Journal of the American College of Cardiology
© 2012 by the American College of Cardiology Foundation
Published by Elsevier Inc.

Vol. 60, No. 1, 2012
ISSN 0735-1097/$36.00
http://dx.doi.org/10.1016/j.jacc.2011.12.055

Hybrid Thoracoscopic Surgical and Transvenous Catheter Ablation of Atrial Fibrillation

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Objectives The purpose of this study was to evaluate the feasibility, safety, and clinical outcomes up to 1 year in patients undergoing combined simultaneous thoracoscopic surgical and transvenous catheter atrial fibrillation (AF) ablation.

Background The combination of the transvenous endocardial approach with the thoracoscopic epicardial approach in a single AF ablation procedure overcomes the limitations of both techniques and should result in better outcomes.

Methods A cohort of 26 consecutive patients with AF who underwent hybrid thoracoscopic surgical and transvenous catheter ablation were followed, with follow-up of up to 1 year.

Results Twenty-six patients (42% with persistent AF) underwent successful hybrid procedures. There were no complications. The mean follow-up period was 470 ± 154 days. In 23% of the patients, the epicardial lesions were not transmural, and endocardial touch-up was necessary. One-year success, defined according to the Heart Rhythm Society, European Heart Rhythm Association, and European Cardiac Arrhythmia Society consensus statement for the catheter and surgical ablation of AF, was 93% for patients with paroxysmal AF and 90% for patients with persistent AF. Two patients underwent catheter ablation for recurrent AF or left atrial flutter after the hybrid procedure.

Conclusions A combined transvenous endocardial and thoracoscopic epicardial ablation procedure for AF is feasible and safe, with a single-procedure success rate of 83% at 1 year. (J Am Coll Cardiol 2012;60:54–61) © 2012 by the American College of Cardiology Foundation

In paroxysmal atrial fibrillation (AF), success rates of catheter ablation (CA) exceed 80%, and recurrence is associated mostly with pulmonary vein (PV) reconnection (1,2). By combining PV isolation, complex and fractionated atrial electrographic ablation, and linear lesions in patients with persistent AF, success rates without antiarrhythmic drugs (AADs) surpass 70% (3,4). However, multiple procedures are often necessary, and creating linear lesions is sometimes challenging.

Surgical AF ablation has evolved from the original Cox maze procedure toward a minimally invasive, video-assisted procedure with new ablation tools to isolate the PVs and create linear lesions without opening the heart (5). Nevertheless, even bipolar radiofrequency (RF) energy cannot guarantee transmural lesions (6). Linear lesions such as the mitral isthmus cannot be created solely from the epicardium, and proving bidirectional block epicardially can be challenging (7).

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Manuscript received September 19, 2011; revised manuscript received December 14, 2011, accepted December 15, 2011.

Combining a transvenous endocardial and thoracoscopic epicardial approach in a single procedure overcomes these shortcomings.

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We report our initial experience with long-term follow-up of minimally invasive epicardial bilateral PV isolation and linear lesions in combination with endocardial proof of conduction block and endocardial touch-up if indicated.

Methods

Patient selection. Twenty-six consecutive patients with symptomatic AF underwent hybrid thoracoscopic surgical and transvenous CA with follow-up of 1 year. Definitions of paroxysmal, persistent, and longstanding persistent AF, success and failure of ablation, and follow-up monitoring were based on the Heart Rhythm Society, European Heart Rhythm Association, and European Cardiac Arrhythmia Society consensus statement (3). Therapy with at least 1 AAD had failed. Other selection criteria were previously failed CA, left atrial volume ≥29 ml/m^2, persistent or longstanding persistent AF, or patient preference for a hybrid procedure instead of a percutaneous approach.

Eleven patients (44%) had prior CA for AF or atrial flutter (AFL). All patients underwent transthoracic echocardiography, cardiac computed tomography, and pulmonary function testing preoperatively.

Hybrid procedure. The procedure was performed under general anesthesia with double-lumen endotracheal tube placement for selective lung ventilation. Transesophageal echocardiography was used to exclude a thrombus in the left atrium (LA). On the right side, a 12-mm camera port was placed in the fifth intercostal space midaxillary line and in the sixth or seventh intercostal space anterior axillary line. A 5-mm working port was placed in the third intercostal space anterior axillary line. The pericardium was opened anterior to the phrenic nerve. Blunt dissection was used to open the transverse and oblique sinuses.

Via the femoral venous approach, a His bundle (St. Jude Medical, St. Paul, Minnesota) and coronary sinus catheter (Medtronic, Minneapolis, Minnesota) were placed under fluoroscopy, and transseptal puncture was performed with a long 8-F sheath (SL0, St. Jude Medical) into the LA. The patient then underwent heparinization (1,000 U heparin per 10 kg body weight and a heparin infusion), with activated clotting time >300 s. During rapid ventricular pacing, we injected contrast through the long sheath to visualize left atrial anatomy. The PVs were mapped with a circular mapping catheter (Lasso, Biosense Webster, Diamond Bar, California). Antral isolation of the right PVs as a pair was performed with 4 to 6 applications using a bipolar RF clamp (Atricure, West Chester, Ohio) (Fig. 1). Each application had a duration of about 15 s, with a median output of 10 to 15 W. The same port incisions were made on the left side but placed more posteriorly (Fig. 2). The pericardium was divided posterior to the phrenic nerve. Left PV isolation was conducted as described earlier. We did not attempt ablation of the ganglionated plexi.

In patients with severe chronic obstructive pulmonary disease , we performed thoracoscopic epicardial isolation of the PVs only on the right, and the left PVs were isolated using a cryothermal energy balloon catheter (Arctic Front, Cryocath, Montreal, Quebec City, Canada) endocardially to avoid bilateral sequential lung deflation.

The end point for PV ablation was entrance and exit block. We defined exit block as local capture in the PV during pacing from the Lasso catheter (output 10 mA, pulse width 2 ms) without conduction to the LA. In the case of sinus rhythm after PV isolation, reinduction of AF was attempted 5 times by pacing in the coronary sinus for 10 seconds at the shortest cycle length resulting in 1:1 atrial capture. AF was considered inducible if it lasted more than 1 min. If AF became noninducible, isoproterenol was infused at rates of 10 to 30 μg/min. If AF had not terminated or still was inducible, linear lesions were deployed.

A roof line (connecting both superior PVs) and an inferior line (connecting both inferior PVs) were made epicardially using a bipolar RF pen or linear pen device (Isolater Pen and Coolrail, Atricure). If the right atrium was dilated, 2 additional ablation lines were placed: 1 encircling the superior caval vein using the clamp, the other connecting both caval veins using the pen.

By making a roof and an inferior line, we isolated the posterior LA (box lesion). If entrance and exit block were not reached, we identified the conduction gaps endocardially and ablated those with a 3.5-mm-tip catheter (Thermo-Cool, Biosense Webster). The location of the linear lesions was visualized with the linear pen device in situ and using fluoroscopy.

A left isthmus line was made in 3 patients using the bipolar RF pen device. The line was started from the ablation line on the antrum of the left inferior PV toward and crossing the coronary sinus. All patients needed endocardial touch-up ablation to reach bidirectional block, starting from the mitral annulus toward or inside the coronary sinus. If the patient was known to have typical AFL or if this arrhythmia occurred during the procedure, the cavotricuspid isthmus (CTI) was ablated endocardially. The endpoint was bidirectional block. In 7 patients, the left atrial appendage was removed using a stapling device.

The pericardium was approximated with a stitch, and a chest tube was placed in both pleural cavities. There was no drain left in the pericardial space.

Abbreviations and Acronyms

AAD = antiarrhythmic drug
AF = atrial fibrillation
AFL = atrial flutter
AT = atrial tachycardia
CA = catheter ablation
CTI = cavotricuspid isthmus
LA = left atrium
PV = pulmonary vein
RF = radiofrequency
SVT = supraventricular tachycardia

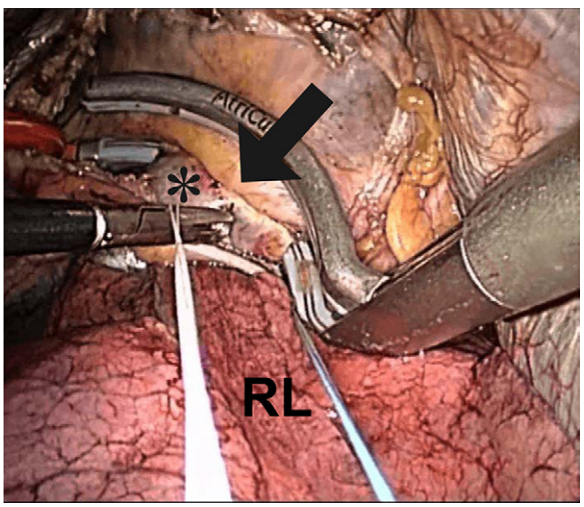

Figure 1 Right Pulmonary Vein Isolation

A large antral lesion **(arrow)** is created using a bipolar radiofrequency clamp, resulting in complete isolation of the right pulmonary veins (PVs). The antrum of the right PVs **(*)** is clearly visible. RL = right lung.

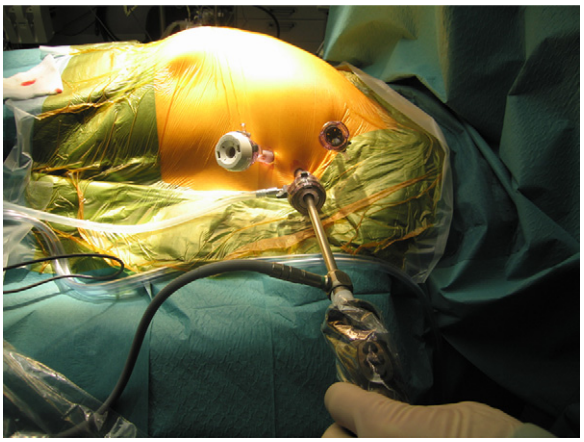

Figure 2 Placement of Ports on the Left Side of the Patient

Low-molecular-weight heparin was started 6 h after the procedure, and on the second post-operative day, acenocoumarol was reinitiated.

Patients restarted as soon as possible their pre-operative AAD regimens. Acenocoumarol and AADs were discontinued after the 6-month monitoring visit confirmed the absence of atrial arrhythmia.

Long-term follow-up. Any symptomatic patient not in sinus rhythm was cardioverted before the 3-month follow-up visit. One patient had a pacemaker, which was used for monitoring. The remaining patients underwent 7-day continuous Holter monitoring at 3, 6, 9, and 12 months. If 7-day Holter monitoring was not available, patients underwent at least 24-h Holter monitoring. According to current guidelines, success was defined as no episode of AF, AFL, or any atrial tachycardia (AT) lasting more than 30 s off AAD after the 3-month blanking period.

Statistical analysis. Data were retrospectively entered into a database. Statistical analysis was performed using SPSS version 16.0 (SPSS, Inc., Chicago, Illinois). Continuous variables are summarized with means and standard deviations. Outcomes are displayed using Kaplan-Meier plots and were compared using log-rank tests. Any episode of AF, AFL, or AT lasting more than 30 seconds detected after the 3-month post-procedural period by electrocardiography, pacemaker interrogation, or 7-day, 48-h, or 24-h continuous Holter monitoring performed at 6, 9, and 12 months was considered failure.

Results

Perioperative results. Twenty-six patients underwent hybrid procedures between May 29, 2008, and February 25, 2010. Patients' baseline characteristics are shown in Table 1. Ten patients had persistent AF, and 1 had longstanding persistent AF. Eleven patients had 1 or 2 (Patient #25) previous CAs. None of the PVs were isolated in those patients, and there were no epicardial scars indicative of transmural lesions. The mean follow-up period was 470 ± 154 days (range: 221 to 858 days). The mean length of hospital stay was 7 ± 2 days (range: 5 to 13 days), and mean intensive care unit stay for post-procedural recovery was 1.0 ± 0.2 days (range: 1 to 2 days). The median length of the hybrid procedure (from initial skin incision to skin closure) was 280 ± 84 min (range: 195 to 505 min).

Eleven patients were in AF at the start of the procedure. In all patients, we achieved bidirectional block of all the PVs (Fig. 3). In 2 patients, we did not perform any other lesion, because AF was not inducible. In 1 patient with inducible AF after PV isolation, we performed an additional roof line only. In 1 patient with inducible right AFL after PV isolation, we performed an additional CTI line only. Thereafter, no arrhythmia could be induced. In 22 patients, we created box lesions epicardially. In 17 patients (77%), we were able to demonstrate endocardial entrance and exit block in the box during sinus rhythm. After endocardial touch-up in 5 patients (23%), we completed the box lesions. In 3 patients, there was a gap at the junction of the right superior PV with the roof of the LA. One patient had a gap in the lateral portion of the roof line, and 1 patient in the middle of the inferior line. Because of ongoing AF or organization into mitral isthmus–dependent AFL, we performed in 3 patients mitral isthmus lines epicardially. In all cases, the lines had to be completed from the endocardium or coronary sinus, with a mean of 1.6 ± 0.5 applications of RF energy, resulting in bidirectional block (Fig. 4). In 2 patients, CTI ablation was performed. One patient needed electrical cardioversion at the end of the procedure because of ongoing AF. All other patients were in sinus rhythm. Twenty-four patients (92%) were discharged on their pre-operative AAD regimens (amiodarone in 6 of 24 [25%]). All patients were discharged on acenocoumarol.

Follow-up. Twenty-four patients (92%) reached 1-year follow-up, and 96% underwent 7-day Holter monitoring 1 year after the procedure. The remaining 2 patients (8%) reached 6-month follow-up, and there was 100% compliance with 7-day Holter monitoring (Table 2).

At 1 year, 22 of 24 patients (92%) were in sinus rhythm, with no episodes of AF, AFL, or AT lasting longer than 30 s on office follow-up, Holter monitoring, or pacemaker interrogation (Fig. 5). None of those patients were on AADs, and 5 (21%) were on acenocoumarol. One-year success, defined according to the Heart Rhythm Society, European Heart Rhythm Association, and European Cardiac Arrhythmia Society consensus statement (freedom from AF, AFL, and AT off AADs), was 93% for patients with paroxysmal AF and 90% for patients with persistent AF. Two of those 22 patients (9%) underwent CA for recurrent AF or left AFL after the hybrid procedure (Table 3). There was no statistically significant difference in patients with or without previous CA regarding the presence of sinus rhythm after 1 year without AADs ($p = 1.00$).

This means a single-procedure success rate (sinus rhythm without AAD and/or redo procedure) of 79% at 1 year for paroxysmal AF (11 of 14 patients) and 90% for persistent

Table 1 Baseline Characteristics

Patient #	Age (yrs)	Sex	EF (%)	AF Type	AF Duration (months)	LA Volume (ml)/ Ipsa (mm)	BMI (kg/m^2)	Previous CA	Hypertension	CAD	$CHADS_2$ Score	COPD	Lesion Set	Follow-Up
1	70	M	63	Pers	12	133/51	24.2	No	Yes	Yes	1	No	PVI, box, mitral isthmus line	1 yr: NSR without AADs
2	54	M	66	Pers	60	110/47	26.3	No	Yes	No	1	No	PVI, box, bicaval line, CTI	2 yrs: NSR without AADs
3	62	M	53	Pers	24	97/53	28.8	Yes	No	Yes	0	No	PVI, box	1 yr: NSR without AADs
4	69	M	44	Pers	72	96/46	31	Yes	No	Yes	0	No	PVI, box, bicaval line, SCV	6 months: NSR with sotalol
5	52	M	43	Pers	36	95/46	24.5	No	No	No	1	No	PVI, box, bicaval line, SCV, ICV	1 yr: NSR without AADs
6	53	F	63	Pers	156	88/42	27.7	Yes	No	Yes	0	No	PVI	1 yr: AF with flecainide
7	50	M	57	Pers	84	86/44	28.3	Yes	No	No	0	No	PVI, box, bicaval line, SCV, ICV	1 yr: NSR without AADs
8	48	F	49	Pers	36	83/40	22.9	No	No	No	0	No	PVI, box, mitral isthmus line	2 yrs: NSR without AADs
9	54	F	47	Pers	12	80/48	29.7	No	No	No	0	No	PVI, box, bicaval line, SCV, ICV	1 yr: NSR without AADs
10	60	M	55	Pers	12	71/36	22.1	No	No	No	0	No	PVI, box	1 yr: NSR without AADs
11	46	M	56	Pers	48	38/32	24.3	Yes	Yes	No	1	Yes	PVI, box, bicaval line, SCV	1 yr: NSR without AADs
12	58	M	67	Parox	36	130/45	28.7	Yes	Yes	Yes	1	No	PVI, box	1 yr: NSR after redo CA LA flutter
13	70	M	63	Parox	36	111/42	23.8	No	Yes	Yes	1	No	PVI, box	1 yr: NSR without AADs
14	62	F	61	Parox	36	110/45	26.2	No	No	Yes	0	No	PVI, box	1 yr: NSR without AADs
15	57	M	62	Parox	24	99/45	30.9	No	Yes	No	1	No	PVI, box	1 yr: AF with sotalol
16	60	M	62	Parox	108	90/48	28.1	No	Yes	Yes	1	Yes	PVI, box	1 yr: NSR without AADs
17	66	M	57	Parox	120	84/45	23.5	No	Yes	Yes	1	Yes	PVI, box	1 yr: NSR after redo CA right PVs and roof line
18	62	M	67	Parox	156	84/46	26.9	No	Yes	No	1	No	PVI	1 yr: NSR without AADs
19	66	M	63	Parox	108	82/44	32.2	Yes	Yes	No	1	No	PVI, CTI line	1 yr: NSR without AADs
20	48	M	63	Parox	120	94/43	31.6	Yes	No	No	0	No	PVI, box	1 yr: NSR without AADs
21	59	M	70	Parox	120	80/45	26.1	No	Yes	Yes	1	Yes	PVI, box	1 yr: NSR without AADs
22	62	F	66	Parox	72	76/49	35.6	No	Yes	Yes	1	Yes	PVI, box, mitral isthmus line, bicaval line, SCV	1 yr: NSR without AADs
23	63	F	65	Parox	92	70/36	19.7	Yes	No	No	0	No	PVI, box, bicaval line	2 yrs: NSR without AADs
24	38	F	60	Parox	36	59/32	23.5	Yes	No	No	0	No	PVI, box, CTI	6 months: NSR without AADs
25	47	M	60	Parox	72	51/36	26.2	Yes	No	No	1	No	PVI, roof line	1 yr: NSR without AADs
26	42	F	60	Parox	60	48/35	23.7	No	No	No	0	No	PVI, box, bicaval line, SCV	1 yr: NSR without AADs

Baseline characteristics of all included patients with lesion set and follow-up results. No patient had previous cardiothoracic surgery or a cerebrovascular accident.

AAD = antiarrhythmic drug; AF = atrial fibrillation; BMI = body mass index; CA = catheter ablation; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; CTI = cavotricuspid isthmus; EF = ejection fraction; ICV = inferior caval vein; LA = left atrial; Ipsa = left parasternal axis; NSR = normal sinus rhythm; Parox = paroxysmal; Pers = persistent; PVI = pulmonary vein isolation; SCV = superior caval vein.

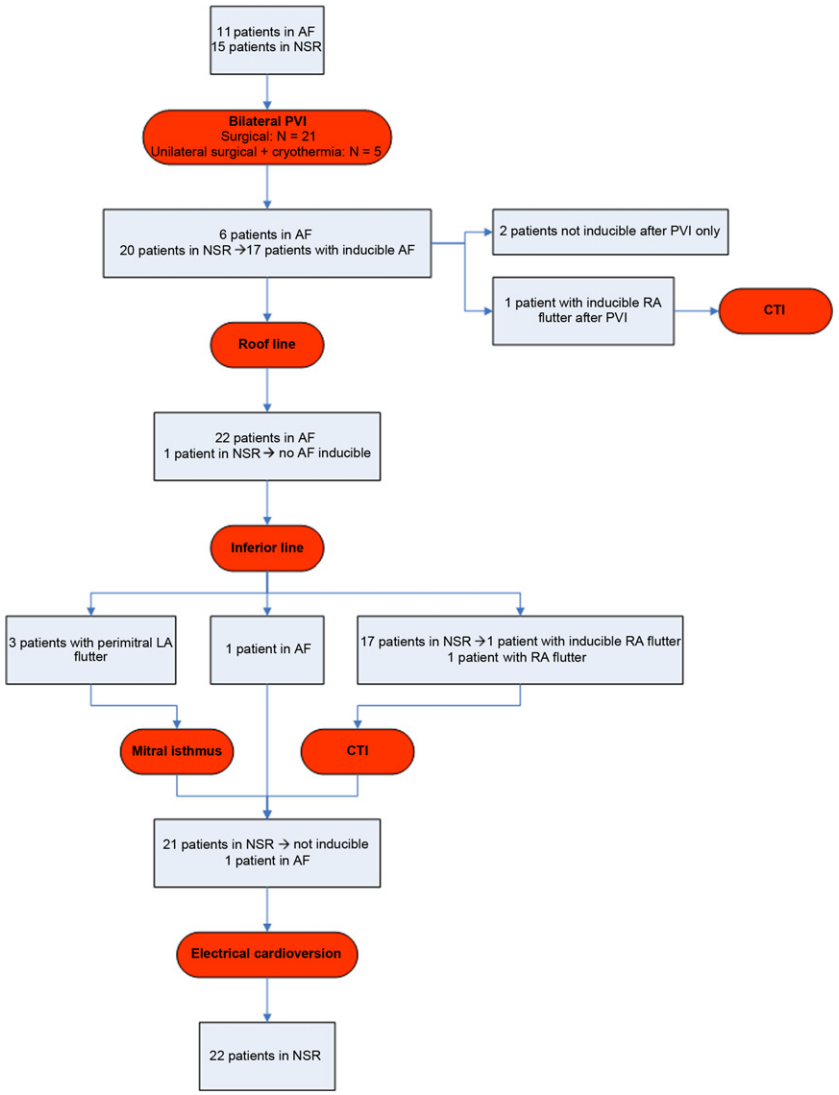

Figure 3 Flow Diagram of the Stepwise Lesion Sets

See text for details. AF = atrial fibrillation; CTI = cavotricuspid isthmus; LA = left atrium; NSR = normal sinus rhythm; PVI = pulmonary vein isolation; RA = right atrium.

AF (9 of 10 patients) and an overall single-procedure success rate of 83% at 1 year.

At 6 months, 2 of 2 patients (100%) were in sinus rhythm, with no episodes of AF, AFL, or AT lasting longer than 30 s. One of these patients was taking flecainide, and they were both on acenocoumarol. None of those patients had an additional CA procedure.

The management of patients with recurrent supraventricular tachycardia (SVT) after the 3-month blanking period is summarized in Table 3. Four of 26 patients (15%) had SVT recurrence, with a mean of 99 ± 94 (range: 29 to 239) SVT-free days after the blanking period. Two of these 4 patients underwent electrophysiologic studies and CA. One patient was found to have AF due to a gap at the junction of the right superior PV with the roof of the LA. The other patient had left AFL. These 2 patients were followed for at least 5 months and did not experience further SVT off AADs. The remaining 2 patients with SVT recurrence were treated with AADs for paroxysmal AF.

Complications. No deaths or conversion to cardiopulmonary bypass were encountered. No patient demonstrated paralysis of the phrenic nerve. One patient had a pleural effusion drained 3 weeks after surgery. One patient stayed hospitalized for 13 days because of difficulty controlling chest pain at the insertion sites of the working ports, without signs of infection.

Discussion

Main findings. This report describes for the first time combined simultaneous thoracoscopic surgical and transvenous CA

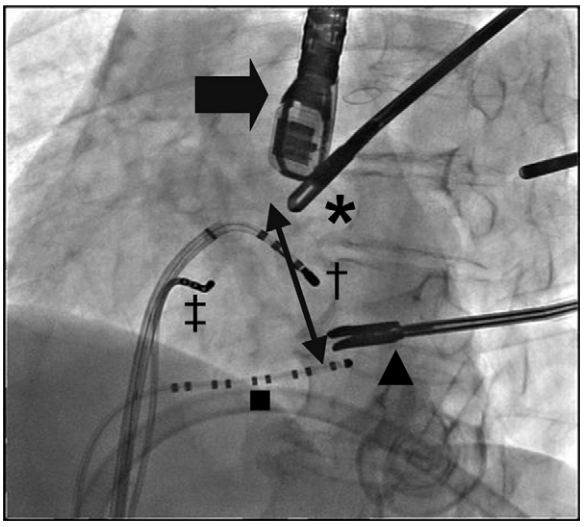

Figure 4 **Linear Lesion at the Mitral Isthmus**

Two instruments placed epicardially visualize the location of this linear lesion (**asterisk** indicates left inferior pulmonary vein, **triangle** indicates coronary sinus). Bidirectional block across the mitral isthmus was determined using the following criteria: 1) widely separated double potentials along the whole linear lesion **(double-headed arrow)**; 2) pacing lateral to the line, resulting in a proximal-to-distal activation sequence in the coronary sinus; 3) pacing immediately septal from this linear lesion with the coronary sinus catheter **(square)**, resulting in late activation (170 to 190 ms) on the ablation catheter **(dagger)** at the lateral side of this line; and 4) the conduction time from the septal side of the linear lesion to the lateral side gets shorter as the septal pacing site is moved farther from the line. **Double dagger** indicates His catheter; **thick arrow** indicates transesophageal echocardiographic probe.

of paroxysmal and persistent AF. These 2 complementary techniques performed in combination bear the potential of treating AF with a single ablation procedure. According to accepted definitions, our overall 1-year freedom from arrhythmia without AADs was 92%, with only 2 patients needing second CA procedures (3). Of note, almost half of the patients with persistent AF and over a third of all patients had 1 or more previous CA. The robustness of the hybrid approach lies in its complementary nature, as represented by the fact that in almost a quarter of patients, CA was needed to finish incomplete epicardial surgical lesions by endocardial touch-up, and additional lesions such as the mitral isthmus line can be performed rather quickly.

Hybrid procedure versus percutaneous CA techniques. Jaïs et al. (8) found that if AF was inducible after PV isolation in patients with paroxysmal AF, the addition of linear lesions, with the end point of noninducibility, resulted in 91% of patients free from arrhythmia without AADs during a follow-up period of 18 ± 4 months. To reach that number, however, 31% of patients needed second procedures. Using the same end point, our success rate off AADs was comparable, but only 9% of patients needed second procedures.

The single-procedure, drug-free success rate of the stepwise ablation approach for persistent AF as described by Haïssaguerre et al. (9) was 62% at 11 ± 6 months. Allowing for repeat procedures and the use of AADs, the 1-year success rate increased to 95%. In our series, we followed a comparable ablation strategy, and the single-procedure, drug-free success rate at 1 year was 83%. Allowing for redo procedures, this number increased to 92%.

The hybrid approach appears to result in better endpoints regarding rhythm control, for both paroxysmal and persistent AF, using the same end points and ablation strategy as described in other trials.

Approximately 80% of patients have at least partial recovery of PV conduction at 4 months after PV isolation with unipolar RF energy (10). Bipolar RF energy, as used in our series, overcomes the heat sink by clamping the tissue and excluding the effect of the circulating blood on ablation, which seems to result in more persistent lesions (11). But even for such devices, epicardial fat can prevent transmurality. In our series, box lesions were incomplete after epicardial ablation alone in 23% of the patients, and endocardial touch-up with unipolar RF energy was necessary to achieve bidirectional block. The possibility to perform such endocardial touch-up is 1 of the major advantages of this procedure.

Hybrid procedure versus surgical ablation techniques. By replacing the incisions of the traditional Cox maze III procedure with less invasive linear lesions of ablation using bipolar RF, Shen et al. (12) introduced the Cox maze IV procedure. This approach still requires cardiopulmonary bypass and at least 1 small right thoracotomy. Freedom from AF recurrence was 91% at 12 months, with 67% of patients off AADs. These figures are comparable with our results, although in the case of the hybrid procedure, neither cardiopulmonary bypass nor a thoracotomy is needed. None of the existing surgical ablation technologies (even bipolar RF energy) can guarantee complete transmurality. We solved this issue by applying RF energy endocardially in the case of incomplete lesions. Another shortcoming of the surgical approach is the inability to precisely locate AF triggers and to map AT or re-entry arrhythmias known to occur during AF ablation (13). In the setting of a hybrid procedure, however, it is possible to perform extensive mapping to tailor the lesion set. Finally, during an epicardial surgical AF ablation on the beating heart, it is technically not possible to create a linear lesion across the CTI. In our series, this was safely performed endocardially in 3 patients.

Hybrid procedure versus surgical ablation with epicardial mapping. In 2009, Lockwood et al. (7) described techniques for assessing conduction block across surgical lesions on the basis of epicardial mapping. Using combinations of a focal and bipolar RF device, as in our series, they achieved complete block across linear lesions by the first set of RF applications in only 21%. Several factors, such as epicardial fat and local myocardial thickness, limit the depth of penetration of RF energy and thus the creation of transmural lesions (14). After localization of the gaps, epicardial ablation was repeated until complete bidirectional block across all the linear lesions was achieved.

Table 2 Monitoring

Patient #	AF Type	AAD Before Procedure	AAD Stop (months)	Holter				
				3 Months	6 Months	9 Months	12 Months	24 Months
1	Pers	Sotalol	6	7 days, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
2	Pers	Sotalol	6	48 h, NSR	7 days, NSR	NA	7 days, NSR	7 days, NSR
3	Pers	Amiodarone	6	24 h, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
4	Pers	Flecainide	Not stopped	24 h, NSR	7 days, NSR	—	—	—
5	Pers	Amiodarone	6	7 days, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
6	Pers	Flecainide	6	48 h, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
7	Pers	Propafenone	6	7 days, NSR	7 days, NSR	7 days, NSR	7 days, NSR	
8	Pers	Disopyramide	6	7 days, NSR	7 days, NSR	NA	7 days, NSR	7 days, NSR
9	Pers	Metoprolol	6	48 h, NSR	7 days, NSR	NA	7 days, NSR	—
10	Pers	Amiodarone	6	7 days, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
11	Pers	Amiodarone	6	7 days, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
12	Parox	Flecainide	4	7 days, AFL	7 days, AFL	7 days, NSR	7 days, NSR	—
13	Parox	Flecainide	6	48 h, NSR	48h, NSR	7 days, NSR	7 days, NSR	—
14	Parox	Sotalol	6	48 h, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
15	Parox	Sotalol	Not stopped	7 days, PAF	7 days, NSR	7 days, NSR	7 days, PAF	—
16	Parox	Amiodarone	6	7 days, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
17	Parox	Amiodarone	6	7 days, NSR	NA	7 days, NSR	7 days, NSR	—
18	Parox	Flecainide	3	PM, NSR	PM, NSR	PM, NSR	PM, NSR	—
19	Parox	Flecainide	6	48 h, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
20	Parox	Flecainide	6	7 days, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
21	Parox	Metoprolol	6	7 days, NSR	7 days, NSR	NA	7 days, NSR	—
22	Parox	Sotalol	6	7 days, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
23	Parox	Flecainide	6	7 days, NSR	7 days, NSR	NA	7 days, NSR	7 days, NSR
24	Parox	Disopyramide	6	7 days, NSR	7 days, NSR	—	—	—
25	Parox	Sotalol	6	7 days, NSR	7 days, NSR	7 days, NSR	7 days, NSR	—
26	Parox	Flecainide	3	7 days, NSR	7 days, NSR	NA	7 days, NSR	—

AAD use and type and results of monitoring in all included patients. The duration of AAD intake after the hybrid procedure (AAD stop) is given for each patient. Patients 6, 12, 15, and 17 had arrhythmia recurrence.
NA = not available; PAF = paroxysmal atrial fibrillation; PM = pacemaker; other abbreviations as in Table 1.

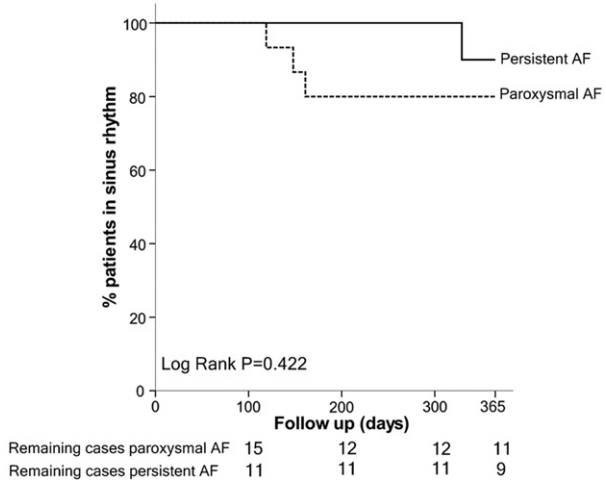

Figure 5 Outcomes of Hybrid Ablation Procedures

Kaplan-Meier curve showing the outcomes of hybrid ablation procedures. At 1-year follow-up, hybrid ablation resulted in an overall single-procedure success rate of 83% (79% for paroxysmal atrial fibrillation [AF] and 90% for persistent AF). An event was considered a patient who, at any time after the blanking period after the blanking period, had recurrent supraventricular tachycardia.

In our series, pacing maneuvers and mapping techniques were performed from the endocardial side. In 23% of our patients, we were not able to create complete box lesions, even after repeating epicardial ablation. To create completely transmural lesions, we applied unipolar RF energy endocardially at the remaining gaps.

Krul et al. (15) described a series of 31 patients with AF treated with thoracoscopic PV isolation and ganglionated plexi ablation. In patients with nonparoxysmal AF, left atrial ablation lines were created, and conduction block was verified epicardially with custom-made catheters. After 1 year, they reported comparable results to ours (86% of patients had no recurrence of SVT off AADs). Although the autonomic nervous system seems to play an important role in AF, there is until now too little evidence to advocate a systematic ganglionated plexi ablation strategy (16,17). In animal models, return of ganglionated plexi activity was observed 4 weeks after selective ablation, and little is known about the electrophysiological impact reinnervation will have on long-term outcomes (18). An important conceptual difference between studies is that Krul et al. (15) could only perform epicardial lesions, without the possibility of adding endocardial lesions including endocardial touch-ups to improve transmurality, as well as performing CTI and left-sided isthmus ablation. In addition, they could check the

Table 3 Supraventricular Tachycardia Recurrence After Hybrid Procedure and Management

Patient #	Time to SVT Recurrence (days)	Type of SVT	Mode of Diagnosis	Management of Recurrence	Recurrence After Additional Therapy	Follow-Up After Additional Therapy (months)	AAD After CA
6	329	AF	ECG	Flecainide	PAF	4	
12	119	Left atrial flutter	ECG	CA	None	5	None
15	148	AF	48-h Holter monitoring	Sotalol	Rare and brief PAF	13	
17	161	AF	ECG	CA	None	8	None

ECG = electrocardiography; PAF = paroxysmal atrial fibrillation; SVT = supraventricular tachycardia; other abbreviations as in Table 1.

completeness of ablation lesions only from the epicardium, which may be insufficient to show complete electrical block.

Study limitations. The small number of patients in this single-center retrospective study prevents definitive conclusions, also in view of the limited power of the log-rank test we used to compare groups. However, future larger studies may corroborate our results.

Although patients with previous CA had at most a PV isolation procedure, and none of the PVs appeared to be isolated in any of these patients, it cannot be excluded that previous CA favorably influenced the results.

The single-procedure success rate was similar, rather than lower, in patients with persistent compared with those with paroxysmal AF. Although this may have been due to the small sample size, it may also be considered an expression of the robustness of the hybrid procedure.

In the present series, the overall clinical success may have not recognized some episodes of asymptomatic arrhythmia by the relatively short periods of ambulatory monitoring performed.

The safety of this procedure may be a concern because of the extent of ablation and the full heparinization during the procedure.

The longer-term impact of this ablation strategy on the atrial systolic function remains unknown.

An ablation strategy based on noninducibility could lead to overtreatment of some patients. As demonstrated by Jaïs et al. (8), despite being still inducible after PV isolation and deployment of linear lesions, some patients remained arrhythmia free without AADs.

Conclusions

A combined transvenous endocardial and thoracoscopic epicardial ablation procedure for paroxysmal and recent persistent AF resistant to AADs has a single-procedure success rate of 83% at 1 year. Recurrent arrhythmias can be handled with AADs or CA.

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Key Words: atrial fibrillation ■ catheter ablation ■ hybrid procedure.