visit, and patients were asked to go to an emergency department if any symptom suggestive of recurrence occurred between scheduled visits. The minimum follow-up of the study population was 6 months after the AF ablation procedure.

### Definitions

*Arrhythmia recurrence* is defined as any arrhythmia of  $\geq 30$  seconds documented by an ECG or device recording system, after a 3-month blanking period. Cavo-tricuspid isthmus-dependent flutter was not considered recurrence.

A *blanking period* of 3 months was employed after ablation. Recurrences within these first 3 months were not classified as failure of the procedure. Any patient suffering a persistent atrial arrhythmia during this period was reverted to sinus rhythm by electrical cardioversion.

### Statistical Analysis

The primary endpoint of the study was freedom from arrhythmia recurrence after a single ablation procedure. Any episode of AF or LA flutter within the first 3 months after the procedure was considered part of the blanking period (not recurrence). The ablation group was blinded to patients and to the physicians evaluating the outcome of the procedure.

On the basis of our group's experience, at 6-month follow-up, we expected 55% of patients to be free of arrhythmia after a single PV isolation procedure. With a sample size of 60 patients per arm, a log-rank test for equality of survival curves will have 80% power and a 2-sided  $\alpha$ -value of 0.05 to detect an expected 20% reduction in freedom from arrhythmia in the LARA-1 group. Randomization was performed according to a computer-generated algorithm in blocks of 20 patients. Inclusion was stopped once 120 patients were enrolled.

Continuous data are presented as the mean value  $\pm$  SD. Qualitative variables are expressed as the number of cases and percentages. To compare means of 2 variables within the same group, we used the paired-samples Student *t* test.

Arrhythmia-free survival curves for each group were compared by log-rank test and presented as Kaplan-Meier plots. Cox's method was used to estimate the effect of the LA roof linear ablation after adjusting for baseline variables. The following potential predictors of recurrence were considered: age, sex, duration of AF, LA diameter, LV end-diastolic, and end-systolic diameters, LVEF, hypertension, and structural heart disease. The backward step-wise method with criteria of  $P < 0.10$  for inclusion and  $P > 0.10$  for removal was used for the final model. A 2-sided probability value  $< 5\%$  ( $P < 0.05$ ) was

considered statistically significant. Statistical analysis was performed using R software (version 3.0.1; the R Project for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria).

## Results

### Baseline Characteristics and Procedural Data

One hundred and twenty patients were randomized for analysis: 59 patients in the LARA-1 group and 61 patients in the LARA-2 group (Figure 1). The mean age was 55±11, 20% were older than 65 years, and 71% were males. A previous history of stroke was noted in 0.8% of patients and the CHA<sub>2</sub>DS<sub>2</sub>-VASc score was ≥1 in 52.5%. No significant baseline differences were observed between groups (Table 1). Procedural details are provided in Table 2.

PV isolation was attempted in all patients. Of these, complete bidirectional conduction block was achieved in 89.1% (88.5% in LARA-1 and 95% in LARA-2; *P*=0.843), with no difference in RF duration (50±12 minutes vs. 47±13 min-

utes; *P*=0.302) or procedural time (172±53 minutes vs. 153±51 minutes; *P*=0.063) between LARA-1 and LARA-2, respectively. There was a trend to longer fluoroscopy time in group LARA-1 that did not reach statistical significance (fluoroscopy time [32±35 minutes vs. 22±13 minutes; *P*=0.053]).

During LA appendage pacing, activation mapping confirmed complete conduction block across the RL in 81.4% of cases in LARA-1 (Figure 4). Patients with successful RL linear block were significantly older (LARA-1 without block: 46±13.7 years vs. LARA-1 with block: 57.1±8.8 years; *P*=0.025). No other predictor for successful RL block could be identified.

Overall, the endpoints of the procedure were confirmed using previously described criteria in 45 and 54 patients of the LARA-1 (PV isolation and LA roof block) and LARA-2 (PV isolation) groups, respectively (76.3% vs. 88.5%; *P*=0.127).

### Follow-up

One LARA-1 patient was lost to follow-up because of cancer and subsequent death. Table 3 summarizes the information at

**Table 1.** Baseline Characteristics

	LARA-1 (n=59)	LARA-2 (n=61)	<i>P</i> Value	Total (n=120)
Age, y	55±11	55±12	0.857	55±11
Males	42 (71.2%)	42 (68.9%)	0.670	84 (70.7)
Hypertension	19 (32.2%)	24 (39.3%)	0.455	43 (35.8%)
Diabetes	2 (3.4%)	4 (6.6%)	0.438	6 (5%)
Previous cardioembolic event	1 (1.7%)	0	0.987	1 (0.8%)
Sports practice	12 (20.3%)	6 (9.8%)	0.117	18 (15%)
Obstructive sleep apnea	3 (5.1%)	5 (8.2%)	0.510	8 (6.7%)
Lone AF	45 (76.3%)	54 (88.5%)	0.127	90 (82.5%)
Structural cardiomyopathy	14 (23.7%)	7 (11.7%)	0.200	21 (17.5%)
Tachycardiomyopathy	1 (1.7%)	0		1 (0.8%)
Ischemic	4 (6.8%)	2 (3.3%)		6 (5%)
Hypertrophic	1 (1.7%)	0		1 (0.8%)
Valvular	6 (10.2%)	1 (1.6%)		7 (5.8%)
Hypertensive	2 (3.4%)	3 (4.9%)		5 (4.2%)
Others	0	1 (1.6%)		1 (0.8%)
CHADS <sub>2</sub> ≥1	20 (33.9%)	26 (42.6%)	0.341	46 (38.3%)
CHA <sub>2</sub> DS <sub>2</sub> -VASc ≥1	31 (52.5%)	32 (52.4%)	1	63 (52.5%)
AF duration, months	59±59	60±56	0.902	60±57
LA anteroposterior diameter, mm	41±6	41±6	0.924	41±6
LV ejection fraction, %	62±7	62±5	0.774	62±6
LV end-diastolic diameter, mm	52±4	51±5	0.108	52±5
LV end-systolic diameter, mm	33±5	32±5	0.534	33±5

AF indicates atrial fibrillation; LA, left atrium; LV, left ventricle.

**Table 2.** Procedural Data

	LARA-1 (n=59)	LARA-2 (n=61)	P Value	Total (n=120)
Procedural time, minutes	172±53	153±51	0.063	163±58
Radiofrequency time, minutes	50±12	47±13	0.302	48±13
Fluoroscopy time, minutes	32±35	22±13	0.053	27±27
PV isolation				
Left superior	59 (100%)	61 (100%)	0.285	120 (100%)
Left inferior	57 (96.6%)	57 (93.4%)	0.416	114 (95%)
Right superior	57 (96.6%)	57 (93.4%)	0.478	118 (98.3)
Right inferior	56 (94.91%)	61 (100%)	0.325	114 (95%)
Overall	52 (88.5%)	58 (95.0%)	0.843	106 (89.1%)
Complications				
Stroke	4 (6.7%)	5 (8.5%)	0.390	9 (7.5%)
Stroke	2 (3.4%)	1 (1.6%)	0.97	3 (2.5%)
Coronary ischemia	0	2 (3.3%)	0.164	2 (1.7%)
Pericarditis	0	1 (1.6%)	0.327	1 (0.8%)
Cardiac tamponade	1 (1.7%)	0	0.303	1 (0.8%)
Esophagitis	0	0	—	0
Fever	1 (1.7%)	0	0.303	0
Vascular complications	0	3 (4.9%)	0.087	3 (2.5%)
PV stenosis	0	0	—	0
Mitral valve rupture	1 (1.7%)	0	—	1 (0.8%)

LARA indicates left atrial roof linear ablation; PV, pulmonary vein.

follow-up. After a mean follow-up of  $15\pm 10$  months (median, 12), 35 patients in group LARA-1 (28 with confirmed conduction block across the RL and 7 without complete RL block) and 34 in group LARA-2 had no documented arrhythmia recurrence after a single ablation procedure. No statistically significant differences were observed in arrhythmia recurrence between those with or without ablation of the LA roof (long-rank test,  $P=0.877$ ; Figure 5A).

In the LARA-1 group, recurrences were the result of AF in 24 patients (40%) and LA flutter in 3 (5.1%). In the LARA-2 group, 27 patients (45%) had AF recurrences, and 5 (8.2%) had new-onset LA flutter. Univariate analysis identified AF duration (hazard ratio [HR], 1.01 [95% confidence interval {CI}, 1.002 to 1.012];  $P<0.01$ ), as the covariate associated with arrhythmia recurrence (Table 4).

The 12-month results (Figure 5B) were not influenced by achievement of complete block across the RL in LARA-1 patients (HR, 0.96 [95% CI, 0.55 to 1.67];  $P=0.880$ ) or by complete bidirectional block of all PV (HR, 0.986 [95% CI, 0.806 to 1.207];  $P=0.843$ ).

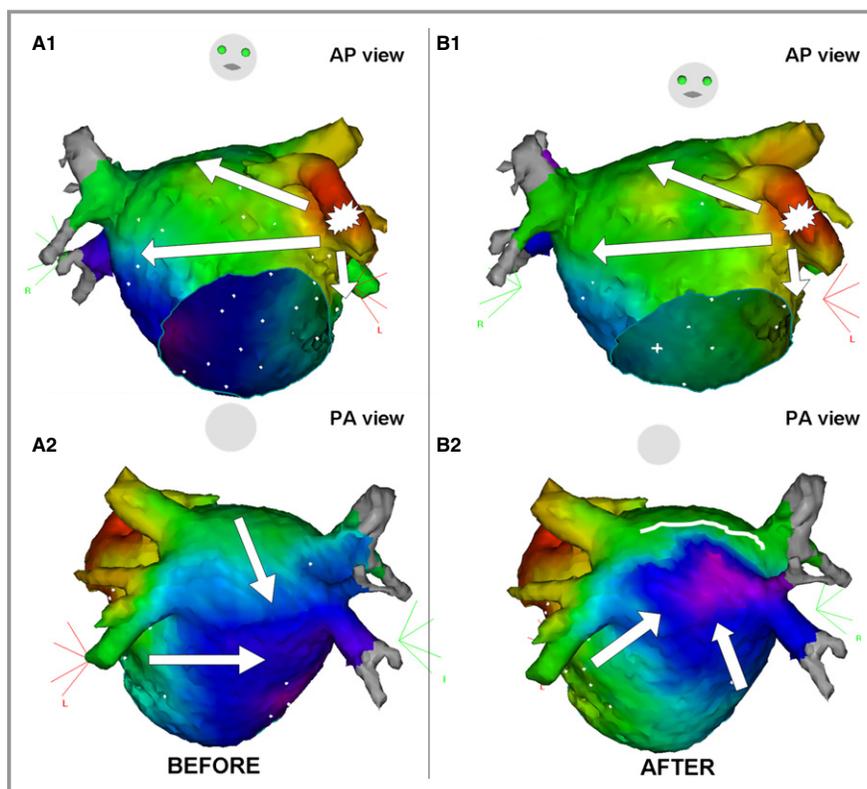
## Complications

In the LARA-1 group, 1 patient experienced cardiac tamponade, which was successfully drained percutaneously, requiring

no further intervention; another patient had a transient cerebrovascular ischemic attack, resolved by unfractionated heparin with no documented lesion on the CT scan and no sequelae. Two patients in the LARA-2 group had transient inferior myocardial ischemia, probably related to air embolism during transeptal catheterization, which was resolved with intravenous nitroglycerin (100  $\mu$ g) within a few minutes; additionally, 1 patient had postprocedural pericarditis without significant pericardial effusion that required nonsteroidal anti-inflammatory therapy for 1 week. Finally, there was 1 mitral valve rupture in the LARA-1 group, secondary to entrapment of the circular catheter among the chords; the patient had to undergo emergent mitral valve repair. No symptomatic stenosis of the PV was documented by MR at 12 months. There were no significant differences in complication occurrence between groups (Table 2).

## Second Ablation Procedures

The ablation procedure was repeated  $15.7\pm 11$  months after the index procedure in 27 (22%) patients (14 in LARA-1 and 13 in LARA-2;  $P=0.92$ ) because of new-onset LA flutter in 6 patients (4 in LARA-1 and 2 in LARA-2;  $P=0.64$ ) and AF recurrence in the remaining 21 patients. Overall, the 120 patients included in the study underwent  $1.41\pm 0.57$  AF



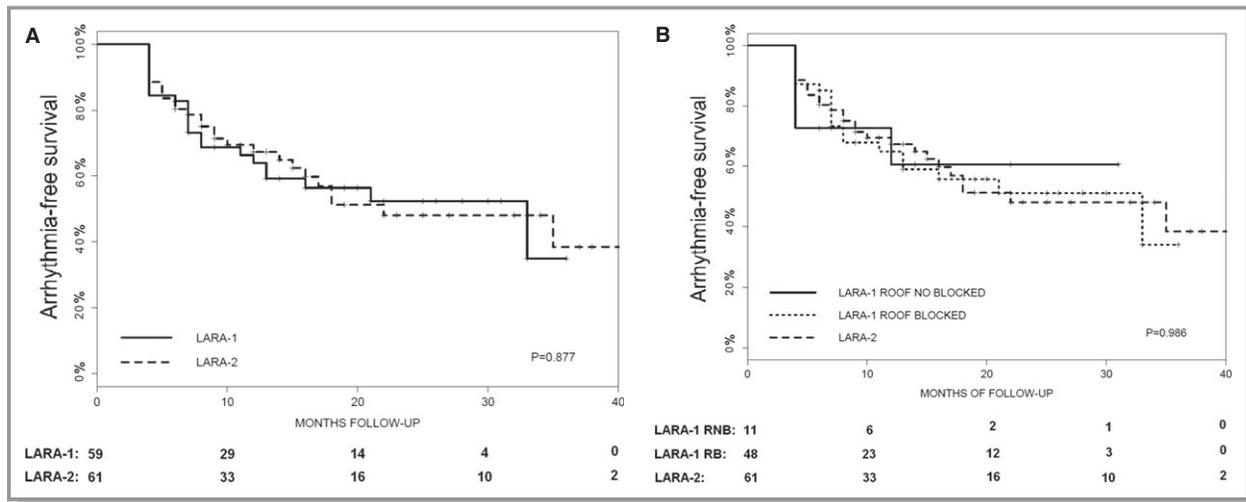
**Figure 4.** Color-coded 3D activation map during pacing from the LA appendage in a patient undergoing a first ablation procedure for paroxysmal AF. A, Anteroposterior and posteroanterior views before linear ablation at the LA roof showing 2 activation fronts at the posterior wall. B, Anteroposterior and posteroanterior views after linear ablation at the LA roof showing the caudocranial activation of the LA posterior wall. AF indicates atrial fibrillation; AP, anteroposterior; LA, left atrium; PA, posteroanterior.

**Table 3.** Follow-up Data After First Procedure

	LARA-1 (n=59)	LARA-2 (n=61)	P Value	Total (n=120)
Follow-up duration, months	13±9	16±11	0.238	15±10
Recurrence rate during blanking period	16 (27.1%)	17 (27.9%)	1	33 (27.5%)
Type of recurrence during blanking period				
Atrial fibrillation	16 (27.1%)	13 (21.3%)	0.594	28 (23.3%)
Left atrial flutter	0	4 (6.6%)	0.136	4 (3.3%)
Other	0	0	—	0
Recurrence rate during follow-up				
>3 months after the procedure	24 (40.7%)	27 (44.3%)	0.832	51 (42.5%)
Complete conduction block across the RL*	20 (42.6%)	—		—
Incomplete conduction block across the RL*	4 (36.4%)	—		—
Type of recurrence during follow-up				
Atrial fibrillation	21 (35.6%)	22 (36.1%)	1	43 (35.8%)
Left atrial flutter	3 (5.1%)	5 (8.2%)	0.751	8 (6.7%)
Other	0	0	—	0

LARA indicates left atrial roof linear ablation; RL, roof line.

\*Comparison between patients in group LARA-1 with complete or incomplete RL conduction block: P=0.655.



**Figure 5.** Accumulated arrhythmia-free survival (Kaplan-Meier) after a single ablation procedure. A, Comparison between the LARA-1 (solid line) and LARA-2 (dotted line) groups. B, Comparison between the LARA-1 patients that achieved conduction block at the roof (solid line), the LARA-1 patients that did not achieve conduction block at the roof (slashed line), and the LARA-2 patients (dotted line). LARA indicates left atrial roof linear ablation.

ablation procedures ( $1.49 \pm 0.646$  in LARA-1 and  $1.34 \pm 0.476$  in LARA-2;  $P=0.114$ ).

Recovery of PV conduction was observed in a mean of  $3.48 \pm 0.749$  PV per patient, while no patient had all PVs isolated. The identified conduction gaps were located at the left superior PV in 17 patients (62.9%), left inferior PV in 19 (70.3%), right superior PV in 20 (74.1%), and right inferior PV in 17 (62.9%). Recovery of conduction across the LA roof line was observed in 6 patients (42.8%). All 6 patients with LA flutter showed gaps at the level of the PV responsible for the

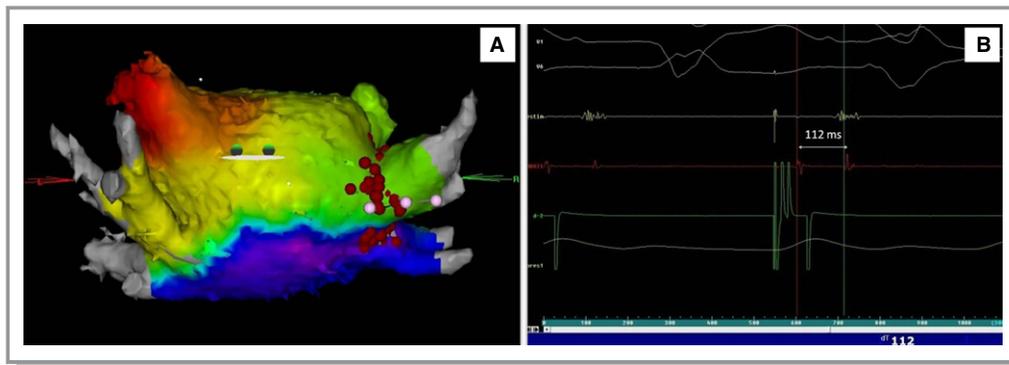
reentrant arrhythmia. There were no macroreentries across the LA roof or mitral-isthmus-dependent flutter. The ablation strategy of the repeat procedures consisted in PV isolation for all patients and ablation along the RL to close the gap in those patients from group LARA-1 with recovered conduction (Figure 6).

After a follow-up of  $15.3 \pm 10.2$  months after the last ablation procedure, 70.8% of the patients of this series remained arrhythmia free with no difference in arrhythmia-free survival between groups (Table 5). Thirty-one patients

**Table 4.** Predictors of All-Cause Recurrence Risk, Uni- and Multivariate Cox Proportional Hazards Models

	No Recurrence (n=69)	Recurrence (n=51)	Univariate		Multivariate	
			HR (95% CI)	P Value	HR (95% CI)	P Value
Age, y	54±12	57±10	1.03 (1.00 to 1.06)	0.055		
Males	50 (72%)	34 (67%)	0.84 (0.47 to 1.52)	0.842		
Hypertension	23 (33%)	20 (39%)	1.38 (0.78 to 2.54)	0.266		
Atrial fibrillation duration, months	48±39	74±72	1.01 (1.00 to 1.01)	0.007	1.01 (1.002 to 1.012)	0.007
Sleep apnea syndrome	3 (4%)	5 (10%)	2.46 (0.97 to 6.28)	0.059		
Athlete	8 (12%)	6 (12%)	0.88 (0.37 to 2.10)	0.771		
Cardiomyopathy	12 (17%)	9 (18%)	0.98 (0.48 to 2.00)	0.948		
LVEF (per % increase)	62±7	62±5	1.00 (0.96 to 1.05)	0.961		
LA diameter	41±5	41±6	1.01 (0.96 to 1.07)	0.599		
CHADS2 score	3 (4%)	2 (4%)	1.23 (0.30 to 5.09)	0.777		
CHA <sub>2</sub> DS <sub>2</sub> -VASc score	31 (45%)	29 (57%)	1.48 (0.84 to 2.62)	0.178		
LARA-1 (roof line)	34 (49%)	24 (47%)	1.04 (0.60 to 1.81)	0.880		

CI indicates confidence interval; HR, hazard ratio; LA, left atrium; LARA, left atrial roof linear ablation; LVEF, left ventricular ejection fraction.



**Figure 6.** Confirmation of persistent conduction block at the LA roof in a patient undergoing a repeat ablation procedure for recurrent paroxysmal AF. A, Color-coded 3D activation map showing a caudocranial activation of the posterior wall. B, Double potential at the roof line (112 ms between spikes). AF indicates atrial fibrillation; LA, left atrium.

had AF recurrence (14 in group LARA-1 and 17 in LARA-2;  $P=0.079$ ).

### Discussion

The main finding of this prospective, randomized study is that linear ablation at the LA roof does not improve 12-month success after PV isolation for paroxysmal AF, independently of the achievement of bidirectional block. Furthermore, the incidence of macroreentrant arrhythmias after a single ablation in this type of patient did not differ significantly between groups.

### Linear Ablation for AF Ablation

Currently, circumferential PV ablation with verification of electrical disconnection, associated or not to additional linear lesions, probably represents the most accepted ablation strategy in PAF.<sup>1-4</sup> However, despite the various ablation strategies available, single-procedure efficacy is still unsatisfactory: 60% to 80% in PAF, with 40% to 50% of patients requiring a second procedure to achieve long-term freedom

from AF.<sup>16-18</sup> Because the efficacy of AF ablation seems to be related to the extent of ablated tissue,<sup>19</sup> there has been a trend toward more-extensive ablation. The creation of additional lesions on top of the isolation of the PV has been proposed in an attempt to obtain success comparable to that obtained with surgical linear ablation lesions. Still, the existing evidence provides contradictory information about the usefulness, number, and location of linear lesions.

The role of additional lines in cases of PAF is particularly unclear. It has been suggested that ablation lines along the roof of the LA and mitral isthmus may improve clinical outcomes in PAF.<sup>7,9,20</sup> Conversely, the exclusion of the LA posterior wall has no effect on the incidence of AF recurrences after circumferential PV ablation, in a randomized trial of 120 patients (60% in PAF).<sup>13</sup> Finally, a randomized, prospective trial comparing segmental PV isolation and circumferential PV ablation plus linear ablation at the LA roof and MI showed that significantly more patients had LA flutter in the linear ablation group.<sup>21</sup>

To our knowledge, only 2 other randomized studies have evaluated the effect of linear ablation at the LA roof, with conflicting results.<sup>9,22</sup> Hocini et al.<sup>9</sup> randomized 90 patients

**Table 5.** Follow-up Data After Last Procedure

	LARA-1 (n=59)	LARA-2 (n=61)	P Value	Total (n=120)
Follow-up duration, months	14.06±8.764	16.39±11.33	0.230	15.25±10.17
Recurrence rate during follow-up				
>3 months after the procedure	15 (25.4%)	19 (31.1%)	0.622	34 (28.3%)
Type of recurrence during follow-up				
Atrial fibrillation	14 (23.7%)	17 (27.9%)	0.755	31 (25.8%)
Left atrial flutter	1 (0.02%)	3 (0.05%)	0.635	4 (0.03%)
Other	0	0	—	0

LARA indicates left atrial roof linear ablation.

to PV isolation with or without LA roof linear ablation (1:1 ratio). In their study, additional roofline ablation was associated with 87% of patients being arrhythmia free without antiarrhythmics, compared with 69% undergoing PV isolation alone, after a follow-up of  $15\pm 4$  months.

More recently, Mun et al.<sup>22</sup> randomized 156 patients into 3 different groups (1:1:1 ratio): PV isolation alone, PV isolation together with LARA, and PV isolation with the “box lesion” (RL+posterior line); the findings did not confirm those described by Hocini et al.,<sup>9</sup> because the addition of the LA roofline did not improve the clinical outcome at  $15\pm 6$  months after the index procedure.

In our randomized study, the deployment of an ablation line at the LA roof did not improve the arrhythmia recurrence rate. The reason for the disparate findings may be related to differences in PV isolation techniques, rather than to the LARA itself. Wider antral PV isolation is likely to reduce the critical mass for maintenance of AF more than the more ostial approach performed by Hocini et al.<sup>9,23</sup>

### Linear Ablation to Prevent LA Macroreentrant Arrhythmias

Linear ablation in addition to PV isolation was initially suggested as a means to prevent atrial tachycardia after circumferential PV ablation.<sup>8</sup> However, previous results from our group<sup>13</sup> and others<sup>21</sup> have not shown any benefit from additional linear lesions in terms of the risk of LA flutter. The present study also supports the idea that additional ablation lines may not be necessary in patients with PAF to prevent post-AF ablation macroreentrant arrhythmias. This is most probably because the predominant underlying mechanism of AF in these patients is mainly focal triggers; the substrate does not play a relevant role. Favoring this theory, all second procedures to treat LA flutter after the index ablation showed a reentrant circuit using gaps located at the previous PV encircling lesions or at the LARA, in accord with other series.<sup>13,24</sup> The difficulty in achieving continuity around ipsilateral PVs has already been described, especially at the septal aspect and the area between the LA appendage and left superior PV.<sup>25</sup> Furthermore, it has been widely shown that macroreentrant arrhythmias during follow-up are frequently related to gaps in previous linear lesions.<sup>6,10,12,21,24,26–29</sup> Therefore, if additional linear lesions are applied, line completeness should be demonstrated by mapping or pacing maneuvers.

### Clinical Implications

The results of the study clearly show that ablation of the LA roof in addition to PV isolation does not add clinical benefit, compared with PV isolation alone in patients with PAF.

Although the total procedural time and RF delivery duration did not increase significantly when the ablation line was added, care must be taken to avoid potential risks, such as perforation or esophageal damage. There was also a trend to longer fluoroscopy time in the LARA-1 group, although it did not reach statistical significance, probably because of lack of statistical power.

On the other hand, linear lesions may promote LA macroreentrant arrhythmias secondary to conduction recovery along the line. Therefore, the results of this randomized study further support the thesis that linear ablation at the LA roof is not necessary as a predefined lesion set to treat PAF.

### Study Limitations

The study was planned to detect an absolute reduction of 20% in the proportion of arrhythmia-free patients assuming that 55% of patients would be recurrence free at 6 months, based on the earlier experience of our group. Yet, the recurrence-free survival at 6 months was closer to 80. This could reduce the power to detect differences among groups within the study. However, the same number of patients were arrhythmia free in both groups; consequently, the formal comparison is far from the 5% significance level and the adjusted HR for arrhythmia recurrence was close to 1. Therefore, the lack of statistical significance may not be attributable to low statistical power. On the other hand, the lack of the sample size was not calculated to take into account possible subgroup analyses; therefore, the absence of identifiable predictors of successful RL block could be secondary to lack of statistical power.

The study cannot exclude that the LA roof linear ablation may have some effect in individual AF cases because the effect of this ablation was evaluated as part of a predefined lesion set performed in all patients. Tailored approaches for AF ablation have been proposed.<sup>30–32</sup> Finally, arrhythmia recurrence was detected by routine 48-hour Holter monitoring and ECG recording when symptoms occurred between scheduled visits. It is likely that some arrhythmia recurrences may have escaped detection in asymptomatic patients. However, this limitation affects both ablation groups equally and therefore should not affect the study conclusions. Moreover, this pragmatic approach has been taken in many other published studies.<sup>7,9,11,33–36</sup>

### Conclusion

This double-blinded, prospective, randomized study shows that there is not sufficient evidence to suggest that linear ablation at the roof of the LA improves the mid-term results of PV isolation for the treatment of PFA, independently of the achievement of bidirectional block.

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## **Benefit of Left Atrial Roof Linear Ablation in Paroxysmal Atrial Fibrillation: A Prospective, Randomized Study**

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