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ORIGINAL ARTICLE

Ablation in selective patients with long-standing persistent atrial fibrillation: medium-term results of the Dallas lesion set

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Abstract

OBJECTIVES: The aim of the study was to investigate the efficacy and safety of the Dallas lesion set, which mimics the Cox-maze III left atrial (LA) lesions, for long-standing persistent atrial fibrillation (LSPAF).

METHODS: Over a 4-year period, 103 LSPAF patients were treated with the Dallas lesion set. Linear lesions were created at the roofline, at the anterior line and between the roofline and left atrial appendage (LAA). All patients underwent ganglionated plexi ablation and LAA excision as well as pulmonary vein isolation. Follow-up at 6, 12 and 24 months was performed by 48-h Holter recordings and real-time 3-dimensional echocardiography.

RESULTS: At the 24-month follow-up, 83 of 103 (80.6%) patients were free of any atrial arrhythmia lasting >30 s, with 77 patients (74.8%) off of antiarrhythmic drugs (AADs). At 3.1 ± 0.7 years, 74 of 103 patients (71.8%) were in sinus rhythm, with 71 patients (68.9%) off AADs. The optimal cut-off value of LA dimension to discriminate atrial arrhythmia recurrence was 55 mm (receiver operating characteristic curve analysis), and the Kaplan–Meier analysis showed that patients with an LA dimension of <55 mm had less recurrence during the follow-up (log-rank test, $P = 0.015$). After 6 months, a significant reduction in LA volume and improvement in LA function was noted in patients without recurrence ($P < 0.05$). In contrast, patients with recurrence showed no improvement in LA volume or function.

CONCLUSIONS: The Dallas lesion set is an effective treatment in patients with LSPAF. It resulted in significant improvement in LA volume and function after restoration of sinus rhythm.

Keywords: Atrial fibrillation • Long-standing persistent atrial fibrillation • Maze procedure • Video-assisted thoracoscopic surgery

INTRODUCTION

Early experience suggests that a minimally invasive surgical approach may be useful in the treatment of patients with atrial fibrillation (AF), since it is possible to create continuous, transmural linear atrial lesions with the use of larger ablation probes and greater energies [1, 2]. For this reason, minimally invasive surgery may have its greatest application in patients with long-standing persistent atrial fibrillation (LSPAF). However, in patients with LSPAF, minimally invasive ablation has had limited success and is associated with a high incidence of recurrence [3]. To improve efficacy and safety, Edgerton *et al.* [4, 5] described the Dallas lesion set that closely replicated the left atrial (LA) lesions of the Cox-maze III procedure and was able to interrupt macroreentrant circuits around the pulmonary veins (PVs) and mitral valve annulus. Their early results suggested that this minimally invasive technique with an extended lesion set increased efficacy over PV isolation alone in patients with LSPAF.

It has been proved that to restore sinus rhythm (SR), both surgical and catheter ablation are effective treatment modalities for patients with AF [6–8]. Reverse morphological remodelling of the LA after restoration of SR by either treatment modality has been demonstrated [9]. However, LA volume and LA function after minimally invasive ablation has only been reported by La Meir using two-dimensional speckle-tracking echocardiography [10]. Recently, real-time 3-dimensional echocardiography (RT3DE) has been shown to be more accurate and reproducible than two-dimensional echocardiography for the quantification of LA volumes [11, 12]. Furthermore, RT3DE may be a novel, reliable technique for the assessment of LA function, providing unique information about phasic changes in LA volume during the cardiac cycle [11, 13].

In the present study, we employed the Dallas lesion set in an attempt to improve the surgical results in patients with LSPAF, and evaluated changes in LA volume and function in patients by RT3DE.

MATERIALS AND METHODS

Patient population

The study was performed at the Atrial Fibrillation Center of Beijing Anzhen Hospital in Beijing. The protocol was in accordance with

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the Helsinki Declaration and was approved by the Institutional Review Board or Ethics Committee of Beijing Anzhen Hospital, Capital Medical University. All patients gave informed consent. We included 103 patients with LSPAF, who underwent video-assisted thoracoscopic surgical ablation between January 2009 and April 2011 at our centre. LSPAF was defined as continuous AF lasting longer than 1 year and resistant to either electrical or pharmacological cardioversion. Patients with a prior catheter ablation, severe structural heart disease, an LA diameter of ≥65 mm or ejection fraction of ≤40% were excluded. Directly before surgery, transoesophageal echocardiography was performed to exclude thrombus in the left atrial appendage (LAA).

Surgical technique

The patients were treated with video-assisted thoracoscopy under general anaesthesia, according to the minimally invasive surgery protocol described by Wolf *et al.* [1] and Edgerton *et al.* [14]. First, the patient was placed in the left lateral decubitus position, and the right hemithorax was entered through a 5–6-cm incision in the right third or fourth intercostal space. A bipolar radiofrequency clamp (Isolator Synergy Ablation Clamp) was placed on the PV antrum proximal to the veins, taking care to avoid direct clamping of the PVs (Fig. 1A). At least three overlapping applications of radiofrequency energy around PVs were performed. The superior vena cava was mobilized, and dissection was performed below the superior vena cava and between the right superior PV and right pulmonary artery. The dissection was continued until the transverse sinus was entered and the dome of the left atrium exposed. This encompassed dissection of the fat pad behind the superior vena cava, which was continued until the muscular dome was clearly exposed. A transverse roof lesion connecting the right superior PV to the left superior PV was created using the bipolar Coolrail linear pen (AtriCure). A linear lesion connecting this roofline to the mitral annulus was directed to the root of the aorta at the junction of the left coronary and the non-coronary cusp (left fibrous trigone lesion). This lesion was created with the Coolrail device and reinforced with ablation from the multifunctional pen (Fig. 1B). Temporary pacing wires were affixed anterior and posterior to the roofline for later use in mapping for conduction block.

Then, the patient was repositioned in the right lateral decubitus position, and the left hemithorax, pericardium and left PVs were exposed through a left minithoracotomy in a similar fashion. The ligament of Marshall was then divided, and dissection between the left superior PV and the left pulmonary artery performed. The bipolar radiofrequency device was manoeuvred around the left PVs and electrical isolation performed. The left side of the roof lesion was completed using the Coolrail linear pen (Fig. 1C). The LAA was amputated using a stapling device (EZ45, Ethicon Endo-Surgery, Inc., Cincinnati, OH, USA) (Fig. 1D), and a short ablation line was made from the left PV isolation line to the base of the resected appendage.

Intraoperative electrophysiological testing

Intraoperative electrophysiological testing included the bilateral PV antrum, baseline and postisolation sensing and pacing and the

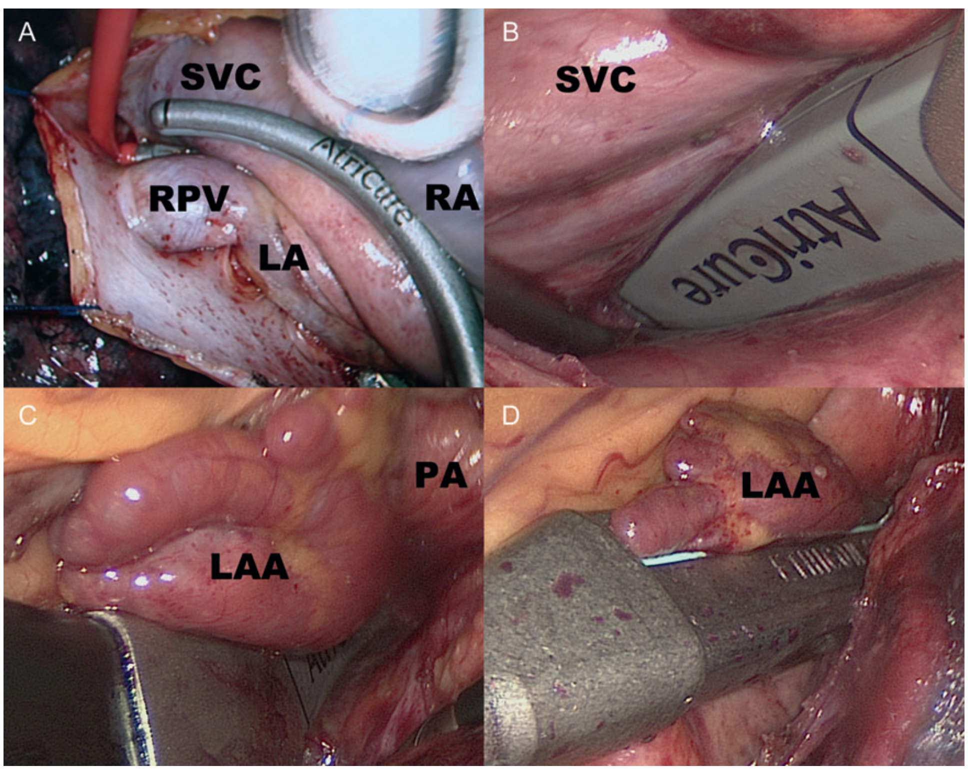


Figure 1: (**A**) Right thoracoscopic view of the bipolar clamp in place in the left atrial (LA) antrum, medial to the right pulmonary veins (RPV). (**B**) The linear bipolar ablation device is positioned behind the superior vena cava (SVC). It is utilized to make a roofline from the right superior pulmonary vein across the dome of the left atrium pointing towards the left superior pulmonary vein. (**C**) The linear ablation device is used to complete the roofline so that it connects the right superior pulmonary vein over to the left superior pulmonary vein as far posteriorly as can be done in the transverse sinus. (**D**) Amputation of the left atrial appendage (LAA) with a stapling device (stapler). PA: pulmonary artery; RA: right atrium.

ganglionated plexi (GP) detection as described previously [2, 15]. Baseline electrical activity of the PVs was recorded using a bipolar isolator multifunctional pen (AtriCure). Entrance block was considered successful if a positive baseline sensing result, consisting of rapid and disorderly atrial potentials, was detected in the PV antrum area before PV ablation and no atrial potentials were detected in the same area after ablation. A temporary pacemaker (Oscor Pace 203H DDD External Dual-Chamber Pacemaker; Oscor, Inc., Palm Harbor, FL, USA.) was placed before the procedure was started. Atrial and ventricular capture, defined as contraction of the chambers in response to the electrical stimulus sent from the temporary pacemaker, indicated a positive baseline pacing result. Failure of capture in the same area after ablation indicated a negative postablation pacing result. A combined positive baseline pacing and negative postablation pacing result indicated exit block. Achieving both entrance and exit block was regarded as a transmural lesion blocking the conduction in the PV antrum area. Ablation of the PVs was repeated until conduction block was confirmed. Conduction block across the roof and anterior trigone lines was also verified according to the method described by Edgerton *et al.* [5].

As recommended by Mehall *et al*. [16], GP activity was mapped using a high-frequency stimulus (10 V, 800 times per second) for at least 5 s. A positive response was defined as sinus bradycardia (fewer than 40 beats per min) or asystole, atrioventricular block or hypotension secondary to ventricular asystole at the onset of high-frequency stimulus. High-frequency stimulation of the GPs was repeated in areas that previously exhibited a positive vagal response. Areas that remained positive were ablated until no further vagal response was seen.

Postoperative medical management

All patients were treated with either aspirin or warfarin, depending on the cardiac failure, hypertension, age, diabetes, stroke ($CHADS_2$) score. The international normalized ratio during the procedure was targeted to be <2.5 but >2.0. All patients were treated with warfarin during the first 3 months after the procedure, which was continued at the discretion of the treating surgeon on the basis of freedom from AF and the $CHADS_2$ score.

All AADs were discontinued starting from 3 months after the procedure. Electric or chemical cardioversion was allowed during the follow-up within the 3-month blanking period to restore SR if necessary.

3-dimensional echocardiography

Patients were imaged with a commercially available system (iE33, Philips Medical Systems, Bothell, WA, USA) equipped with X3, a fully sampled matrix transducer. The RT3DE data sets were stored digitally and quantitative analyses were performed off-line using a semiautomatic, contour-tracing algorithm (Q-Lab, version 5.0, Philips Medical Systems) based on 5 reference points. In all patients, the image quality was sufficient for quantitative analysis, and post-processing of the images was performed within 10 min.

Quantification of LA volume was performed using the semiautomatic, contour-tracing algorithm developed for the left ventricle, but with the use of 5 atrial reference points: 4 at the anterior, inferior, lateral and septal parts of the atrial dome; and 1 at the level of the mitral annulus (Fig. 2). LA volumes were measured at 3 time points during the cardiac cycle: (i) maximum LA volume (LAmax) at end-systole, just before mitral valve opening; (ii) minimum LA volume (LAmin) at end-diastole, just before mitral valve closure and (iii) before atrial active contraction (LApreA) obtained from the last frame before mitral valve reopening or at time of the P wave on the surface electrocardiogram (ECG). LA function was derived from the various LA volumes and expressed according to the following formulas: (i) total atrial emptying fraction (TAEF) = [(LAmax − LAmin)/LAmax] × 100; (ii) active atrial emptying fraction (AAEF) = [(LApreA − LAmin)/LApreA] × 100, which is considered an index of LA active contraction; (iii) passive atrial emptying fraction (PAEF) = [(LAmax − LApreA)/LAmax] × 100, which is considered an index of LA conduit function; and (iv) atrial expansion index (AEI) = [(LAmax − LAmin)/LAmin] × 100, which is considered an index of LA reservoir function.

Follow-up

During the follow-up, patients were seen at the outpatient clinic at 6, 12 and 24 months, and every 1 year thereafter. At each visit, patients were questioned for any adverse events and the existence of palpitations. A routine RT3DE, 12-lead ECG and a 48-h Holter were taken at each visit for every patient until the latest follow-up. Freedom from recurrence was defined as the absence of arrhythmias without using any AADs after the procedure, in accordance with the generally accepted consensus document of 2012 [17]. Accordingly, the study population was divided into two groups: patients with SR (SR group) and patients who had recurrence of AF or flutter (AFL) (AF group).

Statistical analysis

Continuous data are presented as the mean ± standard deviation, and categorical variables are expressed as the number of cases and percentage. The significance of differences between the two groups were assessed using either Student's *t*-test for continuous variables or the χ^2 test for categorical variables. Survival curves of the freedom from atrial arrhythmia recurrence were plotted via the Kaplan–Meier method, with the statistical significance between curves determined using the log-rank test. A Cox regression analysis was used to identify the factors associated with recurrence using those variables with *P*-values <0.05 between patients with and those without recurrence. Variables selected to be tested in the multivariate analysis were those with a *P*-value of <0.05 in the univariate models. The optimal cut-off value of the LA dimension in the prediction of recurrence was identified using receiver operating characteristic (ROC) curve analysis. All tests were two-tailed, and a *P*-value of <0.05 was considered significant. The data were analysed with SPSS for Windows version 12.0 (SPSS, Inc., Chicago, IL, USA).

RESULTS

Demographics and procedural characteristics

The study consisted of 103 LSPAF patients. The mean age was 56.2 ± 8.7 years (range, 32–69), and 63% (65) were male. The time since the first diagnosis of AF was ∼5 years. The mean LA

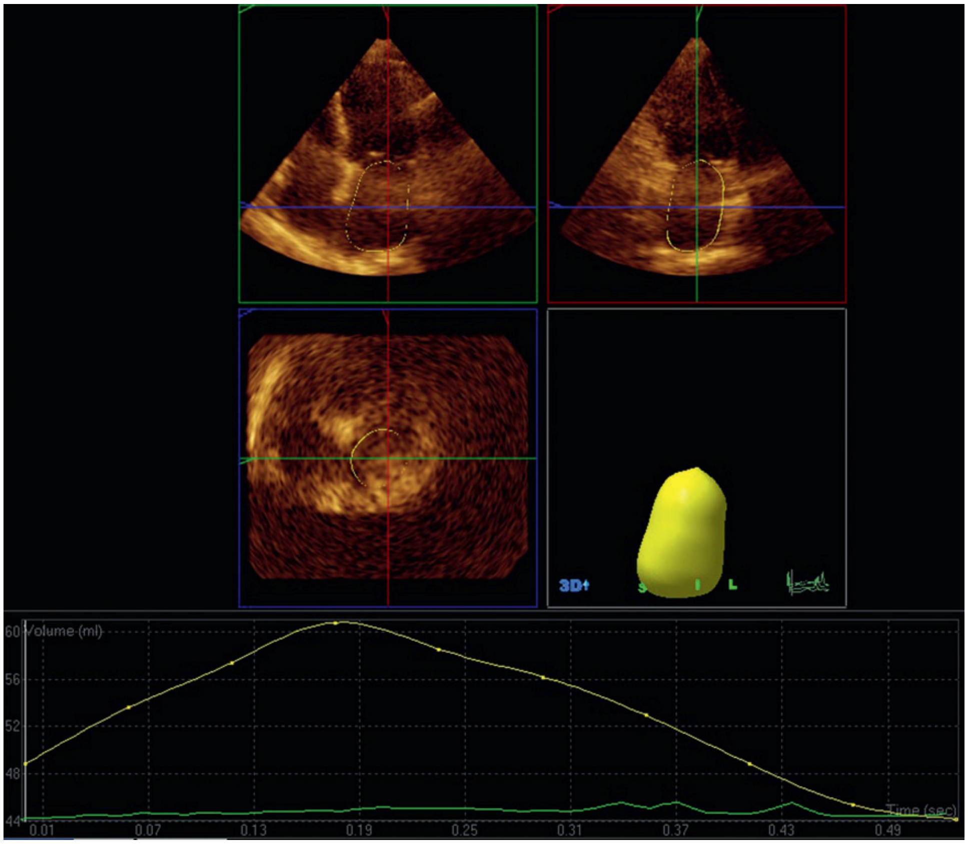


Figure 2: Assessment of left atrial volumes using RT3DE. Automatic border detection is obtained marking 5 reference points in the apical 2- and 4-chamber views (upper panel), and the left atrial 3-dimensional model is provided by the software. The changes in left atrial volumes during the heart cycle are plotted as a curve (lower panel).

dimension was 54.9 ± 3.8 mm. The $CHADS_2$ score was 0 in 19.4%, 1 in 21.3% and >1 in 59.3%.

The mean procedure time was 216 ± 38 min. The mean length of stay from surgery to discharge was 4.5 ± 2.2 days with a median value of 4.0 days. The mean length of intensive care unit and hospital stay was 1.2 ± 0.7 days and 6.7 ± 1.9 days, respectively.

Adverse events

All patients successfully underwent the ablation procedure, and there was no in-hospital mortality, PV injury, reoperation for bleeding, pneumothorax, phrenic nerve lesions, pericardial effusion, lung hernia, pneumonia, strokes, transient ischaemic attacks, renal failure or blood transfusion. One patient had prolonged chest tube placement for pleural effusions.

During the follow-up, 1 patient required pacemaker implantation for sinus node dysfunction. No strokes or transient ischaemic attacks were observed.

Rhythm

No patients were lost during follow-up. The changes in cardiac rhythm after 6 months are described in Fig. 3. At 6 months, 87 of 103 patients (84.5%) were in SR, with 82 patients (79.6%) off AADs. AF and AFL were documented in 13 (12.6%) and 3 (2.9%) patients, respectively. At 12 months, 85 of 103 patients (82.5%) were in SR,

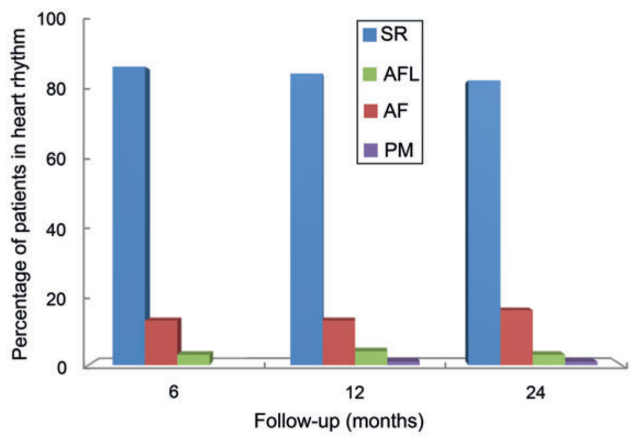


Figure 3: Outcomes in patients as measured by 48-h Holter during follow-up.

with 79 patients (76.7%) off AADs. Recurrent AFL was documented in 1 patient. At the 24-month follow-up, 77 of 103 (74.8%) patients had no atrial arrhythmia lasting >30 s in the absence of AADs. Another 6 patients also remained in SR, but they required AADs during follow-up. Recurrent AF was documented in 2 patients. At 3.1 ± 0.7 years after the procedure, 1 patient was in a paced rhythm, 74 of 103 patients (71.8%) were in SR, with 71 patients (68.9%) off AADs. AF and AFL were documented in 21 (20.4%) and 7 (6.8%) patients, respectively. Among patients in the AF group, the mean duration from ablation to recurrence was 9.3 ± 5.7

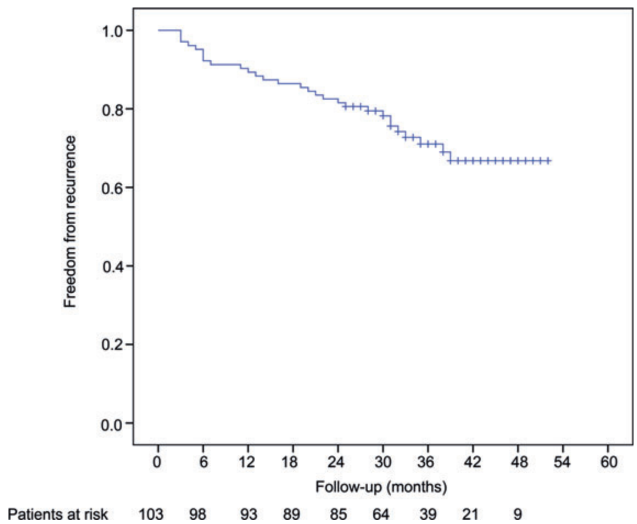


Figure 4: Kaplan–Meier analysis of the freedom from recurrence after the procedure.

months. The freedom from recurrence curve is shown in Fig. 4, and 71.4% (20/28) of recurrences occurred within 2 years of the procedure.

Assessment of left atrial volume and function by real-time 3-dimensional echocardiography

At baseline, conventional two-dimensional colour Doppler echocardiography revealed a significant LA diameter enlargement in the AF group compared with the SR group ($P = 0.001$) (Table 1). This enlargement was accompanied by an increase in the maximum LA volume ($P = 0.02$), but no significant differences in LA function by RT3DE (Table 2). At 6 and 24 months of follow-up, a significant decrease in LA volumes was noted in the SR group, including LAmax ($P = 0.01$), LAmin ($P = 0.04$) and LApreA ($P = 0.03$). Conversely, the AF group showed a trend towards an increase in LA volumes during follow-up. An example of a patient in the SR group with a significant reduction in LAmax and LAmin is shown in supplementary Fig. S1. For LA function, a significant improvement in TAEF ($P = 0.02$), AAEF ($P = 0.03$), AEI ($P = 0.01$) and PAEF ($P = 0.04$) was noted in the SR group throughout the 2 years of follow-up. However, in the AF group, these measurements showed no improvement (Table 2).

Predictors of recurrence and the role of left atrial diameter

The baseline characteristics of patients in SR and AF groups are given in Tables 1 and 2. Patients in the AF group had a larger LA dimension and LAmax, and longer AF duration compared with those in the SR group. A $CHADS_2$ score of ≥2 and LA dimension were found to significantly predict recurrence in the univariate Cox regression models (Table 3). In the multivariate analysis, the LA dimension remained significant in predicting recurrences (Table 3).

The mean LA diameter decreased from 54.9 ± 3.8 to 49.7 ± 1.0 mm ($P = 0.031$). Among patients in the SR group, LA diameter decreased by 6.2 ± 2.1 mm (54.4 ± 3.6 vs 47.2 ± 4.3 mm; $P = 0.027$), whereas in the AF group, the LA diameter did not change significantly (57.8 ± 3.4 vs 56.6 ± 4.9 mm). ROC curve analysis showed that an LA dimension of >55 mm was the optimal cut-off value to discriminate patients with recurrence from those without recurrence (sensitivity, 93.3%; specificity, 47.2%). The area under the ROC curve for LA dimension was 75.9% (95% confidence interval (CI) 0.65–0.87; $P = 0.002$) (See supplementary Fig. S2). An LA dimension of >55 mm was also a significant predictor of recurrence in the Kaplan–Meier analysis (47.8 vs 38.3%; log-rank test, $P = 0.015$) (Fig. 5).

Table 1: Baseline characteristics of the patients with and those without recurrence after the procedure ($n = 103$)

	AF group ($n = 28$)	SR group ($n = 75$)	P-value
Male	15 (53.6%)	50 (66.7%)	0.255
Age, year	56.4 ± 7.9	56.1 ± 6.3	0.581
Medical history			
Hypertension	11 (39.3%)	28 (37.3%)	1.000
Diabetes mellitus	4 (14.2%)	9 (12.0%)	0.746
Coronary artery disease	6 (21.4%)	15 (20.0%)	1.000
Previous stroke/TIA	2 (7.1%)	4 (5.3%)	0.662
LVEF, %	63.6 ± 5.8	62.7 ± 9.9	0.643
LA diameter, mm	57.8 ± 3.4	54.4 ± 3.6	0.001
Duration of AF, year	6.4 ± 2.4	4.3 ± 6.2	0.049
Prior AAD use			
1	7 (25.0%)	22 (29.3%)	0.807
2	9 (32.1%)	15 (20.0%)	0.440
3	7 (25.0%)	11 (14.7%)	0.249
≥4	4 (14.2%)	5 (6.9%)	0.347
Amiodarone	11 (39.3%)	41 (54.7%)	0.189
$CHADS_2$ score			
0	9 (7.1%)	11 (14.7%)	0.055
1	8 (28.6%)	14 (18.6%)	0.290
≥2	11 (39.3%)	50 (67.7%)	0.014

Data are presented as the number (%) of patients or mean ± SD.
AAD: antiarrhythmic drug; AF: atrial fibrillation; LA: left atrium; LVEF: left ventricular ejection fraction; TIA: transient ischaemic attack; SR: sinus rhythm.

DISCUSSION

In this study, we investigated the mid-term results of the Dallas lesion set in LSPAF patients with a median follow-up of 3 years. The main findings were as follows: (i) the percentage of patients free from AF and without AAD after 2 years was 74.8%; (ii) a significant reduction in LA volumes and a clear improvement in LA active contraction and LA reservoir function was observed in patients with a successful ablation procedure and (iii) the LA dimension can identify patients who will have recurrence after the procedure.

The Dallas lesion set

The Cox-maze procedure has been considered the gold standard for surgical treatment of AF; hence, the results of various modifications have been compared with those of the traditional Cox procedure. Replication of this procedure on the beating heart can be challenging when the procedure is attempted using a minimally

Table 2: Left atrial volumes and function at baseline, 6 and 24 months after the procedure in patients with or without recurrence (*n* = 103)

	Total study population (*n* = 103)	AF group (*n* = 28)			SR group (*n* = 75)		
		Baseline	6 months	24 months	Baseline	6 months	24 months
LA size							
LA maximum anteroposterior diameter, mm	56.1 ± 5.8	57.8 ± 3.4	56.6 ± 4.9	57.1 ± 4.2	54.4 ± 3.6[a]	47.2 ± 4.3[ab]	45.8 ± 6.9[ab]
LAmax, ml	47 ± 3	51 ± 6	52 ± 8	53 ± 7	44 ± 5[a]	37 ± 9[ab]	34 ± 10[ab]
LAmin, ml	32 ± 7	33 ± 8	34 ± 10	36 ± 9	32 ± 6	26 ± 9[ab]	21 ± 11[ab]
LApre, ml	29 ± 6	29 ± 8	29 ± 10	30 ± 7	29 ± 9	26 ± 8[ab]	21 ± 7[ab]
LA function							
TAEF, %	43 ± 2	43 ± 9	44 ± 10	44 ± 8	43 ± 5	49 ± 4[ab]	52 ± 5[ab]
AAEF, %	17 ± 3	17 ± 6	16 ± 8	16 ± 9	16 ± 8	19 ± 9[ab]	21 ± 7[ab]
AEI	80 ± 8	81 ± 13	79 ± 18	80 ± 11	79 ± 10	97 ± 12[ab]	110 ± 14[ab]
PAEF, %	32 ± 9	31 ± 8	31 ± 14	31 ± 11	33 ± 4	38 ± 5[ab]	41 ± 6[ab]

[a]Significant vs AF group.
[b]Significant vs baseline.
LA: left atrial; LAmax: maximum LA volume; LAmin: minimum LA volume; LApre: LA volume preatrial contraction; TAEF: total atrial emptying fraction; AAEF: active atrial emptying fraction; AEI: atrial expansion index; PAEF: atrial passive emptying fraction; AF: atrial fibrillation; SR: sinus rhythm.

Table 3: Cox regression analysis for predictors of recurrences

Variables	Univariate analysis			Multivariate analysis		
	HR	95% CI	*P*-value	HR	95% CI	*P*-value
Duration of AF	1.836	1.147–2.174	0.064	1.214	0.892–2.054	0.328
LA diameter, per mm	1.063	1.024–1.095	0.023	1.059	1.021–1.078	0.039
$CHADS_2$ score ≥2	1.643	1.074–2.260	0.047	1.904	1.528–2.732	0.411

AF: atrial fibrillation; HR: hazard ratio; CI: confidence interval; LA: left atrium.

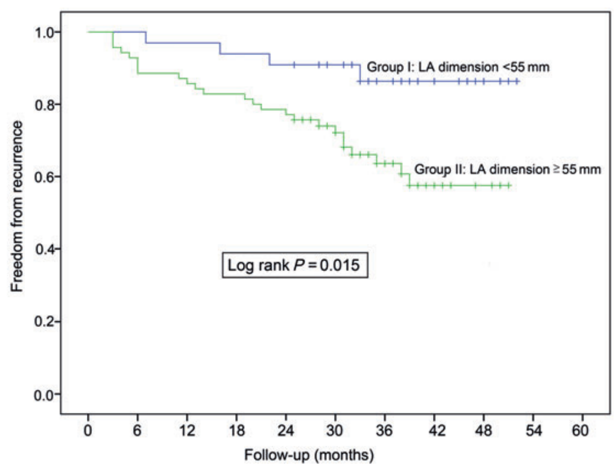
invasive technique with currently available ablative energy sources. Various groups have attempted to simplify the traditional Cox-maze lesion set using various energy sources, with variable degrees of success.

Minimally invasive surgery consisting of bipolar radiofrequency PVI and GP ablation is effective in eliminating AF in patients with paroxysmal AF, but is less effective in those with persistent AF or LSPAF. Lockwood *et al.* described the Dallas lesion set to improve the results in patients with persistent AF and long-standing persistent AF [18, 19]. First, they placed a transverse connecting lesion across the dome of the left atrium connecting the right superior PV with the left superior PV. Then, a short extension of this line was created on the left side that connects it to the base of the LAA. Secondly, they placed another connecting lesion from the left fibrous trigone at the anterior mitral valve annulus across the anterior dome of the atrium to the transverse dome line. With complete conduction block, these lesions should prevent single- or double-loop macroreentrant LA tachycardias from propagating around the PVs or mitral annulus, equivalent to the classic Cox-maze III procedure. It is critical to identify whether conduction block has been achieved and, if not, to locate the gaps in blocks that require further ablation, since residual gaps will support macroreentrant atrial tachycardias.

Although with the roof lesion, there is probably a risk of interatrial conduction delay related to injury to Bachmann's bundle (BB). We did not find any prolongation of the P wave (120 ms or longer) on the Holter and deteriorations of LA transport function during the follow-up. Thus, a thorough understanding and further study of the BB and interatrial conduction after surgical ablation in LSPAF patients is essential.

Left atrial volume and function

Atrial structural remodelling, with altered LA compliance, LA enlargement and impaired contractility, is a hallmark of AF. Reverse remodelling and recovery of atrial function are considered important targets of any AF treatment. Nonetheless, the morphological and functional changes after minimally invasive AF surgical ablation have only been investigated by La Meir *et al.* [10]. They reported that minimally invasive radiofrequency ablation resulted in significant LA reverse remodelling and significant improvement in LA compliance and function after restoration of SR, as demonstrated by two-dimensional speckle-tracking echocardiography. However, this technique needs further validation for this purpose and has some limitations related to the angle



Patients at risk

Group I:	33	33	32	31	30	24	14	10	5
Group II:	70	65	61	58	55	40	25	11	4

Figure 5: Freedom from recurrence curves in two groups of patients that were stratified using LA dimension cut-off value of 55 mm.

dependency of tissue Doppler imaging and the difficult analysis of LA systole with two-dimensional strain. In contrast, RT3DE is well-validated and provides rapid, accurate and automatic detection of phasic changes in LA volume that provides detailed information on passive and active LA function. In this study, RT3DE was used to assess LA volumes and function in patients treated with the Dallas lesion set for LSPAF.

The relation between LA enlargement and AF is complex; structural changes in LA may be related to several factors including pressure or volume overload and AF itself. Supporting the last factor, abnormal atrial histology (fibrosis, necrosis and inflammation) has been found uniformly in patients with LSPAF [7]. Furthermore, LA dilatation has been directly correlated with the duration of AF as a result of LA electrical and structural remodelling. In this study, the AF group demonstrated larger baseline LA volumes than the SR group, and this was probably related to the longer duration of AF or irreversible remodelling. Furthermore, after 6 months, a significant decrease in LA volumes was noted in patients with a successful procedure. These results agree with those of the studies that showed a significant reduction in LA volumes after successful catheter ablation [20–22].

In addition, an improvement in LA function was observed in patients who maintained SR after ablation. To interpret the baseline and follow-up findings of the present study, it is important to consider that the major determinants of AAEF are heart rhythm, atrial contractility and LApreA (Frank–Starling effect). AEI is influenced by left ventricular systolic function (mitral annulus displacement) and by LA wall stiffness. On the contrary, PAEF is mainly related to left ventricular diastolic function.

After 6 months of follow-up, a significant improvement in LA active contraction, reservoir and conduit function was noted in the SR group, but not in the AF group. Because left ventricular systolic and diastolic function did not change after ablation, and LApreA was decreased, the functional improvement in the SR group is probably related to a favourable effect of the long-lasting restoration of SR on the intrinsic characteristics of the atrial myocardium. These findings are consistent with those of previous studies and carry important clinical implications because they may translate into a reduced risk of AF recurrences and thromboembolic complications during the long-term follow-up [6, 9]. However, the impact of LA reverse remodelling and improvement in LA function on cardiovascular outcomes remains to be determined.

In this study, a $CHADS_2$ score of ≥2 and LA dimension were found to be significant predictors of recurrence in the univariate Cox regression models, whereas only LA dimension was an independent predictor in multivariate analysis. Moreover, the LA dimension at a cut-off value of 55 mm identified by the ROC curve analysis also predicted recurrence in the Kaplan–Meier analysis. The assessment of LA size is fundamental in the management of patients with AF, because it has important prognostic value and is used as a surrogate marker of therapy success [23, 24].

Study limitations

The main limitations of this study are the relatively small sample size, the absence of a control group and the fact that the ablation procedure was performed at a single centre. A randomized study with this technology is underway and will better define the efficacy of this novel procedure in accordance with published guidelines. The results of the present study need to be confirmed in a larger population with longer clinical and echocardiographic follow-up. In addition, we did not compare the results of minimally invasive surgery with the findings from patients converted to SR after catheter ablation. This will be the subject of an ongoing study. Finally, recurrences of atrial tachyarrhythmia were diagnosed on the basis of symptoms and Holter monitoring. Certainly, asymptomatic episodes could have been missed. However, our patients were highly symptomatic before the procedure, and any recurrence would probably have been noted, according to what has been previously reported in larger series of patients with AF. We believe that surveillance for recurrence of AF was sufficient for the purposes of the study, which specifically focused on the development of recurrent LSPAF.

CONCLUSIONS

This study demonstrates that a good success rate and a low complication rate are achievable in patients with LSPAF using the Dallas lesion set. Despite the study limitations, the Dallas lesion set resulted, in our experience, in a significant improvement in LA volume and function after restoration of SR as demonstrated by RT3DE analysis.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

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